EXHIBIT NO. 1

18
4-10-12

Northern Virginia Hazard Mitigation Plan

December 7, 2011

Prepared By:
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Executive Summary

Mitigation is commonly defined as sustained actions taken to reduce or eliminate long-term risk to people and property from hazards and their effects. Hazard mitigation focuses attention and resources on community policies and actions that will produce successive benefits over time. A mitigation plan states the aspirations and specific courses of action that a community 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 citizens, businesses, public officials, and other community stakeholders.

The area covered by this plan includes:

Participating Communities	
Counties	**Towns**
Arlington County	Town of Clifton
Fairfax County	Town of Dumfries
Loudoun County	Town of Haymarket
Prince William County	Town of Herndon
	Town of Leesburg
Cities	Town of Middleburg
City of Alexandria	Town of Purcellville
City of Fairfax	Town of Occoquan
City of Falls Church	Town of Quantico
City of Manassas	Town of Round Hill
City of Manassas Park	Town of Vienna

The additional contents of this Plan are designed and organized to be as reader-friendly and functional as possible. While significant background information is included on the processes used and studies completed (e.g., risk assessment, capability assessment), this information is separated from the more meaningful planning outcomes or actions (e.g., mitigation strategy, mitigation action plans).

Chapter 2, Planning Process, provides a complete narrative description of the process used to prepare the Plan. This includes the identification of who was involved, who participated on the planning team, and how the public and other stakeholders were involved. It also includes a detailed summary for each of the key meetings held along with any associated outcomes.

Chapter 3, Regional Information, describes the general makeup of the Northern Virginia region, including prevalent geographic, demographic, and economic characteristics. In addition, transportation, housing, and land-use patterns are discussed. This baseline information provides a snapshot of the regional planning area and thereby assists county and municipal officials to recognize those social, environmental, and economic factors that ultimately play a role in determining community vulnerability to natural hazards.

The Regional Hazard Identification and Risk Assessment (HIRA) is presented in Chapter 4. This section serves to identify, analyze, and assess the Northern Virginia region's overall risk to natural hazards. The risk assessment also attempts to define any hazard risks that may uniquely or exclusively affect the individual municipal jurisdictions.

The Risk Assessment builds on available historical data from past hazard occurrences, establishes detailed profiles for each hazard, and culminates in a hazard risk ranking based on conclusions about the frequency of occurrence, spatial extent, and potential impact of each hazard. FEMA's HAZUS^{MH} loss estimation methodology was also used in evaluating known hazard risks by their relative long-term cost in expected damages. In essence, the information generated through the risk assessment serves a critical function as communities seek to determine the most appropriate mitigation actions to pursue and implement — enabling communities to prioritize and focus their efforts on those hazards of greatest concern and those structures or planning areas facing the greatest risk(s). The hazards analyzed in this plan include: Flood, High Wind, Tornadoes, Winter Storms, Drought, Earthquakes, Landslides, Wildfire, Sinkholes, and Dam Failure.

The Capability Assessment, found in Chapter 5, provides a comprehensive examination of each participating jurisdiction's capacity to implement meaningful mitigation strategies and identifies existing opportunities to increase and enhance that capacity. Specific capabilities addressed in this section include planning and regulatory capability, staff and organizational (administrative) capability, technical capability, fiscal capability, and political capability. Information was obtained through the use of detailed survey questionnaires for local officials and an inventory and analysis of existing plans, ordinances, and relevant documents. The purpose of this assessment is to identify any existing gaps, weaknesses, or conflicts in programs or activities that may hinder mitigation efforts, and to identify those activities that should be built upon to establish a successful and sustainable regional hazard mitigation program.

The Regional Information, Risk Assessment, and Capability Assessment sections collectively serve as a basis for determining the goals for the Hazard Mitigation Plan; each contributing to the development, adoption, and implementation of a meaningful Mitigation Strategy that is based on accurate background information.

The Mitigation Strategy, found in Chapter 6, consists of broad regional goal statements as well as specific mitigation actions for each local government jurisdiction participating in the planning process. The strategy provides the foundation for detailed jurisdictional Mitigation Action Plans, found in Chapter 7, that link specific mitigation actions for each jurisdiction to locally-assigned implementation mechanisms and target completion dates. Together, these sections are designed to make the Plan both strategic (through the identification of long-term goals), but also functional through the identification of short-term and immediate actions that will guide day-to-day decision-making and project implementation.

In addition to the identification and prioritization of possible mitigation projects, emphasis is placed on the use of program and policy alternatives to help make the communities of the Northern Virginia region less vulnerable to the damaging forces of nature while improving the economic, social, and environmental health of the community. The concept of multi-objective planning was emphasized throughout the planning process, particularly in identifying ways to link hazard mitigation policies and programs with complimentary community goals related to housing, economic development, downtown revitalization, recreational opportunities, transportation improvements, environmental quality, land development, and public health and safety.

The Plan Maintenance Procedures, found in Chapter 8, include the measures that the Northern Virginia Regional Commission and participating jurisdictions will take to ensure the Plan's continuous long-term implementation. The procedures also include the manner in which the Plan will be regularly evaluated and updated to remain a current and meaningful planning document.

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Chapter 1: Introduction

Mitigation is commonly defined as sustained actions taken to reduce or eliminate long-term risk to people and property from hazards and their effects. Hazard mitigation focuses attention and resources on community policies and actions that will produce successive benefits over time. A mitigation plan states the aspirations and specific courses of action that a community 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 citizens, businesses, public officials, and other community stakeholders.

A local 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 decisions regarding regulations and ordinances, granting permits, and in funding capital improvements and other community initiatives. Additionally, these local plans will serve as the basis for States to prioritize future grant funding as it becomes available.

It is hoped that the Northern Virginia Hazard Mitigation Plan will be a useful tool for all community stakeholders by increasing public awareness about local hazards and risks, while at the same time providing information about options and resources available to reduce those risks. Teaching the public about potential hazards will help each of the area's jurisdictions protect itself against the effects of the hazards, and will enable informed decision making on where to live, purchase property, or locate businesses.

The areas covered by this plan include:

Table 1.1. Participating Communities

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

I. Background

Natural hazards, such as floods, tornadoes, and severe winter storms are a part of the world around us. Their occurrence is natural and inevitable, and there is little we can do to control their force and intensity.

The Northern Virginia region is vulnerable to a wide range of natural hazards, including flooding, tornadoes, hurricanes, and winter storms. These hazards threaten the safety of residents and 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.

While we cannot eliminate natural hazards, there is much we can do to lessen their potential impacts upon our community and our citizens. 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 both structural measures, such as strengthening or protecting buildings and infrastructure from the destructive forces of potential hazards; and non-structural measures, such as the adoption of sound land-use policies or the creation of 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 increasing growth rates. Now is the time to effectively guide development away from identified hazard areas and environmentally sensitive locations, before unsound development patterns emerge and people and property are placed in harm's way.

One of the most effective tools a community can use to reduce hazard vulnerability is to develop, adopt, and update as needed, a local hazard mitigation plan. A hazard mitigation plan establishes the broad community vision and guiding principles for addressing hazard risk, including the development of specific mitigation actions designed to eliminate or reduce identified vulnerabilities. The Northern Virginia Regional Hazard Mitigation Plan (hereinafter "Hazard Mitigation Plan" or "Plan") is a logical first step toward incorporating hazard mitigation principles and practices into the routine activities and functions of local government within the Northern Virginia region.

The mitigation actions noted in this 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 be used to reduce the future vulnerability of the Northern Virginia region to identified hazards. The Plan has been designed to be a living document, with implementation and evaluation procedures included to help achieve meaningful objectives and successful outcomes.

A. Disaster Mitigation Act of 2000

In an effort to reduce the Nation's mounting natural disaster losses, the U.S. Congress passed the Disaster Mitigation Act of 2000 (DMA 2000) in order 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 on mitigation planning activities, and 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 newly-created Pre-Disaster Mitigation (PDM) program, both of which are 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 Plan has been prepared in coordination with FEMA Region III and the Virginia Division of Emergency Management (VDEM) to ensure that the Plan meets all applicable DMA 2000 and State requirements. A Local Mitigation Plan Crosswalk, found in Appendix A, provides a summary of Federal and State minimum standards and notes the location where each requirement is met within the Plan.

II. Overview of Hazard Mitigation Planning

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 a long-term community vision. 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 the evaluation and enhancement of the mitigation plan itself. These plan maintenance procedures ensure that the plan remains a current, dynamic, and effective planning document over time.

Mitigation planning offers many benefits, including:

- saving lives and property;
- saving money;
- speeding 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 and safety.

Typically, mitigation planning is described as having the potential to produce long-term and recurring benefits by breaking the repetitive cycle of disaster loss. A core assumption of hazard mitigation is that pre-disaster investments will significantly reduce the demand for post-disaster assistance by lessening the need for emergency response, repair, recovery, and reconstruction. Furthermore, mitigation practices will enable local residents, businesses, and industries to re-establish 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 concurrent local planning efforts, and any proposed mitigation strategies must take into account other existing community goals or initiatives that will help complement or hinder their future implementation.

III. Purpose of Plan

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 **natural** hazards;
- Make communities safer places to live, work, and play;
- Qualify for grant funding in both the pre-disaster and post-disaster environment;
- Speed recovery and redevelopment following future disaster events;
- Demonstrate a firm local commitment to hazard mitigation principles; and
- Comply with State and Federal legislative requirements for local multi-jurisdictional hazard mitigation plans.

IV. Authority

Following conditional approval of the plan by both VDEM and FEMA, the plan will be brought forth to each participating jurisdiction to be formally adopted.

The Plan, developed in accordance with current State and Federal rules and regulations governing local hazard mitigation plans, will be adopted by the four counties, five cities, and 11 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. Copies of local adoption resolutions are provided in Appendix B (to be completed after adoption). The Plan shall be routinely monitored 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, at 44 CFR Part 201.

V. Summary of Plan Contents

The additional contents of this Plan are designed and organized to be as reader-friendly and functional as possible. While significant background information is included on the processes used and studies completed (e.g., risk assessment, capability assessment), this information is separated from the more meaningful planning outcomes or actions (e.g., mitigation strategy, mitigation action plans).

Chapter 2, Planning Process, provides a complete narrative description of the process used to prepare the Plan. This includes the identification of who was involved, who participated on the planning team, and how the public and other stakeholders were involved. It also includes a detailed summary for each of the key meetings held along with any associated outcomes.

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The Regional HIRA is presented in Chapter 4. This section serves to identify, analyze, and assess the Northern Virginia region's overall risk to natural hazards. The risk assessment also attempts to define any hazard risks that may uniquely or exclusively affect the individual municipal jurisdictions.

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In addition to the identification and prioritization of possible mitigation projects, emphasis is placed on the use of program and policy alternatives to help make the communities of the Northern Virginia region less vulnerable to the damaging forces of nature, while improving the economic, social, and environmental health of the community. The concept of multi-objective planning was emphasized throughout the planning process, particularly in identifying ways to link hazard mitigation policies and programs with complimentary community goals related to housing, economic development, downtown revitalization, recreational opportunities, transportation improvements, environmental quality, land development, and public health and safety.

The Plan Maintenance Procedures, found in Chapter 8, include the measures that the Northern Virginia Regional Commission and participating jurisdictions will take to ensure the Plan's continuous long-term implementation. The procedures also include the manner in which the Plan will be regularly evaluated and updated to remain a current and meaningful planning document.

Chapter 2: Planning Process

For the 2010 plan update, the Mitigation Advisory Committee (MAC) held six in-person meetings and multiple conference calls during the plan update process. The dates and the description of the activities at these in-person meetings are below, and each meeting was organized and facilitated by the contractor, Dewberry, LLC. Meeting sign-in sheets are located in Appendix C.

Table 2.1. 2010 Meeting Schedule	
Date	**Meeting Purpose**
December 4, 2009	Project Kickoff Meeting
January 15, 2010	Hazard Identification and Risk Assessment Phase I
July 12, 2010	Hazard Identification and Risk Assessment Results and Capability Assessment Briefing
August – September (Jurisdictional Visits)	Mitigation Strategies
October 18, 2010	Mitigation Actions Meeting
January 27, 2010	Draft Plan Conference Call

Kickoff Meeting

The update of the 2006 Northern Virginia Hazard Mitigation plan began with data collection. A kick-off meeting was held on December 4, 2009, with representatives from various counties and cities in the planning region in attendance. A list of participants for each committee meeting can found in Appendix C. At the kickoff meeting, the planning process was discussed in detail, along with the proposed schedule of deliverables. Additionally, the committee was asked to review the list of hazards in the 2006 plan and determine if the list should carry over as-is to the 2010 plan, or if changes were necessary.

Following the kickoff meeting, community, county, State, and Federal resources were identified and contacted to collect pertinent policy and regulatory information from each of the jurisdictions. This information included comprehensive plans, zoning ordinances, development ordinances, and building codes. Dewberry collected information about natural hazards including past occurrences and projected frequencies of future occurrence and the anticipated risk, where available.

Hazard Identification and Risk Assessment Meeting

A second meeting was held on January 15, 2010, to discuss the goals and vision of the plan's HIRA section. The HIRA process involved analyzing the region's greatest hazard threats and determining its most significant vulnerabilities with respect to natural hazards. Risk was determined by looking at the total threat and vulnerability for all of the jurisdictions for each hazard identified by the MAC. The HIRA was performed in large part using GIS data from the participating jurisdictions, HAZUS^{MH} (a GIS-based FEMA loss estimation software), and State sources. At the HIRA results meeting in July 2010, the MAC reviewed the draft HIRA.

Hazard Identification and Risk Assessment Results Meeting
The hazards initially identified in the 2006 plan were discussed and re-prioritized at the July meeting. Using the new prioritization, updates were made to the HIRA.

Simultaneous to conducting the HIRA, Dewberry also assessed the mitigation capabilities of the jurisdictions in the planning region. A capability assessment was performed whereby the existing programs and policies addressing natural hazards were reviewed. A thorough analysis of the adequacy of existing measures was performed, and potential changes and improvements were identified. The committee reviewed the capability assessment at the second HIRA meeting conducted July 12, 2010.

August – September Jurisdictional Meetings
Following the HIRA Results meeting on July 12, each county and city held a meeting to develop jurisdiction-specific mitigation actions. The attendees of these meetings included county and city department representatives and town representatives at the county meetings where appropriate. The first part of each meeting included an overview of the HIRA results, followed by the development of mitigation actions.

Mitigation Actions Meeting
Next, the committee worked to identify and develop potential regional mitigation actions for implementation at the October 18, 2010, Strategies meeting. The MAC considered issues related to potential damage from hazard events within the region and evaluated the 2006 projects and helped draft an action plan that specifies recommended projects, who is responsible for implementing the projects, and when they are to be completed.

Draft Plan Meeting
A draft plan conference call meeting was held on January 27, 2011, where the MAC discussed the draft plan in its entirety and the changes they thought should be made prior to the final draft plan submission to VDEM. Additionally, the committee discussed the public outreach methods being explored and executed within the various jurisdictions. For a detailed explanation of the public outreach methods, see Section II below.

The region will continue to implement the plan and perform periodic reviews and revisions through on-going MAC reviews and revisions. The Arlington County Office of Emergency Management will organize an annual planning review of the mitigation plan, and public meetings will be held during the five-year review/update period.

I. Mitigation Advisory Committee

The planning region convened an advisory committee comprised of representatives from various participating jurisdictions. The MAC worked with the Dewberry team and provided input at key stages of the process. Efforts to involve municipal, city, and county departments and community organizations that might have a role in the implementation of the mitigation actions or policies included invitations to attend meetings and serve on the MAC, access to the project website, e-mail updates, strategy development workshops, plus opportunities for input and comment on all draft deliverables.

The following members were a part of the MAC and were chosen by their respective jurisdictions to participate in the development of this plan:

Table 2.2. Committee Members	
Member	**Jurisdiction**
David Morrison	Arlington County
Joanne Hughes	Arlington County
Charlie McRorie	City of Alexandria
Ken Rudnicki	City of Fairfax
Walter English	City of Fairfax
Dan Ellis	City of Falls Church
John O'Neal	City of Manassas Park
Elizabeth McKinney	Fairfax County
Kevin Johnson	Loudoun County
Alexa Hussar	Prince William County
Pat Collins	Prince William County
Beth Brown	Virginia Department of Emergency Management
Amy Howard, Debbie Messmer	Virginia Department of Emergency Management

II. Public Involvement and Citizen Input

An important component of this planning process is the opportunity for the general public to provide input. Individual citizen and community-based input provided the planning team with a greater understanding of local concerns and increased the likelihood of successfully implementing mitigation actions by developing community "buy-in" from those directly affected by the decisions of public officials. As citizens become more involved in decisions that affect their safety, they are more likely to gain a greater appreciation of the natural hazards present in their community and take the steps necessary to reduce their impact. Public awareness is a key component of any community's overall mitigation strategy aimed at making a home, neighborhood, school, business, or city safer from the potential effects of natural hazards. This public outreach effort was also an opportunity for neighboring jurisdictions, agencies, businesses, academia, nonprofits, and other interested parties to be involved in the planning process. Local jurisdictions included Community Emergency Response Teams (CERTs), the American Red Cross, and Citizen Corp groups in planning meetings and presentations for this plan update. A complete list of public outreach initiatives can be found below; however, it should be noted that many jurisdictions chose to have public outreach meetings following conditional approval of this plan.

The following lists include an explanation of the public outreach efforts accomplished by each participating jurisdiction. This section is considered a work-in-progress and will be completed by formal adoption.

Arlington County

- The Plan has been posted for review and comment on the county's website.

  The Plan project has been presented to the county commission which addresses emergency management issues

Fairfax County (including the Towns of Clifton, Herndon, and Vienna)

- The County and Towns posted the draft plan at www.fairfaxcounty.gov for public comment and review. Please see Appendix H for a screenshot example.
- The County also posted a link to the Plan on their Twitter and Facebook pages, advertising that public review and comments were welcome.
- Fairfax County additionally sent out a newsletter to a group of businesses and non-profits that are part of the Emergency Support Function-15 Council of Governments group, advertising that the Plan was being updated and it could be accessed on the county website.

  The Office of Emergency Management (OEM) also included the link to the Plan in a monthly newsletter that is distributed to all county agencies and partner agencies.
- OEM's Outreach Coordinator also included the Plan update information in a monthly newsletter which is distributed to groups such as Fairfax County Citizen Corp Groups.
- Lastly, the County also utilized its daily newsletter "Newswire," which is circulated to all county employees, elected officials, and partner agencies, and the Tyson's Corner Security Officers Association.

Loudoun County (Including the Towns of Leesburg, Middleburg, Purcellville, and Round Hill)

  A link to the draft plan will be posted to the OEM website, which is www.loudoun.gov/oem, in the summer of 2011.
- OEM will coordinate the set-up of our display board at the government center depicting the hazard maps, vulnerability analysis, and opportunity for the public to provide input. A "do you want to know more?" tag line routing citizens to the website will be added.
- OEM will coordinate with the Loudoun County Public Information Office to distribute messages on Twitter and Facebook announcing the project and directing residents to the website.

Prince William County (including the Towns of Dumfries, Haymarket, Occoquan, and Quantico)

- A link to the draft plan will be posted on the county website for review and comment by the public during the fall of 2011.
- The County posted information about the plan being available for review by the public on their local cable channel.

City of Alexandria

- The City will post a link to the draft plan on their Emergency Management website, requesting that the public review and comment on the plan during the summer of 2011.

- The City printed a hard copy of the plan and displayed it at the Beatley Central Library on 5005 Duke Street for the public to review and comment.

City of Fairfax

- On January 5, 2011, the City of Fairfax OEM presented an overview of the draft 2010 Northern Virginia Hazard Mitigation Plan to its Community Emergency Response Team. A copy of this presentation can be found in Appendix H.
- The City posted a link to the draft plan on their Emergency Management website, requesting that the public review and comment on the plan. A screenshot can be found in Appendix H.

City of Falls Church

Upon receiving the final document the City will provide public outreach via the City website, Facebook, and eFocus (newsletter).

- Upon receiving the final document the City will provide public outreach via eFocus (newsletter).

City of Manassas

The City posted the Plan to the City website during the summer of 2011. Contacts have been made with television media to promote the plan through a news story. This article can be seen in Appendix H.

City of Manassas Park

- The City posted the plan on its website on February 16, 2011. A screenshot of this website can be found in Appendix H.
- The Plan will be featured on the City's cable channel.
- Presentations were made to the Citizen Corps organizations within the city, as well as CERT.

III. Incorporation of Existing Plans and Studies

The Plan incorporates information from a number of other previously produced plans, studies, and reports. These documents include:

- Commonwealth of Virginia Hazard Mitigation Plan, 2010
- Critical Infrastructure Protection in the National Capital Region, 2005
- National Capital Region Hazard Identification and Risk Assessment, 2007
- National Capital Region Strategic Hazard Identification and Evaluation for Leadership Decisions (NCR SHIELD), 2008.

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Chapter 3: Regional Information

I. Northern Virginia Overview

A. Planning Region

The Northern Virginia planning region includes Arlington, Fairfax, Loudoun, and Prince William counties, as well as the cities and towns located within these counties (20 jurisdictions). The communities participating in the 2010 hazard mitigation plan update plan are summarized in Table 3.1 and graphically in Figure 3.1.

The 2006 Hazard Mitigation Plan grouped the Northern Virginia region into four distinct planning areas within the Northern Virginia region to aggregate and summarize historical hazard events and damage figures (Table 3.1). During the kick-off meeting for the plan update it was decided that each jurisdiction should be represented individually; if no information is available it has been noted in the risk assessment.

Table 3.1. 2006 Planning Regions.

Planning Area	Jurisdictions Included
1	Arlington County
2	Fairfax County City of Alexandria City of Fairfax City of Falls Church Town of Clifton Town of Herndon Town of Vienna
3	Loudoun County Town of Leesburg Town of Purcellville Town of Round Hill Town of Middleburg
4	Prince William County City of Manassas City of Manassas Park Town of Dumfries Town of Occoquan Town of Quantico Town of Haymarket

Fourteen jurisdictions participated in the 2006 Hazard Mitigation Plan. For this update, the six towns have joined the planning process and include Clifton, Middleburg, Round Hill, Haymarket, Occoquan, and Quantico.

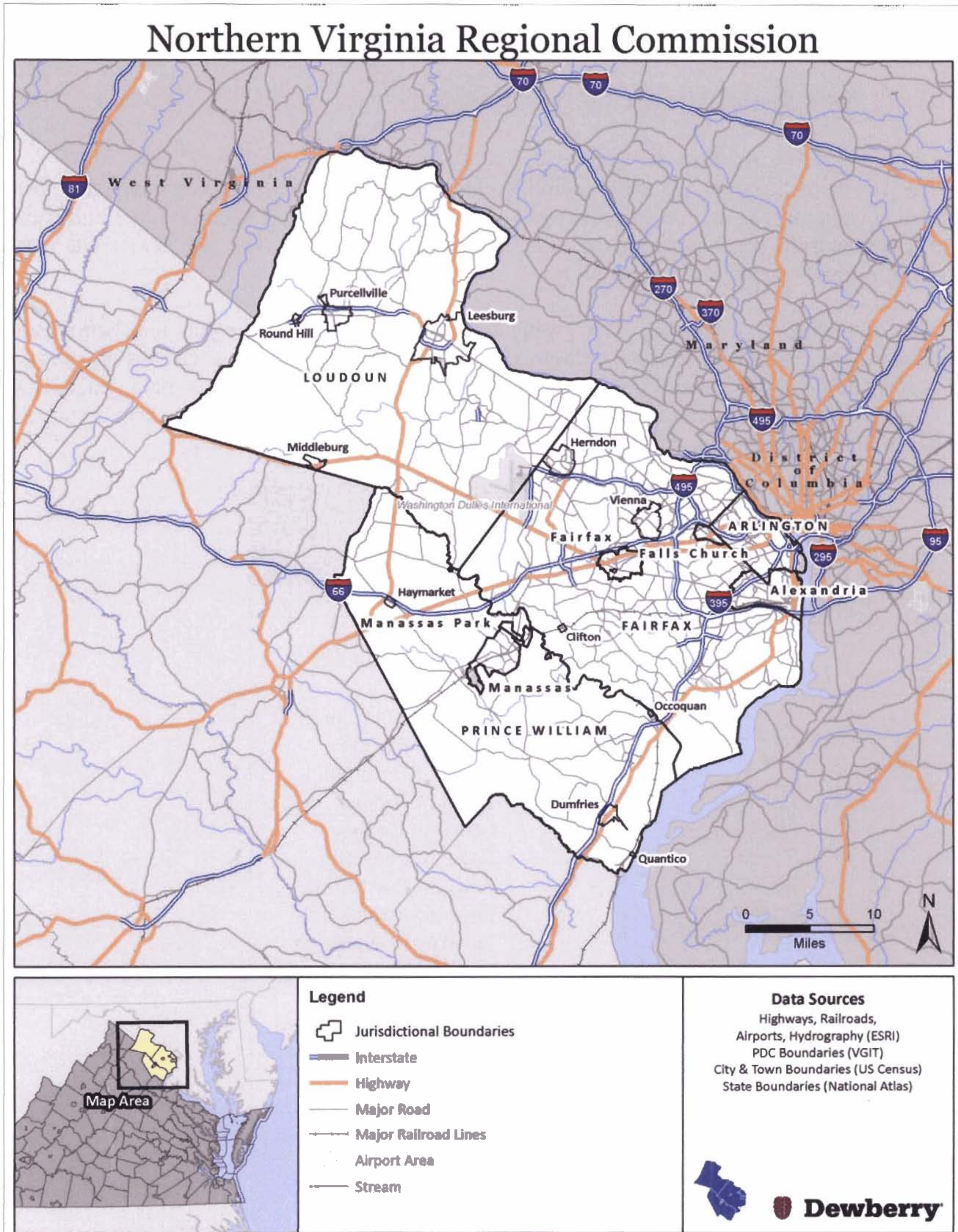


Figure 3.1. Northern Virginia 2010 Hazard Mitigation Plan Update Region

1. County Profiles

Arlington County

The area that encompasses present-day Arlington County was first settled as part of the British Colony of Virginia in the late 1690s. In 1791, George Washington surveyed the area in what was to become the District of Columbia. Congress returned the area to the Commonwealth of Virginia in 1842 as the County of Alexandria. In 1870, the City of Alexandria became independent of Alexandria County, and the county portion was officially renamed Arlington County in 1920. The 2009 census estimate for the county is 212,038, an approximately 12% increase during the past decade.

Arlington is an urban county of about 26 square miles located directly across the Potomac River from Washington DC. Arlington's central location in the Washington DC metropolitan area, its ease of access by car and public transportation, and its highly skilled labor force have attracted an increasingly varied residential and commercial mix. Arlington is one of the most densely populated communities in the nation with more than 7,315 persons per square mile.

Arlington's high population density and its location along the banks of the Potomac River, increase the city's vulnerability to a variety of hazards, most notably flooding. In addition to snow melt and rain-related river flooding episodes, Arlington is also subjected to tidal and storm surge flooding. As sea levels rise, permanent inundation of low lying areas along and near the river shoreline is also a threat. Additionally, winter storms pose significant threats, as evidenced during the 2009 – 2010 winter season.

Fairfax County

The land that is now Fairfax County was part of the Northern Neck Proprietary granted by King Charles II in 1660 and inherited by Thomas Fairfax, Sixth Lord Fairfax of Cameron, in 1719. The county itself was formed in 1742 from Prince William County. The 2009 census population estimate for the county is 1,036,473, an approximately 7% increase during the past decade.

Fairfax County comprises about 407 square miles located directly across the Potomac River from Washington, DC. The county's location in the Washington metropolitan area, its ease of access by car and public transportation, and its highly skilled labor force have attracted an increasingly varied residential and commercial mix. Most commercial development is centered around Tysons Corner, which is the 12th largest central business district in the nation.

Due to its situation on both the Virginia piedmont and the Atlantic coastal plain, the County experiences a variety of weather. The diversity of Fairfax County's landscape increases the County's vulnerability to a variety of hazards, most notably flooding and severe storms. In addition to snow melt and rain-related river flooding episodes, low-lying areas of Fairfax County along the Potomac River are also subject to tidal and storm surge flooding. As sea levels rise, permanent inundation of low lying areas along and near the river shoreline is also a threat. Additionally, winter storms pose significant threats, as evidenced during the 2009 – 2010 winter season.

Loudoun County

Loudoun County was established in 1757 and was formerly part of Fairfax County. It was named after John Campbell, Fourth Earl of Loudoun and past Governor of the Commonwealth of Virginia. It was the most populous Virginia county during the time of the American Revolution. Since 1757, the county seat has always been the Town of Leesburg. In 2010, Loudoun County was ranked by Forbes as America's wealthiest county. The County has a total area of 521 square miles, of which one square mile is water. As of the 2000 Census, it has a population density of 272 per square mile. The population was estimated to be approximately 298,113 in 2009 by the U.S. Census Bureau, a nearly 76% increase over the 2000 population of 169,599.

Geographically, Loudoun County is bounded to the North by the Potomac River, to the south are Prince William and Fauquier counties, and on the west by the watershed of the Blue Ridge Mountains. The Bull Run Mountains and Catoctin Mountain run through the County. There are seven incorporated and 60 unincorporated towns within the County.

Risk factors for the county are in part due to its proximity to the Nation's capital and its growth rate. The county has a risk of flooding due to low lying areas surrounding the Potomac River and other natural hazards and risks, such as storm damage and winter weather. Winter storms pose significant threats, as evidenced during the 2009 – 2010 winter season.

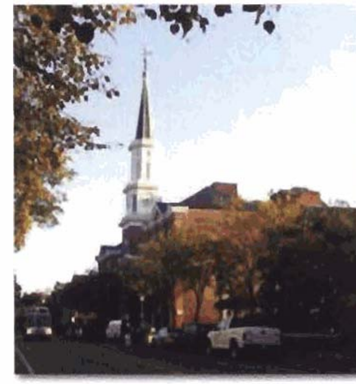
Prince William County

Prince William County was formed in 1730, and was named by the Virginia General Assembly to honor the son of King George II. The county seat is the City of Manassas. Prince William County has a total area of 338 square miles, of which 11 square miles are water. It has a population density of 819 per square mile. In 2009, the population was estimated at 386,934, an approximately 38% increase over the 2000 census. It was the fourth fastest growing county in the United States during that period.

Prince William County has grown more than 200% over a 20-year period. This is because of its central location to the Washington, DC metropolitan area. The population growth rate poses a risk; as open land is developed flood management must be addressed with the increasing amounts of impervious surfaces. Its flood risk is also due to low lying areas surrounding the Potomac River. Other natural hazards and risks are storm damage and winter weather. Winter storms pose significant threats, as evidenced during the 2009 – 2010 winter season.

2. City Profiles

City of Alexandria



What is now the City of Alexandria was first settled as part of the British Colony of Virginia in the late 1690s. In 1791, George Washington included portions of the City of Alexandria in what was to become the District of Columbia. That portion was given back to Virginia in 1846 and the City of Alexandria was re-chartered in 1852. In 1870, the City of Alexandria became independent of Alexandria County, with the remainder of the County changing its name to Arlington County in 1920. The population of the city was 128,283 per the 2000 Census and was estimated to be 141,738 in 2009.

Alexandria's high population density and its location along the banks of the Potomac River, increase the city's vulnerability to a variety of hazards, most notably flooding. In addition to snow melt and rain-related river flooding episodes, Alexandria is also subjected to tidal and storm surge flooding. As sea levels rise, permanent inundation of low lying areas along and near the river shoreline is also a concern. Winter weather and high wind events also pose a significant threat to the city as the 2009 – 2010 winter and summer seasons have proven.

City of Fairfax

Named after Thomas Fairfax, Sixth Lord Fairfax of Cameron, what is now known as the City of Fairfax became an independent city in 1961. This occurred only after having been previously known as Earp's Corner, then Town of Providence, and eventually Town of Fairfax. Its population was 21,498 as of the 2000 Census and was estimated by the Census Bureau to be 24,702 in 2009.

The city's location on the eastern edge of the Virginia Piedmont make it susceptible to natural hazards and risks, such as storm damage and winter weather, as evidenced during the 2009 – 2010 winter season.

City of Falls Church

It is believed that the area was first settled by Europeans in 1699. The city takes its name from what was coined The Falls Church, a building that was built in 1757. The population of the city was 10,377 as of the 2000 Census and was estimated by the Census Bureau to be 11,711 in 2009.

The City of Falls Church comprises about 2.2 square miles located approximately 10 miles west of Washington, DC. The City's proximity to the Washington metropolitan area and its ease of access by car and public transportation have allowed increasingly-varied residential and commercial development. Falls Church is densely populated with more than 5,077 persons per square mile.

The City of Falls Church experiences significant flood threats due to the presence of Four Mile Run and Tripps Run. The City's location on the eastern edge of the Virginia Piedmont make it susceptible to other natural hazards and risks, such as damage from severe storms and winter weather, as evidenced during the 2009 – 2010 winter and summer seasons.

City of Manassas

The City of Manassas played an important role during the American Civil War. The First Battle of Bull Run (also called First Battle of Manassas) was fought in the vicinity in 1861. It was the first land battle of the Civil War. The Second Battle of Bull Run took place August 28-30, 1862. The Town of Manassas was incorporated in 1873 and became an independent city in 1975. The population of the city was 35,135 as of the 2000 Census and was estimated by the Census Bureau to be 36,213 in 2009.

Manassas is subject to high wind events, winter weather, and flooding. Winter storms pose significant threats, as evidenced during the 2009 – 2010 winter season.

City of Manassas Park

The City of Manassas Park was incorporated in 1957 and became an independent city in 1975. It was the last town in Virginia to become a city before a moratorium was placed on other towns achieving similar status. The population of the city was 10,290 as of the 2000 Census and was estimated by the Census Bureau to be 14,026 in 2009.

3. Town Profiles

Town of Dumfries

Dumfries was chartered on May 11, 1749, and is Virginia's oldest continuously chartered town. John Graham gave the land on which the town was founded and is named after his birthplace, Dumfrieshire, Scotland. The population of the town was 4,937 as of the 2000 Census and was estimated by the Census Bureau to be 4,954 in 2009.

Town of Herndon

Incorporated in 1879, the area on which the town was built was originally granted to Thomas Culpeper by King Charles II of England in 1688. Much of the downtown was destroyed on March 22, 1917, by a fire but was rebuilt with brick instead of wood. The population of the town was 21,655 as of the 2000 Census and was estimated by the Census Bureau to be 22,579 in 2009.

Town of Leesburg

Steeped in history, Leesburg is the county seat of Loudoun County. Leesburg was established in 1758, and formally became a town by signed act of the Virginia General Assembly on February 18, 1813. It is located just over 30 miles west-northwest of Washington, DC, at the base of Catoctin Mountain and adjacent to the Potomac River. The principal drainage for the town is Tuscarora Creek and its northern "Town Branch," which empties into Goose Creek to the east of town.

European settlement began in the late 1730s. After its founding, it was the location of the post office and regional courthouse. The town was originally established on 60 acres of land. The population of the town was 28,311 as of the 2000 Census and was estimated by the Census Bureau to be 40,927 in 2009.

Town of Vienna

Originally called Ayr Hill, the village agreed in the 1850s to change its name to Vienna at the request of William Hendrick, a medical doctor who grew up in Vienna, New York. Vienna was incorporated as a town in 1890. The population of the town was 14,453 as of the 2000 Census and was estimated by the Census Bureau to be 15,215 in 2009.

Town of Purcellville

Settled in the mid 1700s, the village was first known as Purcell's Store. The village renamed to Purcellville on July 9, 1852, and was incorporated in 1908. Many present structures in the town reflect the Victorian architecture of the turn of the century. Located in the western portion of Loudoun County, the town has a total area of 2.6 square miles. Wine production is a thriving industry in this area, with approximately 30 wineries in the region. The Blue Ridge Mountains are just to the west and in good weather are usually visible from town. Recreation includes the WO&D bike trail, the western portion of which ends here. The population of the town was 3,584 as of the 2000 Census and was estimated by the Census Bureau to be 5,309 in 2009.

Town of Clifton

Formerly known as Devereux Station, Clifton became the first town in Fairfax County when it incorporated on March 9, 1902. The population of the town was 185 as of the 2000 Census and was estimated by the Census Bureau to be 216 in 2009.

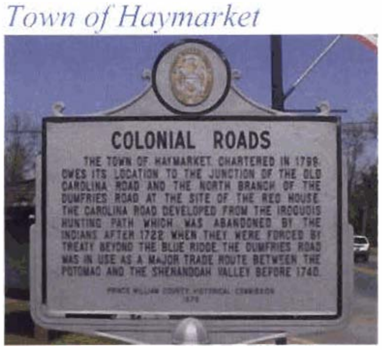
Town of Middleburg

The population of the Town was 632 as of the 2000 Census and was estimated by the Census Bureau to be 976 in 2009. Middleburg is located in Loudoun County and covers approximately 0.6 square miles of land. The population density of the town is 1,083 people per square mile.

Town of Round Hill

Named after the 910 foot hill located just southwest of the town center, and part of the foothills of the Blue Ridge Mountains, Round Hill was incorporated in 1900. The population of the town was 500 as of the 2000 Census and was estimated by the Census Bureau to be 759 in 2009.

Town of Haymarket



Chartered in 1799 by the Virginia General Assembly, the Town of Haymarket was incorporated in 1882. The population of the town was 879 as of the 2000 Census and was estimated by the Census Bureau to be 1,252 in 2009.

Since the 1900s it has been popular for fox hunting and steeple chasing and is also known for its wineries. The town covers 0.5 square miles of land and is located in Prince William County.

Town of Occoquan

Derived from a Dogue Indian word meaning 'at the end of the water,' Occoquan was divided into lots and streets were laid out in 1804 by Nathaniel Ellicott, James Campbell, and Luke Wheeler. The population of the town was 759 as of the 2000 Census and was estimated by the Census Bureau to be 834 in 2009.

Town of Quantico

Located in Prince William County and surrounded by the Marine Corps Base Quantico, the population of the town was 561 as of the 2000 Census and was estimated by the Census Bureau to be 607 in 2009.

B. Geography, Hydrology, and Climate

1. Geography

The Northern Virginia planning region is located at the north-east corner of the Commonwealth of Virginia, lies across the Potomac River from the Nation's Capital, Washington, DC, and is part of the Washington, DC-Maryland-Virginia-West Virginia Primary Metropolitan Statistical Area. Figure 3.1 above is an overview map for the Northern Virginia region including all counties, cities, and towns within the region.

Northern Virginia is made up of the counties of Arlington, Fairfax, Loudoun, and Prince William; the independent cities of Alexandria, Falls Church, Fairfax, Manassas, and Manassas Park; the major towns of Dumfries (Prince William County), Herndon and Vienna (Fairfax County), and Leesburg and Purcellville (Loudoun County); and the smaller towns of Clifton (Fairfax County), Middleburg and Round Hill (Loudoun County), and Haymarket, Occoquan, and Quantico (Prince William County). Figure 3.2 is a base map overview of the Northern Virginia region including all participating county, city, and town jurisdictions, as well as the identification of interstate highways, major roads, major water bodies, and lands outside the authority of participating jurisdictions such as Dulles Airport and U.S. government property.

Northern Virginia is home to numerous Federal government facilities such as the Pentagon, CIA, and U.S. 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 Washington-Dulles International Airport.

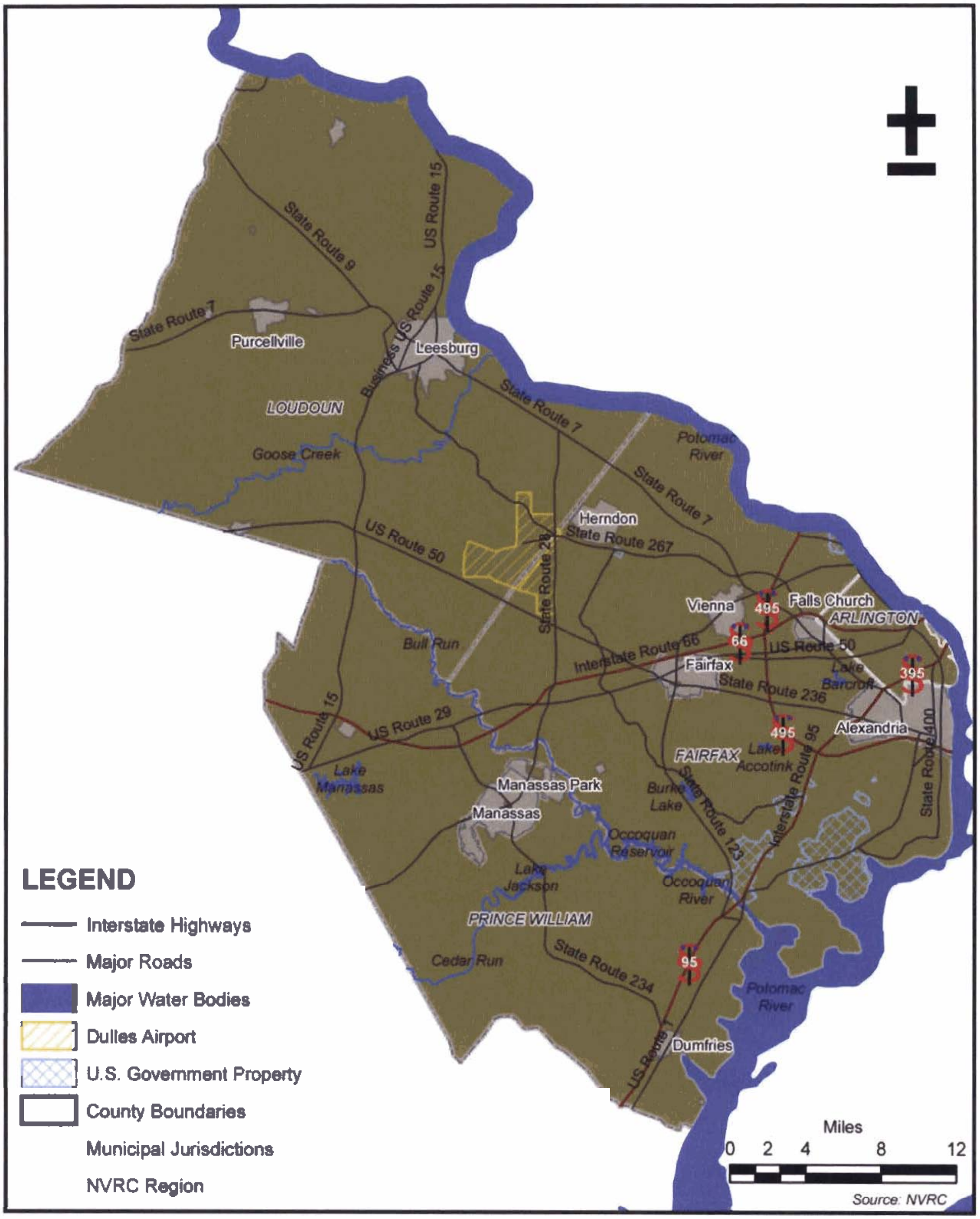


Figure 3.2. Major Features in Northern Virginia
Source: 2006 Northern VA HIRA from Northern Virginia Regional Commission & PBS&J

2. Hydrology

The Northern Virginia Planning District is divided by three physiographic provinces of Virginia: the Coastal Plain, the Northern Piedmont, and the Blue Ridge (Figure 3.3). The Coastal Plain lies roughly east of Interstate 95/395 including the eastern portions of the City of Alexandria, and Fairfax and Prince William Counties. The Northern Piedmont province lies roughly between I-95 and US 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 land area is 1,304 square miles.

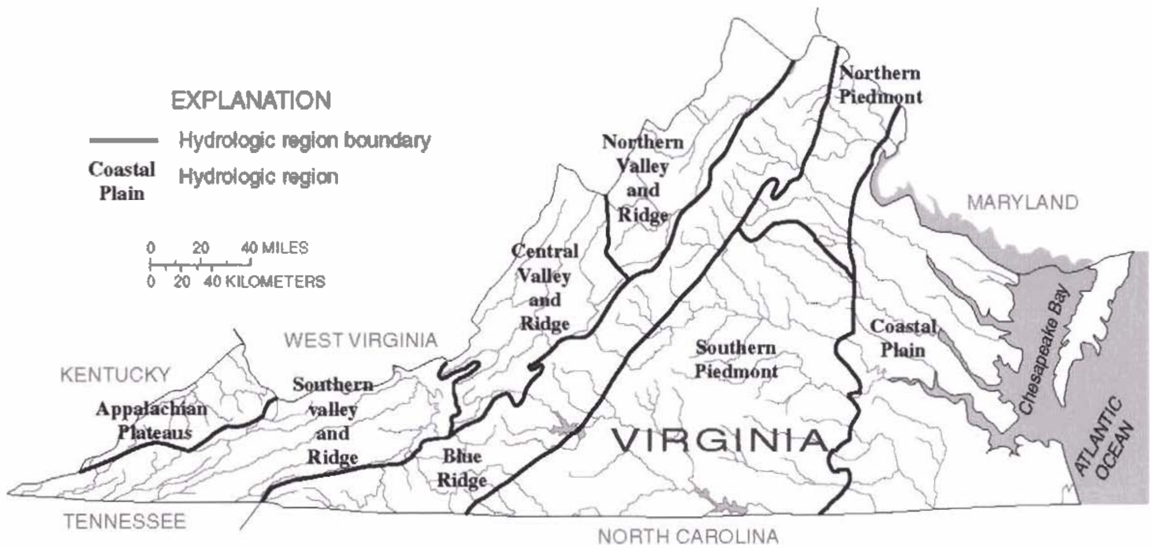


Figure 3.3 Hydrologic Regions of Virginia
Source: U.S. Department of the Interior, U.S. Geological Survey, Fact Sheet 023-01

Northern Virginia lies entirely within the Potomac River watershed. After passing Harper's Ferry, WV, the Potomac forms the border between Maryland and Virginia, flowing in a southeasterly direction. Figure 3.4 provides a general overview of the watersheds in Virginia. The topography of the upper reaches of the basin is characterized by gently sloping hills and valleys. At Great Falls, the stream elevation rapidly descends from over 200 feet to sea level. Eastward of Great Falls, the Basin enters into the Coastal Plain physiographic province. Figure 3.5 illustrates the major physiographic features of Virginia..

3. Climate

The area has a moderate climate. Average temperatures are approximately 50 degrees, and range from January lows in the mid-20s to July highs in the high-80s. Annual rainfall averages above 40 inches and is supplemented with approximately 14 inches of snow.

Climate change is both a present threat and a slow-onset disaster. It acts as an amplifier of existing hazards. Extreme weather events have become more frequent over the past 40 to 50 years and this trend is projected to continue.[1] Rising sea levels, 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 northern Virginia. (see Sea Level Rise Case Study in the Flood section of the HIRA) 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.

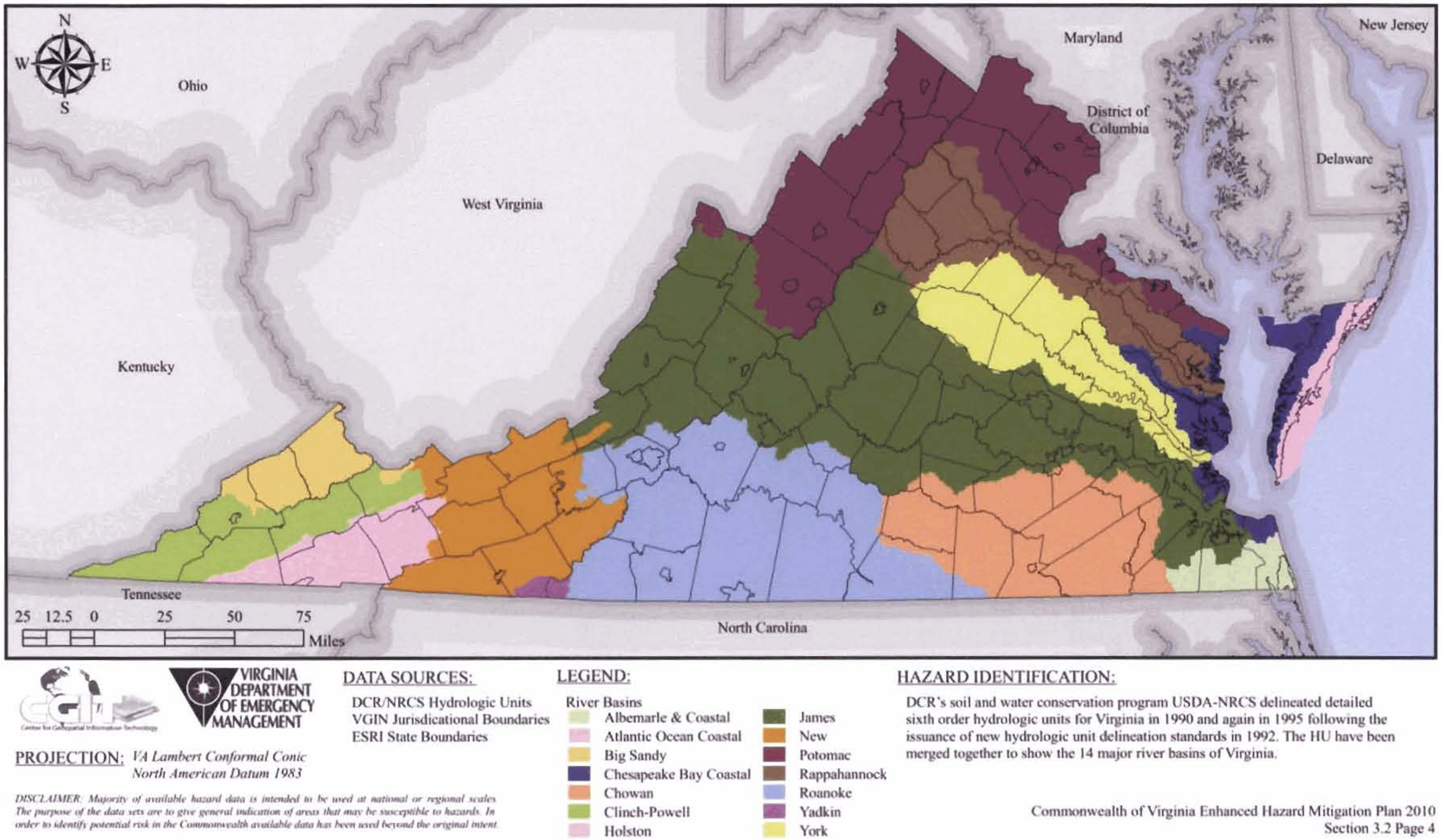
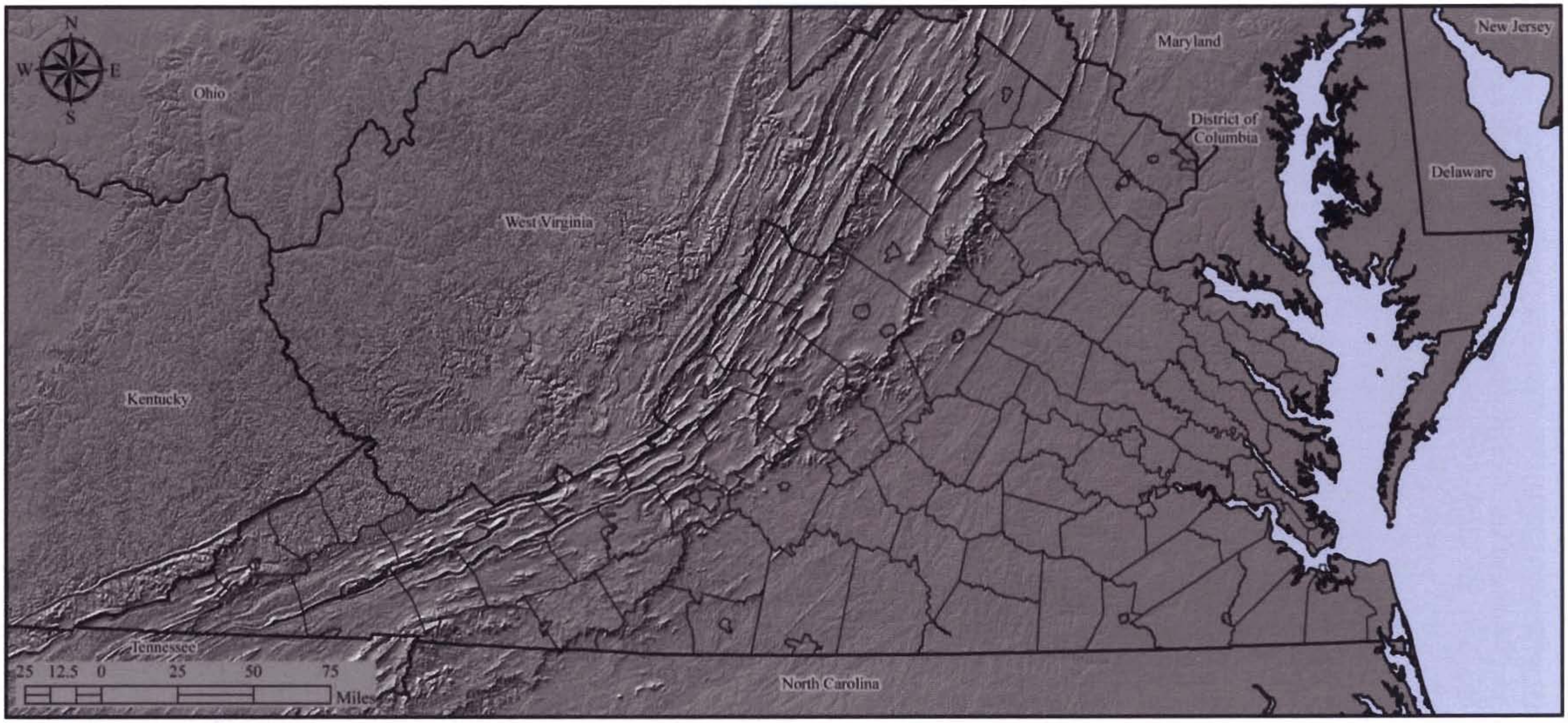


Figure 3.4. Watersheds of Virginia (*Source: Commonwealth of Virginia Emergency Operations Plan HIRA Figure 3.2-2)*



VIRGINIA DEPARTMENT OF EMERGENCY MANAGEMENT

Center for Geospatial Information Technology

DATA SOURCES:
USGS National Map Seamless Server
Shuttle Radar Topography Mission
VGIN Jurisdicational Boundaries
ESRI State Boundaries

LEGEND:
SRTM Hillshade
Mountains
Valleys

PROJECTION: *VA Lambert Conformal Conic*
North American Datum 1983

DISCLAIMER: Majority of available hazard data is intended to be used at national or regional scales. The purpose of the data sets are to give general indication of areas that may be susceptible to hazards. In order to identify potential risk in the Commonwealth available data has been used beyond the original intent.

HAZARD IDENTIFICATION:

The Shuttle Radar Topography Mission (SRTM) is a joint project between NASA and NGA (National Geospatial-Intelligence Agency) to map the world in three dimensions. SRTM data is being used to generate a digital topographic map of the Earth's land surface with data points spaced every 1 arc second for the United States of latitude and longitude (approximately 30 meters).

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Figure 3.5. Shaded Relief of Virginia
(Source: Commonwealth of Virginia Emergency Operations Plan HIRA Figure 3.2-1.)

C. Demographics, Population & Economic Growth

The Washington metropolitan area is projected to experience substantial growth in population, employment, and output over the next 20 years. Proximity to the Nation's capital has been fueling population growth in Northern Virginia for more than 60 years. Since the mid-1930s, when large numbers of Federal workers moved to Washington, DC, during the New Deal and began spilling out into adjoining suburbs, people have been moving into Northern Virginia at an accelerated rate. Like a water faucet turned on and left running, the flow of people has remained vigorous and constant for most of the post-war period.

Today, Northern Virginia is home to over 2 million people. As seen in Table 3.2, demographers are projecting on average, nearly 30,000 newcomers per year through the end of this decade, and approximately 28,000 per year the decade after. By 2020, the population will approach 2.5 million.

Table 3.2 Projected Population Growth in Northern Virginia, 2004-2020 (in millions)

Jurisdiction	2004	2010	2020	2004-2020
Alexandria	134.2	143.9	152.6	18.4
Arlington County	193.2	212.2	233.1	39.9
City of Fairfax	23.3	23.9	26.0	2.7
Fairfax County	1,007.4	1,133.0	1,193.4	186.0
Falls Church	11.2	12.3	14.7	3.5
Loudoun County	241.8	318.1	422.9	181.1
Manassas	37.0	38.0	40.2	3.2
Manassas Park	12.4	15.0	16.5	4.1
Prince William County	344.0	415.3	488.2	144.2
Northern Virginia	**2,004.5**	**2,311.7**	**2,587.6**	**583.1**

Source: Metropolitan Washington Council of Governments, Cooperative Forecasts

The locus of population growth, inexorably pushing outward, is now sweeping across the broad expanse of the outer rim of the Northern Virginia region. This is where the pressure to absorb new metropolitan growth is most intense, and where it will remain concentrated for decades to come. More than 60% of the more than three-quarter million projected newcomers (2000 to 2020) will settle in Prince William and Loudoun Counties.

At the beginning of the 1960s, Northern Virginia was a suburban bedroom community of predominantly middle-class families with children, not dissimilar demographically from hundreds of other places. By the end of the century, it had evolved into a complex blend of urban and suburban influences, an intricate demographic composite formed by the economic growth, transformation, and prosperity of the Washington metropolitan economy, by a rising tide of immigration, aging of the baby boom generation, and other powerful agents of social and demographic change.

A second salient feature of Northern Virginia's demography is the degree of urbanization etched in locality profiles. In many ways, American suburbs have become more urban, as traffic congestion, overcrowding, immigrants, and more diverse homes and lifestyles work their way into suburbia. But urban pressures and forms, while present everywhere, have not impacted suburbia equally. The pressures are more intense, as a general rule, in neighborhoods settled by the first wave of post-war suburbanization, as they age and become part of an expanding urban core.

In Northern Virginia, impacts of urbanization can be observed in the contrasting demographic profiles of close-in and outer-fringe localities. The differences can be traced, primarily, to variations in the affordability, age, and composition of local housing inventories. As types of housing are unevenly distributed across regional and local landscapes, so too is the flow of different population streams as they seek a home in a location and at a price range suitable to their lifestyle, thereby stamping sections of the region with a distinctive demographic coloration. Listed below are some of the major demographic differences found in the close-in and outer-ring suburbs of Northern Virginia.

Northern Virginia Suburbs closest to Washington, DC:
(Primarily in Alexandria, Arlington County, and some inside-the-beltway Fairfax neighborhoods)

- are communities that have changed during the past three decades from conventional family-centered suburbs into new-urban enclaves that, demographically, have become similar to downtown Manhattan, San Francisco, and other U.S. cities
- have become "first-stop" immigrant gateways
- are approaching minority-majority status
- are distinctive and stand out nationally for their high percentage of non-family households, single-person households, childless households, renters, and multi-unit apartment and hi-rise housing (of 50 or more units)
- have among the smallest percentage of school age children, and among the largest percentage of young adults (20 to 35 year old), found anywhere in the U.S.
- average household sizes also are among the smallest in the country
- have high population turnover, people continually moving in and out, with about half of the population replaced every five years
- exhibit evidence of a widening gap between have and have-nots with large numbers at the high end of the income ladder; and large numbers, mainly immigrants and minorities, at the low with very few in the middle.

Outer-ring suburbs of Northern Virginia:
(Primarily in Prince William and Loudoun Counties and parts of Fairfax County)

- are communities that are more traditionally suburban in character
- dominated by families with school-age children, and homeowners who are living in detached single-family houses and townhouses
- have large average household sizes
- have growing foreign-born populations but with socio-economic backgrounds different

from those pouring into the inner core. Outer suburban immigrants, generally, have lived in the U.S. longer, are better educated, are more affluent, and are more likely to live in homes they own

- have fewer poor people, less evidence of a have, have-not divide; many affluent, well educated homes and people; with some pockets of lower income communities but less prevalent than the jurisdictions closer to Washington, DC.

1. Projected Economic Growth

With a gross regional product of nearly $288 billion dollars, the Greater Washington economy is the fourth largest metro market in the United States, and the seventeenth largest in the world. While still relatively strong, the recent downturn has had significant impact on the area's economy. The Department of Labor Statistics reported an unemployment rate of 6.6% for the region in February 2010, as compared to 5.8% in February 2009. Even with the slumping economy, the region's unemployment rate remains considerably lower than the national rate of 9.7%. Looking further ahead, the region is expected to experience continued economic growth. George Mason University's Center for Regional Analysis projects the Washington Metropolitan Area economy (Gross Regional Product) to grow from $352.1 billion in 2010 to $683.7 billion in 2030. The rate of economic growth is nearly double that forecast for New York City or Chicago, but lower than that expected for Dallas-Fort Worth[2].

A few quick facts underscore the strength, performance, and unique structure of its economy, of which Northern Virginia is an important sub-component. Greater Washington:

- is home to the Federal government, the largest purchaser of goods and services in the world. The total value of Federal procurement outlays received by businesses in the National Capital region during fiscal year 2004 was $42.2 billion, up from $12.5 billion in 1990.
- leads the Nation in job growth over the past 20 years, averaging 52,000 new jobs per year, with job growth over the past five years substantially surpassing numbers achieved by other metropolitan areas in the United States. During this time period, the Washington area generated a total of 305,000 new jobs. The next closest metro was Las Vegas, NV, with 150,000 new jobs (about the same number added in Northern Virginia).
  has been significantly outperforming the national economy on most basic indicators of economic activity, (i.e., GRP growth, job growth, unemployment rates).
- has one of the lowest unemployment rates in the country (3.1% in 2004). In 2009, its monthly unemployment rate was the lowest in the Nation, among metro areas, for 11 of 12 months
- is the Nation's third-largest center of bio-science companies; is home to 5,367 associations, the largest concentration in the Nation; and employs more people in technology occupations (76,000) than any other location
- is a top U.S. tourist destination, serving as host to 18.6 million domestic and international visitors in 2002
- is home to a growing list of industries and advanced technologies on the vanguard of innovation. Many of the people and companies building the global communications network, for example, are located here, such as America ONLINE, UUNET

Technologies Inc., PSINet Inc, Lockheed Martin, SPRINT, Comsat, Intelsat, GTE Spacenet, and others.

Northern Virginia is a strong sub-regional component of the larger Washington economy, as are suburban Maryland and the District of Columbia. While all of the sub-regional markets are experiencing job growth, Northern Virginia is significantly outpacing the other two. During the 1990s, for each new job added in Suburban Maryland, Northern Virginia gained two. This decade, the ratio has widened to 2.3 to one. Major employers for manufacturing and non-manufacturing jobs in the Northern Virginia region are shown in Table 3.3.

Table 3.3. Major Employers in Northern Virginia. Source: Virginia Economic Development Partnership (VEDP).

Company	Product/Service	*Estimated Employment*
Manufacturing		
BAE Systems	Aerospace electronic systems	100 - 299
Gannett Company, Inc.	Printing & publishing	1,500 - 2,499
Lockheed Martin Corporation	Electronic components	5,000 - 9,999
Non-Manufacturing		
AOL, LLC	Internet service	2,500 - 4,999
Booz, Allen & Hamilton	Management & technology consulting	10,000+
CACI, Inc.	Computer services	2,500 - 4,999
Computer Sciences Corporation	Information technology services	10,000+
Department of Defense	National security	10,000+
ExxonMobil Corporation	Petroleum products	1,500 - 2,499
Federal Home Loan Mortgage Corp.	Financial services	2,500 - 4,999
General Dynamics Information System	Technology solutions	2,500 - 4,999
George Mason University	Higher education	2,500 - 4,999
INOVA Health System	Health care	10,000+
Northrop Grumman	Professional, scientific, and technical services	5,000 - 9,999
Science Applications International Corp. (SAIC)	Information technology services	5,000 - 9,999
SRA International	Technology solutions	1,000 - 1,499
Verizon Service Corp	Telecommunications	1,000 - 1,499
Wal-Mart Stores, Inc.	Discount retail	2,500 - 4,999

Washington Metro Area Transit Authority	Transit system	1,500 - 2,499

2. Population

According to the U.S. Census Bureau, the population of the Northern Virginia region in 2000 was approximately 1.8 million. The average number of persons per square mile was 1,380, making the region one of the most densely populated in the United States. Table 3.4 shows the total population and population density per square mile, by jurisdiction. As can be seen in the table, the City of Alexandria is the densest jurisdiction while Loudoun County is the least dense. However, when the land comprising Arlington National Cemetery and Regan National Airport are considered, Arlington County is even denser than Alexandria. Figure 3.6 illustrates the distribution of population density, using 2005 estimates, across the region according to census tracts.

Table 3.4. Population Statistics in the Northern Virginia Region, by Jurisdiction (2000)
Source: U.S. Census Bureau

Jurisdiction	Population (April 1, 2000)	2000 Population Density (Square Mile)	2005 Population Estimate	2005 Population Density (Square Mile)	2007 Census Population Estimate	2007 Population Density (Square Mile)
Arlington County	189,453	7,315	197,806	7,573	204,568	7,838
Fairfax County	969,749	2,413	1,036,578	2,550	1,010,241	2,485
Loudoun County	169,599	272	257,240	494	278,797	535
Prince William County	280,813	819	354,039	1,016	360,411	1,034
City of Alexandria	128,283	8,385	138,004	8,955	140,024	9,092
City of Fairfax	21,498	3,467	23,059	3,626	23,349	3,706
City of Falls Church	10,377	5,189	10,648	5,324	10,948	5,474
City of Manassas	35,135	3,514	37,423	3,742	35,412	3,541
City of Manassas Park	10,290	5,717	12,561	5,106	11,426	4,570
Northern Virginia Total	**1,815,197**	**1,357**	**2,067,358**	**1,545**	**2,075,176**	**1,551**

Development Trends, described in the following section, summarize population change for the region. The Risk Assessment Methodology section summarizes the population parameters used in ranking the hazards presented in this report.

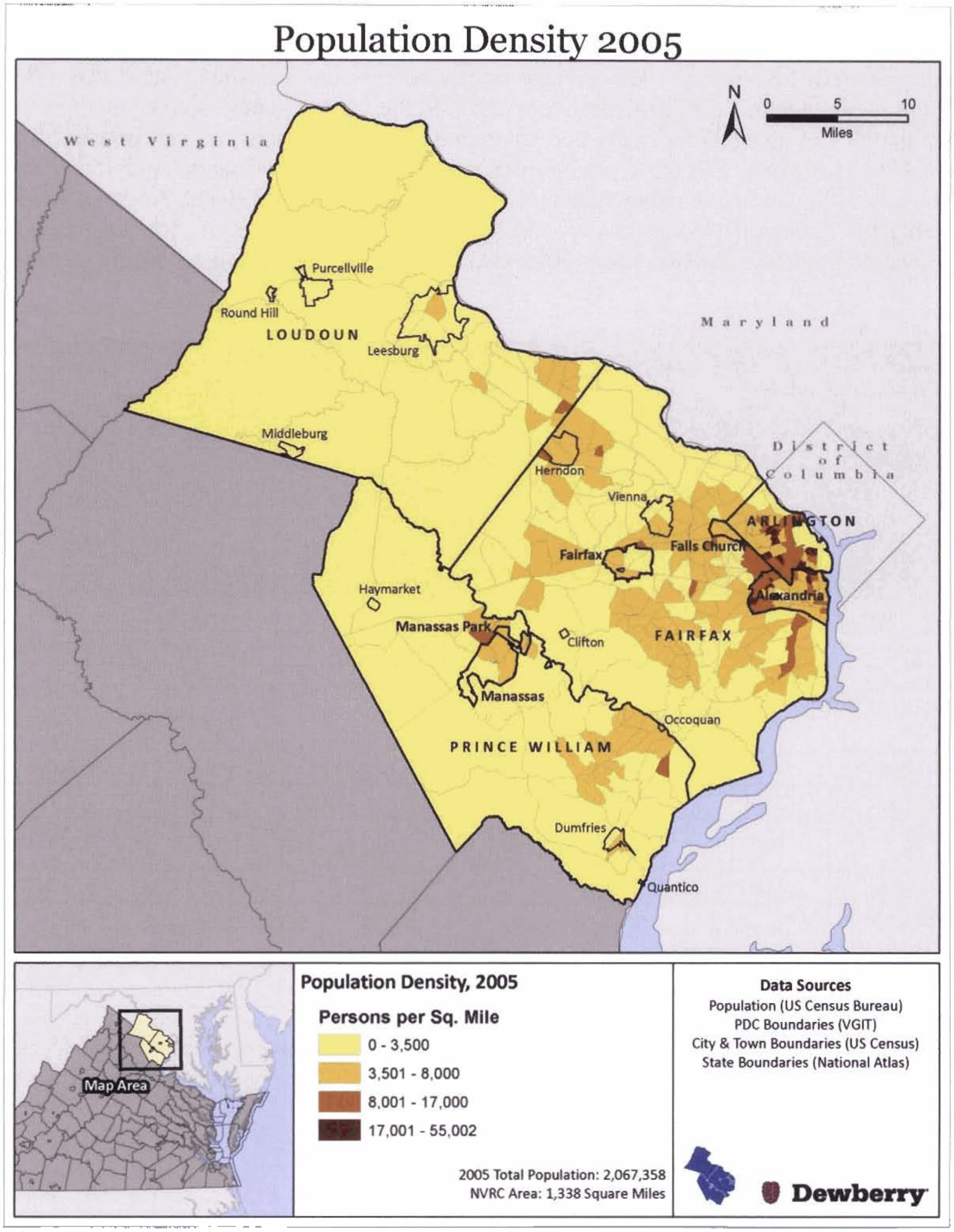

Figure 3.6 Population Density (2005).

3. Housing

A general market inventory of housing in Northern Virginia shows that there is a continual demand for affordable housing, with low vacancy rates throughout the region. Housing demand is being propelled by the highest job growth in the United States.

As tracked by COG, the median sales price of housing has increased 59 percent over the past six years, from $166,548 in 1997 to $265,047 in 2003. Incomes have not been keeping pace with rising housing prices. Between 1998 and 2003, incomes increased by only 17 percent, compared with a housing sales price increase of 59 percent. The Urban Institute estimates that one-quarter of the region's households are carrying unaffordable housing cost burdens. Housing construction has been pushed to outer-ring suburban jurisdictions, where prices still remain somewhat affordable, but savings are counterbalanced to some extent by the increased cost and time of commutes.

D. Land Use, Development, & Zoning

1. Land Use

FEMA requires that State and local mitigation plans evaluate land use and development trends so that mitigation options can be considered in future land-use decisions. Changes in urban and agricultural land cover may help to highlight areas within the State that should be considered in long-term comprehensive plans.

To identify these areas, land cover change was assessed using the National Land Cover Dataset. This dataset is produced by the Multi-Resolution Land Characteristics Consortium (MRLC), a collection of Federal agencies that pool resources to map land cover across the Nation. Using satellite imagery, the MRLC produced datasets for 1992 and 2001 that include 16 land cover classes for various types of urban, agricultural, forested, and other natural areas. It is important to note that the MRLC revised the classification system for 2001. In order to assess change consistently, the 1992 land cover classes were cross referenced to 2001 according to the MRLC 1992-2001 Retrofit Change Product.

The majority of change in Northern Virginia has occurred in forested lands, shown in Table 3.5. From 1992 through 2001, forest land cover has decreased across the region. Each of the four counties experienced decreases, with Fairfax County showing the largest decrease of 23%. Urban land has also decreased in the region, especially in Fairfax County. Loudoun County, however, has witnessed the most urban growth, increasing by 9,838 acres. Agricultural land cover has increased in Fairfax and Prince William Counties, 54% and 17% respectively; while Loudoun County has shown a small decrease of 5%. Figures 3.7 and 3.8 show the distribution of land cover for Northern Virginia.

Table 3.5. National Land Cover Changes 1992 to 2001.

Jurisdiction	Urban Change (Acres)	Forest Change (Acres)	Agricultural Change (Acres)	Wetland Change (Acres)
Arlington County	-628.49	-1,693.09	385.19	146.34
Fairfax County	-16,529.25	-27,808.21	13,700.61	-1,425.55
Town of Herndon	-84.73	-228.18	-72.06	-28.91
Town of Vienna	-688.53	-274.21	111.2	9.56
Town of Clifton	-43.59	-12.23	24.24	1.33
Loudoun County	9,838.96	-17,791.12	-8,349.58	72.95
Town of Leesburg	1,596.13	-1,517.62	-1,259.64	-15.12
Town of Purcellville	215.95	-160.57	-489.49	0
Town of Middleburg	-27.8	-37.14	-52.93	0
Town of Round Hill	22.68	-38.25	-56.49	-3.11
Prince William	-1,350.38	-16,364.01	8,406.07	840.43
Town of Dumfries	-65.61	14.9	12.45	-41.37
Town of Haymarket	-44.92	4.67	-45.59	3.78
Town of Occoquan	-17.57	-4.23	-4.89	1.56
Town of Quantico	-2.67	-2.22	6.23	-3.78
Alexandria	-211.27	-695.65	-62.49	-39.14
Fairfax City	-555.1	-640.05	245.75	23.57
Falls Church	-288.89	-48.93	20.02	-0.44
Manassas	-231.29	-294.45	-328.03	10.01
Manassas Park	-121.65	-86.73	31.36	-1.33
Total	***-9,218.03***	***-67,677.32***	***12,221.91***	***-449.24***

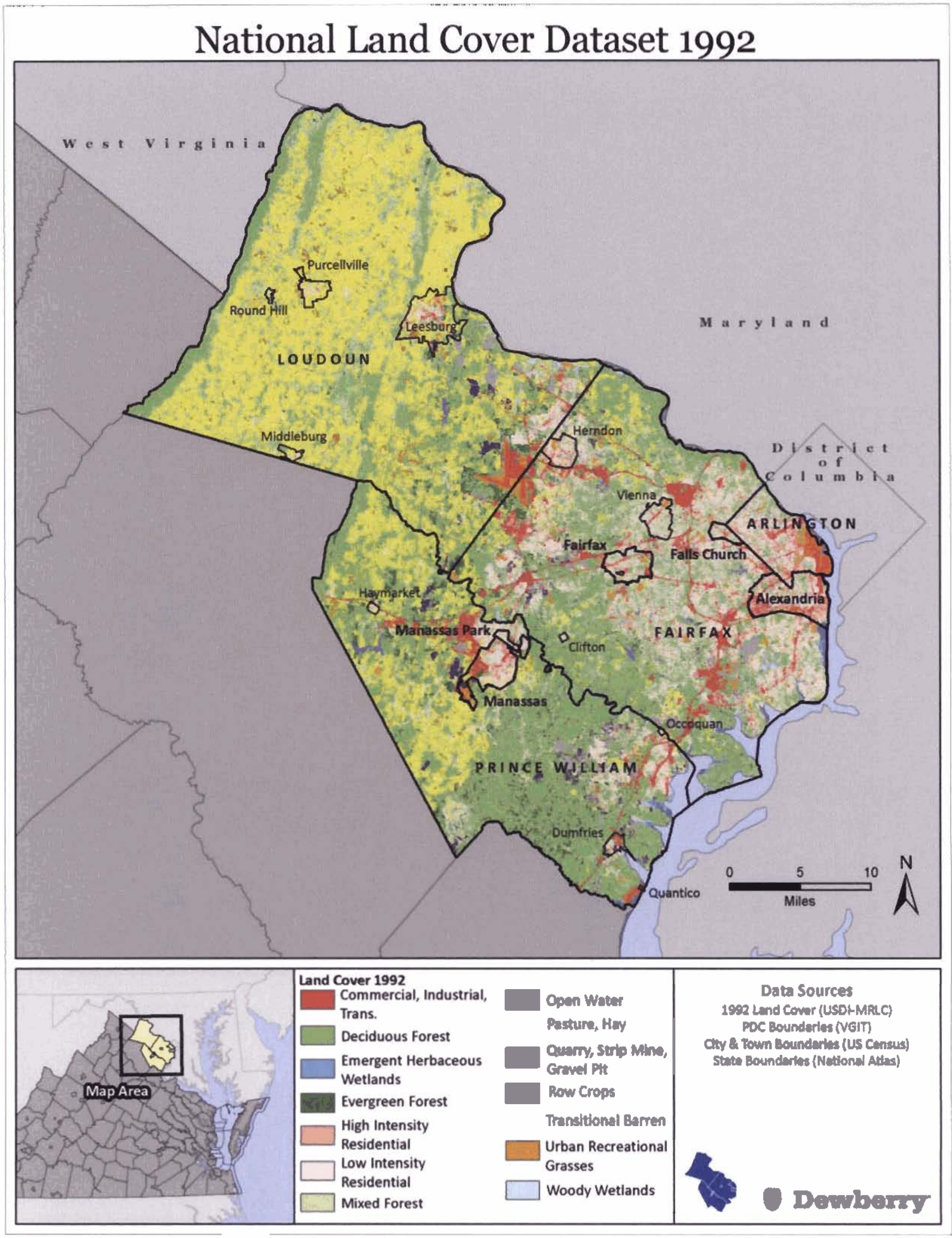

Figure 3.7. 1992 Land Cover categories.

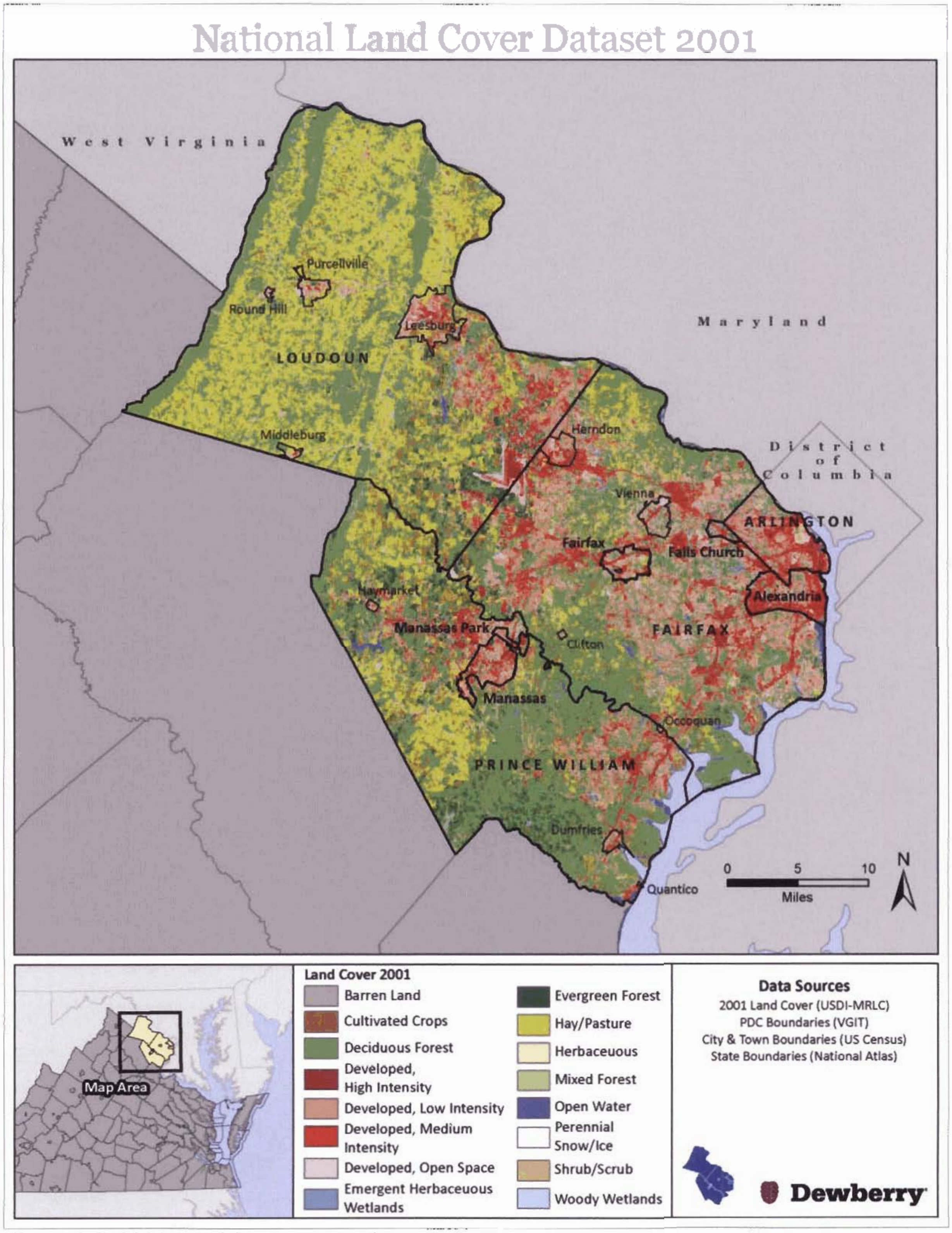

Figure 3.8. 2001 Land Cover categories.

2. Development Trends

A general analysis of land uses, development trends, and zoning within the planning area is an important factor in formulating mitigation options that influence future land use and development decisions. In many cases, local development policies greatly influence the degree of future vulnerability in communities across the region. The vulnerability of future buildings, infrastructure, and critical facilities is a great concern to community leaders across the Northern Virginia region and, as discussed in the Capability Assessment section, many of the day-to-day activities in local governments in the region are designed to deal with these challenges.

One of the most critical indicators to review in considering local development trends is population growth. The average rate of population change in the Northern Virginia region from 2000 to 2009 was 24.6 percent, which is significantly higher than the average growth rate for the State of Virginia during this same time period (11.4 percent). Table 3.6 shows the breakdown of population growth rates, by jurisdiction. As can be seen in the table, Fairfax County has the highest population in the region (1,036,473 people) while Loudoun County experienced the highest growth rate based upon percent change (75.78%). The region as a whole has experienced a 19% growth in the past nine years and accounts for over a quarter of the Commonwealth's total population.

Total population and population density have been used in the risk assessment ranking methodology. Refer to the Risk Assessment and Methodology section for more details on these ranking parameters.

Table 3.6. Northern Virginia Population Change (2000 – 2009).

Jurisdiction*	2000 Census (April 1, 2000)**	Provisional 2009	Percent Change
Arlington County	189,453	212,038	11.92%
Fairfax County	969,749	1,036,473	6.88%
Town of Herndon	21,655	22,579	4.27%
Town of Vienna	14,453	15,215	5.27%
Town of Clifton	185	216	16.76%
Loudoun County	169,599	298,113	75.78%
Town of Leesburg	28,311	40,927	44.56%
Town of Purcellville	3,584	5,309	48.13%
Town of Middleburg	632	976	54.43%
Town of Round Hill	500	759	51.80%
Prince William County	280,813	386,934	37.79%
Town of Dumfries	4,937	4,954	0.34%
Town of Haymarket	879	1,252	42.43%
Town of Occoquan	759	834	9.88%
Town of Quantico	561	607	8.20%

Table 3.6. Northern Virginia Population Change (2000 – 2009).			
Jurisdiction*	**2000 Census (April 1, 2000)****	**Provisional 2009**	**Percent Change**
City of Alexandria	128,283	141,738	10.49%
City of Fairfax	21,498	24,702	14.90%
City of Falls Church	10,377	11,711	12.86%
City of Manassas	35,135	36,213	3.07%
City of Manasss Park	10,290	14,026	36.31%
Northern Virginia Total	**1,815,197**	**2,161,948**	**19.10%**
VIRGINIA TOTAL	**7,079,030**	**7,882,590**	**11.35%**

*Town estimates are accounted for in County Totals. Town estimates are from the US Census Bureau June 2010

**Included all official corrections to the 2000 Census counts.
Source: Weldon Cooper Center for Public Service www.coopercenter.org/demographics

3. Zoning

Zoning is also a critical indicator to review in considering local development trends. Zoning Geographic Information Systems (GIS) data was provided by the majority of the jurisdictions participating in the plan update. The following section summarizes the results of this data. In some cases, zoning generalizations were made in order to compare the jurisdictions to each other. In all of the jurisdictions, residential zoning is by far the largest classification, often followed by commercial.

Fairfax County has five zoning categories; residential zoning occupies approximately 82% of the total area of the county followed by planned units (12%). Commercial and Industrial make up 6% of the county land area.

Arlington County has 28 zoning classifications. Close to 44% of the land area zones are considered One-Family Dwelling Districts, and 30% is in the Special District. In order to compare to the other jurisdictions, the classifications were grouped into commercial, industrial, residential, and other. This resulted in 61% residential, 31% other, 7% commercial, and less than 1% is industrial based on land area.

The City of Alexandria has 32 zoning classifications. The residential single family zone on an 8,000 square foot lot represents the largest category with over 14% of the land area of the city. The coordinated development district represents almost 12% of the land area. In order to compare to the other jurisdictions, the classifications were grouped into commercial, industrial, residential, and other. This resulted in 58% residential, 24% commercial, 15% other, and less than 3% industrial based on land area.

The City of Falls Church has 13 zoning classifications; low density residential represents the largest category with 48% of the land area of the city and medium density residential represents 18% of the land area. In order to compare to the other jurisdictions, the classifications were grouped into commercial, industrial, residential, and other. This resulted in 76% residential, 14% commercial, 8% industry, and less than 3% other (or transitional) based on land area.

The City of Fairfax has 16 existing zoning classifications; residential single detached represents the largest category with 45% of the land area of the city, and open space recreation and historic presents 11% of the land area. In order to compare to the other jurisdictions, the classifications were grouped into commercial, industrial, residential, institutional, and other. This resulted in 55% residential, 14% commercial, 19% other, 9% institutional, and approximately 3% other based on land area.

The City of Fairfax also provided Future Zoning categories. Based on this information, the city has 14 future zoning classifications; residential low is the largest category with 34% of the land area of the city; business commercial represents 12% of the land area. In order to compare to the other jurisdictions (and existing zoning of the city), the classifications were grouped into commercial, industrial, residential, institutional, and other. This resulted in 55% residential, 12% commercial, 8% institutional and approximately 3 percent other based on land area. It appears that the future zoning for the city will result in a slight decrease in the commercial and institutional categories.

4. Transportation

Northern Virginia and the Washington, DC, metropolitan area is served by an extensive transportation network. There are 12 interstates and 42 highways in the Northern Virginia region. Transportation within the Northern Virginia region is primarily dependent upon a network of major highways (VA Rt. 7, I-66, US50, US29/211, I-95/395, and US1) that radiate out from the urban core (Washington, DC, Arlington, and Alexandria); one major circumferential highway (I-495/95, the Capital Beltway); and other primary cross-county roads such as the Fairfax County Parkway and the Prince William Parkway. Figure 3.1 above provides the major overview of the highways and interstates in the planning region.

The Washington Area's Metro primarily serves the inner localities with 11 stations in Arlington County, four stations in the City of Alexandria, and five stations in Fairfax County. The Virginia Railway Express (VRE) commuter rail system serves communities to the west, cutting through central Fairfax County to the cities of Manassas and Manassas Park, and to the south in eastern Prince William County continuing to the City of Fredericksburg. Several bus systems (Metrobus, Alexandria's DASH, Arlington's ART, Falls Church's George, Fairfax County's Connector, Fairfax City's CUE, and Prince William's PRTC/Omniride) provide service throughout the region.

Commercial air service includes the Ronald Reagan Washington National Airport and Washington Dulles International Airport. Figure 3.2 shows the location of the airports in the planning region.

Nevertheless, these transportation systems are being strained by the growing population, housing, and employment patterns. From 1982 to 1997, population increased by 28.3%, but vehicle miles traveled grew by 81.5%, according to the Texas Transportation Institute. Between 1990 and 2000, the length of the average one-way, home-to-work commute increased from 28.2

minutes to 31.7 minutes, and this number has risen further since 2000. Workers are leaving home earlier and coming home later to make up the time that it takes to get where they need to go.

The Texas Transportation Institute 2005 Urban Mobility Report shows the Metropolitan Washington region ranks as follows:

- Number 3 in average hours lost sitting in traffic (69 – 3 hours more than previous year).
- Number 3 in congestion cost per commuter ($1,669 – $80 more than previous year).
- Number 4 in excess fuel consumed per commuter due to congestion (42 gallons/year – 2 gallons more than previous year).
- Number 5 in total excess gallons of fuel consumed due to congestion (88 million gallons – 4 million more than previous year)
- Number 7 total regional congestion cost ($2.465 billion/year – $209 million more than previous year).
- Number 7 in total delay due to congestion (145 million hours/year – 9 million more than previous year). Total Delay due to congestion rank changed from #8 to #7 - worsened.

Transportation systems are key in providing effective emergency response, but can also influence the impact of natural disasters. This can be a particularly crucial issue in Northern Virginia due to the high levels of traffic congestion. In addition to more immediate needs, businesses and employees suffer economic consequences when roads are closed due to natural disasters.

Day to day traffic reports frequently report accidents or simply high volume levels that may bring a particular highway to a standstill. The attack on the Pentagon on September 11, 2001, Hurricane Isabel in 2004, and normal winter storms bring the regional highway system to a stop and taxes the transit system to the limits.

Northern Virginia, the Commonwealth of Virginia, and the metropolitan area as a whole are actively addressing transportation through significant updates in regional plans; expansion of transit to areas such as Tysons Corner, Reston, and Dulles Airport; and introduction of operational measures such as HOT lanes (charging tolls on high occupancy vehicle lanes) to address congestion. However, under present development scenarios, Northern Virginia is expected to experience funding shortages for its transportation needs in the tens of billions of dollars in the next 25 years.

E. Northern Virginia Populations at Risk

In the context of hazard mitigation and emergency management, when assessing populations at risk, a group's "vulnerability" is broadly defined as the potential for increased harm or loss by the emergency or disaster. This applies to people, property, and land area. Risk to people is termed 'social vulnerability' by one of the most highly respected models for risk assessment, the Social Vulnerability Index created by Cutter et al (2003). It describes pre-event population vulnerability based on the characteristics and geographic location of people grouped using U.S. Census demographic categories and measurement units (tracts and blocks). Using a method such as the Social Vulnerability Index used during the Northern Virginia Hazard Mitigation planning process allows emergency managers a "first look" at populations at the highest risk due to characteristics that amplify their risk. Following further examination of population trends and specific community needs, local emergency management departments can then direct appropriate preparedness, response, recovery, and mitigation planning and program delivery to specific communities to help them better prepare for and recover from disaster.

Over the past decade, members of academia have researched and validated how to quantify and measure risk, or "social vulnerability," which can prove difficult as most of the variables that factor into risk assessment applied to segments of society are qualitative rather than quantitative. Such an analysis can help a community increase communication approaches to different members of the community through the most appropriate communication networks.

The analysis used in the 2010 Northern Virginia Hazard Mitigation Plan update closely follows a national model and method presented in the peer-reviewed and published article Cutter et al (2003)[3], a groundbreaking study that defined and quantified the measures of social vulnerability. The Social Vulnerability Index has been slightly altered for the Northern Virginia analysis to accommodate available data. The analysis was conducted using data from the 2000 Census as the best available data for this study. *It should be noted, it was necessary to rely upon the 2000 Census because the plan is regional, and updated, consistent population data across all metrics was not uniformly available for each of the 20 participating jurisdictions within the Northern Virginia planning region. Changes in population numbers since that time should be considered when analyzing the results.*

Dewberry performed this analysis to confirm that the rich diversity of Northern Virginia presented differing challenges. This analysis is meant to provide the first regional assessment of population demographics viewed in terms of specific Census-defined groups and their relative risk to natural and human-caused hazards due to various comparative societal factors. The results must be viewed through a sharper interpretive lens by the Northern Virginia Emergency Managers who have intimate knowledge of their jurisdiction. This information is provided to begin the conversation about populations at risk; it is recommended that resources be obtained to continue a more detailed assessment once the 2010 Census data, American Community Survey, and updated U.S. Department of Agriculture (USDA) Land-Use Cover Data set becomes available in 2011. An understanding of local conditions must be applied when interpreting the results of the analysis.

The Northern Virginia analysis was performed at the Census tract level to provide insight into regional population trends. A total of 330 tracts were included in the analysis. It should be noted, the 2010 U.S. Census and American Community Survey categories will not change from those used in the 2000 Census available for this analysis. Census questionnaire answers are "self-determined" by each respondent, so they can be biased due to a variety of factors.

There were eight major factors that influenced social vulnerability when analyzing the 30 Social Vulnerability variables for Northern Virginia, as determined by the Cutter et al article. It is important to understand that to the extent that areas in Northern Virginia have social vulnerability, these were the factors that influenced that vulnerability through the analysis. It is also important to note that most factors are largely influenced by multiple variables and that the name assigned to each factor is not necessarily reflective of one single variable, but rather the most dominant variables listed.

The eight factors were:

1. Socio-economic status;
2. Wealth;
3. Elderly populations;
4. Female heads of Large Households in densely populated areas;
5. Rural areas;
6. Female labor force;
7. Asian Population (as defined by the U.S. Census Bureau); and
8. Households living in Manufactured Housing.

The Region at a Glance

The main contributors to the region's vulnerability score provided a lens through which to begin to understand statistically-based indicators of factors which contribute to public risk. However, analysis of 2010 Census data overlaid with local knowledge of communities and societal groups is necessary to more precisely identify those most vulnerable to emergencies, hazard events, or disasters. However, the analysis did provide some interesting and relevant trends that guided the Northern Virginia MAC and participating jurisdictions in creating new mitigation strategies, such as:

- Assess growth and land use during the 2000 – 2010 decade to determine whether rapid suburban expansion in the Sterling to Purcellville and Manassas corridors has challenged emergency preparedness, response, and mitigation communication in specific demographic terms for new residents – immigrant, elderly (Leisure World complex east of Leesburg), and others.
- Expand code requirements to require redundant mechanical systems, especially in communities targeted at retirees.
- Design and build new schools to serve as community shelters.
- Assess if an under-assessed Hispanic service and farm labor force is at risk due to limited communication pathways.
- Determine whether school systems that rapidly expanded during the past 20 years have adequate natural hazard monitoring systems (tornado, winter storm, severe storm); are plans in place and exercised to ensure appropriate school closures or sheltering-in-place.
- Consider new multi-household housing units, especially for elderly, to have on-site generators for power redundancy.

  Work with Cooperative Extensive Service/USDA agencies and Loudoun and Prince William Soil and Water Conservation Districts to determine if agricultural land owners have special hazard mitigation challenges regarding power outages and livestock feeding, access. etc.
- Determine most effective emergency management and hazard mitigation notification communication networks to reach military and immigrant communities who are not familiar with the area.
- Verify that targeted elderly populations can be reached through redundant communication networks.
- Work with advocates for elderly populations to consider education and outreach for seniors to facilitate personal disaster preparedness plans.
- Develop and distribute homeowner hazard mitigation tool kits to property owners that focus on easy mitigation actions homeowners can take.

Provide multi-language hazard mitigation tool kits through community churches and other organizations.
Work with landlords to distribute multi-cultural hazard mitigation information to renters, as appropriate, regarding renter's insurance, what to do in an emergency, etc.

Analysis Challenges

One of the great challenges in emergency management and all government support services to residents in the Northern Virginia region that is not fully captured by this vulnerability analysis, is the richness of the immigrant population. For example, children in Arlington County schools speak more than 120 languages and come from homes where English is the secondary language. While the Asian population, which includes many of Middle Eastern and Indian origin (as defined by the U.S. Census), is significant, the communication and cultural understanding challenges are the same for someone of any non-American origin.

Another significant challenge in this analysis is the use of 2000 Census data. It is obvious that the region has experienced great socio-economic, population, and land-use changes during the period from 2000-2010 which are not reflected in this analysis. This analysis used the 2000 Census tract data because more recent data was not uniformly available for each jurisdiction in the region. Further demographic and cultural analysis should be considered once 2010 data sets are available to provide a more current snapshot of the region. However, the trends shown in this analysis are worth consideration in planning emergency management communication, emergency sheltering, and other support programs.

It is vitally important to realize that the Census is determined by how those who responded characterized themselves. It is highly probable that someone from India or of Indian descent did categorize themselves as Native American Indian. Also, it is impossible to fully characterize the richness of the Northern Virginia area in the relatively narrow terms of the U.S. Census, so someone that is characterized as Caucasian may be a recent immigrant with multiple challenges in terms of being prepared for disasters or knowing how to mitigate against natural or human-caused hazards. However, since "Asians" did show as an indicator of populations at risk for this particular region, the term can be used as a placeholder for multiple immigrant communities as the challenges are not exclusive to just residents of Asian origin or descent.

As Census 2010 and other data sets emerge, it will become increasingly apparent that Northern Virginia is experiencing change based on factors which attract thousands of new residents to the area annually. Many of the desirable factors that attract businesses and people to the area present the greatest challenges to Northern Virginia Emergency Managers and cause significant hazard mitigation challenges including: growth, dense populations, over-taxed transportation routes, communication, and knowledge of how to mitigate vulnerable buildings and prepare for disasters.

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Chapter 4: Regional Hazard Identification and Risk Assessment (HIRA)

***Requirement §201.6(c)(2):** The plan shall include a risk assessment that provides the factual basis for activities proposed in the strategy to reduce losses from identified hazards. Local risk assessments must provide sufficient information to enable the jurisdiction to identify and prioritize appropriate mitigation actions to reduce losses from identified hazards.*

I. Introduction

The 2006 planning area for this study included the unincorporated areas of Arlington, Fairfax, Loudoun, and Prince William counties; the Cities of Alexandria, Fairfax, Falls Church, Manassas, and Manassas Park; and the Towns of Herndon, Vienna, Leesburg, Purcellville, and Dumfries. The 2010 update to the plan was expanded to include several additional jurisdictions. This update includes:

Counties
Arlington County
Fairfax County
Loudoun County
Prince William County

Cities
City of Alexandria
City of Fairfax
City of Falls Church
City of Manassas
City of Manassas Park

Towns
Town of Clifton
Town of Dumfries
Town of Haymarket
Town of Herndon
Town of Leesburg
Town of Middleburg
Town of Purcellville
Town of Occoquan
Town of Quantico
Town of Round Hill
Town of Vienna

Although some anecdotal information may be included regarding the villages and towns located within these counties, these areas are not fully included in this study due to the lack of data available. For the purpose of simplicity, the study area will be referred to as the Northern Virginia planning area throughout the remainder of this chapter.

The MAC is made up of public representatives, private citizens, businesses, and organizations and was brought together to provide input at key stages of the hazard identification and vulnerability assessment process. Efforts to involve county, city, and town departments and community organizations that might have a role in the implementation of mitigation actions or policies included invitations to attend meetings and serve on the MAC, e-mails of minutes and updates, and opportunities for input and comment on all draft deliverables. Additional information on how this chapter was developed in coordination with the MAC is available in the Planning Process Chapter.

The purpose of this section of the plan is to:

1) Identify the natural hazards that could affect the Northern Virginia planning area;

2) Assess the extent to which the area is vulnerable to the effects of these hazards; and
3) Prioritize the potential risks to the community.

The first step, identifying hazards, will assess and rank all the potential natural hazards in terms of probability of occurrence and potential impacts. It will also identify those hazards with the highest likelihood of significantly impacting the community. This section will be completed based on a detailed review of the planning area hazard history. The 2010 update evaluated and reviewed the 2006 ranking and it was decided by the steering committee to expand the ranking and better align it with the Commonwealth of Virginia's methodologies.

The hazards determined to be of the highest risk are analyzed further to determine the magnitude of potential events, and to characterize the location, type, and extent of potential impacts. This will include an assessment of what types of development are at risk, including critical facilities and community infrastructure. Finally, a prioritization of the risk to the planning area was compiled, to serve as an overall guide for the communities when planning development, implementing policy, and identifying potential mitigation measures.

The 2010 update to this plan included the review, revision, and reformatting of the 2006 HIRA. The foundation of the 2006 hazard identification remained valid with the additional communities added to the analysis.

II. Data Availability and Limitations

This study includes data collected from a variety of resources including local, State, and national datasets. Whenever possible, data has been incorporated into a GIS to aid in analysis and to develop area-wide maps for depicting historical hazard events, hazard areas, and vulnerable infrastructure. Critical facility data has been collected from the FEMA loss estimating module, Hazards U.S. ($HAZUS^{MH}$), and has been supplemented, to the extent possible, by local data. The local data provided is summarized below in the Building Inventory & Local Critical Facility Data section.

In accordance with FEMA mitigation planning guidance, the results of this study are based on the best available data. In most cases, detailed data regarding the structural characteristics of facilities does not exist in a usable format. Recognizing this deficiency in detailed local data, the strategy developed as part of the full mitigation plan will address these needs by recommending specific measures to increase the level of detail of data to prepare usable and effective hazard assessments. By enhancing the building inventory, a greater level of vulnerability analysis, and consequently risk assessment, will be possible. The Northern Virginia Regional Planning Commission (NVRC) and individual jurisdictions should actively pursue funding for this strategy.

Local Critical Facility and Building Data
Building inventories were provided by the jurisdictions participating in this plan. In most cases, the building inventory captures only the location and shape of structures. Characteristics such as structure and construction type, (i.e., residential wood frame home) are not recorded. This data was utilized to determine the risk to buildings based on the extent of known hazard areas that can

be spatially defined through GIS technology. Hazards without known recurrence probabilities or mapped hazard extents are not deemed unique enough to make definitive risk and vulnerability assessments for potentially at-risk buildings or facilities that differentiate them from other areas of the region. The hazard specific sections provide the analysis, if relevant, for the critical facilities and buildings at risk. Table 4.1 summarizes local building inventories per jurisdiction.

Table 4.1. Local Building Inventory per Jurisdiction

Jurisdiction	Number of Buildings
Arlington County	42,866
Fairfax County	231,412
Town of Clifton	143
Town of Herndon	4,175
Town of Vienna	6,224
Loudoun County	82,519
Town of Leesburg	9,754
Town of Purcellville	3,148
Town of Middleburg	574
Town of Round Hill	464
Prince William County	141,579
Town of Dumfries	1,739
Town of Haymarket	554
Town of Occoquan	274
Town of Quantico	228
City of Alexandria	41,158
City of Fairfax	7,986
City of Falls Church	4,602
City of Manassas	8,024
City of Manassas Park	4,152

Local critical facility and infrastructure data were provided in some form by each jurisdiction. However, a comprehensive inventory consistent across jurisdictions does not exist because there is no universally accepted definition of what constitutes critical facilities and infrastructure, nor is one associated with FEMA and DMA 2000 planning requirements. For purposes of this plan, critical facilities and infrastructure are identified as "*those facilities or systems whose incapacity or destruction would present an immediate threat to life, public health, and safety, or have a debilitating effect on the economic security of the region.*" This includes the following facilities and systems based on their high relative importance for the delivery of vital services, the protection of special populations, and other important functions in the Northern Virginia region:

- Emergency Operations Centers (EOCs);
- Hospitals and medical care facilities;
- Police stations;

- Fire stations;
- Schools (particularly those designated as shelters);
- Hazardous material facilities;
- Potable water facilities;
- Wastewater facilities;
- Energy facilities (electric, oil, and natural gas); and
- Communication facilities.

In preparing the inventory of critical facilities for the Northern Virginia region, each participating jurisdiction was asked to submit best available GIS data layers for their primary critical facilities to be used in combination with HAZUS^{MH} inventory data. This resulted in the identification of hundreds of critical facilities for the Northern Virginia region. It is understood that this listing is incomplete due to data limitations associated with both the local GIS and HAZUS^{MH} inventories, but that further enhancements to the data will be made over time and incorporated during future plan updates. When analysis for critical facilities was performed, both the local and HAZUS^{MH} summary results are presented in the hazard specific sections. Additional information about the data sources behind the HAZUS^{MH} stock inventory may be found by following this link: http://www.fema.gov/plan/prevent/hazus/hz_database.shtm.

During the 2010 update, each of the localities was provided a data matrix to assist them in compiling local data. The Data Matrix found in Appendix D1 contains the populated data matrices for localities that provided data during the data collection phase of this update. Table 4.2 summarizes the main critical facility types provided. Figures 4.1 through 4.4 show the provided critical facility locations within each of the jurisdictions.

Prince William County and the Cities of Manassas and Manassas Park did not provide critical facility data in GIS format for the plan update. In each of the hazard sections, the analysis for critical facilities was performed with both local data and HAZUS^{MH} data to ensure each locality is represented in the hazard risk assessments.

Arlington County provided several different types of critical facilities that are represented in Table 4.2. The remaining jurisdictions in the planning region provided the basic critical facility categories of EOCs, Schools, Police Stations, Fire Stations, Hospitals, and Nursing Homes. For consistent analysis across the region, these six critical facility categories were used for the hazard specific analysis.

Fairfax County provided an update to their critical facility inventory at the end of the planning process; these changes have not been reflected in the HIRA analysis or maps, only in the table below.

The names and information for the HAZUS^{MH} and local critical facilities in the hazard risk zones are available in Appendix D2 Critical Facility-Risk.

Table 4.2: Jurisdiction-provided critical facilities.

Jurisdiction	EOCs	Schools	Police	Fire Station	Fire Dept.	Hospital	Nursing Homes	TOTAL
Arlington County	5	34	1	10	2	2	15	**69**
Fairfax County	2	257	26	36	2	19	157	**499**
Town of Herndon	-	7	1	1	-		-	**9**
Town of Vienna	-	8	1	1	-	1	-	**11**
Town of Clifton	-	-	-	1	-		-	**1**
Loudoun County	-	62	-	-	-	1	-	**63**
Town of Leesburg	-	17	-	-	-	1	-	**18**
Town of Purcellville	-	4	-	-	-	-	-	**4**
Town of Middleburg	-	1	-	-	-	-	-	**1**
Town of Round Hill	-	-	-	-	-	-	-	**0**
Prince William County	-	-	-	-	-	-	-	**0**
Town of Dumfries	-	-	-	-	-	-	-	**0**
Town of Haymarket	-	-	-	-	-	-	-	**0**
Town of Occoquan	-	-	-	-	-	-	-	**0**
Town of Quantico	-	-	-	-	-	-	-	**0**
City of Alexandria	**	28	1	9		1	7	**46**
City of Fairfax*	-	3	5	-	-	1	-	**9**
City of Falls Church**	-	-	1	-	-	-	-	**1**
City of Manassas	-	-		-	-			**0**
City of Manassas Park					-			**0**
Total	**7**	**421**	**36**	**58**	**4**	**26**	**179**	**731**

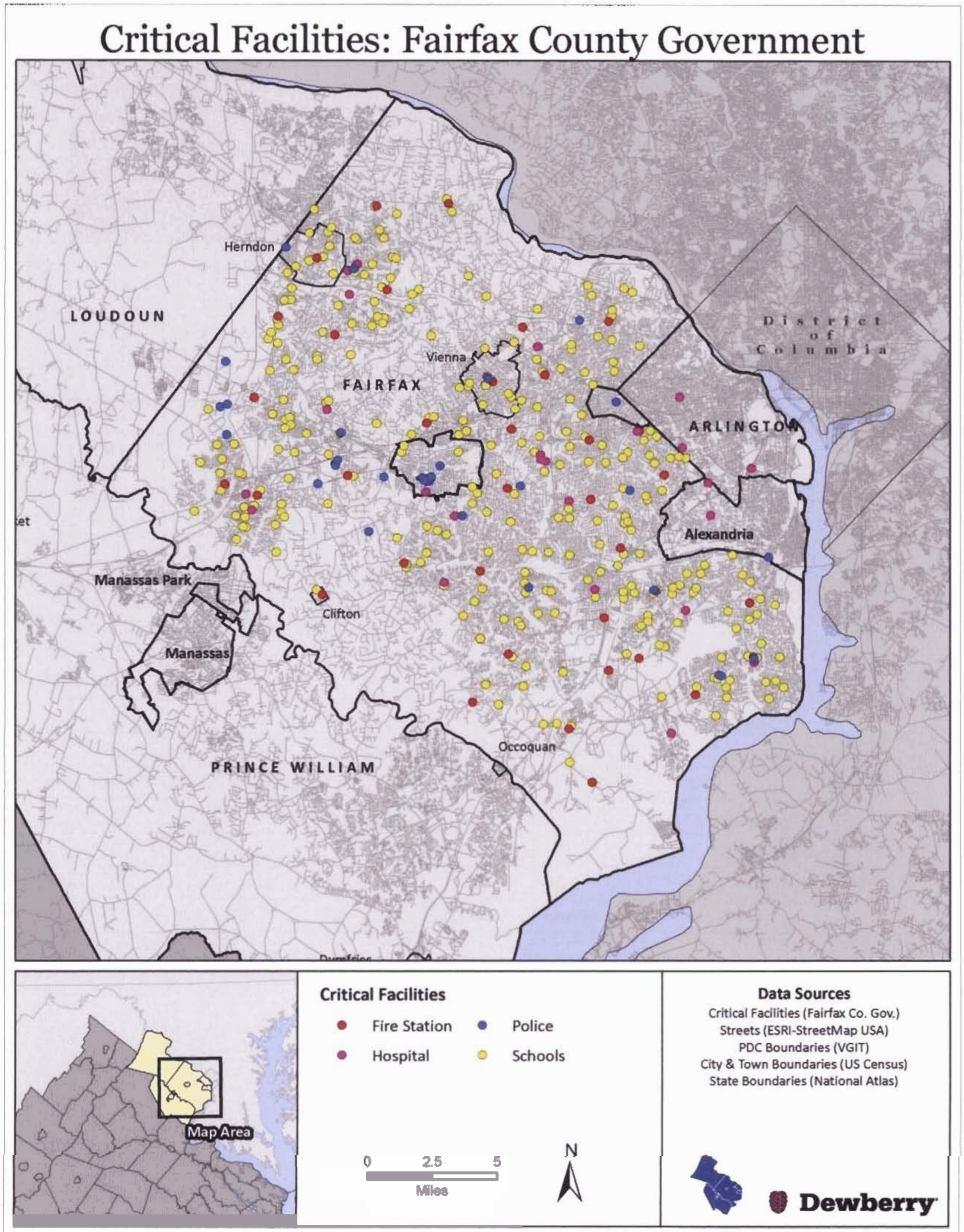

Figure 4.1. Fairfax County local critical facility data.

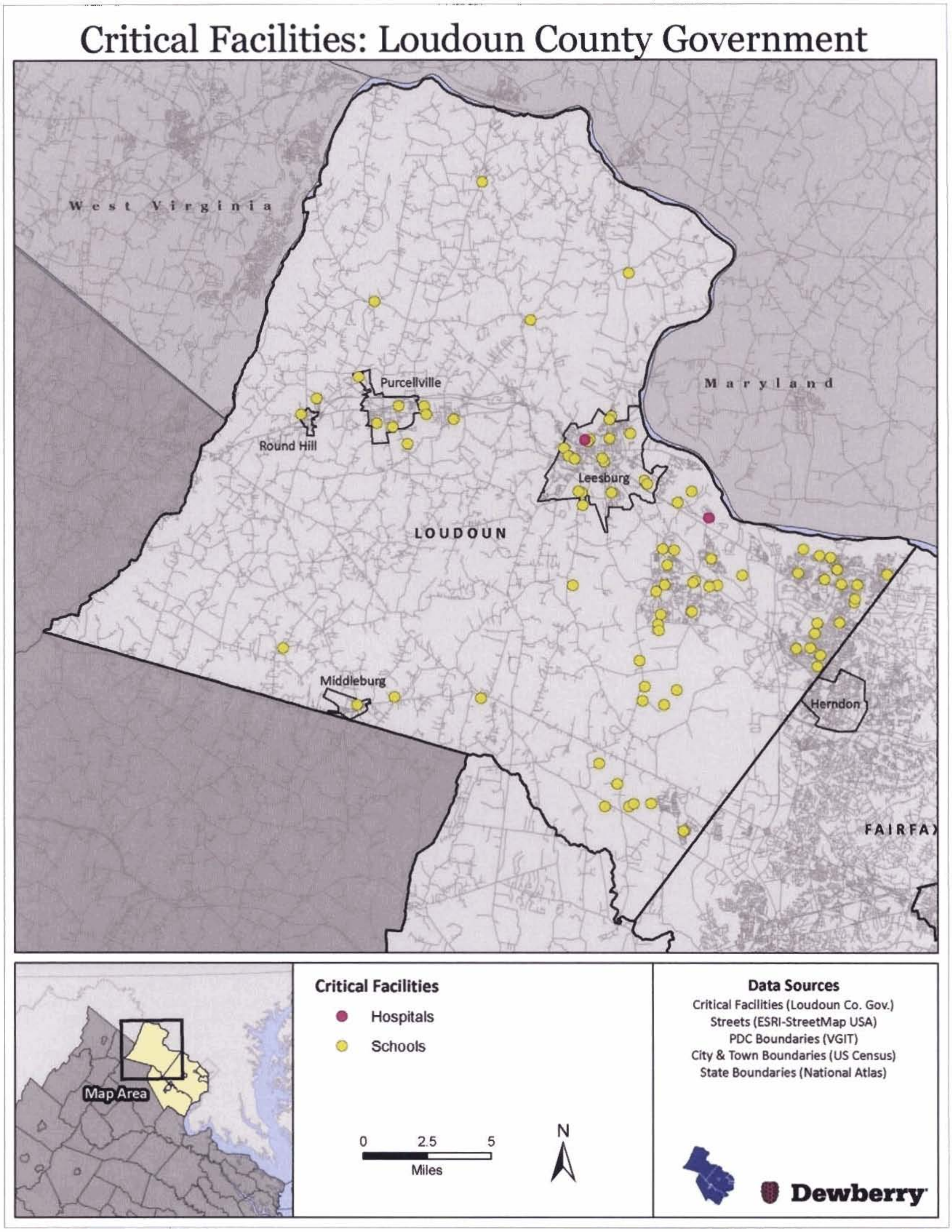

Figure 4.2. Loudoun County local critical facility data.

Critical Facilities: City of Alexandria Government

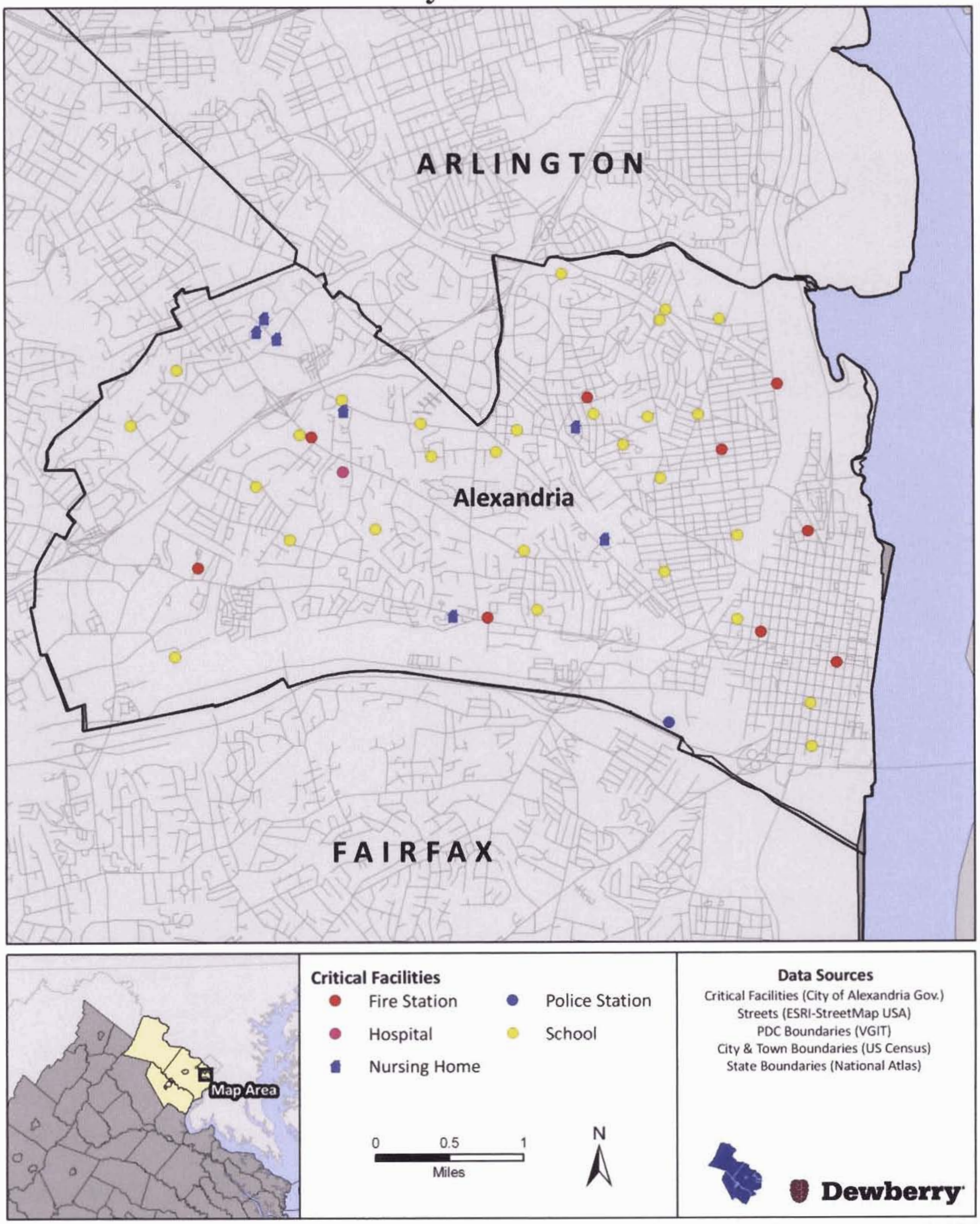

Figure 4.3. City of Alexandria local critical facility data.

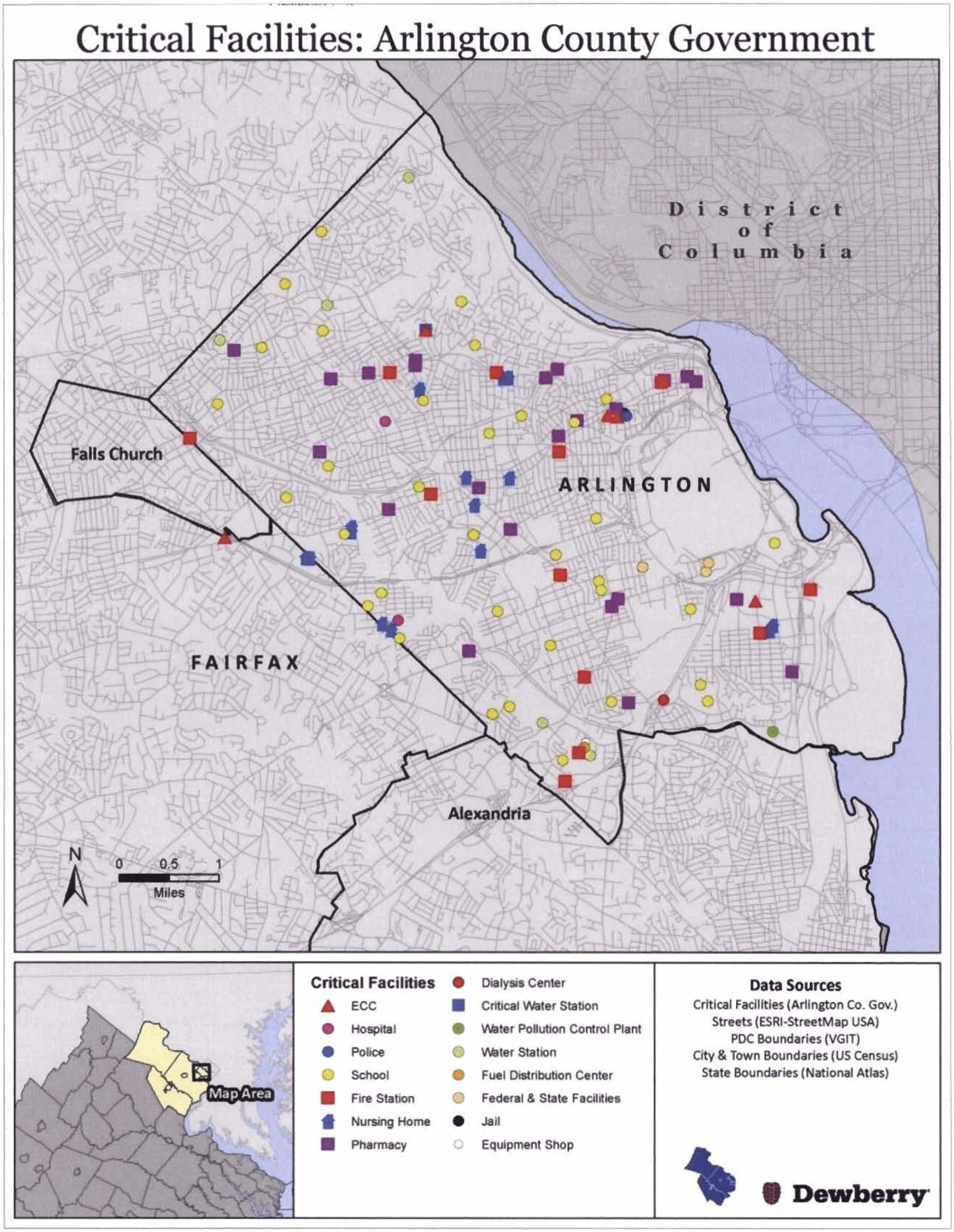

Figure 4.4. Arlington County local critical facility data.

HAZUS^{MH} MR4

HAZUS^{MH} essential facilities data was used to supplement the hazard specific analysis. This data provides a uniform look at essential facilities in the region. There are 762 facilities, including medical care facilities, police stations, EOCs, fire stations, and schools provided by HAZUS. Facilities within towns have been manually edited from the county totals based on the point location of the data.

HAZUS^{MH} essential facilities are facilities vital to emergency response and recovery following a disaster, including medical care facilities, emergency response facilities, and schools. School buildings are included in this category because of the key role they often play in housing people displaced from damaged homes.

Fairfax County has the largest number of essential facilities, 355, with over 85% of those facilities labeled as grade schools. Table 4.3 below shows the number of facilities in each of the HAZUS^{MH} essential facility classes. Figures 4.5 through 4.8 show the distribution of HAZUS^{MH} essential facilities within the regions. With many national datasets, accuracy and completeness leave much to be desired. Mitigation actions address the need for better regional spatial data for analysis.

The names and information for the HAZUS^{MH} and local critical facilities in the hazard risk zones are available in Appendix D2.

Table 4.3: HAZUS-MH MR4 Essential Facilities for Northern Virginia planning area.

Jurisdiction	EOC	Fire Station	Hospitals	Police Stations	Schools (grade)	Total
Arlington County	-	3	3	1	43	**50**
Fairfax County	-	35	8	9	303	**355**
Town of Herndon	-	1	-	1	8	**10**
Town of Vienna	-	1	-	1	11	**13**
Town of Clifton	-	1	-	-	-	**1**
Loudoun County	1	8	3	-	61	**73**
Town of Leesburg	-	2	-	5	17	**24**
Town of Purcellville	-	-	-	1	3	**4**
Town of Middleburg	-	-	-	1	2	**3**
Town of Round Hill	-	1	0	-		**1**
Prince William County	-	9	1	5	114	**129**
Town of Dumfries	-	-	-	1	2	**3**
Town of Haymarket	-	-	-	1	-	**1**
Town of Occoquan	-	-	-	1	-	**1**
Town of Quantico	-	-	-	1	-	**1**
City of Alexandria*	-	1	1	2	31	**35**
City of Fairfax	-	4	-	4	14	**22**

Table 4.3: HAZUS-MH MR4 Essential Facilities for Northern Virginia planning area.						
Jurisdiction	**EOC**	**Fire Station**	**Hospitals**	**Police Stations**	**Schools (grade)**	**Total**
City of Falls Church	-	-	-	1	5	6
City of Manassas	-	1	1	5	19	26
City of Manassas Park	-	1	-	-	3	4
Total	1	68	17	40	636	762

*The HAZUS MH stock inventory for the City of Alexandria differs from reality. There are actually nine fire stations and one police station in the City of Alexandria.

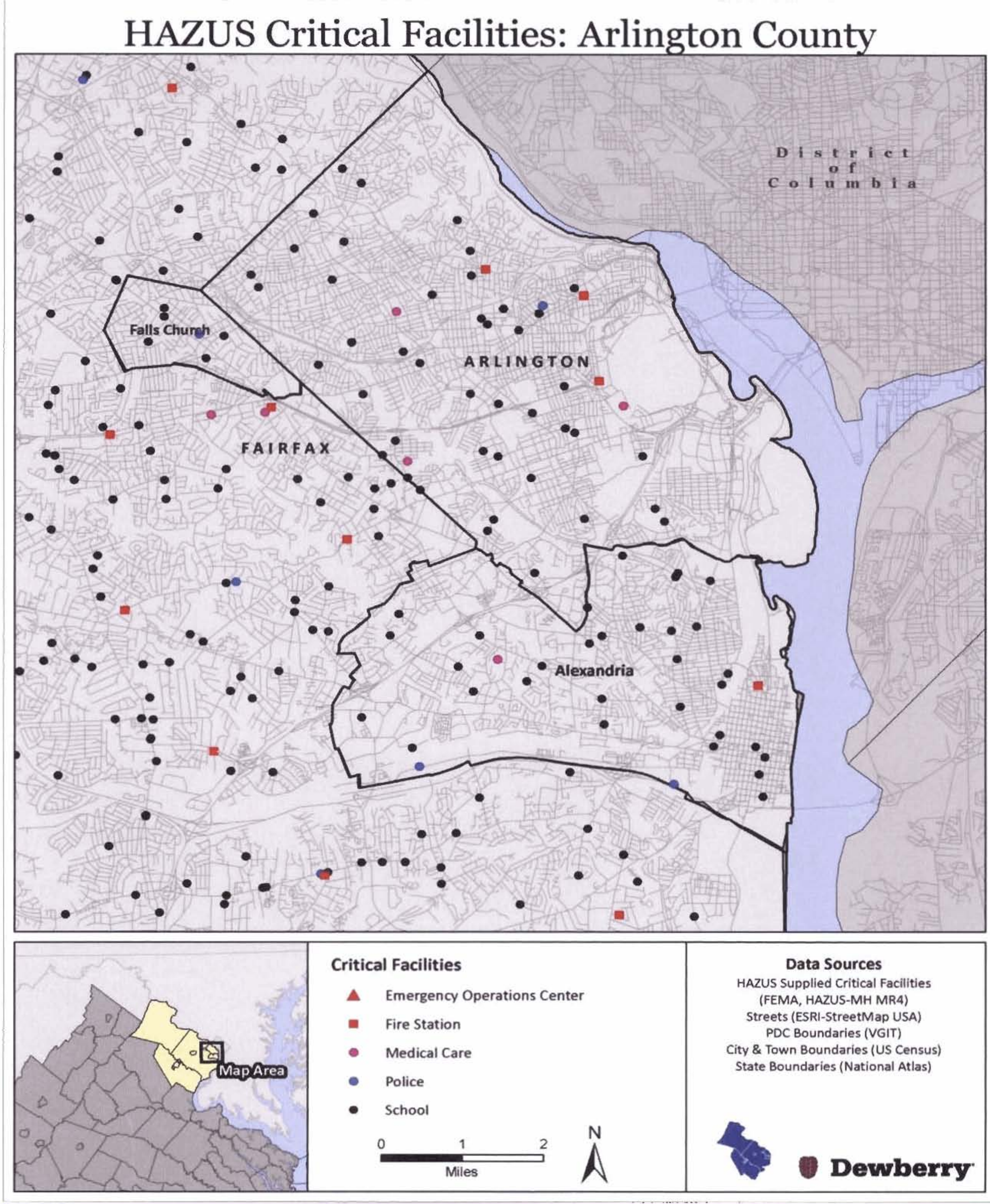

Figure 4.5. Arlington County HAZUS^{MH} critical facility data.

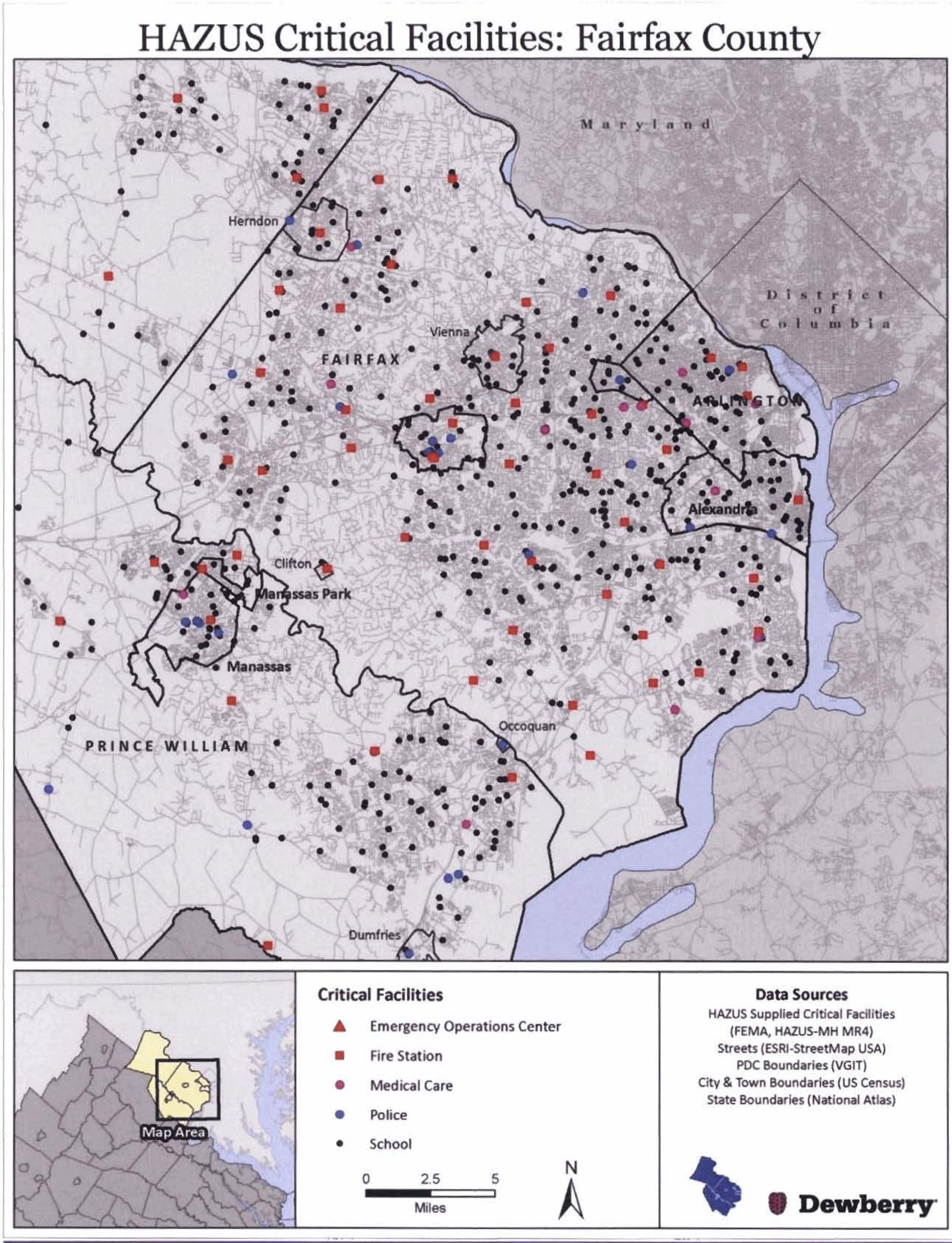

Figure 4.6. Fairfax County HAZUS^{MH} critical facility data.

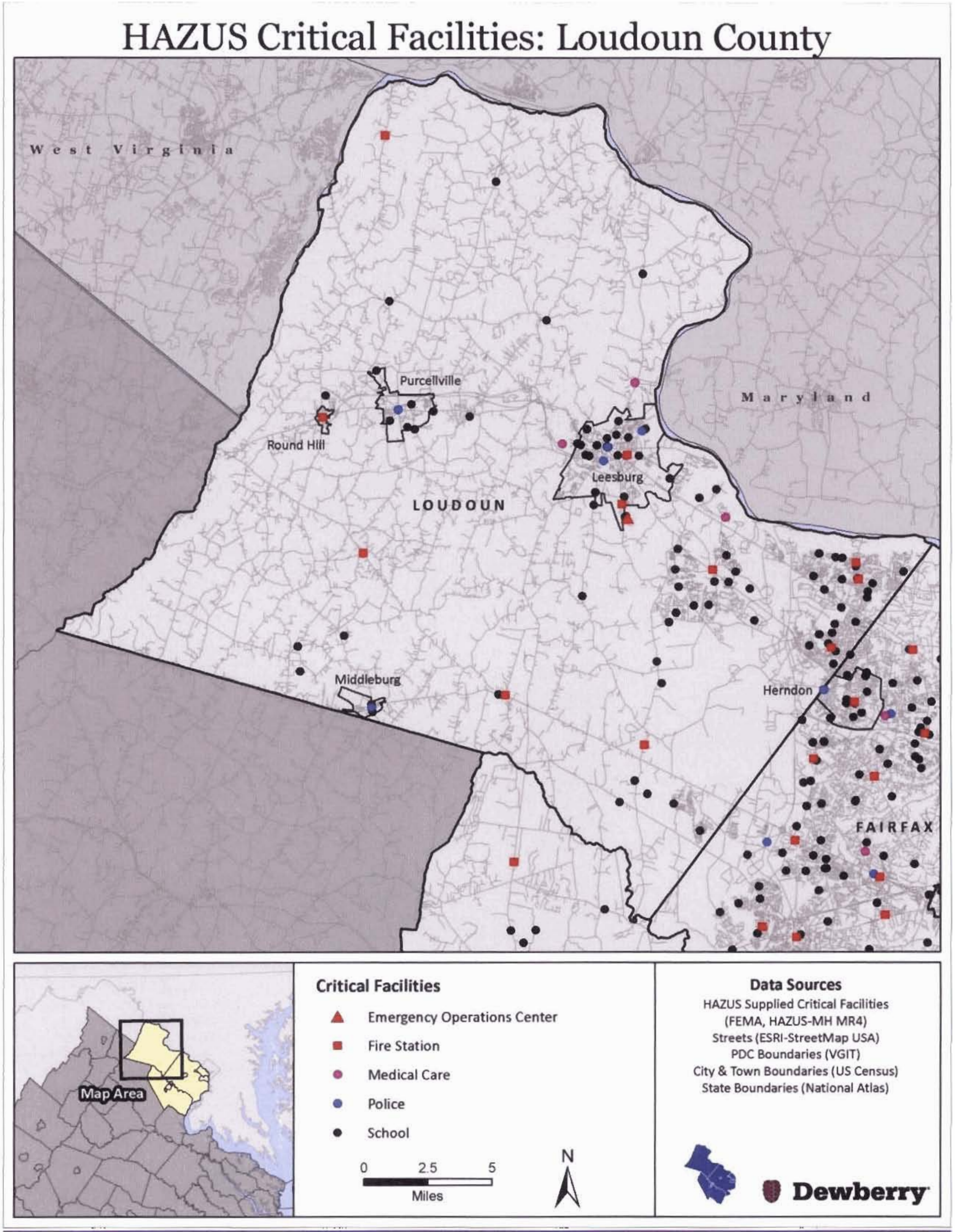

Figure 4.7. Loudoun County HAZUS^{MH} critical facility data.

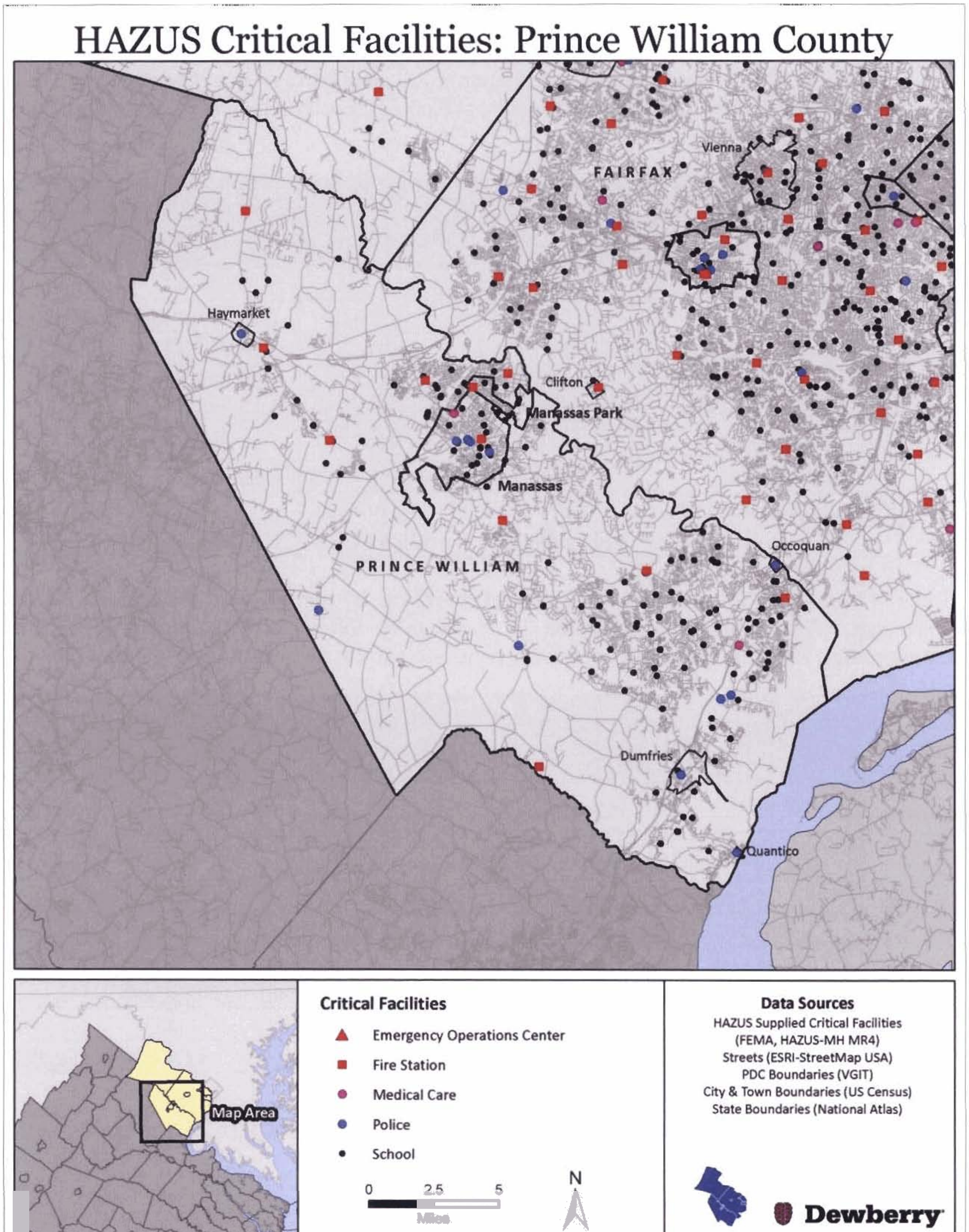

Figure 4.8. Prince William County HAZUS^{MH} critical facility data.

Data

The HAZUS^{MH} building stock for Northern Virginia contains 564,247 structures with an estimated exposure value of approximately $159 million (2002 dollars). HAZUS^{MH} estimates 92% of the region's general occupancy is categorized as residential, which represents 77% of the building value for the region. Fairfax County represents 56% of the region's total building value summarized in Table 4.4.

Table 4.4 Total Building Value per Jurisdiction

Jurisdiction	Residential	Non-Residential	Total	% Total
Arlington County	$12,867,851	$4,075,592	$16,943,443	10.7%
Fairfax County	$69,782,043	$18,936,097	$88,718,140	55.8%
Loudoun County	$12,240,971	$4,016,883	$16,257,854	10.2%
Prince William County	$16,183,895	$3,853,944	$20,037,839	12.6%
City of Alexandria	$8,360,736	$3,759,489	$12,120,225	7.6%
City of Falls Church	$772,821	$396,977	$1,169,798	0.7%
City of Manassas	$2,090,589	$899,122	$2,989,711	1.9%
City of Manassas Park	$589,358	$170,266	$759,624	0.5%
Total	**$122,888,264**	**$36,108,370**	**$158,996,634**	-

Table 4.5 shows the estimated total exposure values by jurisdiction. Residential housing represents 77% of the building value in the region, followed by commercial properties representing 17%. The remaining occupancy types account for the remaining 6% of the region.

Table 4.5 Building stock exposure for general occupancy type by jurisdiction.

Jurisdiction	Residential	Commercial	Industrial	Agriculture	Religion	Government	Education	Total
Arlington County	$12,867,851	$2,997,089	$228,293	$16,366	$412,483	$243,309	$178,052	**$16,943,443**
Fairfax County	$69,782,043	$14,551,381	$1,714,269	$179,020	$1,309,470	$289,035	$792,922	**$88,618,140**
Loudoun County	$12,240,971	$2,837,905	$575,890	$99,322	$256,349	$88,186	$159,231	**$16,257,854**
Prince William County	$16,183,895	$2,749,642	$485,743	$105,462	$252,167	$75,096	$175,834	**$20,027,839**
City of Alexandria	$8,360,736	$2,447,302	$199,685	$12,880	$379,692	$83,617	$636,313	**$12,120,225**
City of Falls Church	$772,821	$309,040	$25,472	$4,580	$38,994	$7,529	$11,362	**$1,169,798**
City of Manassas	$2,090,589	$629,525	$161,690	$7,612	$42,905	$25,566	$31,824	**$2,989,711**
City of Manassas Park	$589,358	$103,628	$42,782	$4,805	$4,209	$3,500	$11,342	**$759,624**
Total	**$122,888,264**	**$26,625,512**	**$3,433,824**	**$430,047**	**$2,696,269**	**$815,838**	**$1,996,880**	**$158,886,634**

Building stock exposure is also classified by building type. General Building Types have been developed as a means to classify different building construction types. This provides an ability to differentiate between buildings with substantially different damage and loss characteristics. Model building types represent the average characteristics of buildings in a class. The damage and loss prediction models are developed for model building types and the estimated performance is based upon the "average characteristics" of the total population of buildings within each class. Five general classifications have been established, including wood, masonry, concrete, steel, and manufactured homes (MH). A brief description of the building types is available in Table 4.6. The HAZUS^{MH} inventory serves as the default when a user does not have better data available.

Table 4.6: HAZUS-MH General Building Type Classes.

General Building Type	Description
Wood	Wood frame construction
Masonry	Reinforced or unreinforced masonry construction
Steel	Steel frame construction
Concrete	Cast-in-place or pre-cast reinforced concrete construction
MH	Factory-built residential construction

Wood construction represents the majority (60%) of building types in the region, followed by masonry, which represents 27% of building stock exposure. The remaining percentage is distributed among other building types. Table 4.7 below provides building stock exposure for the five main building types. *The differences in the building stock tables are a result of aggregation by HAZUS^{MH} and rounding.* HAZUS^{MH} only provides building stock for the counties and cities in Northern Virginia. Towns participating in this plan are represented in their respective county totals.

Table 4.7: Building stock exposure for general building type by jurisdiction.

Jurisdiction	Wood	Masonry	Concrete	Steel	MH	Total
City of Alexandria	$6,412,296	$3,477,780	$605,578	$1,620,688	$3,877	**$12,120,219**
Arlington County	$9,632,111	$4,755,713	$733,158	$1,819,227	$3,238	**$16,943,447**
Fairfax County	$54,518,093	$23,632,992	$2,350,441	$8,137,070	$79,531	**$88,718,127**
City of Falls Church	$638,496	$321,708	$42,290	$167,207	$98	**$1,169,799**
Loudoun County	$9,792,019	$4,268,333	$443,420	$1,745,598	$8,475	**$16,257,845**
City of Manassas	$1,647,936	$791,647	$123,189	$419,862	$7,082	**$2,989,716**
City of Manassas Park	$469,785	$193,413	$15,994	$80,215	$217	**$759,624**
Prince William County	$12,484,085	$5,242,591	$505,278	$1,742,746	$63,120	**$20,037,820**
Total	**$95,594,821**	**$42,684,177**	**$4,819,348**	**$15,732,613**	**$165,638**	**$158,996,597**

III. Hazard Identification

Requirement §201.6(c)(2)(i): [The risk assessment shall include a] description of the type ... of all natural hazards that can affect the jurisdiction.]

While there are many different natural hazards that could potentially affect the Northern Virginia planning area, some hazards are more likely to cause significant impacts and damages than others. This analysis will attempt to quantify these potential impacts and identify the hazards that pose the greatest possible risk.

The potential hazards that could affect the Northern Virginia planning area include: flooding, high winds, tornadoes, land subsidence, winter storms, severe thunderstorms, earthquakes, wildfires, landslides, droughts, extreme temperatures, and erosion. Some of these hazards are interrelated (i.e., hurricanes can cause flooding and tornadoes), and some consist of hazardous elements that are not listed separately (i.e., severe thunderstorms can cause lightning; hurricanes can cause coastal erosion). It should also be noted that some hazards, such as severe winter storms, may impact a large area yet cause little damage; while other hazards, such as a tornado, may impact a small area yet cause extensive damage. Several of these hazards have been included together (i.e., winter storm/extreme cold, high winds/thunderstorms/hurricane winds). The hazard description in each hazard section provides a general description for each of the hazards listed above, along with their hazardous elements.

Depending on the severity, location, and timing of the specific events, each of these hazards could have devastating effects on homes, businesses, agricultural lands, infrastructure, and ultimately citizens. In order to gain a full understanding of the history of these hazards in the planning area, detailed data related to the hazard history was compiled and available in each of the hazard sections. Appendix D3 contains the National Climactic Data Center (NCDC) storm events database used in the 2010 analysis.

For the 2006 plan, information was collected from meetings with local community officials, existing reports and studies, State and national data sets, and local newspaper clippings, among others sources. The 2010 plan updated the 2006 information based on the National Weather Service's (NWS) NCDC storm events, and local, State and national datasets.

The historical data collected includes accounts of all the hazard types listed above. However, some have occurred much more frequently than others with a wide range of impacts. By analyzing the historical frequency of each hazard, along with the associated impacts, the hazards that pose the most significant risks to the Northern Virginia planning area can be identified. This analysis will allow the jurisdictions included in this study to focus their hazard mitigation plans on those hazards that are most likely to cause significant impacts to their community.

To a large extent, historical records are used to identify the level of risk within the Northern Virginia region with the assumption that the data sources cited are reliable and accurate. Unless otherwise cited, all data on historical weather-related events is based on information made available through the Storm Event Database by the NWS NCDC[4]. From a regional planning perspective, it is important to use a consistent source for hazard-related data such as the NCDC.

That being said, descriptions of historical hazard events and numerical damage data are based on the collection of information reported by local offices of the NWS and should only be considered approximate figures for general analysis and planning purposes.

To complete the risk assessment, best available data was collected from a variety of sources, including local, State and Federal agencies, and multiple analyses were performed qualitatively and quantitatively (further described below). Additional work will be done on an ongoing basis to enhance, expand, and further improve the accuracy of the baseline established here, and it is expected that this vulnerability assessment will continue to be refined through future plan updates as new data and loss estimation methods or tools become available to NVRC and its jurisdictions.

The findings presented in the hazard risk assessments and in the overall results were developed using best available data, and the methodologies applied have resulted in an approximation of risk. These estimates should be used to understand relative risk from hazards and the potential losses that may be incurred. However, uncertainties are inherent in any loss estimation methodology, arising in part from incomplete scientific knowledge concerning specific hazards and their effects on the built environment, as well as incomplete data sets and approximations and simplifications that are necessary in order to provide a meaningful analysis. Further, most data sets used in this assessment contain relatively short periods of records which increases the uncertainty of any statistically-based analysis.

Federally Declared Disasters

Presidential disaster declarations are issued for county (including towns) or independent city jurisdictions when an event has been determined to be beyond the capabilities of State and local governments to respond. There have been a total of 52 declared disasters in Virginia, and 14 of those disasters have been declared in at least one community in the Northern Virginia planning area since 1965. The City of Alexandria has been declared in 11 of these events, and Arlington and Fairfax Counties have been declared in 9 of the disasters. Prior to January 1, 1965, presidential disaster declarations did not have county or independent city designations. The region has also experienced a significant number of additional emergencies and disasters that were not severe enough to require Federal disaster relief through a presidential declaration. Table 4.8 summarizes the disasters and the localities that were included in the declaration.

Wind related events (severe storms, tornados, and flooding) dominate the Northern Virginia declared hazards, followed by winter storms events.

Table 4.8: Major disaster declarations for Northern Virginia planning area (1965-April 2010)

Date of Declaration	Disaster	Declared Jurisdiction								
		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
4/27/2010	Severe Winter Storms and Snowstorms	✓	✓	✓	✓	✓	✓	✓	✓	✓
2/16/2010	Severe Winter Storm and Snowstorm	✓	✓		✓	✓	✓	✓	✓	✓
7/13/2006	Severe Storms, Tornadoes, and Flooding	✓	✓			✓				
9/18/2003	Hurricane Isabel	✓	✓	✓	✓	✓	✓	✓	✓	✓
3/27/2003	Severe Winter Storm	✓	✓	✓	✓	✓	✓	✓	✓	✓
9/11/2001	Terrorism	✓								
2/28/2000	Severe Winter Storm	✓	✓	✓	✓	✓	✓		✓	
10/12/1999	Hurricane Floyd		✓				✓			
10/23/1996	Hurricane Fran				✓					
2/2/1996	Blizzard of 1996	✓	✓	✓	✓	✓	✓	✓	✓	✓
11/10/1985	Severe Storms & Flooding					✓				
10/10/1972	Severe Storms & Flooding					✓				
10/7/1972	Severe Storms & Flooding					✓				
6/29/1972	Tropical Storm Agnes	✓	✓	✓	✓	✓	✓	✓		

Source: Federal Emergency Management Agency (FEMA)

NCDC Storm Events Database

NCDC Storm Data is published by the National Oceanic and Atmospheric Administration (NOAA), part of the U.S. Department of Commerce. The storm events database contains information on storms and weather phenomena that have caused loss of life, injuries, significant property damage, and/or disruption to commerce. Efforts are made to collect the best available information, but because of time and resource constraints, information may be unverified by the NWS. The NWS does not guarantee the accuracy or validity of the information. Although the historical records in the database often vary widely in their level of detail, the NWS does have a set of guidelines used in the preparation of event descriptions.[5]

It should be noted that NCDC is well known for having limited records of geological hazards (i.e., earthquake, landslide, and karst). In the absence of better data it was decided to proceed with the records available in NCDC for these events, in all cases. NCDC records for these events are severe under-representations of what has happened in Northern Virginia's past. To date, no comprehensive digital databases exist for these hazards[6].

Event records from February 1, 1951, through August 31, 2009, have been used for the HIRA analysis. There have been 3,161 events recorded in the NCDC storm events database for the Northern Virginia planning area spanning 1950 through 2009; 795 of those events have not been included in the analysis. High wind and winter storm events make up over 72% of the records and almost 25% of the recorded property damages, followed by flood events (19% of the events and 11% of the property damages). Tornado events account for only 3% of the events but over 64% of the recorded property damages. Table 4.9 shows the number of NCDC events for each county and city by hazard type. Table 4.10 summarizes, by jurisdiction, the total injuries, deaths, and damages. NCDC data is only provided for the counties and cities in the Northern Virginia planning area. Town information is included in the county totals. Table 4.11 summarizes, by hazard, the years of record, number of events, and damages incurred.

Figure 4.9 summarizes the number of reported events in the NCDC storm events database by year. As shown, reporting of events has significantly improved in the past 20 years. More than 80% of the recorded events are from 1990 to 2009.

Table 4.9: Number of Events in the NCDC database.						
Jurisdiction	**Drought**	**Flood**	**High Wind**	**Tornado**	**Winter Storm**	**Total**
Arlington County	20	50	94	2	113	**279**
Fairfax County	20	101	209	19	126	**475**
Loudoun County	31	75	244	24	144	**518**
Prince William County	20	75	128	13	128	**364**
City of Alexandria	20	47	60	1	111	**239**
City of Fairfax		5	20			**25**
City of Falls Church	20	38	46	1	111	**216**
City of Manassas	20	46	54	2	124	**246**
City of Manassas Park		2	1	1		**4**
Total	**151**	**439**	**856**	**63**	**857**	**2,366**

Table 4.10: Jurisdictional totals of NCDC database.					
Jurisdiction	**Injuries**	**Fatalities**	**Total Events**	**Total Crop Damage**	**Total Property Damage**
Arlington County	5	1	279	$2,860,525	$10,502,359
Fairfax County	59	2	475	$2,620,475	$160,083,383
Loudoun County	11	0	518	$7,317,346	$13,658,281
Prince William County	18	2	364	$3,080,631	$26,141,962
City of Alexandria	0	0	239	$2,860,525	$4,759,845
City of Fairfax	0	1	25	$0	$94,131
City of Falls Church	0	1	216	$2,860,525	$10,005,946
City of Manassas	0	0	246	$3,014,556	$16,055,674
City of Manassas Park	5	0	4	$0	$12,041
Total	**98**	**7**	**2,366**	**$24,614,583**	**$241,313,623**

Table 4.11: Jurisdictional totals of NCDC database.						
Hazard Type	Timeframe	Years of Record	Number of Events	Total		
				Property Damage	*Crop Damage*	*Property + Crop Damages*
Drought	1993-2009	17	151	$0	$16,030,513	$16,030,513
Flood	1993-2009	17	439	$25,708,755	$2,386,304	$28,095,058
High Wind	1955-2009	21	856	$54,960,271	$6,002,154	$60,962,425
Tornado	1951-2009	59	63	$154,079,301	$46,308	$154,125,609
Wildfire	1995-2009	15	0	$0	$0	$0
Winter Storm	1993-2009	17	857	$6,565,296	$149,305	$6,714,601
Landslide	1993-2009	17	0	$0	$0	$0
		Total	**2,366**	**$241,313,623**	**$24,614,583**	**$265,928,206**

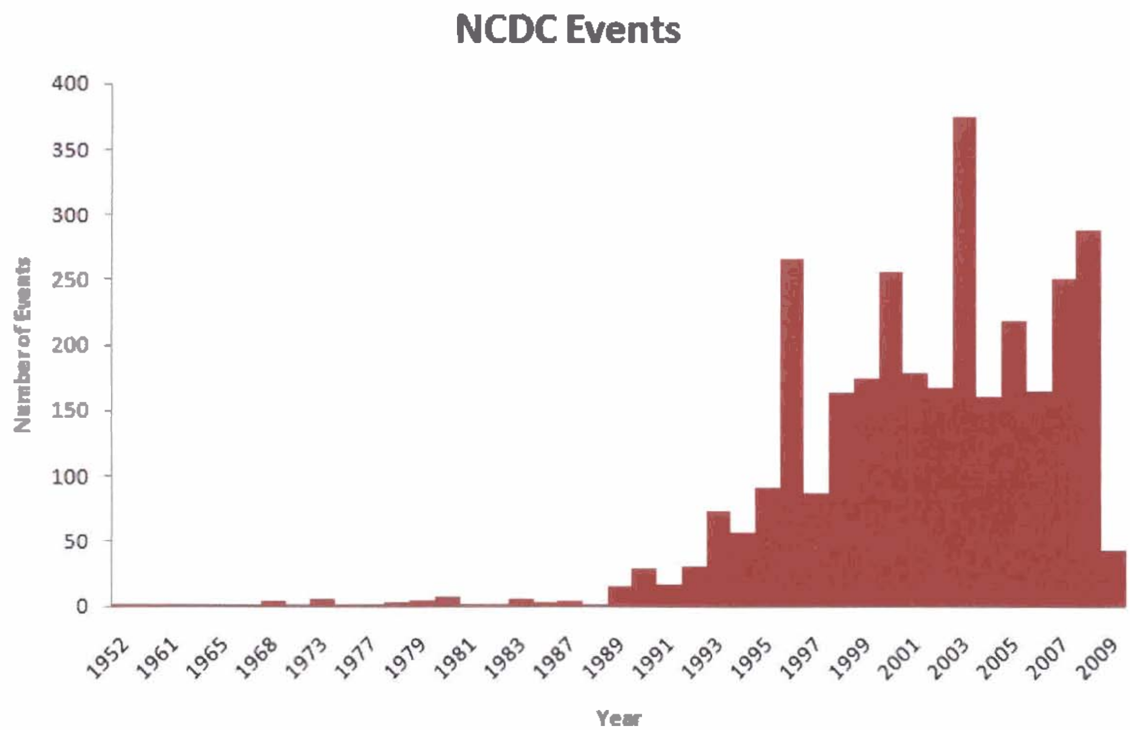

Figure 4.9: Number of reported NCDC events (1950 – 2009).

To use the NCDC data in the same fashion as it was used in the *Commonwealth of Virginia Hazard Mitigation Plan* Risk Assessment, the data had to be processed. The following excerpt on processing the NCDC data has been taken from Virginia's hazard mitigation plan. The data used in the Virginia plan was provided by VDEM for the Northern Virginia plan update. The storm events used for the Virginia plan span February 1, 1951, through May 31, 2008. Storm events from June 1, 2008, through August 21, 2009, were provided by the NWS and processed, according to the procedure outlined below, for the update.

NCDC Normalizing Data

Information for specific hazard events is sometimes reported by the NWS and found in the NCDC database only at a zonal level. This is particularly true for events that impact a wide area, such as winter storm and drought events. Each zone may contain one or many political jurisdictions. These zonal events may include information regarding deaths, injuries, and damages caused by the event, but may not break these down by individual jurisdiction. To accurately count the number of events occurring in a single county or city, the zonal data records were expanded into a set of individual city/county records, based on NCDC zone definitions. For example, if there were three political jurisdictions in a given zone, a record in the database for a winter storm covering that zone would be replaced with three records for that storm, corresponding to each of the political jurisdictions. During this process, the damages, fatalities, and injuries associated with a storm event in a certain zone were divided evenly among the political jurisdictions in that zone.

Injuries and fatalities, once normalized, were combined into a single number. While there is no good method to equate injuries with fatalities, FEMA's cost-benefit analysis documentation has suggested that the cost of a fatality is 176 times the cost of an injury. Therefore, fatalities have been multiplied by a factor of 176 and added to the injuries for each jurisdiction. Table 4.8 above shows the normalized total of injuries and deaths by hazard type.

General time statistics were generated to determine how the different hazards were represented in the NCDC data. This consisted of developing percentile (tabular and graphical) and histograms of events versus date for each hazard type. For all events except high wind, the percentile graph was relatively linear. This suggests that reporting has remained roughly equal over the entire period of record, and all records should be counted. However, the high wind period of record showed very few events between 1955 and 1989, and a linear trend after that. Therefore, since a longer period of record is only necessary when the data has been reported consistently, high wind was only evaluated using the period of record from 1989 to 2009 for the annualized data analysis.

Once the zonal records were replaced with individual jurisdictional records, the NCDC database was used to calculate a variety of summary statistics on a jurisdictional basis. For example, the total number of each type of storm event, and the total damages associated with a storm event, were summarized on a statewide and jurisdictional basis. Statistics were generated for the dates of events in each HIRA category, percentile (tabular and graphical), and a histogram of events versus date. For all events except high wind, the percentile graph was relatively linear. This suggests that reporting has remained roughly equal over the entire period of record, and all records should be counted. However, the high wind period of record showed very few events between 1955 and 1989, and a linear trend after that. Therefore, since a longer period of record is only useful when the data has been reported consistently, high wind was only evaluated using the period from 1989 to 2008 for the annualized data analysis.

NCDC Inflation Computation

The damages entered into the NCDC Storm Events database portray how much damage was incurred in the year of the event. Due to inflation and the changing value of money, the values of damages incurred have been adjusted so that they reflect their worth in 2007. This process was done by obtaining information from the Bureau of Labor Statistics, which provides a yearly index of Consumer Prices. Each value was multiplied by the index of its year of occurrence and subsequently divided by the index value in 2007, the target year. The year 2007 was chosen because it was the most recent full year available in the index values list at the time of this writing, but the values could have been adjusted to any other year without changing the relative ranking of each hazard.

NCDC Annualizing Data

After the data was normalized, inflation accounted, and summary statistics calculated, the data was annualized in order to be able to compare the results on a common system (i.e., ranking the hazards). In general, this was completed by taking the parameter of interest and dividing by the length of record for each hazard. The annualized value should only be utilized as an estimate of what can be expected in a given year. Deaths/injuries, property and crop damage, and events were all annualized in this fashion, on a per-jurisdiction basis. The NCDC formatted data that was used in the analysis is available through VDEM. High wind events before 1989 have not been included as they would skew the record due to the reasons described under the normalizing data section.

NCDC Data Compilation

The NCDC Storm Events database uses very detailed event categories. The reported storm events were summarized in simplified classifications to correspond to the major hazard types considered in this plan. Table 4.12 shows how the NCDC categories were grouped into the HIRA hazard categories. The ranking methodologies, explained later in this section, summarize how the NCDC data was used in ranking the hazards.

Table 4.12: NCDC categories to align with hazards addressed in the HIRA.

HIRA Category	NCDC Event Categories	Number of NCDC Events for each Category in NOVA
Drought	DROUGHT	144
	DROUGHT/EXCESSIVE HEAT	7
Flood	COASTAL FLOOD	3
	COASTAL FLOODING	
	FLASH FLOOD	132
	FLASH FLOODING	1
	FLOOD	288
	FLOOD/FLASH FLOOD	6
	STORM SURGE	4
	STORM SURGE/TIDE	2
	TIDAL FLOODING	2
	URBAN/SMALL STRM FLDG	1
High Wind	GUSTY WIND	1
	GUSTY WIND/HVY RAIN	5
	GUSTY WINDS	12
	HIGH WIND	114
	HIGH WINDS	27
	STRONG WIND	82
	THUNDERSTORM WIND	133
	THUNDERSTORM WINDS	43
	TROPICAL STORM	21
	TSTM WIND	416
	WET MICROBURST	2

Table 4.12: NCDC categories to align with hazards addressed in the HIRA.		
HIRA Category	**NCDC Event Categories**	**Number of NCDC Events for each Category in NOVA**
Tornado	FUNNEL CLOUD	10
	TORNADO	53
Winter Storm	BLIZZARD	1
	HEAVY SNOW	115
	ICE	1
	ICE STORM	63
	SNOW	26
	SLEET/SNOW	1
	WINTER STORM	340
	WINTER WEATHER	195
	WINTER WEATHER/MIX	115
N/A	AGRICULTURAL FREEZE	3
	BLACK ICE	11
	DENSE FOG	133
	DUST DEVIL	1
	FREEZE	1
	FREEZING FOG	12
	FROST/FREEZE	67
	HAIL	300
	HEAT	11
	HEAVY RAIN	107
	RIP CURRENT	7
	UNSEASONABLY COLD	6
	UNSEASONABLY WARM	7
	UNUSUALLY WARM	1
	EXTREME COLD	16
	EXTREME COLD/WIND CHILL	17
	EXCESSIVE HEAT	25
	LIGHTNING	70

IV. Ranking and Analysis Methodologies

HAZUS^{MH} Methodology

HAZUS^{MH} is FEMA's nationwide standardized loss estimation software package, built upon an integrated GIS platform with a national inventory of baseline geographic data (including information on the Northern Virginia region's general building stock and dollar exposure). Originally designed for the analysis of earthquake risks, FEMA has expanded the program to allow for the analysis of multiple hazards including flood and wind events. By providing estimates on potential losses, HAZUS^{MH} facilitates quantitative comparisons among hazards and may assist in the prioritization of hazard mitigation activities.

HAZUS^{MH} uses a statistical approach and mathematical modeling of risk to predict a hazard's frequency of occurrence and estimated impacts based on recorded or historic damage information. The HAZUS^{MH} risk assessment methodology includes distinct hazard and inventory parameters. For example, wind speed and building type were modeled using the HAZUS^{MH} software to determine the impact (damages and losses) on structures. Figure 4.10 shows a conceptual model of HAZUS^{MH} methodology. More information on HAZUS^{MH} loss estimation methodology is available through FEMA at www.fema.gov/hazus.

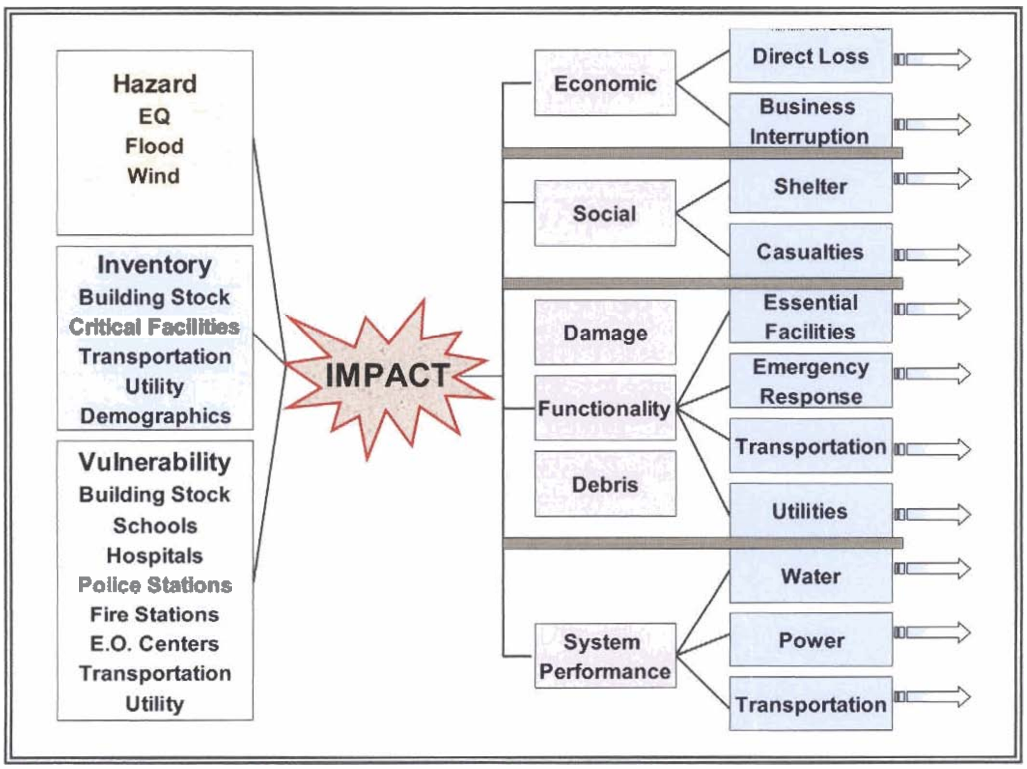

Figure 4.10 Conceptual Model of HAZUS^{MH} Methodology

The 2006 and 2010 update of the risk assessment utilized HAZUS^{MH} to produce regional profiles and estimated losses for hazards addressed in this section: hurricane winds, earthquake and flood (only in 2010). For each of these hazards, $HAZUS^{MH}$ was used to generate probabilistic "worst case scenario" events to show the maximum potential extent of damages. It is understood that those events of less severe magnitude which could occur would likely result in fewer losses than those calculated here. During the update additional scenarios were completed for flood and earthquake to further define the region's risk.

Supplemental Annualized Loss Estimate Methodology

The first step in conducting supplemental annualized loss calculations and risk assessment included the collection of relevant GIS data from local, State and national sources. This began with the collection of local data from each participating jurisdiction through NVRC (considered most accurate), then continued up to best available data at the national inventory level (considered least accurate). The data determined to be "best available" was then used for purposes of this assessment. Data matrices were compiled based on the data provided by each of the localities; these may be found in Appendix D1.

In order to generate hazard loss estimates beyond hurricane winds and earthquake, the following steps were conducted independent of the $HAZUS^{MH}$ analysis:

- For the flood, drought, severe thunderstorm, tornado, wildfire and winter storm hazards, best available data on historical hazard occurrences (limited to NOAA NCDC and Virginia Department of Forestry [VDOF] records) was used to produce an annualized loss estimate of potential damages. Using this data, annualized loss estimates were generated by totaling the amount of property damage over the period of time for which records were available, and calculating the average annual loss. The 2010 update includes inflated property and crop damages whereas the 2006 plan did not take this into account.
- For the hazards of extreme temperatures, erosion, sinkholes, landslides, and dam failure, meaningful historical data (meaning data which would have included past property damages and other essential indicators) was virtually non-existent, and therefore annualized potential losses for these hazards could not be calculated.

Critical Facility and Building Risk

In addition to generating annualized loss estimates for particular hazards, GIS technology was further utilized to identify, quantify, and analyze potentially at-risk community assets such as public buildings, critical facilities, and infrastructure. This analysis was completed for hazards that can be spatially defined in a meaningful manner (i.e., hazards with an officially determined geographic extent) and for which digital GIS data layers are readily available. The analysis resulted in the identification of potentially at-risk community assets based upon their location in relation to identified hazard areas. Results of this analysis are contained within each of the hazard specific sections.

For the flood hazard, GIS was used to further assess risk utilizing the FEMA Digital Flood Insurance Risk Maps (DFIRMs) in combination with locally-available GIS data layers. Primary data layers used include local building footprints and tax parcel data. For the 2006 plan, total floodplain exposure was determined for each jurisdiction by calculating the assessed building value for all pre-Flood Insurance Rate Map (FIRM) structures located in identified flood hazard areas. Exposure values do not include any estimated values for building contents. The methodology used for determining potential flood loss estimates assumes that pre-FIRM structures would not have been constructed to minimum National Flood Insurance Program (NFIP) standards, and therefore are more likely to be vulnerable to the flood hazard than post-FIRM structures. Pre-FIRM structures were identified by comparing the date of construction for each structure to the NFIP entry date for that jurisdiction. For the 2010 plan, exposure values were not readily available and as a result only the count of building parcels in the Special Flood Hazard Area (SFHA) are summarized in the flood section.

2006 Ranking Methodology

To drive the risk assessment effort for the Northern Virginia region, two distinct methodologies were applied. The first includes a ***quantitative*** analysis that relies upon best available data and technology, while the second methodology includes a ***qualitative*** analysis that relies more on local knowledge and rational decision making. Upon completion, the methodologies are combined to create a "hybrid" approach for assessing hazard vulnerability for the Northern Virginia region that allows for some degree of quality control and assurance. The quantitative assessment focuses on estimated hazard loss estimates and specifically at-risk community assets, while the qualitative assessment is comprised of a scoring system built around values assigned by the MAC as to the likelihood of occurrence, spatial extent, and potential impact of each hazard studied.

The quantitative methodology consists of utilizing HAZUS^{MH}, a GIS-based loss estimation software available from the FEMA, as well as a detailed GIS-based approach independent of the HAZUS^{MH} software. These two GIS-based studies together help form a quantitative risk assessment.

The qualitative assessment relies less on technology, but more on historical and anecdotal data, community input, and professional judgment regarding expected hazard impacts. The qualitative assessment completed for the Northern Virginia region is based on the Priority Risk Index (PRI), a tool used by PBS&J to measure the degree of risk for identified hazards in local communities. The PRI is also used to assist community officials in ranking and prioritizing those hazards which pose the most significant threat to their area based on a variety of important factors.

While the quantitative assessment focuses on using best available data, computer models, and GIS technology, the PRI system relies more on historical data, local knowledge, and the general consensus of the MAC. The PRI is used for hazards with no available GIS data or relevant information to perform quantitative analysis, and also provides an important opportunity to compare, crosscheck, or validate the results of those that do have available data.

The PRI results in numerical values that allow identified hazards to be ranked against one another (the higher the PRI value, the greater the hazard risk). PRI values are obtained by assigning varying degrees of risk to five categories for each hazard (probability, impact, spatial extent, warning time, and duration). Each degree of risk has been assigned a value (1-4) and an agreed upon weighting factor, as summarized in Table 4.13. The PRI weighting scheme may also be adjusted by the MAC based upon any unique concerns for the region.

To calculate the PRI value for a given hazard, the assigned risk value for each category is multiplied by the weighting factor. The sum of all five categories equals the final PRI value, as demonstrated in the example equation below:

PRI Value =
(Probability x .30) + (Impact x .30) + (Spatial Extent x .20) + (Warning Time x .10) + (Duration x .10)

According to the weighting scheme applied for the Northern Virginia region, the highest possible PRI Value is 4.0. Prior to being finalized, PRI values for each hazard were reviewed and accepted by the MAC.

Table 4.13 : Summary of Priority Risk Index

PRI Category	Degree of Risk			Assigned Weighting Factor
	Lev	Criteria	Index Value	
Probability	Unlikely	Less than 1% annual probability	1	30%
	Possible	Between 1 and 10% annual probability	2	
	Likely	Between 10 and 100% annual probability	3	
	Highly Likely	100% annual probability	4	
Impact	Minor	Very few injuries, if any. Only minor property damage and minimal disruption on quality of life. Temporary shutdown of critical facilities.	1	30%
	Limited	Minor injuries only. More than 10% of property in affected area damaged or destroyed. Complete shutdown of critical facilities for more than one day.	2	
	Critical	Multiple deaths/injuries possible. More than 25% of property in affected area damaged or destroyed. Complete shutdown of critical facilities for more than one week.	3	
	Catastrophic	High number of deaths/injuries possible. More than 50% of property in affected area damaged or destroyed. Complete shutdown of critical facilities for 30 days or more.	4	
Spatial Extent	Negligible	Less than 1% of area affected	1	20%
	Small	Between 1 and 10% of area affected	2	
	Moderate	Between 10 and 50% of area affected	3	
	Large	Between 50 and 100% of area affected	4	
Warning Time	More than 24 hours	Self explanatory	1	10%
	12 to 24 hours		2	
	6 to 12 hours		3	
	Less than 6 hours		4	
Duration	Less than 6 hours	Self explanatory	1	10%
	Less than 24 hours		2	
	Less than one week		3	
	More than one week		4	

Using both the qualitative and quantitative analyses to evaluate the hazards that impact the region provides members of the MAC with a dual-faceted review of the hazards. This allows officials to not only recognize the potentially most costly hazards, but also to plan and prepare for hazards that although not causing much monetary damage could put a strain on the local resources needed to recover after their impact on the region.

For the 2010 update, the 2006 PRI assessment was determined to be valid and supports the updated ranking and loss estimates.

2010 Ranking Methodology

During the January 2010 HIRA kick-off meeting, committee members liked the new NCDC ranking methods developed for the Commonwealth of Virginia's Emergency Operations Plan HIRA. It was agreed that this approach would be used in the update to the Northern Virginia plan update. Methods used in 2006 were kept in the update for archival and comparative purposes.

Since the methodology for the update was to mirror the State plan, with updated storm event records, the following has been taken from the Commonwealth of Virginia Emergency Operations Plan Annex 3 (Volume II) of the Standard and Enhanced Hazard Mitigation Plan Ranking Methodology.

All conclusions of the HIRA completed for the Northern Virginia region are presented at the end of each of the hazard specific sections. Overall hazard rankings, in cases such as wind and winter storm, were altered based on review and feedback from the steering committee.

Ranking Methodology

To compare the risk of different hazards, and prioritize which are more significant, requires a system for equalizing the units of analysis. Under ideal conditions, this common unit of analysis would be "annualized dollars." However, such an analysis requires reliable probability and impact data for all the hazards to be compared. As this is often not the case, many hazard prioritization methods are based on scoring systems, which allow greater flexibility and more room for expert judgment.

The Virginia Tech Center for Geospatial Information and Technology's (CGIT) and VDEM have developed a standardized methodology to compare different hazards' risk on a jurisdictional basis. As some of the hazards assessed in this plan did not have precisely quantifiable probability or impact data, a semi-quantitative scoring system was used to compare all of the hazards. This method prioritizes hazard risk based on a blend of quantitative factors from the available data. A number of parameters have been considered in this methodology, all of which could be derived from the NCDC database:

- History of occurrence;
- Vulnerability of people in the hazard area;
- Probable geographic extent of the hazard area; and
- Historical impact, in terms of human lives and property.

The ranking methodology tries to balance these factors, whose reliability varies from hazard to hazard due to the nature of the underlying data. Each parameter was rated on a scale of one (1) through four (4). The exact weights were highly debated, but the final conclusion was that the population vulnerability and density would each be weighted at 0.5 with a geographic extent at 1.5, relative to the other parameters. These scores are summed at a jurisdictional level for each hazard separately, permitting comparison between jurisdictions for each hazard type. A summation of all the scores from all hazards in each jurisdiction provides an overall "all-hazards" risk prioritization. The following sections provide an overview of the six parameters that were used in ranking the hazards that impact Virginia.

The NCDC data, as described above, is far from a complete data source. This data was used for the ranking because of its standardized collection of many of the hazards of interest. The data only partially represents the geological hazards, and as a result, the ranking can only characterize the current form of the data. As other data sources become available, the ranking will need to be reassessed to make sure the parameters are still valid for ranking the hazards.

Population Vulnerability and Density

Population vulnerability and density are simple, yet important factors in the risk ranking assigned to a jurisdiction. In general, a hazard event that occurs in a highly populated area has a much higher impact than a comparable event that occurs in a remote, unpopulated area. Two population parameters were used, accounting for jurisdictions with high populations and jurisdictions with densely populated areas. Each parameter was given a weighting of 0.5 in an effort to avoid overwhelming the overall ranking methodology with pure population data.

Population vulnerability was calculated as a percent of the total population of Virginia present in each jurisdiction. The 2007 U.S. Census population projections for each jurisdiction were divided by the total population for the State and a value between one and four was assigned based on a geometric breaks pattern. By ranking jurisdictions this way, those cities and counties with significantly larger populations have effectively been given extra weight. Table 4.14 below describes the breaks and assigned scores for population vulnerability.

Table 4.14: Population Vulnerability as the percentage of people that will be affected by the occurrence of the hazard.

Population Vulnerability	
Rank	*Definition*
1	<= 0.229 % of the total population of the State
2	0.230% - 0.749% of the total population of the State
3	0.750% - 2.099% of the total population of the State
4	> = 2.100% of the total population of the State

Population density was based on the population per square mile for each jurisdiction. The 2007 population projections for each jurisdiction were divided by the total area for the jurisdiction; a value between one and four was assigned based on geometric intervals. By ranking jurisdictions this way, those cities and counties with densely populated areas have effectively been given extra weight. Table 4.15 below describes the breaks and assigned scores for population density.

Table 4.15: Population Density as the number of people per square mile that will be affected by the occurrence of the hazard.	
Population Density	
Rank	*Definition*
1	<= 60.92 people/sq mi
2	60.93 – 339.10 people/sq mi
3	339.11 - 1,743.35 people/sq mi
4	>= 1,743.36 people/sq mi

Geographic Extent

Probable geographic extent (GE) would ideally be measured consistently for each hazard; however, the available data sources vary widely in their depiction of hazard geography. As a result, one uniform ranking system could not be accomplished at this time. In this version of the plan each hazard has been assigned individual category break points based on the available hazard data. In the overall scoring system, geographic extent was given a 1.5 weighting relative to the other parameters, as geographic extent was deemed to be critically important, and more reliable than some of the other parameters. GE data sources, ranking criteria, and category breaks are summarized in Table 4.16 below.

Table 4.16: Geographic Extent as the percentage of a jurisdiction impacted by the hazard.			
Geographic Extent			
Hazard	*Description*	*Category Breaks*	
		Rank	*Definition*
Flood	Percent of a jurisdiction that falls within FEMA Special Flood Hazard Area (SFHA).	*1*	*<=2.99%*
		2	*3.00-4.99%*
		3	*5.00 -9.99%*
	Data: FEMA Floodplains (DFIRMs)	*4*	*>=10.00%*
High Wind	Average maximum wind speed throughout the entire jurisdiction.	*1*	*<= 59.9*
		2	*60.0 - 73.9*
	Data: HAZUS^{MH} 3-second Peak Gust Wind Speeds	*3*	*74.0 - 94.9*
		4	*>= 95.0*
Wildfire	Percent of jurisdiction that falls within a "high" risk.	*1*	*<= 9.9%*
		2	*10.0% - 19.9%*
		3	*20.0% - 49.9%*
	Data: VDOF Wildfire Risk Assessment	*4*	*>= 50.0%*
Karst	Percent of jurisdiction where the risk is "high" for karst related events.	*1*	*<= 24.9%*
		2	*25.0% - 49.9%*
		3	*50.0% - 74.9%*
	Data: USGS Engineering Aspects of Karst	*4*	*>= 75.0%*

Table 4.16: Geographic Extent as the percentage of a jurisdiction impacted by the hazard.			
Geographic Extent			
Hazard	*Description*	*Category Breaks*	
		Rank	*Definition*
Landslide	Percent of jurisdiction where a high landslide risk exists.	*1*	*<= 24.9%*
		2	*25.0% - 49.9%*
	Data: USGS Landslide Incidence & Susceptibility	*3*	*50.0% - 74.9%*
		4	*>= 75.0%*
Earthquake	Average 2,500-year return period max percent of gravitational acceleration (PGA).	*1*	*<= 0.069*
		2	*0.070 - 0.159*
		3	*0.160 - 0.299*
	Data: HAZUS^{MH} 2,500-year PGA	*4*	*>= 0.300*
Winter Storm	Average annual number of days receiving at least 3 inches of snow, calculated as an area-weighted average for each jurisdiction.	*1*	*<= 1.49*
		2	*1.50 - 1.99*
		3	*2.00 - 2.99*
	Data: NWS snowfall statistics	*4*	*>= 3.0*
Tornado	Annual tornado hazard frequency (times 1 million), calculated as an area-weighted average for each jurisdiction.	*1*	*<= 1.24*
		2	*1.25 - 9.99*
		3	*10.00 - 99.9*
	Data: NCDC tornado frequency statistics	*4*	*>= 100.00*

Annualizing the Data for Analysis

Data from the NCDC database was annualized in order to compare the results on a common system. In general, this was completed by taking the parameter of interest and dividing by the length of record for each hazard. The annualized value should only be utilized as an estimate of what can be expected in a given year.

Deaths/injuries, property and crop damage, and events were all annualized in this fashion. A summary of the parameters and the period of record used for each hazard can be found above further describes the NCDC data.

Annualized Deaths and Injuries

Deaths and injuries are also an important factor to evaluate when determining risk ranking. Using NCDC data, past deaths and injuries were computed for drought, flood, high wind, tornado, wildfire, and winter storm. The remaining hazards have no reported deaths or injuries in this database and as a result were assigned a ranking of one (1).

In order to consolidate the data, fatalities were given a weight of 176 times that of an injury, and then added together. This follows the standard practice used for FEMA cost benefit analysis[7]. The combined injury/death values were annualized over the period of record for each event category and scored, using natural breaks (Table 4.17). A summary of deaths/injuries and the period of record used for each hazard can be found in the description of the NCDC data.

Table 4.17: Annualized Deaths and Injuries as the number of deaths or injuries that a hazard event would likely cause in a given year

Annualized Deaths and Injuries	
Rank	*Definition*
1	<= 1.019 deaths and/or injuries per year
2	1.020 – 6.279 deaths and/or injuries per year
3	6.280 – 13.199 deaths and/or injuries per year
4	>= 13.200 deaths and/or injuries per year

Annualized Crop and Property Damage

Crop damage and property damage were also analyzed separately in order to give each jurisdiction a score of one (1) to four (4). This data was obtained from the NCDC storm events database and annualized according to the period of record for each event category (Table 4.18).

Table 4.18: Annualized Crop and Property Damage as the estimated damages that a hazard event will likely cause in a given year.		
Annualized Crop and Property Damage		
Rank	*Definition: Crop Damage*	*Definition: Property Damage*
1	*<= $25,711 per year*	*<= $ 136,129 per year*
2	*$25,712 – $100,270 per year*	*$136,130 - $432,555 per year*
3	*$100,271 - $291,384 per year*	*$432,556 - $1,111,067 per year*
4	*>= $291,385 per year*	*>= $1,111,068 per year*

Annualized Events

While each hazard may not have a comprehensive database of past historical occurrences, the record of historical occurrences is still an important factor in determining where hazards are likely to occur in the future. Annualizing the NCDC storm events data yields a rough estimate of the number of times a jurisdiction might experience a similar hazard event in any given year. To do this, the total number of events in the NCDC database, for each specific hazard in each jurisdiction, was divided by the total years of record for that hazard to calculate an "annualized events" value.

It should be noted that there were no significant events reported for land subsidence (karst), earthquake, and landslide in NCDC; as a result, the events for these hazards all received a rank of one (1). Table 4.19 describes the annual frequency breaks for events.

Table 4.19: Annualized Events as the number of times that a hazard event would likely happen in a given year.	
Annualized Events	
Rank	***Definition***
1	<= 0.09 events per year
2	0.10 – 0.99 events per year
3	1.00 – 4.99 events per year
4	>= 5.00 events per year

Overall Hazard Ranking
The scores from each of these categories were added together for each hazard to estimate the total jurisdictional risk due to that hazard. As discussed previously, the population parameters were each given a weighting of 0.5 (for a total of 1.0 for all population parameters), and Geographic Extent was given a weighting of 1.5 relative to the other factors. The total scores were broken into five categories to better illustrate the distribution of risk scores. Those jurisdictions with scores from 0 to 8.49 were determined to have a low risk in that hazard category; scores 8.50 through 9.99 were considered medium-low risk; between 10.0 and 11.49, medium risk; between 11.50 and 12.99 were considered medium-high risk; and jurisdictional hazard scores greater than 13.00 were given a high rating.

In order to assess the total risk of a county or city across all hazard categories, each of the previous categories were summed across the different hazard types. Overall, all-hazards ranking counties with a low risk have a score less than 86.00; those with a medium-low risk between 86.01 and 93.50; medium risk between 95.51 and 100.00; medium-high risk between 100.01 and 108.00; and those with a high risk have a score greater than or equal to 108.01.

This revision does not include a map of the overall hazards ranking, as was done in the 2006 version of this plan, to avoid overarching conclusions about the ranking and what communities are at risk. Knowing which communities are high for multiple hazards is important for determining mitigation actions, but one overall map, taken out of context, would lead to inaccurate statements about risk in the Commonwealth. The plan's committee members fully supported, and even suggested, that this revision not include this graphic.

Comparison of Methodologies
Differences in 2006 and 2010 annualized loss estimates can be attributed to several factors:

- Time frame of storm events database and/or data sources;
- Inflation of storm events database (taken into account in 2010); and
- Methodologies used for analysis (i.e., HAZUS^{MH})

Results of the updated ranking align nicely with the quantitative and qualitative methodologies used in the 2006 plan. See the Overall Risk Assessment Results section for hazard specific comparisons.

Additional Risk Assessments Completed for the Northern Virginia Region
The Northern Virginia Planning region, as discussed in other sections of this plan, has numerous plans that document different aspects of the risk to natural and man-made hazards. Some of these plans are briefly outlined below:

March 2007 NCR HIRA *National Capital Region Hazard Identification and Risk Assessment: A Uniquely Regional Perspective:* This plan discusses natural and human-caused hazards and provides risk summaries for each of the hazards. Hazards that were determined to impact/disrupt regional continuity were used to create scenarios to further analyze the hazard and determine estimated damages/impact and estimated casualties. Additional hazards were reviewed, risks profiled, and determined not to disrupt regional continuity. The scenarios in this report represent worst-case scenarios and should be used in conjunction with the information presented in this HIRA.

Hazards that Disrupt Regional Continuity:

- Communicable Disease (Pandemic Flu)
- Severe Storms (Hail. Nor'easters, Rain, Thunderstorms)
- Extreme Temperatures
- High Winds
- Tropical Cyclones (Tropical Storms and Hurricanes)
- Winter Storm/Blizzard
- Drought
- Flooding (Flash, Riverine)
- Accidental Release of Communicable Diseases
- Nuclear Detonation
- Aerosol Anthrax Attack
- Chemical Attack (Chlorine Tank Explosion)
- Radiological Dispersal Device (RDD) Attack
- Armed Attack (Beltway Sniper)
- Aircraft as Weapon (9-11 Attacks)
- Cyber Attack or Malfunction
- Toxic Industrial Chemical Spill (Chemical Spill into Water)

Hazards that do not disrupt Regional Continuity:

- Landslide
- Land Subsidence
- Coastal Erosion
- Earthquake
- Tsunami
- Wildfire
  Plague
- Foreign Animal Disease
- Food and Water Contamination (intentional release)
  IED/Conventional Bomb
- Blistering Agents
- Nerve Agents
- Nuclear Reactor Incident, Research and Test Reactors, and Improvised Nuclear Device
- Nuclear Bomb
- Urban Fire
- Hostage Taking/ Assassination
- Civil Disobedience
  Maritime Attacks
  Radio Frequency/EMP
- Workplace Violence

November 2008 NCR SHIELD

National Capital Region Strategic Hazard Identification and Evaluation for Leadership Decisions (NCR SHIELD) *Assessment of Risk to the National Capital Region from Terrorist Attacks and Natural Hazards: Risk Management Strategic Recommendations.* This assessment is also scenario-based. For terrorism, Department of Homeland Security standards for terrorist attack were discussed. For Natural hazards, the FEMA categorization for the different hazard types was used. Analysis was limited to those scenarios that can cause loss of life over 100 people or property loss of over $25 million. Some hazards were not included due to comparatively lower consequences. The scales used for natural and terrorist events are not comparable.

- Highest risk scenarios are:
  - For Terrorism— Improvised Explosive Device and Vehicle-borne Improvised Explosive Device
  - For Natural Hazards—Extreme Heat and Flooding
- Highest consequence scenarios are, for wide-area attacks on the NCR:
  - For Terrorism—Nuclear Attacks, Contagious and Non-Contagious Human Disease (Biological Attacks)
  - For Natural Hazards—Pandemic Disease
- Highest risk sectors are:
  - For Terrorism—Banking & Finance, Commercial, Government Facilities, Transportation
  - For Natural Hazards—Commercial, Electric, Healthcare & Public Health, Transportation

September 2005 CIP MCR RBFRS

Critical Infrastructure Protection in the National Capital Region *Risk-Based Foundations for Resilience and Sustainability* created by University Consortium for Infrastructure Protection managed by the Critical Infrastructure Protection Program School of Law George Mason University. In 2002, the National Capital Region's Eight Commitments to Action identified critical infrastructure protection as a high priority of the region's homeland security strategy. Teams of experts in each of the eight critical infrastructures review literature and investigated vulnerability with key managers of the facilities. Each sector has listed key findings and listed recommendations, some of which include:

- Healthcare and public health sector is the least advanced due to its extensive redundancy and geographical dispersion.
- Banking and finance and telecommunications have a very high level of risk management due to close working relationships with government agencies that stress reliability and risk management.

V. Flood

NOTE: As part of the 2010 plan update, the Flood hazard was reexamined and a new analysis performed. This new analysis included, but was not limited to: 1) refreshing the hazard profile; 2) updating the previous occurrences; 3) determining annualized number of hazard events and losses by jurisdiction using NCDC and other data sources where available; 4) updating the assessment of risk by jurisdiction based on new data; and 5) ranking of the hazard by jurisdiction using the methodology described in detail in the HIRA Introduction section. Erosion in Northern Virginia is often the result of flooding and has been incorporated into the Flood section for this update. In addition, each section of the plan was also reformatted to improve clarity, and new maps and imagery, when available and appropriate, were inserted.

A. Hazard Profile

1. Description

Flooding - Flooding is the most frequent and costly natural hazard in the United States; a hazard that has caused more than 10,000 deaths since 1900. Nearly 90% of presidential disaster declarations result from natural events where flooding was a major component.

Floods are generally the result of excessive precipitation, and can be classified under two categories: general floods, precipitation over a given river basin for a long period of time; and flash floods, the product of heavy, localized precipitation in a short time period over a given location. The severity of a flooding event is determined by the following: 1) a combination of stream and river basin topography and physiography; 2) precipitation and weather patterns; 3) recent soil moisture conditions; and 4) the degree of vegetative clearing.

Generally, floods are usually long-term events that may last for several days. The primary types of general flooding include riverine, coastal, and urban flooding. 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.

Hurricane Isabel September 2003
Bellevue section of Fairfax County
(Photo from Fairfax County)

Flash Flooding - Flash flooding events can occur from a dam or levee failure within minutes or hours of heavy amounts of rainfall, or from a sudden release of water held by an ice jam. Most flash flooding is caused by slow-moving thunderstorms in a local area or by heavy rains associated with hurricanes and tropical storms. Although flash flooding occurs often along mountain streams, it is also common 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 of 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 average global sea level has been rising at the rate of about 3.1 mm per year (data from 1993 to 2003)[8]. This same trend is apparent in the historical gage records for Washington, DC, (Station 8594900) along the tidally-influenced Potomac River where rates have averaged about 3.2 mm/year.

Sea Level Rise

Sea level rise is expected to continue and possibly accelerate as the planet warms. Based on output from multiple computer models, a low sea level rise scenario is one with a sea level rise of 7 to 15 inches by 2100. A high scenario would include a sea level rise of 10 to 23 inches by 2100. Neither scenario includes the possibility of ice sheet melting contributing to sea level rise. Some scientists suggest that should the Greenland and West Antarctic ice sheets collapse; sea level rise will be on the order of several feet higher than the high scenario shown here. [9]

Using the high Intergovernmental Panel on Climate Change (IPCC) emissions growth scenario and overlaying corresponding projected sea levels expected with that scenario, it is anticipated that significant portions of the eastern sections of Old Town Alexandria, including the eastern portions of King Street will be at risk of inundation (Figure 4.11). A study being conducted by NVRC as part of Sustainable Shorelines & Community Management indicates that approximately 49 buildings may be inundated under a high sea-level rise scenario.

Also at risk of inundation under projected rises in sea-level is Ronald Reagan Washington National Airport. Situated along the banks of the Potomac, the airport opened in 1941. The site had originally been mostly underwater and was built up by sand and gravel fill. Approximately 200 acres of the airport are within 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 (See Figure 4.12).

Other low-lying areas in Northern Virginia are also at risk for sea level rise inundation. Portions of Four Mile Run in Arlington and Alexandria, Dangerfield Island, Jones Point, Huntington, Belle Haven/New Alexandria, Dyke Marsh, Hallowing Point, Occoquan NWR, Town of Quantico, the Occoquan River and various tidal embayments may be impacted.

In addition to producing high resolution sea level rise and storm surge inundation mapping for Northern Virginia, the NVRC study, completed in late 2010, will also quantify specific elements vulnerable for both the built and natural environments and develop strategies to protect, adapt or retreat communities located in areas at risk.

Figure 4.11. Projected "high scenario" sea-level rise for Old Town, Alexandria Year 2100.
Source: NVRC, 2010

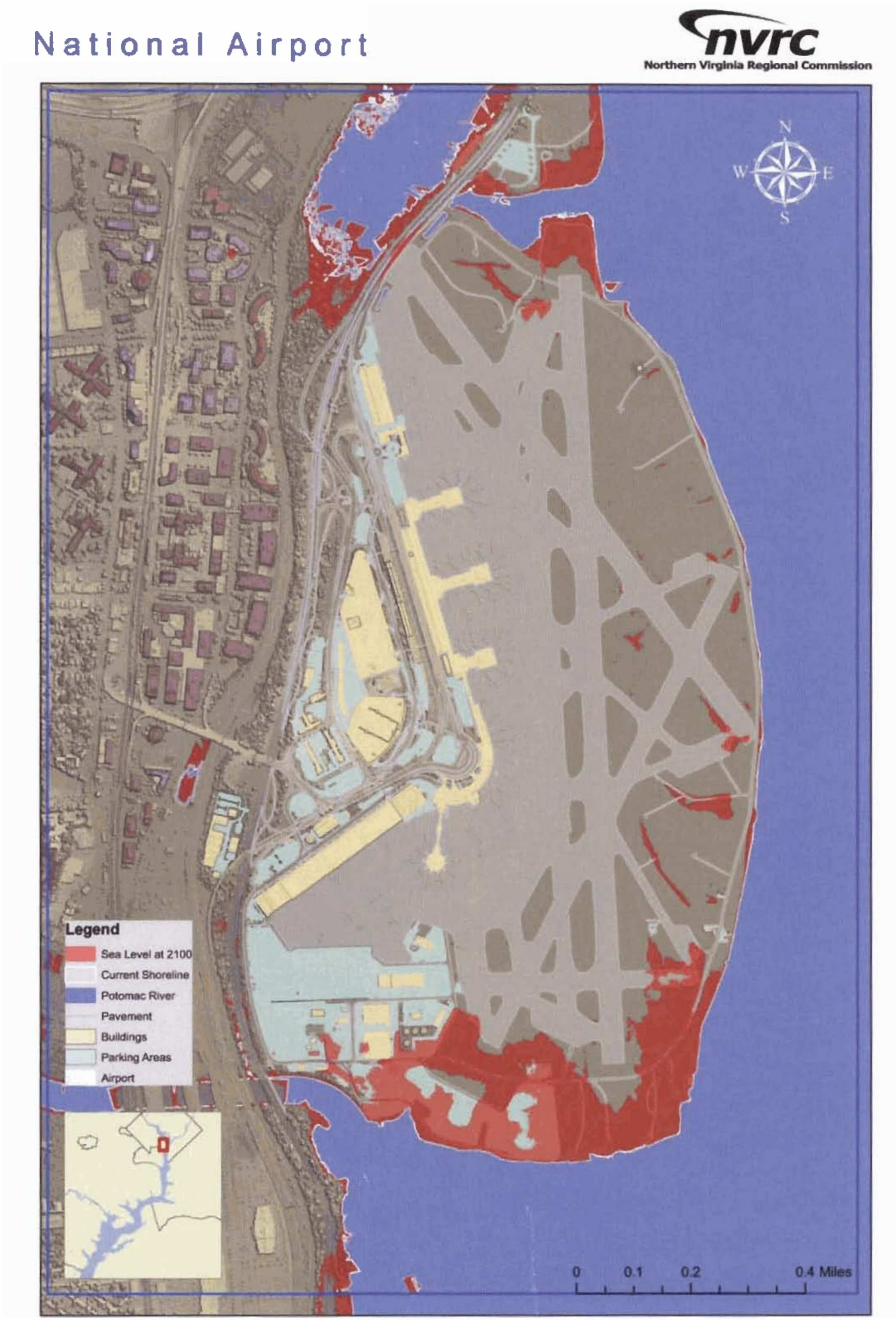

Figure 4.12. Projected "high-scenario" sea-level rise for Ronald Reagan Washington National Airport Year 2100.
Source: NVRC, 2010

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, or geologic, erosion has occurred since the Earth's formation and continues at a very slow and uniform rate each year.

There are two general causes of soil erosion: wind and water. Both can cause significant soil loss. Winds blowing across sparsely vegetated or disturbed land can pick up soil particles and transport them to another location. Water flowing over land also transports soil particles to other locations. Wind erosion generally impacts wider, less well defined areas than water erosion, but water erosion is capable of transporting 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 the result of lateral and uplift wind forces separating individual soil particles from the soil mass and transporting them until the wind speed and resulting forces decrease to where they are insufficient to support and transport the particles. Generally, individual wind erosion events in areas of exposed silt and clay are relatively minor. However, if the exposed soil consists of sand, and the sand becomes airborne, the rate of erosion can increase by a factor of 10. Airborne sand acts as an abrasive as it is blown across the surface, which acts to dislodge significantly more soil that the wind alone.

The main causes of water erosion are stream or overland flow, and wave action. Stream or overland flow erosion is the result of mechanical or chemical removal, and transportation of soil particles to a new location. Mechanical erosion is caused by hydrodynamic forces pushing particles down-gradient; 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. Water quality impacts both chemical and mechanical erosion; water with relatively a 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 of long 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 gained increased public attention. Implementation of erosion control measures consistent with sound agricultural and construction operations was needed to minimize the adverse effects associated with increasing settling out of the soil particles due to water or wind. The increase in government 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. 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.

There is no known database of historic erosion events in the Northern Virginia region. Erosion events are often extremely localized in nature and often go unreported unless they damage infrastructure or the resulting topography presents a new hazard.

As far as coastal and tidal erosion, Prince William, Fairfax, and Arlington Counties and the City of Alexandria all have tidal shorelines along the Potomac River and its associated embayments and tributaries. The accretion and erosion of these shorelines are greatly 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, soil), as well as human activities (e.g., land use, dredging, and shoreline stabilization).

In September 1992, NVRC prepared a study entitled "Tidal Shoreline Erosion in Northern Virginia" which discusses the erosion situation for various segments of the shoreline in the Northern Virginia region, as well as identifies the locations of "priority" erosion concern. The report is intended to serve as a valuable resource document for State and local officials to assist them in planning for shoreline and erosion control throughout Northern Virginia, and is hereby incorporated by reference. In addition, the report augments a DBase IV 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 an excellent historical record for current planning efforts, and also future research.

According to the report, 20% of the Northern Virginia shoreline has been artificially stabilized with 32 miles of hard structures. Prince William County has approximately 48 miles of shoreline with 8.7 miles of artificial shoreline stabilization structures. 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%). The City of Alexandria has the shortest shoreline length (8.8 miles), with the largest percent stabilized (58%, or 5.1 miles). Arlington County has 13.3 miles of tidal shoreline, with 4.9 miles of hardened shoreline (37%). This information has not been updated since the 2006 plan creation.

The probability of future erosion events remains likely in localized areas throughout the Northern Virginia region. According to projects researching the changing climate, including sea-level risk and increased storm events, erosion would be expected to increase.

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. 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 in the Hazard Analysis section, NVRC prepared a study titled "Tidal Shoreline Erosion in Northern Virginia," which discusses the erosion situation for various segments of the shoreline in the Northern Virginia region, as well as identifies the locations of "priority" erosion concern. This publication is hereby incorporated by reference, as will be future updates to shoreline erosion studies in the Northern Virginia region.

2. Geographic Location/Extent

There are numerous rivers and streams flowing through the Northern Virginia region. When heavy or prolonged rainfall events occur, these rivers and streams are susceptible to some degree of flooding. The most notable of these water bodies is the Potomac River, which in the past has been the source for 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. The topography of the upper reaches of the basin is characterized by gently sloping hills and valleys.

At Great Falls in Maryland, the Potomac River starts its rapid descent to sea level by plunging 76 feet through a deep gorge in less than one mile. Eastward of Great Falls, the Potomac flows between Washington, DC, Arlington, and Alexandria. Here the river dramatically 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 continues on through the coastal plain and eventually grows 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 prone to this type of flooding are known as floodplains or SFHAs. These locations, which are more commonly defined as the "100-year floodplain" (areas with a one-percent-annual-chance of flooding), are routinely surveyed and mapped by FEMA as part of a Flood Insurance Study sponsored by the NFIP. These studies and associated maps are then provided to local communities in order to regulate the development of land within these hazard areas.

Figure 4.12 shows the potential flood hazard areas throughout the Northern Virginia region based on the FEMA DFIRM and Q3 data. Jurisdiction specific flood maps that show the FEMA floodplain in relation to dominant geographic features in the region can be found in Appendix D4.

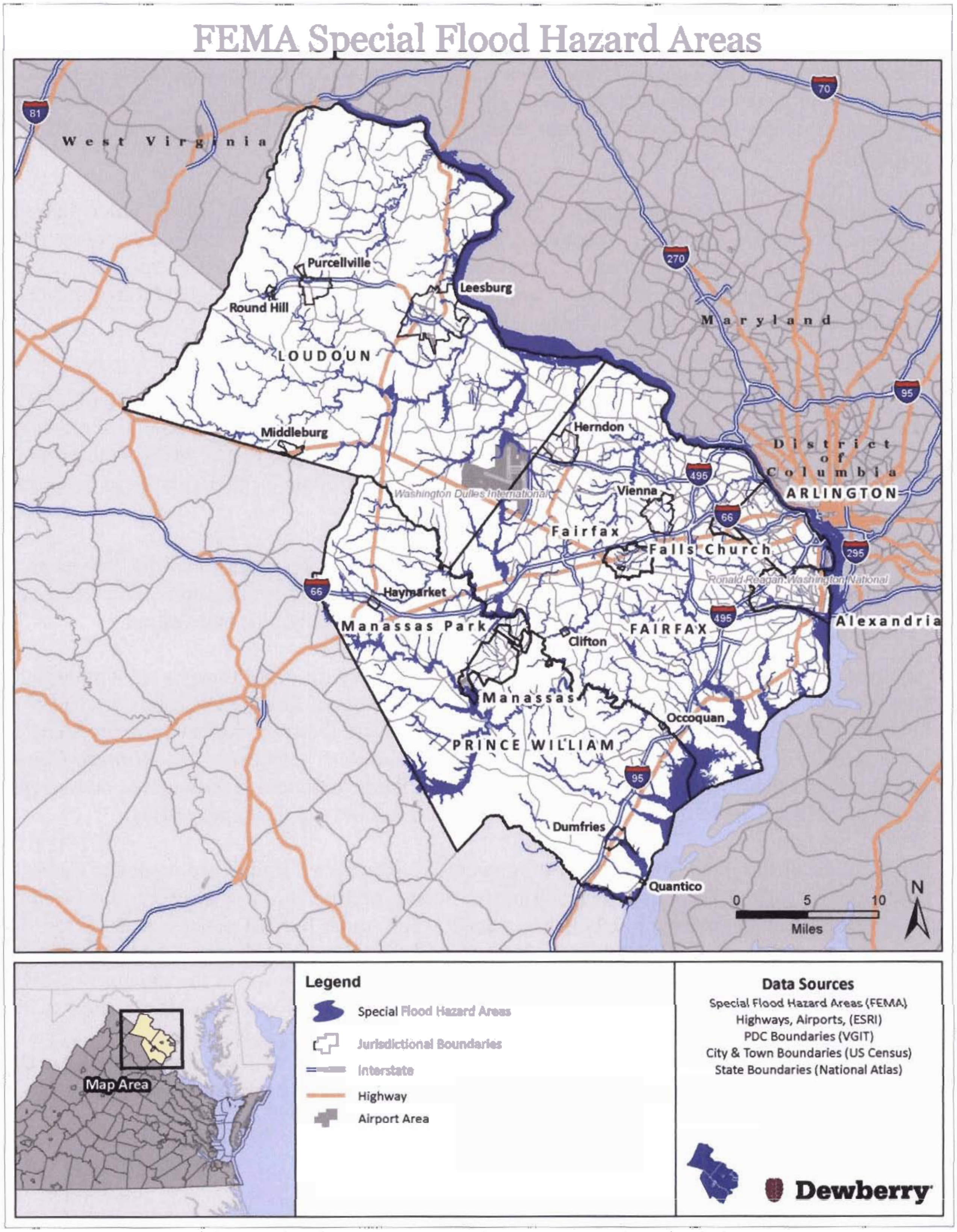

Figure 4.12 FEMA Digital Flood Insurance Rate Maps (DFIRM) and Q3 data.

There have been a number of past flooding events throughout the region, ranging widely in terms of location, magnitude, and impact. The most frequent flooding events are quite localized in nature, resulting 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 is difficult to obtain. Table 4.20 summarizes the number of flood events (by county) since 1993 which have caused a notable impact on the Northern Virginia region as recorded by the NCDC. This includes 439 flood events that have caused approximately $28 million in property and crop damages, as well as one death and one injury in Arlington County.

Table 4.20 Flood Events in the Northern Virginia Region, 1993–2009 based on NCDC storm events data

Jurisdiction	# of Flood Events	Property Damage	Crop Damage	Property + Crop Damage
Arlington County	50	$4,405,124	$341,254	$4,746,378
Fairfax County	101	$13,254,002	$378,349	$13,632,352
Loudoun County	75	$3,449,790	$229,495	$3,679,285
Prince William County	75	$2,225,367	$410,387	$2,635,753
City of Alexandria	47	$628,307	$341,254	$969,561
City of Fairfax	5	$0	$0	$0
City of Falls Church	38	$576,049	$341,254	$917,302
City of Manassas	46	$1,170,116	$344,312	$1,514,428
City of Manassas Park	2	$0	$0	$0
Total	**439**	**$25,708,755**	**$2,386,304**	**$28,095,058**

3. Magnitude or Severity

Flooding only impacts a community to the degree that it affects the lives of its citizens and the community functions overall. Therefore, the most vulnerable areas of a community will be those most affected by floodwaters in terms of potential loss of life, damages to homes and businesses, and disruption of community services and utilities. For example, an area with a highly developed floodplain is significantly more vulnerable to the impacts of flooding than a rural or undeveloped floodplain where potential floodwaters would have little impact on the community.

The severity of a flood on a community can be magnified to the degree floodwaters affect special needs populations and critical facilities. Special needs populations are those that may require special assistance during a flood event, may not be able to protect themselves prior to an event, or may not be able to understand potential risks. These can include non-English populations, elderly populations, or those in a lower socioeconomic group. (Further discussed in the Populations at Risk section above)

The impacts of floodwaters on critical facilities, such as police and fire stations, hospitals, and water or wastewater treatment facilities can greatly increase the overall effect of a flood event on a community. In general, relatively few of these facilities are located in areas with a high risk to flooding.

As discussed above, relative sea-level rise due to land subsidence and global sea level changes that are projected to occur in association with climate change and the possibility of more intense precipitation events, which may translate into greater storm water run-off into the future, are expected to exacerbate flooding hazards.

4. Previous Occurrences

June 23-27, 2006

A nearly stationary front draped across the area combined with several low pressure systems and produced several waves of heavy rainfall across Northern Virginia over this 5-day stretch. Rainfall totals over this period were in the double digits at several locations. The pinnacle of the flooding seemed to occur on June 26. The VRE commuter line ceased operations and flooding in underground tunnels forced much of the Washington Metro rail service to close. Numerous roadways across the region were also underwater. Water rescues were needed for motorists that became trapped in floodwaters. In Huntington, flooding-related damages lead to 158 homes being declared uninhabitable due to contamination and lack of utilities.

September 23, 2003

Six inches of rain in four hours caused major flooding across the region, but particularly in Loudoun County. During the morning of the 23rd, heavy rain fell on top of already saturated ground from Hurricane Isabel, which struck a few days before. This led to widespread flooding of roads, waterways, and other low lying areas. Widespread flooding was reported, especially in the Leesburg, Purcellville, Bluemont, Aldie, and Middleburg areas. Across the county, over 50 roads were affected by flooding. Lime Kiln Road, Evergreen Mills Road, and Route 15 were underwater for over 24 hours after Goose Creek surged nearly 11 feet above bankful stage. The Little River flooded the Oatlands Mill area and five people had to be rescued from their homes by boat. One farmhouse along Oatlands Mills Road had water up to its second story, and in Aldie the local firehouse sustained significant flood damage. St. Louis Road was completely washed away. In Leesburg, Tuscarora Creek and Town Branch overflowed into yards, basements, and parking lots. Two vans in a parking lot along Town Branch were washed downstream and residents along Shenandoah Street had to be evacuated. The Sheriff's Office administrative building was heavily damaged after the heavy rain collecting on the roof caused the ceiling to collapse. Across the county 60 basements were flooded.

Street flooding during the flood of August 11, 2001. Flooding occurred along a narrow band from Warrenton, Virginia through Fairfax County, and extended into northern Washington, DC. Up to seven inches of rain fell in some areas. (Photo courtesy of WJLA)

August 11, 2001

Showers and thunderstorms with very heavy rainfall and frequent lightning moved across Northern Virginia during the afternoon of the 11th. In Loudoun County, high water stranded motorists in Sterling and the bridge at Lawson Road in Leesburg was impassible after a stream overflowed its banks. Water covered roads in the City of Fairfax. In McLean, four houses were flooded and two cars were submerged by flood waters. Also in McLean, a car and a dumpster were washed downstream after Pimmit Run overflowed. In Arlington County,