

## 5.0 Hazard Identification and Risk Assessment (HIRA)

The Crater Planning District Commission (PDC) and the Richmond Regional PDC, on behalf of the jurisdictions which comprise their regions, have updated the 2011 Hazard Identification and Risk Assessment (HIRA) to serve as a guide to all communities in the regions when assessing potential vulnerabilities to natural hazards. When initialing developing the plan in 2005, and updating it in 2011 and 2017, every effort was made to gather input from all aspects of the project area communities to ensure that the results of this analysis are as accurate as possible. Regional hazard and vulnerability maps are presented in this section. Appendix G contains localized maps for each jurisdiction.

The Crater PDC region includes four cities, six counties, and eight incorporated towns. The Richmond Regional PDC region includes one city, seven counties, and one incorporated town. Charles City and Chesterfield counties are members of both the Richmond Regional and Crater PDCs. The analysis in this section of the plan addresses risks and vulnerabilities to all of the cities, counties and towns in the region; results are presented on a variety of scales such as regional, county/city or county/city/town to best illustrate the available data.

The purpose of the HIRA is to:

- Identify what hazards could affect the planning regions.
- Profile hazard events and determine what areas and community assets are the most vulnerable to damage from these hazards.
- Estimate losses and prioritize the potential risks to the community.

The first step, hazard identification, identifies all natural hazards which the Hazard Mitigation Technical Advisory Committee felt might affect the PDCs. The hazards are ranked to determine what hazards are most likely to impact region's communities. Hazards determined to have significant impact are analyzed in the greatest detail to determine the magnitude of future events and the vulnerability of the community and its critical facilities. Hazards that receive a moderate impact ranking are analyzed with available data to determine the risk and vulnerability to the specified hazard. The limited impact hazards are analyzed using the best available data to determine the risk to the community.

### 5.1 Critical Facilities

NOTE: Specific information about critical facilities has been redacted from this public copy of the plan to address public safety concerns. This information is available to public safety officials in a redacted Appendix I

A critical facility is defined as a facility in either the public or private sector that provides essential products and services to the general public; is otherwise necessary to preserve the

welfare and quality of life in the community; or fulfills important public safety, emergency response, and/or disaster recovery functions.

For the 2017 update, the Richmond Regional and Crater PDC staffs worked with members of the HMTAC to identify the following as the types of structures that could be consider as a critical facility.

**Public Safety:**

Police, Emergency Operations Centers, Sheriff, Fire, Correctional Facilities, and Emergency Management

**Infrastructure:**

Cell towers, fuel storage, pumping stations, water and wastewater treatment facilities, and transportation structures

**Government Facilities:**

Courthouses and judicial facilities, government offices and facilities

**Medical Facilities:**

Hospitals, nursing facilities, rehabilitation centers and outpatient centers

**Education:**

K – 12 public schools, colleges and universities, technical schools

This type of information was compiled for the region and used in the hazard analysis as well as for the vulnerability analysis and development of 2017 – 2022 regional and local mitigation actions.

## **5.2 Land Cover and Land Use**

Based on the U.S. Geological Survey (USGS) National Land Cover Data (NLCD), there are nine main land cover definitions with the majority in the “developed” categories that include developed open space, low intensity, medium intensity, and high intensity development. A summary of the land cover categories is included in Appendix B; maps of the jurisdictions are in Appendix G.

Land use was available for the majority of the communities in the Richmond PDC but not in the Crater PDC. As a result, most of the discussion is based on current land cover from NLCD. For the communities that provided land use data or where it was included in community comprehensive plans, future land use and development trends are described in detail in Section 4.0, Community Profile. The development trends described in the Community Profile section should be considered in mitigation actions and future updates to this plan.

### 5.3 Data Limitations

In order to gain a full understanding of the hazards, an extensive search of historic hazard data was completed. This data collection effort used meetings with local community officials, existing reports and studies, state and national datasets, and other sources. A comprehensive list of sources used for this plan can be found in Section 9.0 of this document.

Whenever possible, data has been incorporated into a Geographic Information System (GIS) to aid analysis and develop area-wide maps for depicting historical hazard events, hazard areas, and vulnerable infrastructure. Critical facility data has been collected from local jurisdictions and has been supplemented from FEMA's loss estimating software, Hazus-MH.

In accordance with FEMA's mitigation planning guidance, the results of this study are based on the best available data. The amount of detailed data regarding the location of structures, characteristics of facilities, and other community-related data varies from jurisdiction to jurisdiction. For instance, Charles City County had structure point information that provides an approximate location of the structure while other jurisdictions had building footprint data (except the City of Colonial Heights) which was used for the flood TEIF 2.0 analysis.

Recognizing this deficiency in detailed local data, one ongoing strategy included as part of this mitigation plan, is to increase the quality and detail of data to prepare usable and effective hazard assessments.

Information from the National Climatic Data Center's (NCDC) Storm Event Database was used to inform the weather-related hazard analysis. The NCDC receives storm data from the National Weather Service (NWS), which in turn receives it from a variety of sources, which include but are not limited to: county, state, and federal emergency management officials, local law enforcement officials, Skywarn spotters, NWS damage surveys, newspaper clipping services, the insurance industry, and the general public. An effort is made to use the best available information, but because of time and resource constraints, information from these sources may be unverified by the NWS. Therefore, the recurrence intervals and other historical analysis presented may not be 100% accurate but instead are based on best available data. In addition, there may be discrepancies in data reporting between jurisdictions that have similar experience or exposure to hazards (e.g., neighboring Charles City and New Kent Counties). Data is only available at a county or regional level for some hazard events including winter storms and droughts. A particular drought or winter storm event in the NCDC database may contain property or crop loss dollar figures, but the single event record may contain multiple counties with no indication of how the dollar damages were distributed. In these instances, lacking better data, the loss figures

were “normalized” by spreading losses in equal proportions to all counties listed in the event record.

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 2011. 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 2011, the target year.

After the data was normalized, inflation accounted for, and summary statistics calculated, the data was annualized in order to be able 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 used as an estimate of what can be expected in a given year. Property and crop damage, and the number of events were all annualized in this fashion, on a per-jurisdiction basis.

## **5.4 Hazard Identification**

### **5.4.1 Types of Hazards**

Although all types of disasters are possible for any given area in the United States, the most likely hazards that could potentially affect the communities in the planning regions were determined through research and analysis conducted for the 2011 Hazard Mitigation Plans and discussion with community officials. The hazard categories were reviewed again during the 2017 plan update and it was agreed that they still represent the main types impacting the region. These hazards include:

- Landslides
- Shoreline erosion
- Droughts
- Flooding
- Earthquakes
- Hurricanes
- Sinkholes
- Wind
- Tornadoes
- Wildfires
- Winter weather
- Thunderstorms
- Extreme heat

In addition, the HMTAC included mass evacuation to the list of hazards to be considered in the plan as was done in 2011.

### **5.4.2 Planning Consideration**

Hazards were ranked based on analysis conducted for the 2011 update, consideration of the hazard analysis presented in the March 2013 Virginia State Hazard Mitigation Plan, input



from the 2017 HTMAC, and a new analysis performed for the 2017 update to determine what hazards might have the largest impact on their communities. The results are summarized in Table 5-2. As a result of this analysis, the hazards were broken down into four distinct categories which represent the level of consideration they will receive throughout the planning process. These categories are *Significant*, *Moderate*, *Limited*, and *None*. For the 2017 update rankings only the categories of *Significant*, *Moderate*, or *Limited* were used. Certain hazards were not addressed or did not need any updating as a result of the infrequency of occurrence and/or limited impact.

**Table 5-2. Planning Consideration Levels by Hazard Type for 2017 Update**

Hazard Type	2011 Planning Consideration Level	Commonwealth of Virginia 2013 HIRA Hazard Ranking	2017 HTMAC Preliminary Ranking	2017 HIRA Ranking Analysis**
Flooding	Significant	High	Moderate	Moderate
Wind*	Moderate	Medium-High	High	Limited
Tornado*	Moderate	Medium-High	High	Significant
Hurricane*	Moderate	Not ranked	High	Significant
Winter weather	Moderate	Medium-High	High	Moderate
Thunderstorms* (including Hail and Lightning)	Moderate	Negligible	High	Moderate
Droughts (with Extreme Heat)*	Moderate	Droughts = Medium Extreme Heat = Negligible	Limited	Limited
Mass evacuation	Moderate	Not ranked – Discussed in other Commonwealth of Virginia emergency operations plans	Limited	Limited
Wildfires	Limited	Medium	Limited	Limited
Earthquakes	Limited	Medium-Low	Limited	Limited
Landslides/shoreline erosion*	Limited	Landslide = Medium-Low Erosion = Negligible	Limited	Limited
Karst	Limited	Low	Limited	Limited
* Some event types were combined (Droughts/Heat and Landslide/Erosion) or separated (Wind/Tornado and Hurricanes/Thunderstorms) from other plans and votes to accommodate the 2017 HTMAC's current concerns for their regions.				
** Ranking analysis explained in section 5.4.3 Analysis and Data Sources.				

Because some of the hazards included in the hazard identification analysis are similar, some hazards will be discussed simultaneously later in this analysis. For instance, the Wind section includes hurricanes, other tropical disturbances, and thunderstorm winds while tornadoes were evaluated in their own section. A detailed discussion of the potential hazards that have been identified as *Significant* and *Moderate* events is provided in the sections that follow. A brief discussion of the *Limited* events is also included.

### 5.4.3 Analysis and Data Sources

Table 5-3 provides a list of the natural hazards, the analysis type and data source included in this plan. In order to focus on the most critical hazards that may affect the Planning District communities, hazards assigned a level of *Significant* or *Moderate* will receive the most extensive attention in the remainder of the planning analysis, while those with a *Limited* planning consideration level will be assessed in more general terms. The hazards with a planning level of *None* will not be addressed in this plan. The hazards assigned a ranking of *None* are not critical enough to warrant further evaluation; however, these hazards should not be interpreted as having zero probability or impact. It should also be noted that all sources, especially the NCDC and National Weather Service, only include events that are reported and may not include all events. However, they provide good databases and can help provide a better picture to help understand and mitigate damages.

**Table 5-3 HIRA Overview – Hazards, Analysis and Data Source**

Hazards	Analysis	Data Sources
Flooding	Covered by HIRA flood analysis	FEMA Digital Flood Insurance Rate Map (DFIRM), Q3, and FIRM Mapping; HAZUS census block values; NCDC; TEIF 2.0 analysis
Hurricanes	Covered by HIRA flood and hurricane wind analysis	FEMA DFIRM, Q3, and FIRM Mapping and American Society of Civil Engineers Design Wind Speed Maps, FEMA HAZUS model; NCDC; National Hurricane Center
Wind	Covered by HIRA hurricane wind analysis	FEMA HAZUS model; NCDC
Winter storms	Covered by HIRA winter storm analysis	NCDC; NWS; PRISM Climate Group; VDOT; IEM
Droughts	Covered by HIRA drought analysis	NCDC; U.S. Drought Monitor; U.S. Census Bureau 1990 Water Source Data
Tornadoes	Description and regional maps	NCDC; Severe Weather Data GIS Data; VDEM
Wildfires	Covered by HIRA wildfire analysis	VDOF; NCDC
Earthquakes	None, due to infrequency of occurrence	USGS

**Table 5-3 HIRA Overview – Hazards, Analysis and Data Source**

Hazards	Analysis	Data Sources
Landslides/ shoreline erosion	None, due to infrequency of occurrence	USGS; NCDC

The final analysis for the HIRA Ranks were established using the following Criteria in Table 5-4. This table shows what scores were given and the criteria needed to get these scores. This was based off a FEMA Hazard Priority Ranking Criteria and modified to include what information was available at the time of publishing this document.

**Table 5-4. Hazard Priority Ranking Criteria for Richmond and Crater Regions**

Probability	Score	Vulnerability	Score	Maximum Impact (Annual Damages)*	Score	Warning Time	Score
<b>Unlikely</b> - No documented NCDC occurrences with annual probability < 0.01	0.5	Limited Rank by 2017 HMTAC Preliminary Ranking	1	No NCDC data found to evaluate. Does not mean there was no damages.	0	<b>Extended</b> - Three days or more	1
<b>Somewhat Likely</b> - Infrequent occurrence with at least one NCDC documented event and annual probability between 0.5 and 0.01	1	Moderate Rank by 2017 HMTAC Preliminary Ranking	2	Based on NCDC data, score award by percent of total annual damages done by event. Hazard receive their percent of points from 0.01 to 3 max)	0.01 - 3	<b>Limited</b> - 2 days	2
<b>Likely</b> - Frequent occurrence with at least some NCDC documented events and annual probability between 1 and 0.5	1.5					<b>Minimal</b> - 1 day	2
<b>Highly Likely</b> - Common events with annual probability > 1	3	High Rank by 2017 HMTAC Preliminary Ranking	3			<b>No Notice</b> - < 24 Hours	3

After scores were assigned to each hazard, the scores were then summed together and divided by 4 (because there were 4 categories) to find the average score. Scores between 2.5 and 3.0 were given “significant,” 2.0 to 2.5 were assigned “moderate,” and everything less than 2 were assigned “limited.” These scores, ranks, and assigned categories for each hazard type are shown in Table 5-5. The final ranking in order from most significant to limited are shown in Table 5-6.

**Table 5-5. HIRA Priority Ranking Analysis**

Hazard Type	Probability\History	Vulnerability	Maximum Impact (Annual Damages)	Warning Time	2017 Analysis Score	2017 Ranking Category
<b>Drought</b>	3	1	2.23	1	1.81	Moderate
<b>Earthquake</b>	0.5	1	0	3	1.13	Limited
<b>Flood</b>	3	2	1.94	2	2.24	Moderate
<b>Hurricanes</b>	3	3	3.00	2	2.75	Significant
<b>Karst</b>	0.5	1	0	3	1.13	Limited
<b>Landslide</b>	0.5	1	0	3	1.13	Limited
<b>Mass Evacuation</b>	0.5	1	0	1	0.63	Limited
<b>Thunderstorm</b>	3	3	1.34	2	2.34	Limited
<b>Tornado</b>	3	3	1.92	3	2.73	Significant
<b>Wildfire</b>	0.5	1	0	3	1.13	Limited
<b>Wind</b>	1.5	3	0.68	2	1.79	Limited
<b>Winter</b>	3	3	1.33	1	2.08	Limited

**Table 5-6. HIRA Priority Analysis Rank**

Hazard Category	Rank Score	Rank	Rank Category
<b>Hurricanes</b>	2.75	1	Significant
<b>Tornado</b>	2.73	2	Significant
<b>Thunderstorm</b>	2.34	3	Moderate
<b>Flood</b>	2.24	4	Moderate
<b>Winter</b>	2.08	5	Moderate
<b>Drought</b>	1.81	6	Limited
<b>Wind</b>	1.79	7	Limited
<b>Wildfire</b>	1.13	8	Limited
<b>Earthquake</b>	1.13	8	Limited
<b>Landslide</b>	1.13	8	Limited
<b>Karst</b>	1.13	8	Limited
<b>Mass Evacuation</b>	0.63	12	Limited

From this analysis, hurricane and tornado events seem to be the most significant types of hazards for the study region. Thunderstorm, flood, and winter events were determined to be moderate events, with everything else being labeled as limited. It should be noted that wildfire, earthquake, landslide, karst, and mass evacuation events were not included in the NCDC database. This does not mean that they did not happen or cause damages, but were given 0 scores as a maximum threat because there was no data to confirm what percent of damages that they may have caused.

## 5.5 Major Disasters

Eighty-eight disasters have been declared in the planning region since 1965. One third of the events were hurricane disasters, one quarter were associated with severe storms, one fifth were snow and ice related, a few drought and flood disasters, and several unique events were included like a West Nile Virus disaster declared on May 30, 2000. It should be noted that flooding is often included in severe storm, hurricane, and coastal storm disasters. A summary of the total events declared and what kinds are shown in Table 5-7, while the individual events declared for each county are shown in Table 5-8.

**Table 5-7. Presidential Declared Disaster Types Overall Counties**

<b>Incident Type</b>	<b>Total Occurrences</b>
Hurricane	29
Severe Storm	20
Snow	17
Flood	8
Drought	6
Severe Ice Storm	2
Earthquake	1
Fire	1
Coastal Storm	1
Tornado	1
Freezing	1
Other	1
<b>Total Events</b>	<b>88</b>

**Table 5-8. Presidential Declared Disaster by County and City, 1965 - 2016**

Jurisdiction	Hurricanes	Severe Storms	Snow and Ice	Flood	Drought	Other	Totals
Charles City County	6	3	3	1	1	-	14
Chesterfield County	12	4	6	4	2	1	29
City of Colonial Heights	5	2	3	1	-	-	11
Dinwiddie County (incl. Town of McKenney)	6	4	3	1	2	-	16
City of Emporia	6	3	2		-	-	11
Goochland County	5	2	3	2	2	1	15
Greensville County (incl. Town of Jarratt)	6	3	2	-	1	-	12
Hanover County (incl. Town of Ashland)	6	3	4	1	2	-	16
Henrico County	8	2	5	2	1	-	18
City of Hopewell	6	2	3	1	-	-	12
New Kent County	8	3	4	-	1	-	16
City of Petersburg	5	3	4	1	-	-	13
Powhatan County	6	2	3	3	2	-	16
Prince George County	6	3	4		1	-	14
City of Richmond	6	3	4	2	-	-	15
Surry County (incl. Towns of Claremont, Dendron, Surry)	10	3	8	3	1	-	25
Sussex County (incl. Towns of Stony Creek, Wakefield, Waverly)	19	13	11	4	4	2	53

Appendix B-2 lists the presidentially declared disasters that have occurred in the Richmond-Crater region planning districts. The appendix demonstrates and dates which hazards have impacted each of the communities in the planning regions.

## 5.6 Flooding

### 5.6.1 Hazard Profile

A flood occurs when an area that is normally dry becomes inundated with water. Floods may result from the overflow of surface waters, overflow of inland and tidal waters, or mudflows. Flooding can occur at any time of the year, with peak hazards in the late winter and early spring. Snowmelt and ice jam breakaway contribute to winter flooding, and seasonal rain patterns contribute to spring flooding. Torrential rains from hurricanes and

tropical systems are more likely to occur in late summer. Development of flood-prone areas tends to increase the frequency and degree of flooding.

The most significant natural hazard to affect the region is flooding. The region is relatively flat, falling in the Piedmont and Coastal Plain regions. The western portion of the study area is characterized by a more rolling topography but the part east of the Fall Line can be locally quite rugged where short, high gradient streams have incised steep ravines. Several rivers flow through the region including the James, York, Pamunkey, Chickahominy, Appomattox, and North Anna Rivers. Numerous creeks crisscross the study area.

Much of the flooding in the region is the by-product of hurricanes and tropical storms. Flooding also may occur following a period of intense or sustained rainfall. The floods caused by Tropical Storm Gaston in 2004 are characteristic of this type of flooding. The intense rainfall combined with the inability of the City of Richmond's storm water system to handle the increased flow led to a great deal of damage in the Shockoe Bottom area. The duration of flood events vary depending on the specific characteristics of the rain event. Floodwaters generally recede rapidly after the rain event has ended, but can last from a few hours to a few days.

### 5.6.2 Magnitude or Severity

Flooding can range from minor street flooding to widespread inundation along and near waterways. Flood-producing storms can occur throughout the year. Historically, the most common months for significant flooding have been August and September, the height of the hurricane season.

Floods pick up chemicals, sewage, and toxins from roads, factories, and farms; therefore, any property affected by a flood may be contaminated with hazardous materials. Debris from vegetation and human-made structures may also become hazardous following the occurrence of a flood. In addition, floods may threaten water supplies and water quality, as well as initiate power outages.

If a significant flood event occurs, there is a potential for a variety of secondary impacts. Some of the most common secondary effects of flooding are impacts to infrastructure and utilities, such as roadways, water service, and wastewater treatment. Many of the roadways in the Planning District are vulnerable to damage due to floodwaters. The effect of flood damages to roadways can limit access to areas, cutting off some residents from emergency services as well as other essential services.

### 5.6.3 Hazard Areas

The portions of the planning region most susceptible to flooding are those directly adjacent to the area's major waterways. However, flooding can occur along the smaller tributaries throughout the area.



Specific areas that are susceptible to flooding were determined during the initial plan kick-off meeting as well as during the 2011 update. These areas were taken into account when completing the HIRA and are available in jurisdictional executive summaries. These areas can be used to assist with mitigation actions.

Land use information was available for the Richmond PDC. Based on analysis conducted for the 2006 plan, the dominant land use inside floodplains was determined. Much of the land in the region's floodplains is designated for agricultural uses. Some localities, however, allow residential uses within agriculture areas. Agriculture is the dominant land use in Charles City, Goochland, Hanover, and Powhatan Counties. Henrico County's floodplain land use is mostly residential and the City of Richmond's is industrial or park.

### 5.6.4 Hazard History

Table 5-9 includes descriptions of major flood events in the region. Events have been broken down by the date of occurrence and, when available, by individual community descriptions. When no community-specific description is given, the general description applies to the entire region.

**Table 5-9. History of Flood Events and Damages, 2011–2016**

Date	Damages
August 27, 2011	Hurricane Irene impacted the area with heavy rainfall and gusty winds which knocked power out to millions of people in the area. It took electrical crews several days to fully restore power in the planning area. Irene originated east of the Lesser Antilles and tracked north and northwest into the western Atlantic. The hurricane reached Category 3 intensity with maximum sustained winds of near 120 mph at its strongest point. The hurricane made an initial U.S. landfall in the eastern portions of the North Carolina Outer Banks on August 27, 2011 as a Category 1 hurricane. The storm then tracked north/northeast along the coast slowly weakening before making its final landfall in Brooklyn, New York on August 28 as a high-end tropical storm. Rainfall totals with the hurricane ranged from around two inches in western sections of the planning region to 5 to 9 inches in eastern sections closest to the coast. At its closest pass, Irene brought sustained winds of 30 to 45 mph with gusts of 60 to nearly 70 mph to the planning area. The winds downed power lines and trees throughout the area. A man was killed when a tree fell on his home near Colonial Heights. (Source: National Weather Service/Wakefield Office)
September 4, 2011	Tropical Storm Lee moved inland along the Mississippi/Louisiana Gulf Coast on September 4, 2011. The remnants of the weakening storm tracked northeast, producing rainfall over a wide swath extending from the Gulf Coast to New England. Rainfall totals generally ranged from 4 to 8 inches in the planning area with the heaviest totals falling just east of Interstate 95. The rain fell on soils saturated only days earlier with Hurricane Irene's passage. The result was widespread flooding, particularly over the eastern sections of the planning region. Gusty winds in thunderstorms knocked down trees that had already been weakened from the hurricane resulting in thousands of power outages. (Source: National Weather Service/Wakefield Office)
October 1, 2015	The combination of upper divergence and lift east of the closed low, and a strong persistent low level flow off the Atlantic and associated low level moisture convergence and isentropic lift, along with a plume of tropical moisture getting entrained into the system, provided a band of heavy rain showers and a few thunderstorms that at times trained over the same areas and persisted for many

**Table 5-9. History of Flood Events and Damages, 2011–2016**

Date	Damages
	<p>hours. The heaviest rain occurred from the Columbia vicinity, southeastward across lower Richland Co, Sumter Co, Calhoun Co, Clarendon Co and lower Orangeburg Co. The heaviest rainfall occurred late Saturday night Oct 3rd into the morning hours of Sunday Oct 4th. At times, rainfall rates of 2" inches per hour affected those locations for several hours. This heavy and persistent rainfall occurred over urban areas where runoff rates were high, and over grounds already wet from recent rains. This heavy rainfall caused numerous roadway and bridge closings due to dam failures, along with culvert and pipe washouts across the region. Numerous lifesaving swift water rescues were performed. In general, a significant gradient in rainfall amounts occurred in our CWA, with 1-2 inches west of the Savannah River, 2-4 inches just on the east side of the Savannah River, with amounts ramping up to around 10 inches eastward into West Central Midlands, with 10-20 inches from Columbia SE across the Eastern Midlands. The NWS had been advertising this very heavy rainfall and flooding potential well in advance of the event. During this event, Columbia Metro Airport set a new record for both the greatest one and two day rainfall totals:</p> <ul style="list-style-type: none"> <li>• Greatest 1-day rainfall.... 6.71 inches set on October 4, 2015</li> <li>• Old 1-day rainfall record..... 5.79 inches set on July 9, 1959</li> <li>• Greatest 2-day rainfall..... 10.28 inches set on October 3-4, 2015</li> <li>• Old 2-day rainfall record..... 7.69 inches set on August 16-17, 1949</li> </ul> <p>(Source: National Weather Service)</p>
*History from 1771-2010 in Appendix B-3	

Table 5-10 provides the number and damage costs of recorded flood events by jurisdiction. It should be noted that these results represent only those events recorded by the NCDC storm events database for flood; therefore some, particularly local, events may not be included in this table. Some of the events listed in the table may actually be regional events impacting multiple jurisdictions. Significant hurricane events resulting in flooding have been included although it should be noted that some minor hurricanes may have resulted in flooding but may not have been recorded in the NCDC as flood events; see the hurricane/wind section for information on those events. Chesterfield (22) and Surry (16) Counties have the highest number of flood events and while Greenville County had over \$1M in property damages. The City of Richmond experienced over \$63,000 in crop damages for the NCDC period of record (1993–2017).

**Table 5-10. Flood Damage to Property and Crops, 1993 - 2016**

Jurisdiction	Flood Events	Property Damages	Crop Damages
Charles City County	7	-	-
Chesterfield County	22	\$287,458	\$2,986
City of Colonial Heights	5	\$71,663	-
Dinwiddie County (incl. Town of McKenney)	8	\$12,223	\$3,285
City of Emporia	3	-	-

**Table 5-10. Flood Damage to Property and Crops, 1993 - 2016**

<b>Jurisdiction</b>	<b>Flood Events</b>	<b>Property Damages</b>	<b>Crop Damages</b>
Goochland County	5	\$38,818	\$11,944
Greensville County (incl. Town of Jarratt)	13	\$1,065,175	-
Hanover County (incl. Town of Ashland)	9	\$158,993	\$25,082
Henrico County	3	-	-
City of Hopewell	6	\$71,663	\$47,776
New Kent County	14	\$109,340	-
City of Petersburg	14	\$141,487	-
Powhatan County	10	\$38,966	-
Prince George County	10	-	-
City of Richmond	14	\$94,711	\$63,618
Surry County (incl. Towns of Claremont, Dendron, Surry)	16	\$64,535	\$37,014
Sussex County (incl. Towns of Stony Creek, Wakefield, Waverly)	15	\$265,726	\$62,187
<b>Totals</b>	<b>174</b>	<b>\$2,420,758</b>	<b>\$253,890</b>

Note: Only floods, not hurricanes.

Source: National Climatic Data Center.

### 5.6.5 Hydrology

The Richmond-Crater region lies within three major watersheds – the James, Chowan, and York. The James watershed spans 10,236 square miles, the largest in Virginia. The Chowan River basin spans 3,675 square miles. The York watershed covers a much smaller area with a drainage basin of 2,669 square miles. Numerous rivers flow through the region including:

- James
- York
- Appomattox
- Blackwater
- Meherrin
- Pamunkey
- Chickahominy
- North Anna
- Nottoway

The James River runs directly through the City of Richmond. The Meherrin River runs through the center of the City of Emporia, while the Appomattox flows through the City of Petersburg. The City of Hopewell is located at the confluence of the Appomattox and James Rivers.

In addition, several large creeks such as Stony Creek, which passes through the center of the Town of Stony Creek, run through the region. Swift Creek forms the northern boundary of the City of Colonial Heights. Figure 5-2 illustrates the location of the major watershed boundaries for the region.

In 2009, the U.S. Army Corps of Engineers (USACE), Norfolk District, completed a stream and rain gauging network study within the Chowan River Basin. The study identified gauging station needs that would improve flood forecasts by the NWS. An additional study in 2009 evaluated water resource issues, such as environmental restoration, flood risk management, navigation, and water quality. These two studies helped to determine Risk Mapping, Assessment, and Planning (Risk MAP) program activities implemented in the Chowan River Basin. The three Risk MAP activities included:

- Assessment of basin flood hazard data.
- Establishment of local community officials' knowledge and understanding of flood risk management concepts and increasing public awareness of flood hazards and the National Flood Insurance Program (NFIP).
- Support to state and local governments to engage in risk-based mitigation planning.<sup>1</sup>

The Chowan River Basin report provides an in-depth assessment of the river basin and mitigation activities for understanding flood risk. Areas of concern are highlighted throughout the report; this should be used to further facilitate mitigation actions in this plan.

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<sup>1</sup> Risk Mapping, Assessment and Planning (Risk MAP) Report. Chowan River Basin, Virginia. By USACE, Norfolk District for FEMA Region III. Final May 5, 2011.



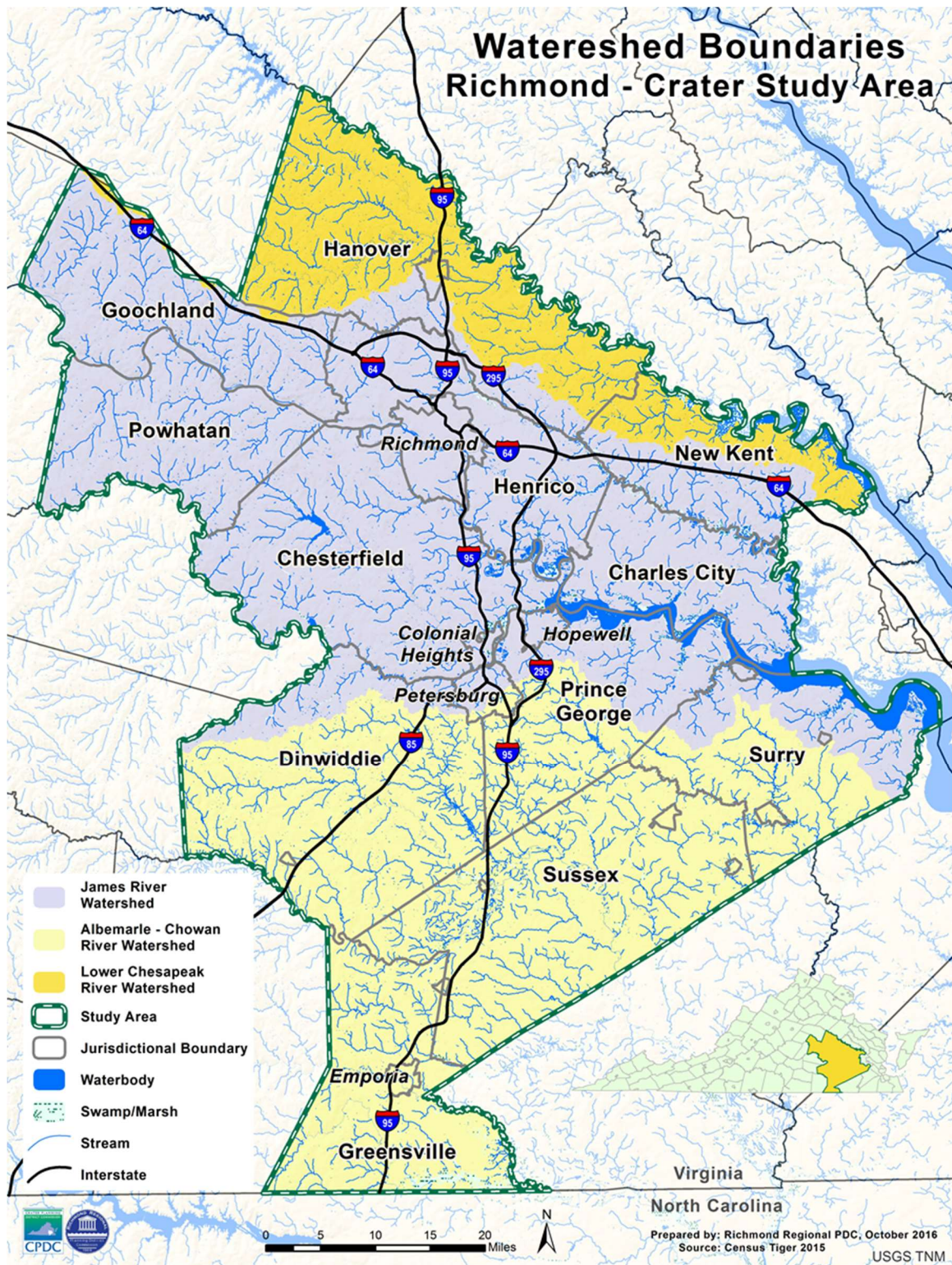


Figure 5-2. Map of Watershed Boundaries

### 5.6.6 Flood Maps

FEMA, through the NFIP, has developed Flood Insurance Rate Maps (FIRMs) that identify flood zones through detailed hydrologic and hydraulic studies. These flood zones represent the areas susceptible to the 1% annual chance flood (100-year flood) and the 0.2% annual chance flood (500-year flood). In most places in the region, there is little to no difference in the 100-year and 500-year floodplain. Whenever possible, FEMA also determines a base flood elevation (BFE) for the 100-year floodplain, which is the calculated elevation of flooding during this event. The BFE is a commonly used standard level for determining flood risk and managing potential floodplain development. Although each specific flood event is different, these maps provide a more definitive representation of the highest flood risks in the communities.

Since the 2006 analysis, FEMA's Digital Flood Insurance Rate Maps (DFIRMs) were made available for the majority of the region in digital format. This data was made available by VDEM as an export of the National Flood Hazard Layer (NFHL), preliminary DFIRMs and digitized FIRMs. The NFHL dataset is a compilation of effective DFIRM databases and Letters of Map Change. The NFHL is updated as studies become effective and extracts are made available to the public monthly. The preliminary DFIRMS that have been made available through FEMA and become the governing maps for the locality once adopted by the local government elected body and labeled as "effective." For jurisdictions where the digital FIRMs were not available from FEMA, this plan uses digitized versions of these maps supplied by VDEM. These are used to get a general sense of where flooding occurs for those locations and have not been attributed with the flood zones. For local planning and flood enforcement, localities should always use the effective flood data from FEMA. Figure 5-3 shows the extent of the mapped floodplains in the region; Table 5-6 shows the type of FIRM that was available for analysis.



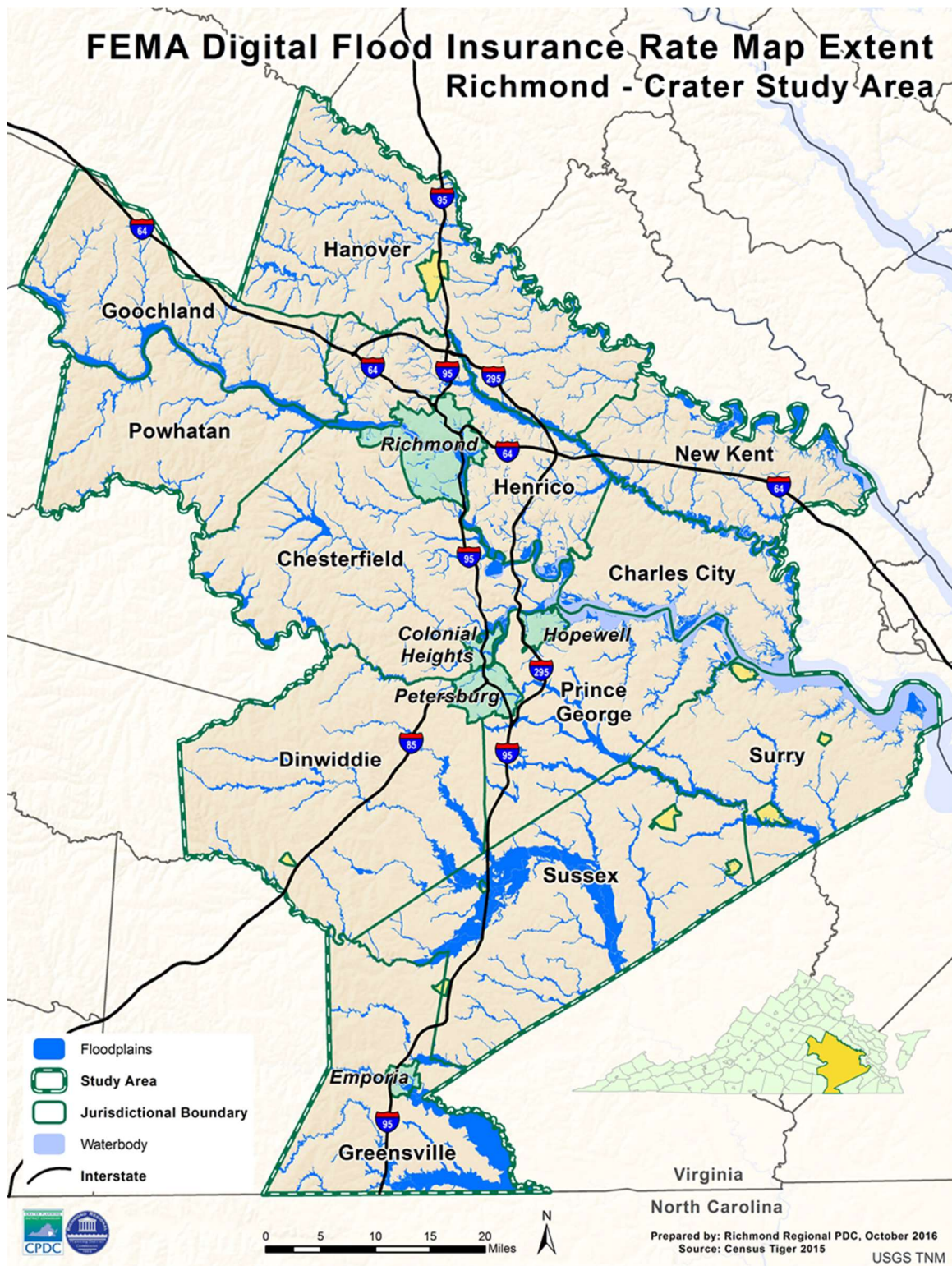


Figure 5-3. FEMA Digital Flood Insurance Rate Map Extent



### 5.6.7 National Flood Insurance Program

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

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

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

Floodplain management regulations are the cornerstone of NFIP participation. Communities that participate in the NFIP are expected to adopt and enforce floodplain management regulations. These regulations apply to all types of floodplain development and ensure that development activities will not cause an increase in future flood damages. Buildings are required to be elevated at or above the BFE. It should be noted that Chesterfield, Goochland, and Powhatan Counties all have very strong floodplain management programs.

Table 5-11 shows the dates that each of the jurisdictions were identified with Flood Hazard Boundary Maps (FHBM), the date the first Flood Insurance Rate Maps (FIRMs) became effective, the date of the current FIRMs used for insurance purposes, and the date the community entered into the NFIP. This table also shows the FIRM source that was used for the flood analysis.

**Table 5-11. Communities Participating in the NFIP as of August 10, 2016**

County/City Name	Jurisdiction Name	Initial FHBM Identified	Initial FIRM Identified	Current Effective Map Date	Reg-Emer Date
Charles City County	Charles City County	01/17/75	09/05/09	07/06/15	09/05/09
Chesterfield County	Chesterfield County	01/10/75	03/16/83	12/18/12	03/16/83
City of Colonial Heights	City of Colonial Heights	06/14/74	09/02/81	08/02/12	09/02/81
Dinwiddie County	Dinwiddie County	11/15/74	01/17/79	06/16/11	01/17/79
	<i>Town of McKenney</i>	-	06/16/11	(NSFHA)	11/20/81
City of Emporia	City of Emporia	07/23/76	02/02/89	07/07/09	09/30/77
Goochland County	Goochland County	02/21/75	03/01/79	12/02/08	03/01/79
Greensville County	Greensville County	12/20/74	09/29/78	07/07/09	09/29/78
	<i>Town of Jarratt*</i>	07/30/76	10/08/82	07/07/09(M)	10/08/82
Hanover County	Hanover County	12/13/74	09/02/81	12/02/08	09/02/81
	<i>Town of Ashland</i>	05/24/74	12/02/08	12/02/08	05/26/78
Henrico County	Henrico County	11/22/74	02/04/81	12/18/07	02/04/81
City of Hopewell	City of Hopewell	06/14/74	09/05/79	07/16/15	09/05/79
New Kent County	New Kent County	01/31/75	12/05/90	08/03/15	12/05/90
City of Petersburg	City of Petersburg	05/31/74	03/16/81	02/04/11	03/16/81
Powhatan County	Powhatan County	09/13/74	09/15/78	02/06/08	09/15/78
Prince George County	Prince George County	01/24/75	05/01/80	06/02/15	05/01/80
City of Richmond	City of Richmond	12/06/74	06/15/79	07/16/14	06/15/79
Surry County	Surry County	12/06/74	11/02/90	05/04/15	11/02/90
	<i>Town of Claremont</i>	04/04/75	11/02/90	05/04/15	10/16/90
	<i>Town of Dendron**</i>	-	-	-	-
	<i>Town of Surry**</i>	-	-	-	-
Sussex County	Sussex County	06/09/78	03/02/83	07/07/09	03/02/83
	<i>Town of Jarratt*</i>	07/30/76	10/08/82	07/07/09(M)	10/08/82
	<i>Town of Stony Creek</i>	08/09/74	09/16/82	07/07/09	09/16/82
	<i>Town of Wakefield**</i>	-	-	-	-
	<i>Town of Waverly**</i>	-	-	-	-

\*Town of Jarratt is listed in Greensville County in the FEMA Community Status Book Report

\*\*Town not in FEMA Community Status Book Report

Source: <http://www.fema.gov/cis/VA.html>

As of June 30, 2017, there were 3,423 flood insurance policies-in-force in the region, accounting for 3.3% of the total policies in the Commonwealth. These policies amounted to more than \$929 million in total insurance coverage. Approximately 1,327 claims have been filed, accounting for \$21.6 million in payments. The City of Richmond makes up 49% of the total claims payments followed by Henrico County (14%) and Chesterfield County (12%). Table 5-12 shows NFIP policy statistics for each of the participating jurisdictions in the region.

**Table 5-12. NFIP Policy and Claim Statistics by Jurisdiction**

County/City Name	Jurisdiction Name	Policy Statistics (as of 06/30/2016)		Claim Statistics (01/01/1978 – 06/30/2016)	
		Policies- In-Force	Insurance In-Force	Total Claims	Total Payment
Charles City County	Charles City County	20	\$6,320,700	7	\$42,606
Chesterfield County	Chesterfield County	864	\$231,463,100	175	\$2,580,112
City of Colonial Heights	City of Colonial Heights	112	\$27,581,600	79	\$1,061,117
Dinwiddie County	Dinwiddie County	39	\$10,729,600	2	\$11,979
	<i>Town of McKenney</i>	-	-	-	-
City of Emporia	City of Emporia	38	\$5,400,900	10	\$6,060
Goochland County	Goochland County	47	\$14,506,100	12	\$137,267
Greensville County	Greensville County	17	\$3,630,900	4	\$26,145
	<i>Town of Jarratt</i>	-	-	-	-
Hanover County	Hanover County	177	\$51,675,300	23	\$253,608
	<i>Town of Ashland</i>	44	\$13,629,600	3	\$4,655
Henrico County	Henrico County	986	\$246,491,700	240	\$2,978,970
City of Hopewell	City of Hopewell	26	\$7,607,000	11	\$101,018
New Kent County	New Kent County	119	\$34,367,100	29	\$488,862
City of Petersburg	City of Petersburg	137	\$38,183,500	76	\$481,948
Powhatan County	Powhatan County	30	\$8,480,000	1	4867.3
Prince George County	Prince George County	94	\$25,420,500	27	\$223,737
City of Richmond	City of Richmond	586	\$183,772,500	515	\$10,666,886
Surry County	Surry County	25	\$7,135,400	40	\$1,172,614
	<i>Town of Claremont</i>	16	\$4,319,800	38	\$1,273,693
	<i>Town of Dendron</i>	-	-	-	-
	<i>Town of Surry</i>	-	-	-	-
Sussex County	Sussex County	24	\$5,016,700	12	\$47,630
	<i>Town of Jarratt</i>	-	-	-	-
	<i>Town of Stony Creek</i>	22	\$3,653,500	23	\$96,039
	<i>Town of Wakefield</i>	-	-	-	-

**Table 5-12. NFIP Policy and Claim Statistics by Jurisdiction**

County/City Name	Jurisdiction Name	Policy Statistics (as of 06/30/2016)		Claim Statistics (01/01/1978 – 06/30/2016)	
		Policies- In-Force	Insurance In-Force	Total Claims	Total Payment
	<i>Town of Waverly</i>	-	-	-	-
<b>Region Total</b>		<b>3,423</b>	<b>\$929,385,500</b>	<b>1,327</b>	<b>\$21,659,816</b>
<b>Virginia Total</b>		<b>104,766</b>	<b>\$26,627,973,200</b>	<b>44,762</b>	<b>\$637,755,766.40</b>

### 5.6.8 FEMA Repetitive Loss and Severe Repetitive Loss Properties

A repetitive loss (RL) property is a property that is insured under the NFIP and has filed two or more claims in excess of \$1,000 each, within a 10-year period. Nationwide, RL properties constitute 2% of all NFIP insured properties, but are responsible for 40% of all NFIP claims. Mitigation for RL properties is a high priority for FEMA, and the areas in which these properties are located typically represent the most flood prone areas of a community.

The identification of RL properties is an important element to conducting a local flood risk assessment, as the inherent characteristics of properties with multiple flood losses strongly suggest that they will be threatened by continual losses. RL properties are also important to the NFIP, since structures that flood frequently put a strain on NFIP funds. Under the NFIP, FEMA defines an RL property as “any NFIP-insured property that, since 1978 and regardless of any change(s) of ownership during that period, has experienced: a) four or more paid flood losses; or b) two paid flood losses within a 10-year period that equal or exceed the current value of the insured property; or c) three or more paid losses that equal or exceed the current value of the insured property.” A primary goal of FEMA is to reduce the numbers of structures that meet these criteria, whether through elevation, acquisition, relocation, or a flood control project that lessens the potential for continual losses.

According to FEMA, there are currently 14 RL properties within the Richmond-Crater region accounting for 66 losses. The specific addresses of the properties are maintained by FEMA, VDEM, and local jurisdictions, but are deliberately not included in this plan as required by law.<sup>2</sup>

More than \$1.61 million has been paid in total repetitive losses on 66 losses with an average claim of \$48,400. This is a decline of about 87% since the 2011 plan but represents the ten-year rolling period eliminating Hurricane Isabel and Gaston losses. Table 5-13

<sup>2</sup> NFIP repetitive loss data is protected under the federal Privacy Act of 1974 (5 U.S.C. 552a) which prohibits personal identifiers (i.e., owner names, addresses, etc.) from being published in local mitigation plans.

shows the total number of properties, total number of losses experienced, and losses paid for all of the communities within the planning region. The majority of the RL properties are residential.

A severe repetitive loss (SRL) property has: a) at least four NFIP claims payments of more than \$5,000 each, with the cumulative amount of such claims payments exceeding \$20,000; or b) at least two separate claims payments with the cumulative amount exceeding the market value of the building. Chesterfield County has one SRL property, City of Colonial Heights has two, Henrico County has five, Prince George County has one, and the Town of Claremont has one. Compared to previous mitigation plans, there are significantly less RL and SRL properties as of 2017 than were in the 2011 plan due to the rolling ten year period of the FEMA-provided lists.

**Table 5-13. NFIP Repetitive Loss and Severe Repetitive Loss Property Claim Information**

County/City Name	Jurisdiction Name	RL Buildings	RL Losses	Total Payments	Property value	SRL Buildings	Number of Claims	Building Payments	Average Claim	Property Value
Charles City County	Charles City County	-	-	-	-	-	-	-	-	-
Chesterfield County	Chesterfield County	1	4	\$70,732.52	\$373,439.00	1	4	\$70,732.52	\$17,683.13	\$374,439.00
City of Colonial Heights	City of Colonial Heights	2	10	\$217,911.69	\$1,000,000.00	2	10	\$217,911.69	\$43,552.34	\$1,000,000.00
Dinwiddie County	Dinwiddie County	-	-	-	-	-	-	-	-	-
City of Emporia	City of Emporia	-	-	-	-	-	-	-	-	-
Goochland County	Goochland County	-	-	-	-	-	-	-	-	-
Greensville County	Greensville County	-	-	-	-	-	-	-	-	-
Hanover County	Hanover County	-	-	-	-	-	-	-	-	-
	Town of Ashland	-	-	-	-	-	-	-	-	-
Henrico County	Henrico County	6	40	\$956,563.38	\$2,018,327.00	5	40	\$956,563.38	\$138,203.73	\$1,585,330.00
City of Hopewell	City of Hopewell	-	-	-	-	-	-	-	-	-
New Kent County	New Kent County	-	-	-	-	-	-	-	-	-
City of Petersburg	City of Petersburg	-	-	-	-	-	-	-	-	-
Powhatan County	Powhatan County	-	-	-	-	-	-	-	-	-
Prince George County	Prince George County	1	4	\$72,822.55	\$253,076.00	1	4	\$72,822.55	\$18,205.64	\$253,076.00
City of Richmond	City of Richmond	3	4	\$113,231.76	\$27,500.00	-	-	-	\$28,307.94	-
Surry County	Surry County	-	-	-	-	-	-	-	-	-
	Town of Claremont	1	4	\$176,688.15	\$204,365.00	1	4	\$176,688.15	\$44,172.04	\$204,365.00
Sussex County	Sussex County	-	-	-	-	-	-	-	-	-
	Town of Stony Creek	-	-	-	-	-	-	-	-	-
<b>TOTAL FOR REGIONS</b>	<b>REGIONAL TOTAL</b>	<b>14</b>	<b>66</b>	<b>\$1,607,950.05</b>	<b>\$3,876,707.00</b>	<b>10</b>	<b>62</b>	<b>\$1,494,718.29</b>	<b>\$290,124.82</b>	<b>\$3,417,210.00</b>



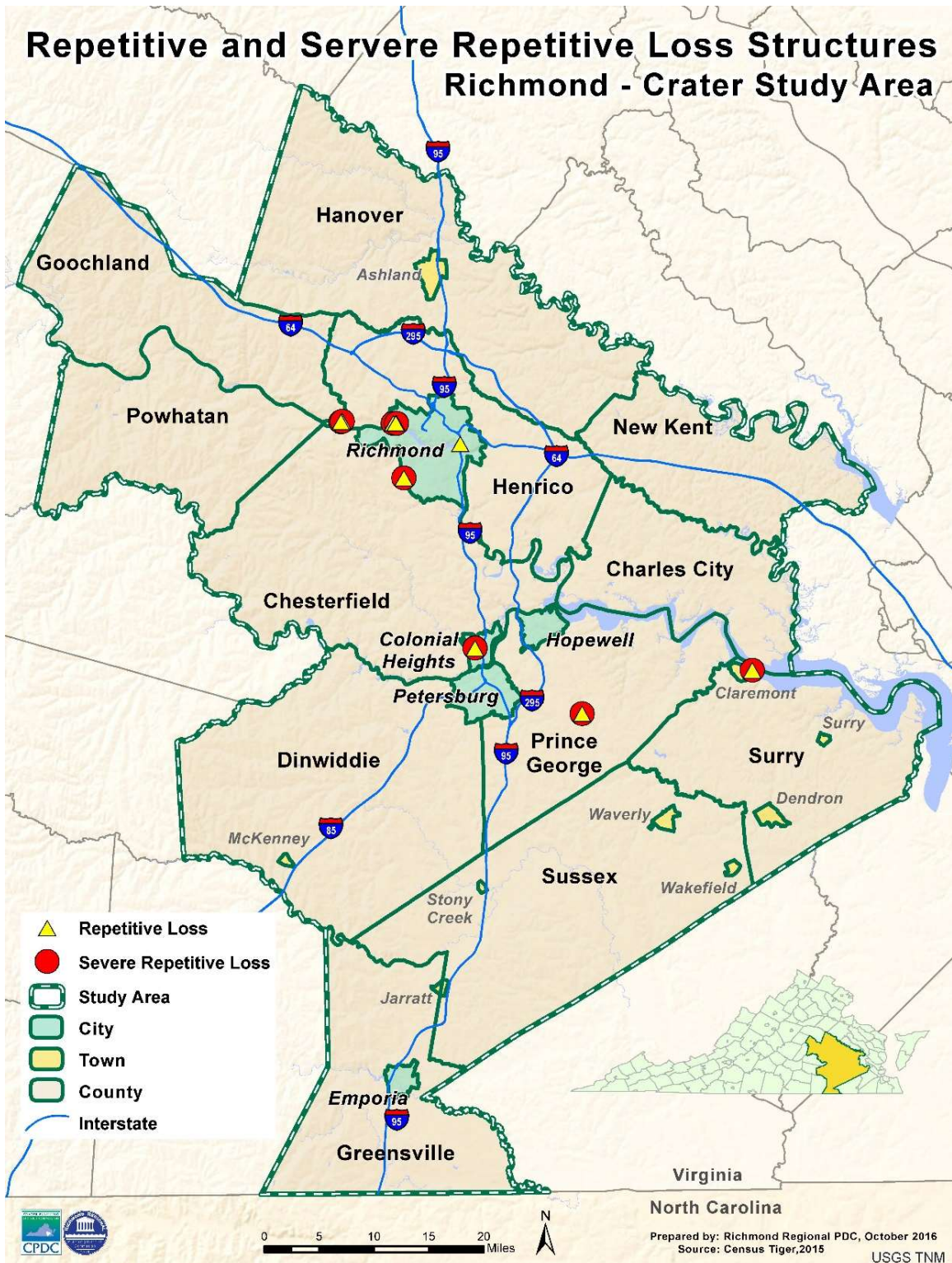


Figure 5-4. Repetitive and Severe Repetitive Loss Properties



## 5.6.9 Vulnerability Analysis

### Probability

Floods typically are characterized by frequency, for example, the “1%-annual chance flood,” commonly referred to as the “100-year” flood. While more frequent floods do occur, in addition to larger events that have lower probabilities of occurrence, for most regulatory and hazard identification purposes, the 1%-annual chance flood is used.

### Impact and Vulnerability

Flooding impacts a community to the degree that it affects the lives of its citizens and overall community functions. 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 less impact on the community.

A number of factors contribute to the relative vulnerabilities of certain areas in the floodplain. Development, or the presence of people and property in the hazardous areas, is a critical factor in determining vulnerability to flooding. Additional factors that contribute to flood vulnerability range from specific characteristics of the floodplain to characteristics of the structures located within the floodplain. The following is a brief discussion of some of these factors and how they may relate to the area.

**Flood depth:** The greater the depth of flooding, the higher the potential for significant damages.

**Flood duration:** The longer duration of time that floodwaters are in contact with building components, such as structural members, interior finishes, and mechanical equipment, the greater the potential for damage. Floodwaters may linger because of the low relief of the area, but the degree varies.

**Velocity:** Flowing water exerts force on the structural members of a building, increasing the likelihood of significant damage. A 1-foot depth of water, flowing at a velocity of 5 feet per second or greater, can knock an adult over and cause significant scour around structures and roadways.<sup>3</sup>

**Elevation:** The lowest possible point where floodwaters may enter a structure is the most significant factor contributing to its vulnerability to damage due to flooding. Data on the specific elevations of structures in the Richmond-Crater region has not been compiled for use in this analysis.

**Construction type:** Certain types of construction are more resistant to the effects of floodwaters than others. Masonry buildings, constructed of brick or concrete blocks, are

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<sup>3</sup> FEMA. *Principles and Practices for Retrofitting Flood Prone Residential Buildings* (FEMA 259). June 2001.

typically the most resistant to flood damages simply because masonry materials can be in contact with limited depths of water without sustaining significant damage. Wood frame structures are more susceptible to flood damage because the construction materials used are easily damaged when inundated with water. The type of construction throughout the Planning District varies from area to area.

### *Risk Methodologies*

Several methodologies were used to quantify vulnerability due to flooding. The following sections highlight risk and potential losses to structures, risk to critical facilities, and jurisdictional risk based on census blocks. The risk analyses completed in the 2006 mitigation plan should be referenced for comparison, but has not been kept for the flood, wind, and critical facilities evaluations. These have been updated and expanded based on best available data (structures, DFIRMs, and Census Block data). Appendix B provides a detailed summary of the analysis completed and the accompanying GIS files. This data should be referenced for specific information on structures and critical facilities at risk, and for use in potential mitigation projects.

The section on Structures at Risk for the 2006 plan was based on 10% greater than the average house value by census block; as a result, the values presented most likely underestimated vulnerability since only residential housing units were accounted for. For the 2017 analysis, a new methodology called Total Exposure In Floodplain (TEIF) version 2.0 was used. This TEIF 2.0 methodology uses the effective SFHA with building footprint, tax assessed value, and estimated contents value provided by the jurisdictions to find the annualized estimated losses from floods. These values were then generalized to 1000 ft<sup>2</sup> blocks to highlight potential loss areas and not target individual structures.

The section on Critical Facilities at Risk for the 2006 plan was based on data compiled from the PDCs and supplemented with HAZUS-MH, ESRI, and U.S. census data; this data was not maintained and is thought to be out of date. The 2017 plan update uses only data furnished by the localities supplemented with state databases and does not include data from HAZUS-MH, ESRI, or the U.S. Census. The Richmond Regional PDC was able to create a critical facility GIS layer, with jurisdictional input, that best represents their critical facilities. The same critical facility risk analysis was performed for the update as in the original plan. The resulting figures may be found in redacted Appendix I for local emergency management and regional planning purposes.

### *TEIF 2.0 Revised Analysis for 2017 Update*

In support of FEMA's RiskMAP Program, FEMA endeavored to produce national-level flood risk analyses to estimate the potential losses from flooding across the Lower 48 states. This effort occurred circa 2009/2010 and produced a product known as the 2010 AAL Study Results. The 2010 AAL Study and its associated results were intended to be a mechanism for FEMA - as well as local stakeholders - to assist in the prioritization of flood mitigation activities across the lower 48 states. Further information on the 2010 AAL Results and its

use in RiskMAP Risk Assessments can be viewed in Guidance for Flood Risk Analysis and Mapping (May 2014). Notably, there were some problem areas within FEMA Region III in which the Hazus software was unable to produce valid results for the 2010 AAL Study in certain coastal areas. Lack of estimated flood damages limited the Region's ability to assess potential damage across the entirety of the regional geography. Consequently, FEMA Region III considered alternative methodologies which brought about the concept of Total Exposure In Floodplain (TEIF). The TEIF 1.0 approach was created during 2013 in FEMA Region III and a more refined enhanced method of TEIF 2.0 has been used since 2015 based on the availability of local data and local hazard mitigation plan update cycle... Each analysis type performed over recent years seeks to transcend the previous and as noted, fill analysis gaps where such gaps may exist. Chronologically the first analysis performed was the FEMA AAL Project, then TEIF1.0 and finally TEIF2.0.

FEMA Region III has performed the TEIF 2.0 analysis to help local jurisdictions supplement Hazard Mitigation Plans as well as general hazard mitigation planning efforts. A primary assumption of the planning process is that FEMA, states and local jurisdictions have limited resources and not all issues can be solved at the same time; consequently, way to define priorities (i.e. ranking) is a valuable tool to the planning process. TEIF 2.0 is an analysis methodology that estimates the exposure or replacement value of buildings that are exposed to the Special Flood Hazard Area (SFHA) and subsequently rank the estimated (or) potential losses based on what is exposed to flooding in the special flood hazard area.

The TEIF 2.0 methodology uses building footprints from local jurisdictions to subsequently disperse total replacement values of buildings at the census block-level in FEMA's Hazus software & corresponding Hazus stock data products. The TEIF methodology divides or apportions building replacement values by proportionate methods (area of each respective building footprint). For example if a census block is known to have \$1M of value associated with all buildings and there are a total of ten (10) buildings in the census block - each building having the same exact size – a proportional distribution would dictate that each building has a value of \$100,000. After Hazus values are dispersed to the building footprints, the buildings that intersect the SFHA can be identified and the portions (or percent area) of buildings that are within the floodplain can be calculated. Ultimately, the dispersed replacement values can be tallied (or summarized) for the dollar value associated with each respective building that is entirely or partially in the floodplain. These values are then generalized into 1000 ft<sup>2</sup> blocks to comply with regulations <sup>4</sup> and not target individual structures or building owners.

In Table 5-14, individual jurisdictions were evaluated and ranked in the study area using the TEIF 2.0 revised analysis (except for City of Colonial Heights, which did not have building footprints at time of analysis). The City of Richmond has the highest flood risk estimated at nearly \$217M in damages.

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<sup>4</sup> Federal Privacy Act of 1974 (5 U.S.C. 552a) which prohibits personal identifiers (i.e., owner names, addresses, etc.) from being published in local mitigation plans.

**Table 5-14: TEIF 2.0 (Oct 2016) Flood Risk**

County/City	Jurisdiction	Annual Flood Risk	RANK <sub>3</sub>
Richmond City	Richmond city	\$216,860,946.07	1
Henrico	Henrico County	\$192,425,423.55	2
Chesterfield	Chesterfield County	\$148,205,562.76	3
Petersburg City	Petersburg City	\$87,017,560.55	4
Hanover	Hanover County	\$61,441,447.65	5
Colonial Heights City	Colonial Heights City	\$56,748,000.00 <sup>2</sup>	6
Hopewell City	Hopewell City	\$38,315,100.27	7
New Kent	New Kent County	\$26,067,007.09	8
Emporia City	Emporia City	\$24,920,647.06	9
Prince George	Prince George County	\$24,254,929.53	10
Sussex	Sussex County	\$22,090,235.97	11
Sussex	Stony Creek Town	\$18,266,774.55	12
Hanover	Ashland Town	\$14,059,819.51	13
Dinwiddie	Dinwiddie County	\$13,507,442.21	14
Goochland	Goochland County	\$12,715,952.30	15
Surry	Surry County	\$7,735,588.38	16
Powhatan	Powhatan County	\$7,674,751.05	17
Greensville	Greensville County	\$6,613,369.74	18
Surry	Claremont town	\$6,330,052.27	19
Charles City	Charles City County	\$2,833,653.27	20
Sussex	Wakefield Town	\$301,433.37	21
Sussex	Waverly Town	\$0.00	22
Dinwiddie	McKenney Town	\$0.00	22
Sussex	Jarratt Town	\$0.00	22
Surry	Dendron Town	\$0.00	22
Surry	Surry Town	\$0.00	22

<sup>1</sup> FEMA Region III - TEIF 2.0 October 2016. Value represents estimated loss to buildings only; value does not include estimated loss to contents or any other element.

<sup>2</sup> TEIF 2.0 not performed in Colonial Heights because GIS Building Footprints were not available; value is based on Hazus Level 1 depth grid creation per discharge analyses where, flow discharges are from FEMA Flood Insurance Study (FIS 510039V000A Revised: August 2, 2012) and ground data utilized includes 10m National Elevation Dataset (NED) Digital Elevation Model (DEM) obtained October 2016.

<sup>3</sup> RANK- this is NOT a statewide rank only internal to Crater-Richmond PDC's.

The flood maps for the TEIF 2.0 results can be found in Appendix G.



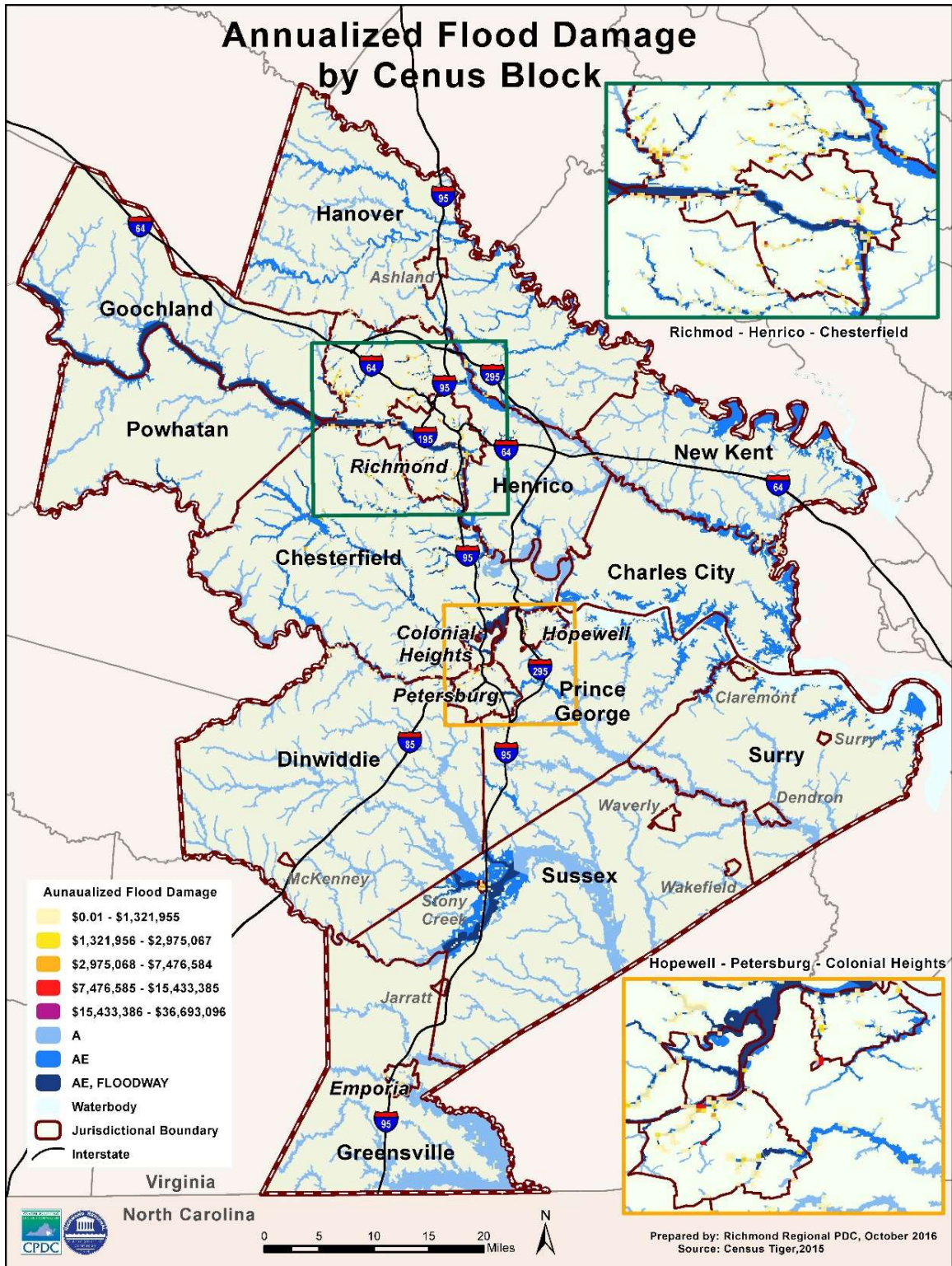


Figure 5-6. FEMA Flood Zones

### Annualized NCDC Events and Damages

For comparison, the National Climatic Data Center (NCDC) flood events have been annualized and summarized in Table 5-15. Based on past occurrences, the region can expect \$2.67 million in property damages as compared to the estimated \$6.5 million based on the TEIF analysis.

Recurrence intervals can be estimated using the number of flood occurrences over a period of time. According to the NCDC database, there have been 174 recorded flood events for the region that have caused notable floods in the past 17 years, for a flood recurrence interval of approximately 14.5 events per year, with each event averaging about \$333,000 in property and around \$34,900 in crop damages, for a total of about \$367,900 in damages. Greenville, Sussex, and Chesterfield Counties will likely experience the most flooding events for the region.

**Table 5-15. Annualized Flood Events and Losses, 1993 - 2016**

Jurisdiction	Annualized Number of Events	Annualized Property Losses	Annualized Crop Losses	Annualized Total Losses
Charles City County	0.29	\$0	\$0	\$0
Chesterfield County	0.92	\$287,458	\$2,986	\$290,444
City of Colonial Heights	0.21	\$71,663	\$0	\$71,663
Dinwiddie County (incl. Town of McKenney)	0.33	\$158,993	\$25,082	\$184,075
City of Emporia	0.13	\$12,223	\$3,285	\$15,508
Goochland County	0.21	\$0	\$0	\$0
Greenville County (incl. Town of Jarratt)	0.54	\$71,663	\$47,776	\$119,439
Hanover County (incl. Town of Ashland)	0.38	\$109,340	\$0	\$109,340
Henrico County	0.13	\$141,487	\$0	\$141,487
City of Hopewell	0.25	\$0	\$0	\$0
New Kent County	0.58	\$38,966	\$0	\$38,966
City of Petersburg	0.58	\$38,818	\$11,944	\$50,761
Powhatan County	0.42	\$0	\$0	\$0
Prince George County	0.42	\$94,711	\$63,618	\$158,329
City of Richmond	0.58	\$1,065,175	\$0	\$1,065,175
Surry County (incl. Towns of Claremont, Dendron, Surry)	0.67	\$64,535	\$37,014	\$101,548
Sussex County (incl. Towns of Stony Creek, Wakefield, Waverly)	0.63	\$265,726	\$62,187	\$327,913
<b>Total</b>	<b>7.27</b>	<b>\$2,420,758</b>	<b>\$253,890</b>	<b>\$2,674,649</b>

**Source:** National Climatic Data Center.

## **5.7 Wind (including Hurricanes and Thunderstorms)**

Wind can be one of the most destructive forces of nature. Strong winds can erode mountains and shorelines, topple trees and buildings, and destroy a community's critical utilities and infrastructure. The analysis in this section focuses on hurricane and tropical storm winds as the most likely type of widespread wind hazards to occur in the region, though more localized damage from high winds also can be caused by straight-line wind events, thunderstorms, and tornadoes. Thunderstorms are capable of producing multiple hazards, including flooding rainfall, hail, cloud-to-ground lightning, and damaging wind. The most frequent hazards associated with severe thunderstorms in the region are excessive winds often leading to power outages and localized flooding often due to inadequate drainage or storm water management. (See Flood section) and damaging wind gusts that are analyzed in this section. Hail and lightning are analyzed in the Thunderstorm section.

### **5.7.1 Hazard Profile**

A tropical cyclone is a low-pressure area of closed circulation that forms over a large tropical body of water. Tropical cyclones rotate counterclockwise throughout the Northern Hemisphere and are called tropical depressions when their wind speed is less than 39 mph, but become tropical storms when their wind speeds are between 39 mph and 73 mph. When these wind speeds reach 74 mph they become hurricanes.

The hurricane season in the North Atlantic runs from June 1 until November 30, with the peak season between August 15 and October 15. The average hurricane duration after landfall, is 12 to 18 hours. Wind speeds may be reduced by 50% within 12 hours after the storm reaches land. Tropical storms are capable of producing great amounts of in a short period of time. The region experienced more than 12inches of rain historically during Tropical Depressions Camille, Isabel and Gaston over a shore duration. Hurricanes also can spawn tornadoes.

Storm surge flooding can push inland as was experienced in Claremont and Sunset Beach in Surry County during Hurricane Isabel. Riverine and urban flooding associated with heavy inland rains can be extensive. Many areas of the Coastal Plain region are flat, and intense prolonged rainfall tends to accumulate without ready drainage paths. High winds associated with hurricanes can have two significant effects: 1) widespread debris from damaged and downed trees and damaged buildings, and 2) power outages.

### **5.7.2 Magnitude or Severity**

The strength of a hurricane is classified according to wind speed using the Saffir-Simpson Hurricane Damage Scale. This scale is used to give an estimate of the potential property damage and flooding expected along the coast from a hurricane landfall. Wind speed is the determining factor in the scale, as storm surge values are highly dependent on the slope of



the continental shelf in the landfall region. Table 5-16 provides a description of typical damages associated with each hurricane category.

**Table 5-16. Saffir-Simpson Hurricane Damage Scale**

Hurricane Category	Sustained Winds (mph)	Damage Potential	Description
1	74–95	Minimal	Minimal damage to unanchored mobile homes along with shrubbery and trees. There may be pier damage and coastal road flooding, with storm surge 4–5 feet above average.
2	96–110	Moderate	Moderate damage potential to mobile homes and piers, as well as significant damage to shrubbery and trees with some damages to roofs, doors, and windows. Impacts include flooding 2–4 hours before arrival of the hurricane in coastal and low-lying areas. Storm surge can be 6–8 feet above average.
3	111–130	Extensive	Extensive damage potential. There will be structural damage to small residences and utility buildings. Extensive damage to mobile homes and trees and shrubbery. Impacts include flooding 3–5 hours before the arrival of the hurricane cutting off the low-lying escape routes. Coastal flooding has the potential to destroy small structures, with significant damage to larger structures as a result of the floating debris. Land that is lower than 5 feet below mean sea level can be flooded 8 or more miles inland. Storm surge can be 6–12 feet above average.
4	131–155	Extreme	Extreme damage potential. Curtain wall failure as well as roof structure failure. Major damage to lower floors near the shoreline. Storm surge generally reaches 13–18 feet above average.
5	> 155	Catastrophic	Severe damage potential. Complete roof failure on residence and industrial structures, with complete destruction of mobile homes. All shrubs, trees, and utility lines blown down. Storm surge is generally greater than 18 feet above average.

### 5.7.3 Hazard History

Figure 5-8 shows how the frequency and strength of extreme windstorms vary across the United States. The map was produced by FEMA and is based on 40 years of tornado history and more than 100 years of hurricane history. Zone IV, the darkest area on the map, has experienced both the greatest number of tornadoes and the strongest tornadoes. As shown by the map key, wind speeds in Zone IV can be as high as 250 mph. Most of the

planning region falls within Zone II (winds up to 160 mph) and is considered to be susceptible to hurricanes.



**Figure 5-8. Wind Zones in the United States**  
Source: FEMA

The region is categorized by the American Society of Civil Engineers in its *Minimum Design Loads for Buildings and Other Structures* (ASCE 7) as located in a 90-mph wind zone, based on a 50-year recurrence interval. Based on ASCE 7, the potential wind speed for an event with a 100-year recurrence interval was estimated to be 107% of the 50-year wind speed, or 96.3 mph. The Virginia Uniform Statewide Building Code requires a 90 mph minimum design wind speed.

High wind events have occurred in every portion of the region. There are no proven indicators to predict specifically where high winds may occur, and wind events can be expansive enough to affect the entire area. The counties on the eastern side of the region are marginally closer to the coast and might experience higher wind speeds from tropical storms or hurricanes that make landfall on the Virginia coast.

Based on NCDC historical data dating back to the mid-1990s, there have been 2 deaths and 35 injuries in the region that have resulted from wind, and approximately 8 deaths that have resulted from hurricanes. Table 5-17 includes descriptions of tropical storm and hurricane events in the region, of which there are several. Events have been broken down by the date of occurrence and when available, by individual community descriptions. When no community-specific description is available, the general description applies to the entire region. Although NCDC and VDEM were the primary source of general descriptions, other sources are referenced where more specific information was available.

**Table 5-17. History of Wind Events and Damages, 2011–2016**

Date	Damages
August 27, 2011	Hurricane Irene – See full description in Flood section.
September 4, 2011	Hurricane Lee – See full description in Flood section.
June 29, 2012	<p>A devastating line of thunderstorms known as a derecho moved east-southeast at 60 miles per hour (mph) from Indiana in the early afternoon to the Mid-Atlantic region around midnight. Winds were commonly above 60 mph with numerous reports of winds exceeding 80 mph. Some areas reported isolated pockets of winds greater than 100 mph. Nearly every county impacted by this convective system suffered damages and power outages. To make matters worse, the area affected was in the midst of a prolonged heat wave. Unlike many major tornado outbreaks in the recent past, this event was not forecast well in advance. Warm-season derechos, in particular, are often difficult to forecast and frequently result from subtle, small-scale forcing mechanisms that are difficult to resolve more than 12-24 hours in advance.</p> <p>(Source: <a href="http://www.nws.noaa.gov/os/assessments/pdfs/derecho12.pdf">http://www.nws.noaa.gov/os/assessments/pdfs/derecho12.pdf</a>)</p>
October 26, 2012	<p>Hurricane Sandy made landfall along the southern New Jersey shore on October 29, 2012, causing historic devastation and substantial loss of life. The National Hurricane Center (NHC) Tropical Cyclone Report estimated the death count from Sandy at 147 direct deaths. In the United States, the storm was associated with 72 direct deaths in eight states: 2 in Virginia. The storm also resulted in at least 75 indirect deaths (i.e., related to unsafe or unhealthy conditions that existed during the evacuation phase, occurrence of the hurricane, or during the post-hurricane/clean-up phase). These numbers make Sandy the deadliest hurricane to hit the U.S. mainland since Hurricane Katrina in 2005, as well as the deadliest hurricane/post-tropical cyclone to hit the U.S. East Coast since Hurricane Agnes in 1972.</p> <p>(Source: <a href="http://www.nws.noaa.gov/os/assessments/pdfs/Sandy13.pdf">http://www.nws.noaa.gov/os/assessments/pdfs/Sandy13.pdf</a>)</p>
*History from 1827-2010 in Appendix B-3	

The most significant Hurricanes and Tropical Storms are shown in Figure 5-10. The National Oceanic Atmospheric and Atmospheric Administration's (NOAA) Coastal Services Center maintains historical hurricane, tropical storm, and tropical depression track data dating back to the mid-1880s. Figures 5-10 through 5-12 show all tropical system and hurricane tracks through and near the region between 1950 and 2009. Most of the tropical systems to pass directly over the region have been at either tropical storm or tropical

depression strength, but several hurricanes have directly impacted the area including the Irene and Lee Hurricanes.



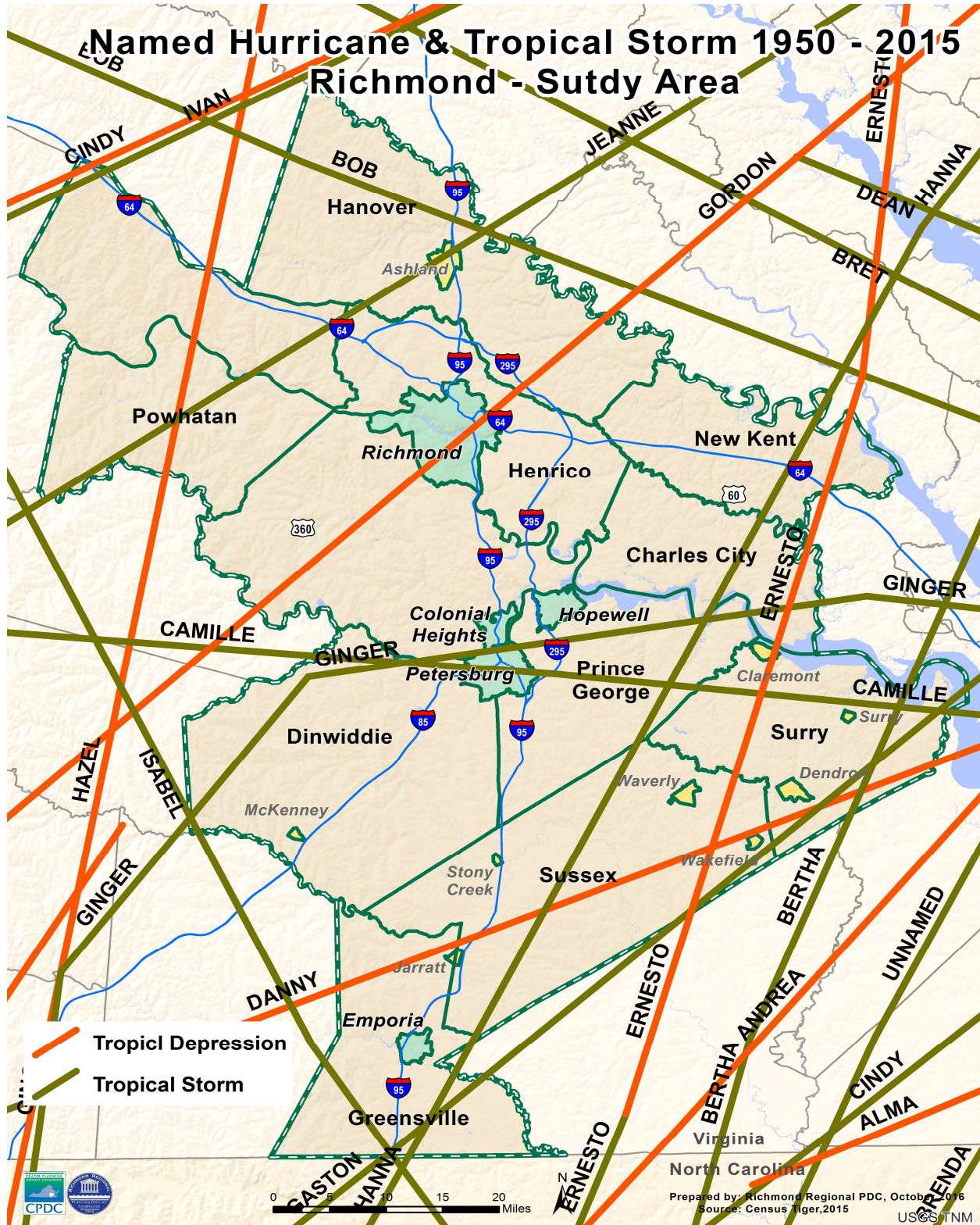


Figure 5-10. Named Hurricane and Tropical Cyclone Tracks, 1950–2013



## **5.7.4 Vulnerability Analysis**

### *Probability*

Hazus has used to complete the wind analysis for vulnerability and loss estimates. The Hazus software has been developed by FEMA and the National Institute of Building Sciences. Level 1, with default parameters, was used for the analysis done in this plan. For analysis purposes, the U.S. Census tracks are the smallest extent in which the model runs. The results of this analysis are captured in the vulnerability analysis and loss estimation.

Hazus-MH uses historical hurricane tracks and computer modeling to identify the probable tracks of a range of hurricane events and then assigns potential wind gusts that result. Figures 5-13 through 5-15 are individual wind speed maps (50-year, 100-year, and 1,000-year events) for the jurisdictions in the region. When a hurricane impacts these areas, these maps can be used to determine what areas are more likely to be impacted than others (at the U.S. Census track level).

### *Impact and Vulnerability*

Results from the model were used to develop the annualized damages. The impacts of these various events are combined to create a total annualized loss or the expected value of loss in any given year. Figure 5-16 illustrates annualized damages from hurricane winds. Widespread extreme thunderstorm wind events, such as those associated with well-developed squall lines, may have wind gusts of a similar magnitude to those of the 50- or 100-year hurricane wind event.

In all cases, HAZUS estimates the highest wind gusts to occur over the eastern and southeastern portions of the region, nearest the coast.

The type of building construction will have a significant impact on potential damages from high wind events. Basic Building Types in declining order of vulnerability are: manufactured, non-engineered wood, non-engineered masonry, lightly engineered and fully engineered buildings. A summary of basic building types – listed in order of decreasing vulnerability (from most to least vulnerable) is provided below.

The region includes a variety of building types. The primary residential construction type is wood framed, varying from single story to multiple stories, although some masonry and steel properties are present as well. As mentioned in the previous list, non-engineered wood-framed structures are among the most susceptible to potential damage. With the prevalence of this type of construction throughout the Richmond-Crater region, a majority of structures in the area could be classified to have a high level of vulnerability to damages due to a high wind event. Table 5-18 illustrates the building stock exposure broken down by the type of occupancy, for a total exposure of more than \$79.3 billion. As seen in the

table, almost 72% of the building stock for the region is considered residential, 18% of the building stock is commercial, and almost 6% is industrial. The majority of the region's building stock is wood. The building stock type is a main parameter used by HAZUS to determine potential damages; building stock characteristics are important in determining the strength of the structure and how it withstands wind speeds produced by storm events. Specific details on HAZUS loss estimation and building stock can be found online at [http://www.fema.gov/plan/prevent/hazus/hz\\_manuals.shtm](http://www.fema.gov/plan/prevent/hazus/hz_manuals.shtm).

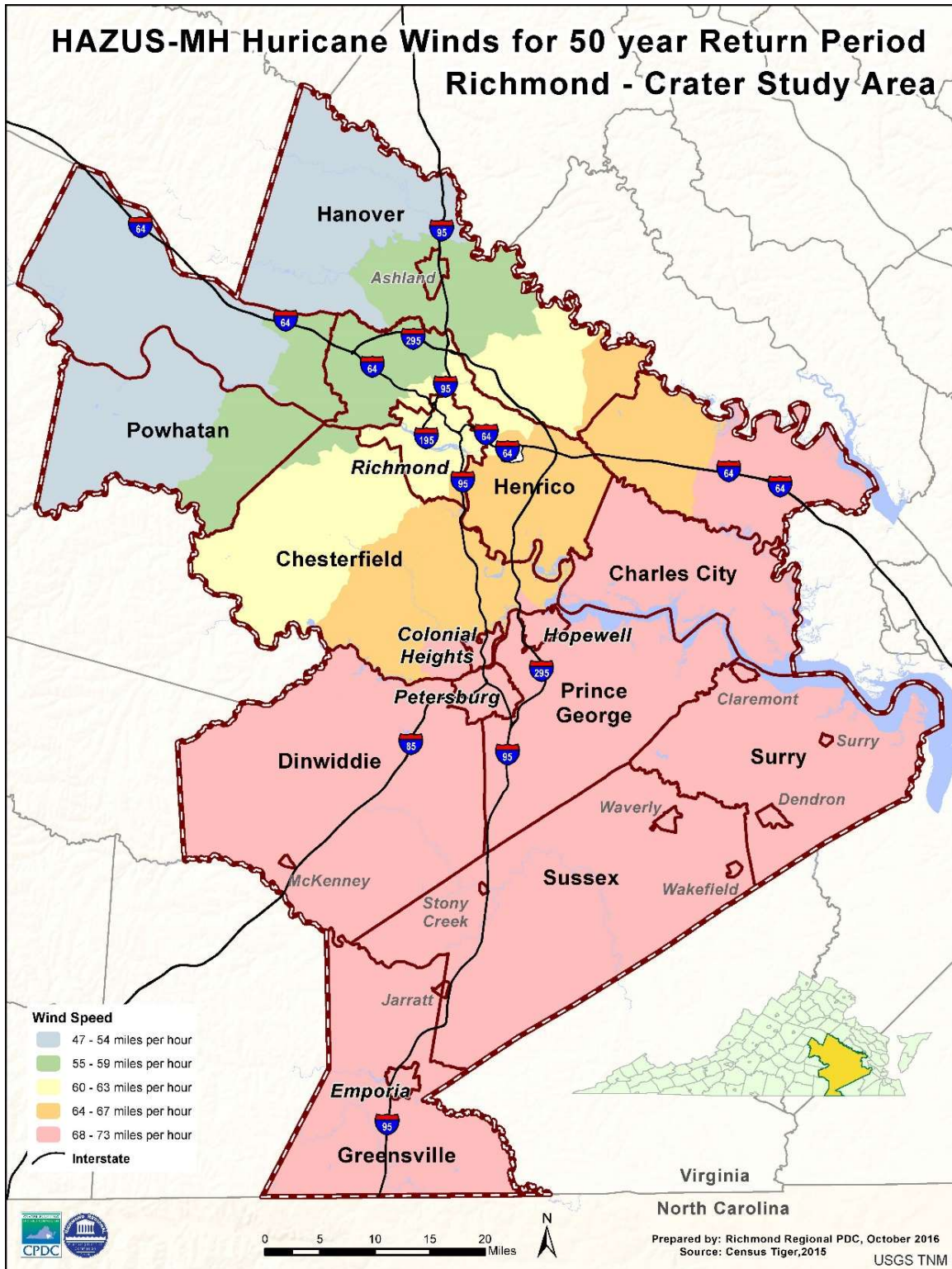


Figure 5-13. Hazus Hurricane Winds for 50-year Return Period

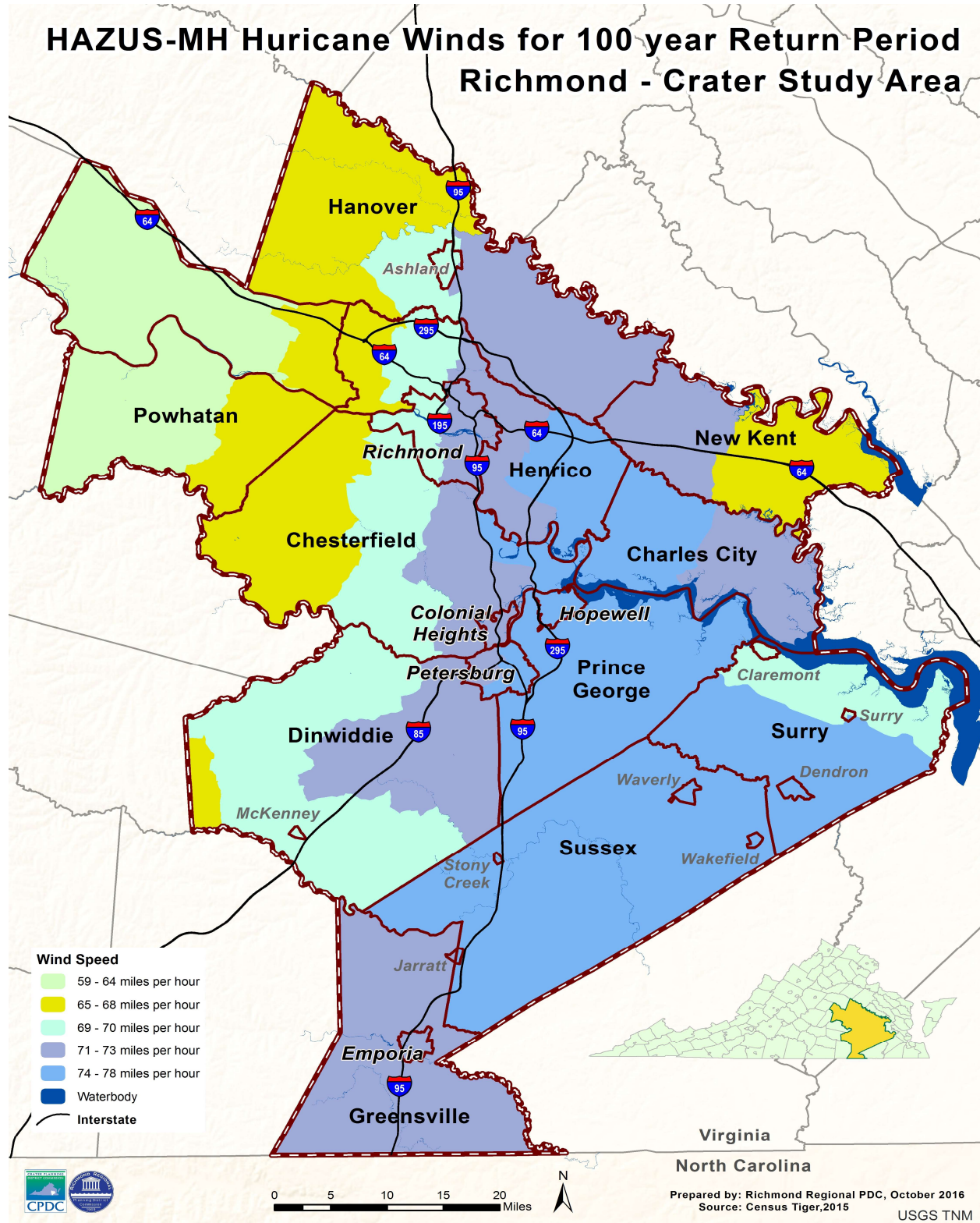


Figure 5-14. HAZUS-MH Hurricane Winds for 100-year Return Period



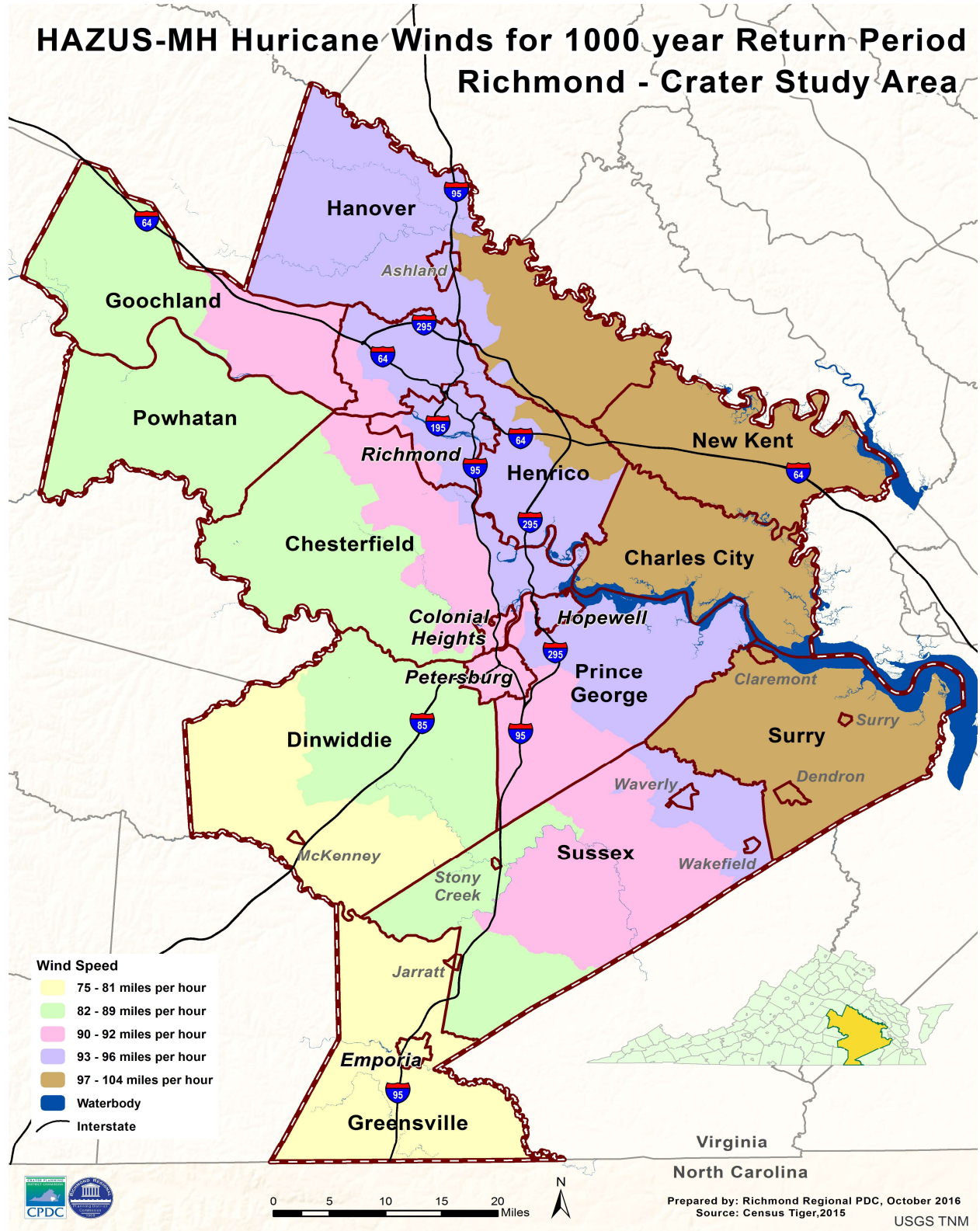


Figure 5-15. HAZUS-MH Hurricane Winds for 1,000-year Return Period



**Table 5-18. HAZUS Wind Analysis Damages for 100-year event**

Jurisdiction	Residential	Commercial	Industrial	Agricultural	Religious	Government	Education	Total
Charles City County	\$108,877.70	\$1,661.01	\$429.04	\$268.30	\$381.95	\$239.87	\$159.05	\$112,016.92
Chesterfield County	\$1,953,673.59	\$45,387.75	\$17,667.64	\$1,344.37	\$4,587.23	\$2,646.18	\$2,728.99	\$2,028,035.75
Colonial Heights city	\$149,680.36	\$14,770.46	\$873.95	\$109.62	\$771.20	\$357.23	\$343.15	\$166,905.97
Dinwiddie County	\$196,098.64	\$3,267.09	\$867.86	\$332.85	\$585.07	\$566.84	\$509.17	\$202,227.52
Emporia city	\$73,579.69	\$7,118.41	\$3,815.26	\$67.38	\$913.11	\$274.19	\$519.59	\$86,287.63
Goochland County	\$172,917.13	\$2,409.33	\$615.39	\$252.85	\$338.71	\$153.23	\$87.89	\$176,774.53
Greensville County	\$66,553.53	\$1,141.82	\$879.23	\$185.52	\$422.54	\$14.88	\$37.67	\$69,235.19
Hanover County	\$1,148,479.33	\$22,145.97	\$7,866.53	\$1,120.84	\$2,203.72	\$649.93	\$3,304.26	\$1,185,770.58
Henrico County	\$1,718,625.62	\$76,972.87	\$37,897.11	\$2,022.37	\$6,102.87	\$2,582.52	\$5,221.15	\$1,849,424.51
Hopewell city	\$197,915.84	\$8,737.86	\$3,397.54	\$121.23	\$1,803.42	\$482.45	\$673.90	\$213,132.24
Jarratt town*	-	-	-	-	-	-	-	-
McKenney town*	-	-	-	-	-	-	-	-
New Kent County	\$381,016.11	\$2,699.79	\$1,759.29	\$187.16	\$483.96	\$314.71	\$336.08	\$386,797.10
Petersburg city	\$272,210.70	\$20,962.86	\$16,551.25	\$122.48	\$2,499.92	\$809.91	\$751.52	\$313,908.64
Powhatan County	\$228,147.84	\$1,220.43	\$466.11	\$127.98	\$241.38	\$65.80	\$457.79	\$230,727.33
Prince George County	\$377,787.09	\$6,921.27	\$2,460.96	\$394.47	\$958.33	\$1,411.10	\$1,193.27	\$391,126.49
Richmond city	\$989,837.11	\$89,028.83	\$24,746.34	\$772.80	\$15,082.47	\$8,120.71	\$7,014.40	\$1,134,602.66
Surry town*	-	-	-	-	-	-	-	-
Sussex County	\$76,234.87	\$1,698.86	\$1,459.69	\$277.80	\$580.82	\$462.84	\$228.08	\$80,942.96
Wakefield town*	-	-	-	-	-	-	-	-
<b>Grand Total</b>	<b>\$8,111,635.15</b>	<b>\$306,144.61</b>	<b>\$121,753.19</b>	<b>\$7,708.02</b>	<b>\$37,956.70</b>	<b>\$19,152.39</b>	<b>\$23,565.96</b>	<b>\$8,627,916.02</b>

### Risk and Loss Estimation

As shown in Figures 5-13 through 5-15, there is a slight variation (around 10%) from the eastern to western portions of the region of wind speed in the 50-, 100-, and 1,000-year storm events. In general, critical facilities located in the eastern portion of the region will have slightly higher vulnerability than those in the western portion of the region due to a greater likelihood of higher winds associated with tropical storms and hurricanes. Building construction type will largely determine the vulnerability of a particular facility. As described previously in the section on Building Types, wood-framed structures are more vulnerable to wind than those constructed of masonry or steel.

The Hazus hurricane model only allows for analysis at the U.S. Census track level, which is smaller than most of the towns in the region. Individual maps are found in each jurisdiction's Executive Summary (Appendix G). These maps show the census blocks where hurricane losses occur.

In addition to widespread wind events associated with tropical storms and hurricanes, NCDC records show that the region experiences a significant number of other types of wind events that produce damaging wind gusts. These range from wide-scale events associated with fronts, storm systems, squall lines, or large thunderstorm complexes to smaller scale phenomena such as single-cell thunderstorm events. For example, thunderstorm winds downed numerous trees causing power outages throughout central Virginia in June and July, 2017. Numerous traffic intersections lost power to traffic signals, in one instance causing a fatal accident in Henrico County. Table 5-19 illustrates the historical annual hurricane occurrence in the region with Prince George, Chesterfield, and Henrico counties most affected by potential annual damages.

**Table 5-19. Annualized Hurricane Events and Losses, 1993 - 2016**

Jurisdiction	Annualized Number of Events	Annualized Property Losses	Annualized Crop Losses	Annualized Total Losses
Charles City County	0.08	\$3,937	\$28,352	\$32,289
Chesterfield County	0.17	\$1,951,015	\$10,695	\$1,961,710
City of Colonial Heights	-	-	-	-
City of Emporia	-	-	-	-
City of Hopewell	-	-	-	-
City of Petersburg	-	-	-	-
City of Richmond	-	-	-	-
Dinwiddie County	0.08	\$304,949	\$118,207	\$423,155
Goochland County	0.04	-	\$15,302	\$15,302

**Table 5-19. Annualized Hurricane Events and Losses, 1993 - 2016**

Jurisdiction	Annualized Number of Events	Annualized Property Losses	Annualized Crop Losses	Annualized Total Losses
Greensville County	0.17	\$19,373	\$4,423	\$23,796
Hanover County	0.08	\$4,423	\$17,692	\$22,115
Henrico County	0.17	\$982,142	\$43,258	\$1,025,400
New Kent County	0.08	\$1,106	\$5,396	\$6,502
Powhatan County	0.04	\$216,288	\$19,412	\$235,700
Prince George County	0.25	\$1,305,028	\$931,931	\$2,236,959
Surry County	0.17	\$367,252	\$115,894	\$483,146
Sussex County	0.13	\$4,733	\$44,231	\$48,964
<b>Total</b>	<b>1.46</b>	<b>\$5,160,245</b>	<b>\$1,354,793</b>	<b>\$6,515,038</b>

Source: National Climatic Data Center.

## 5.8 Tornadoes

### 5.8.1 Hazard Profile

A tornado is classified as a rotating column of wind that extends between a thunderstorm cloud and the earth's surface. Winds are typically less than 100 mph, with the most violent tornado wind speeds exceeding 250 mph. The rotating column of air often resembles a funnel-shaped cloud. The widths of tornadoes are usually several yards across, and in rare events can be more than a mile wide. Tornadoes and their resultant damage can be classified into six categories using the Fujita Scale. This scale assigns numerical values for wind speeds inside the tornado according to the type of damage and degree of the tornado. Most tornadoes are F0 and F1, resulting in little widespread damage. Tornado activity normally spans from April through July but tornadoes can occur at any time throughout the year. In Virginia, peak tornado activity is in July. Hot, humid conditions stimulate tornado growth.

### 5.8.2 Magnitude or Severity

Strong tornadoes may be produced by thunderstorms and are often associated with the passage of hurricanes. On average, about seven tornadoes are reported in Virginia each year. The total number may be higher as incidents may occur over areas with sparse populations, or may not cause any property damage.

Tornado damage is computed using the Fujita Scale, as seen in Table 5-20. Classification is based on the amount of damage caused by the tornado, where the measure of magnitude is based on the impact.

**Table 5-20. Fujita Tornado Intensity Scale**

Classification	Max. Winds (mph)	Path Length (miles)	Path Width (miles)	Damage
F0	less than 73	less than 1.0	less than 0.01	Chimneys damaged, trees broken
F1	73–112	1.0–3.1	0.01–0.03	Mobile homes moved off foundations or overturned
F2	113–157	3.2–9.9	0.03–0.09	Considerable damage, mobile homes demolished, trees uprooted
F3	158–206	10–31	0.10–0.29	Roofs and walls torn down, trains overturned, cars thrown
F4	207–260	32–99	0.30–0.90	Well-constructed walls leveled
F5	261–318	100–315	1.0–3.1	Homes lifted off foundations and carried some distance, cars thrown as far as 300 feet

Source: National Weather Service.

The classification of a tornado gives an approximate depiction of what the corresponding damage will be. Hazus analysis for hurricane wind shows that wind speeds with a 1,000-year hurricane event are roughly the same as a weak to mid-range EF1 (defined below) tornado. These usually result in minimal extensive damage. Damage likely to occur would be to trees, shrubbery, signs, antennas, and some damage to roofs and unanchored trailers. An Enhanced Fujita Scale (EF Scale) was developed and implemented operationally in 2007. The EF Scale was developed to better align tornado wind speeds with associated damages. Table 5-21 provides a side-by-side comparison of the F Scale and the EF Scale.

**Table 5-21. Fujita Scale Vs. Enhanced Fujita Scale**

Fujita Scale			Enhanced Fujita Scale	
F Number	Fastest 1/4-mile (mph)	3-second gust (mph)	EF Number	3-second gust (mph)
0	40–72	45–78	0	65–85
1	73–112	79–117	1	86–110
2	113–157	118–161	2	111–135
3	158–207	162–209	3	136–165
4	208–260	210–261	4	166–200
5	261–318	262–317	5	Over 200

### 5.8.3 Hazard History

Table 5-22 includes descriptions of major tornado events that have touched down in the region since 2011. Other events are included in Appendix B. Events have been broken down by the date of occurrence and, when available, by individual community descriptions. When no community description is available, the general description applies to the entire region. Although not comprehensive in terms of tornado fatalities and injuries, the NCDC database indicates that since 1950 there have been ten deaths and 347 injuries in the region due to tornadoes.

**Table 5-22. History of Tornado Events and Damages, 2011–2016**

Date	Damages
April 16, 2011	<b>Dinwiddie County:</b> A high-end EF1 tornado touched down near Doyle Road west of Glebe Road and tracked to the Five Forks area, some 8 miles east/northeast. The twister injured at least four people, downed hundreds of trees, knocked down power lines, and damaged (minor to moderate) several homes.
October 14, 2011	<b>New Kent County:</b> Preliminary information showed the tornado had 95 mph winds and was 200 yards wide. A school and a dozen homes suffered damage. One injury was reported. (Source: The Virginian-Pilot)
June 30, 2012	<b>Hanover County:</b> An EF-0 tornado traveled 4.5 miles in Mechanicsville. It reached wind speeds up to 80 mph. It was only on the ground periodically. Several roads were closed due to downed trees and power lines. (Source: <a href="http://www.nbc12.com/story/18927663/national-weather-service-confirms-tornado-in-hanover-county">http://www.nbc12.com/story/18927663/national-weather-service-confirms-tornado-in-hanover-county</a> )
May 22, 2014	<b>Prince George County:</b> _ The tornado was confirmed near the city of Prince George. The storm intensified northwest of Richmond, then produced wind damage in the City of Richmond, with trained storm spotters periodically reporting a funnel cloud in the Metro as it raced southeast. At 5:45 p.m., a tornado touched down on Kurnas Lane, destroying a shed, snapping trees and causing minor damage to a home. The tornado was rated an EF-0, with winds of 70 mph. It was 25 yards wide, and was on the ground for 75 yards. No injuries were reported. <b>Sussex County:</b> The tornado was confirmed near Waverly in Sussex county at 6:20 p.m. The tornado developed just north of Highway 460 and south of Petersburg Road, about mile northwest of Waverly. It moved south and crossed Highway 460 just north of Waverly. It struck an auto parts store, causing minor damage. Many large trees were uprooted along Highway 460, and the highway was closed due to trees on the road. The tornado tracked southward to North Church Street, causing minor damage to the First Baptist Church. Many large trees fell into the nearby cemetery, causing damage. The tornado moved across New Street, snapping trees and damaging homes. The tornado lifted shortly after crossing Highway 460 on the west side of Waverly. This tornado was classified as an EF-0 tornado, with winds of 75 mph. It was 100 yards wide, and was on the ground for 1.5 miles. No injuries were reported.



**Table 5-22. History of Tornado Events and Damages, 2011–2016**

Date	Damages
	(Source: <a href="http://wtvr.com/2014/05/23/two-tornadoes-confirmed-from-may-22-storm/">http://wtvr.com/2014/05/23/two-tornadoes-confirmed-from-may-22-storm/</a> )
Feb 25, 2016	<p>Virginia State Police confirmed three deaths and eight with minor injuries after a confirmed tornado hit the Town of Waverly in in Sussex County. Emergency management officials spotted the twister moving along Route 460 and into Waverly. Crews spotted a church and trailer in the storm. Snapped trees and signs were also spotted. Troopers began responding to the damage along Route 40 in Waverly around 2:40 p.m. That's where officials said a 50-year-old man, 26-year-old man and 2-year-old boy were killed when their mobile home was destroyed. The victims, whose bodies were transported to the Office of the Medical Examiner in Norfolk for positive identification, were found about 300 yards from the mobile home. Officials said four other structures suffered damage in the town.”</p> <p>(Source: <a href="http://wtvr.com/2017/02/24/2-killed-in-wavery-tornado/">http://wtvr.com/2017/02/24/2-killed-in-wavery-tornado/</a>)</p> <p>This was the first deadly tornado in Virginia since 1950.</p> <p>(Source: <a href="http://www.vaemergency.gov/news-local/tornado-history/">http://www.vaemergency.gov/news-local/tornado-history/</a>)</p>

\*History from 1790-2010 in Appendix B-3



**Figure 5-17. A deadly EF-1 Tornado in Waverly that killed 3 people on 25 February 2016**

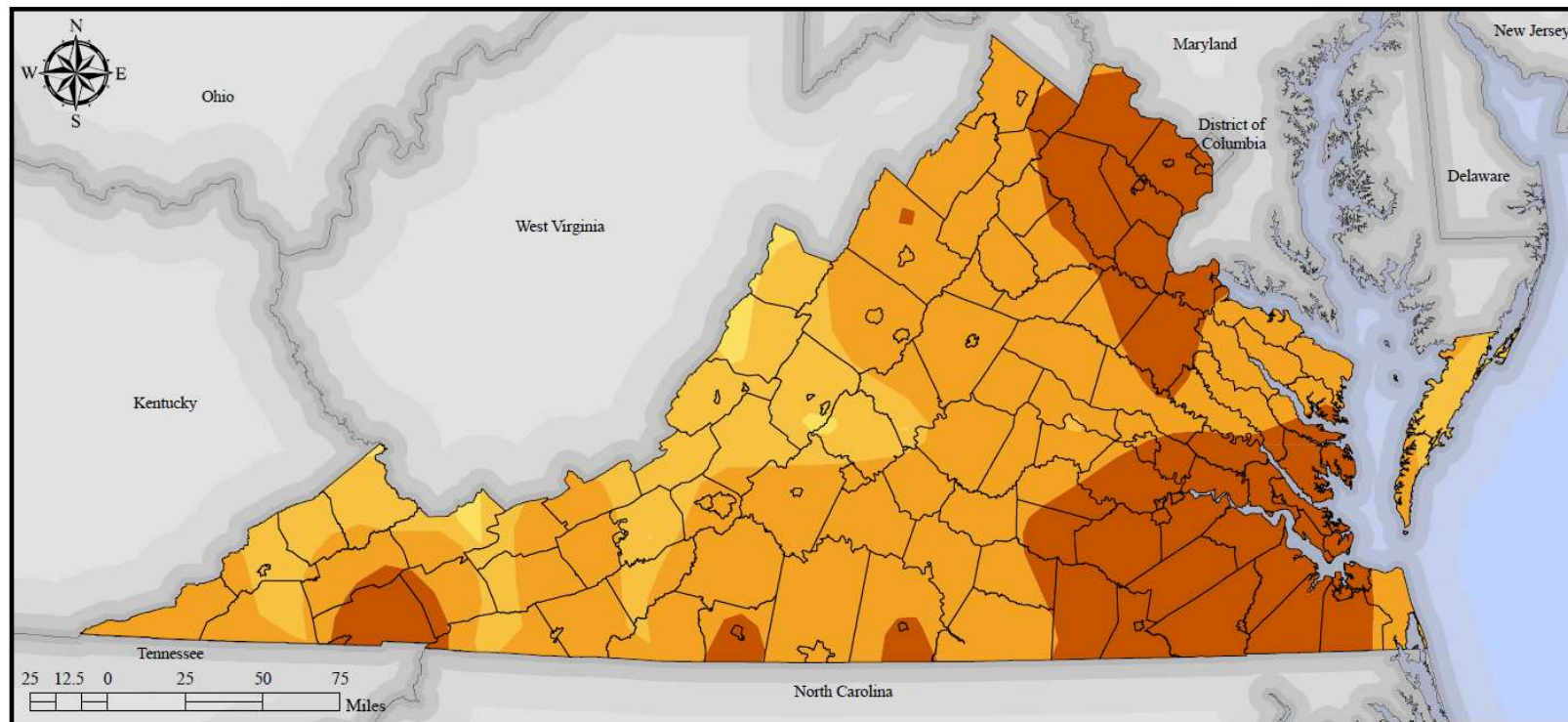
Source:

<https://www.google.com/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&ved=&url=http%3A%2F%2Fwina.com%2Fnews%2F064460-nelson-buckingham-eligible-for-disaster-help%2F&psig=AFQjCNE74OiF3712rKcf1Vxrlat-acX-iQ&ust=1477429571046170>

Figure 5-18 presents the results of a tornado frequency analysis performed as part of the 2013 Virginia State Hazard Mitigation Plan update. The analysis suggests that relative to the entire Commonwealth of Virginia, the region is considered to be “Medium-High” to “High” in terms of tornado frequency. Even so, annualized tornado frequency is quite low and calculated as being between 0.0000101 and 0.000316 for any particular point in the region, with no one specific jurisdiction more likely to experience tornadoes than another.

Table 5-23 presents a calculation of annualized tornado occurrence by jurisdiction based on NCDC tornado data. The annual tornado frequency, a reasonable predictor of future tornado probability, ranges from 0.27 to 0.02 which roughly correlates to a tornado occurring every 4 to 50 years.

Table 5-24 and Figure 5-19 show tornado occurrences in the region since 1950.



**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.

**DATA SOURCES:**

SVRGIS  
VGIN Jurisdictional Boundaries  
ESRI State Boundaries

**LEGEND:**

Annual Tornado Hazard Frequency <i>Times One Million</i>	
0 - 1.25	Low
1.251 - 10	Medium-Low
10.1 - 100	Medium-High
100.1 - 316	High

**HAZARD IDENTIFICATION:**

Annual tornado hazard frequency is an estimate of the frequency with which a point will experience a tornado, interpolating from neighboring tornado impact areas over the historical period of record. This map shows hazard frequency of any intensity of tornado. Note that "high" frequency in the state of Virginia is still rather low in comparison to many midwestern and southern states.

Commonwealth of Virginia Hazard Mitigation Plan 2013

**Figure 5-18: Historical Tornado Hazard Frequency Analysis**

Source: 2013 Virginia State Hazard Mitigation Plan

**Table 5-23. Annualized Tornado Events and Losses, 1950 - 2016**

<b>Jurisdiction</b>	<b>Annualized Number of Tornado Events</b>	<b>Annualized Property Damages</b>	<b>Annualized Crop Damages</b>	<b>Annualized Total Losses</b>
Charles City County	0.03	\$13,988	-	\$13,988
Chesterfield County	0.26	\$201,639	-	\$201,639
City of Colonial Heights	0.02	\$33,106	-	\$33,106
Dinwiddie County (incl. Town of McKenney)	0.03	\$3,337	-	\$3,337
City of Emporia	0.06	\$85,942	-	\$85,942
Goochland County	0.08	\$891,490	-	\$891,490
Greensville County (incl. Town of Jarratt)	0.14	\$73,980	-	\$73,980
Hanover County (incl. Town of Ashland)	0.14	\$1,272,733	-	\$1,272,733
Henrico County	0.14	\$24,560	-	\$24,560
City of Hopewell	0.09	\$18,033	-	\$18,033
New Kent County	0.29	\$27,280	-	\$27,280
City of Petersburg	0.18	\$114,430	-	\$114,430
Powhatan County	0.08	\$16,581	-	\$16,581
Prince George County	0.05	-	-	-
City of Richmond	0.15	\$20,546	-	\$20,546
Surry County (incl. Towns of Claremont, Dendron, Surry)	0.12	\$21,636	-	\$21,636
Sussex County (incl. Towns of Stony Creek, Wakefield, Waverly)	0.14	\$75,448	-	\$75,448
<b>Total</b>	<b>2</b>	<b>\$2,894,729</b>	<b>\$0</b>	<b>\$2,894,729</b>

\*Particularly damaging tornado events in 1984 and 1993 play a significant role in this loss estimate.

Source: National Climatic Data Center.

**Table 5-24. Tornado Touchdowns by Fujita Rating, 1950 - 2017**

<b>County</b>	<b>EF0</b>	<b>EF1</b>	<b>EF3</b>	<b>F0</b>	<b>F1</b>	<b>F2</b>	<b>F3</b>	<b>F4</b>	<b>Total</b>
Charles City County					2				<b>2</b>
Chesterfield County	1			3	8	3			<b>15</b>
City of Colonial Heights		1							<b>1</b>
Dinwiddie County (incl. Town of McKenney)				1		1			<b>2</b>
City of Emporia				1			1		<b>2</b>
Goochland County	1	1				1	1		<b>4</b>

**Table 5-24. Tornado Touchdowns by Fujita Rating, 1950 - 2017**

County	EF0	EF1	EF3	F0	F1	F2	F3	F4	Total
Greensville County (incl. Town of Jarratt)		1		3	1	2			7
Hanover County (incl. Town of Ashland)		1		1	4		1	1	8
Henrico County	1	1		1	3	1			7
City of Hopewell		2		1	1				4
New Kent County	5	1		5	1		1		13
City of Petersburg		1		4	6				11
Powhatan County	1	1		2	1				5
Prince George County				1					1
City of Richmond	1	1		3		3			8
Surry County (incl. Towns of Claremont, Dendron, Surry)		2	1	2	2		1		8
Sussex County (incl. Towns of Stony Creek, Wakefield, Waverly)	2	1		1	2	1	1		8



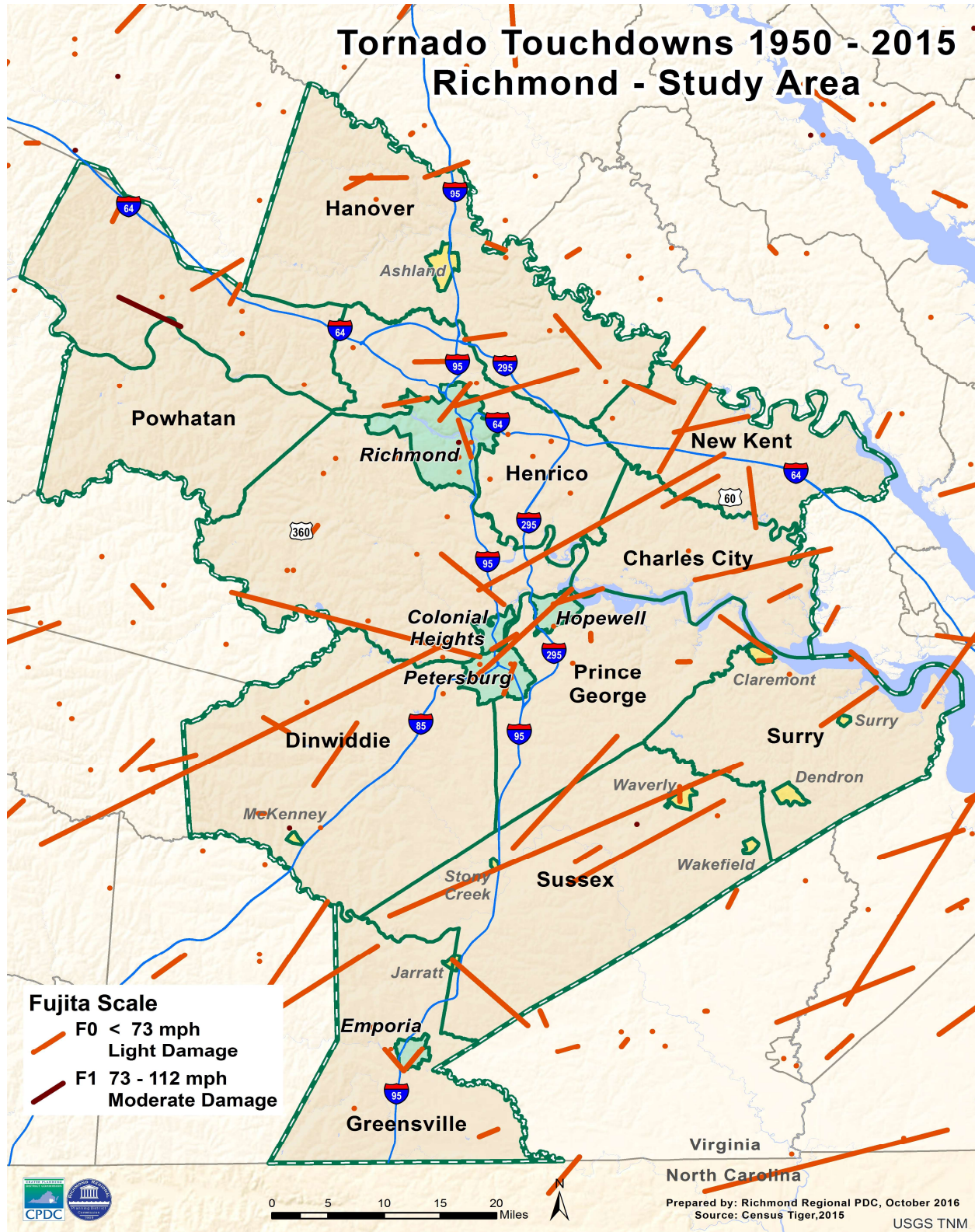


Figure 5-19. Tornado Touchdowns, 1950–2016

## **5.8.4 Vulnerability Analysis**

### *Probability*

Tornadoes are considered to be low-frequency, high-impact events. Electrical utilities and communications infrastructure are vulnerable to tornadoes. Damage to power lines or communication towers has the potential to cause power and communication outages for residents, businesses, and critical facilities. In addition to lost revenues, downed power lines present a threat to personal safety. Further, downed wires and lightning strikes have been known to spark fires.

### *Impact and Vulnerability*

A structure's tornado vulnerability is the same as that for other types of extreme wind events and is based in large part on building construction and standards as discussed previously in greater detail in the section on Building Types (within the Wind Hazard section). Other factors such as location, condition, and maintenance of trees also play a significant role in determining vulnerability.

Human vulnerability is based on the availability, reception, and understanding of early warnings of tornadoes (e.g., Tornado Warning issued by the NWS) and access to substantial indoor shelter. In some cases, despite having access to technology (computers, radio, television, cell phones, outdoor sirens, etc.) that allow for receiving warnings, language differences may prevent some individuals from understanding them. Once warned of an impending tornado hazard, to seek shelter indoors on the lowest floor of a substantial building away from windows is recommended as the best protection against bodily harm.

### *Risk and Loss Estimation*

Although historical data indicates that there has been some small variation in the distribution of tornadoes across the region, the probability of experiencing a tornado is roughly equal for all of the jurisdictions. With this being the case, the vulnerability of critical facilities across the area is largely determined by construction type of each particular facility. Wood-framed structures are generally considered to be more vulnerable to tornado damage than steel, brick, or concrete structures.

Table 5-26 illustrates that based on the historical record, two tornado events occur annually in the region resulting in about \$2.9 million in damages. This loss figure is skewed by two particularly damaging tornado events that occurred on August 6, 1993 (which impacted multiple jurisdictions) and May 8, 1984. The City of Petersburg was hit hard in both instances and has a very high annualized tornado loss estimate as a result.

Jurisdictional executive summaries highlight hazards and vulnerability within the community.

## 5.9 Thunderstorms (including Hail and Lightning)

### 5.9.1 Hazard Profile

Thunderstorms are caused when air masses of varying temperatures and moisture content meet. All thunderstorms produce lightning. Droplets of water in a thunderstorm may get picked up in the storm's updraft, a column of rising air. The updraft can carry the droplets to levels of the atmosphere where temperatures are below freezing. The frozen droplets, now hail, may then fall due to gravity injuring people, property and animals.

### 5.9.2 Magnitude or Severity

A bolt of lightning can reach temperatures approaching 50,000 degrees Fahrenheit. Lightning can remain in-cloud or can contact the ground or other surfaces. A cloud-to-ground bolt of lightning can sometimes strike locations 10 or more miles away from the parent thunderstorm, producing the effect that the lightning came from 'out of the blue' or without warning. In the past 30 years, lightning has killed an average of 58 people per year in the United States.<sup>5</sup>

Hail can be smaller than a pea, or as large as a softball, and can be very destructive to automobiles, glass surfaces (e.g., skylights and windows), roofs, siding, plants, and crops.<sup>6</sup>

### 5.9.3 Hazard History

Virginia averages 40 to 50 thunderstorm days per year.<sup>7</sup> Thunderstorms can occur at any time during any season, but are most common in the late afternoon and evening hours during the summer months. In addition to flooding rainfall, damaging winds, and sometimes tornadoes thunderstorms might also produce large hail and deadly lightning.

Past occurrences of thunderstorm events that produced damage, injuries, or fatalities as a result of hail or lightning are listed in Table 5-25 and shown in Figure 5-20. The NCDC database shows that at least two people in the region have been killed and three others injured as a result of lightning since 1993. The database did not indicate any deaths or injuries in the region during this period as a result of hail.

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<sup>5</sup> <http://www.weather.gov/os/lightning/overview.htm>; NWS; retrieved April 11, 2011.

<sup>6</sup> *Talking About Disaster*.

<sup>7</sup> Sammler, William. Personal interview, September 15, 2005. (National Weather Service, Warning Coordination Meteorologist, Wakefield, Virginia office.)

**Table 5-25. History of Hail/Lightning Events and Damages, 2010–2016**

Date	Damages
August 12, 2010	<b>Hanover County:</b> Hail, two inches in diameter, damaged vehicles in the county east of Old Cold Harbor.
June 29, 2012	The June 2012 Mid-Atlantic and Midwest derecho was one of the most destructive and deadly fast-moving severe thunderstorm complexes in North American history. The progressive derecho tracked across a large section of the Midwestern United States and across the central Appalachians into the mid-Atlantic states on the afternoon and evening of June 29, 2012, and into the early morning of June 30, 2012. It resulted in 20 deaths, widespread damage and millions of power outages across the study region. (Source: <a href="https://en.wikipedia.org/wiki/June_2012_North_American_derecho">https://en.wikipedia.org/wiki/June_2012_North_American_derecho</a> )
June 13, 2013	On the morning of the 13, another linear complex of severe storms developed along a line near the southern border of Ohio. The storms eventually strengthened into a powerful derecho and raced to the south and east. Fatalities and injuries occurred as a result of falling trees and power lines as the storms ripped through Virginia, along with numerous reports of damaging winds and power outages. The derecho downed numerous trees and damaged structures with winds up to 80 mph (130 km/h) in some areas. (Source: <a href="https://en.wikipedia.org/wiki/June_12%E2%80%9313,_2013_derecho_series">https://en.wikipedia.org/wiki/June_12%E2%80%9313,_2013_derecho_series</a> )
May 22, 2014	A large Hail and Thunderstorm event came through the region. Some hail was reported to be as large as ping pong balls. Several areas were affected from fallen electric lines. The NCDC data reports that 12 direct deaths in the study region resulted from this event. (Source: NCDC data & <a href="http://www.nbcwashington.com/news/local/Severe-Thunderstorms-DC-Area-May-22-260300391.html">http://www.nbcwashington.com/news/local/Severe-Thunderstorms-DC-Area-May-22-260300391.html</a> )
February 24, 2016	This storm started in the north eastern states and traveled down through Virginia and south. During the thunderstorm, hail in some parts of the region were as large as 3 inches in diameter. (Source: <a href="http://www.weather.gov/akq/Feb24-2017TOR">http://www.weather.gov/akq/Feb24-2017TOR</a> )



### 5.9.4 Risk Assessment

#### Probability

Although most frequent in the Southeast and parts of the Midwest, thunderstorms are a relatively common occurrence across the region and have been known to occur in all calendar months. No one portion of the central Virginia region is deemed more likely to experience thunderstorms than another. Table 5-26 indicates the annualized number of hail and damaging lightning events by jurisdiction based on NCDC data.

#### Impact and Vulnerability

Electrical utilities and communications infrastructure are vulnerable to lightning. Damage to power lines or communication towers due to direct lightning strikes have the potential to cause power and communication outages for residents, businesses, and critical facilities. In addition to lost revenues, downed power lines present a threat to personal safety. Further, downed wires and lightning strikes have been known to spark fires.

A structure's thunderstorm vulnerability is based in large part on building construction and standards. Other factors, such as location, condition, and maintenance of trees also plays a significant role in determining vulnerability. Windows, roofs, and siding are most vulnerable to the impacts of large hail.

Human vulnerability is based on the availability and reception of early warnings of significant thunderstorm events (i.e., Severe Thunderstorm Warning issued by the NWS) and access to substantial indoor shelter. Seeking shelter indoors on the lowest floor of a substantial building away from windows is recommended as the best protection against thunderstorm-related hazards.

#### Risk and Loss Estimation

A quantitative assessment of critical facilities at risk for hail and lightning damage was not feasible for this plan update. It is important to note, however, that not all critical facilities have redundant power sources and may not even be wired to accept a generator for auxiliary power. Future plan updates should consider including a more comprehensive examination of critical facilities that are vulnerable to these hazards.

Table 5-26 is based on NCDC historical data; on average, the region experiences approximately six to seven hail storms annually and one damaging lightning event every two years. In terms of damages, roughly \$1,600 in losses is attributed to hail and about \$23,900 to lightning annually.

The jurisdictional executive summaries highlight hazards and vulnerability within the community.

**Table 5-26. Annualized Thunderstorm (with Hail and Lightning)  
Events and Losses, 1956 - 2016**

Jurisdiction	Annualized Thunderstorm Events	Annualized Property Losses	Annualized Crop Damages	Annualized Total Losses
Charles City County	0.95	\$1,535	-	\$1,535
Chesterfield County	3.98	\$15,640	-	\$15,640
City of Colonial Heights	0.59	\$4,370	-	\$4,370
Dinwiddie County (incl. Town of McKenney)	0.54	\$1,408	-	\$1,408
City of Emporia	0.70	\$1,199	-	\$1,199
Goochland County	0.82	\$3,764	-	\$3,764
Greensville County (incl. Town of Jarratt)	1.41	\$3,673	-	\$3,673
Hanover County (incl. Town of Ashland)	2.03	\$10,713	\$1	\$10,714
Henrico County	2.03	\$2,972	-	\$2,972
City of Hopewell	1.13	\$2,513	-	\$2,513
New Kent County	3.16	\$15,037	-	\$15,037
City of Petersburg	4.26	\$36,087	-	\$36,087
Powhatan County	1.54	\$5,979	-	\$5,979
Prince George County	1.80	\$4,538	-	\$4,538
City of Richmond	2.74	\$6,247	-	\$6,247
Surry County (incl. Towns of Claremont, Dendron, Surry)	1.38	\$2,224	-	\$2,224
Sussex County (incl. Towns of Stony Creek, Wakefield, Waverly)	1.80	\$3,418	-	\$3,418
<b>Total</b>	<b>30.86</b>	<b>\$121,316</b>	<b>\$1</b>	<b>\$121,317</b>

Source: National Climatic Data Center.

## 5.10 Winter Weather

### 5.10.1 Hazard Profile

Winter weather comes in many forms ranging from sub-freezing temperatures and dangerously low wind chills to an assortment of precipitation including freezing rain, sleet and snow. Snow typically maintains its crystalline structure from the clouds in which it forms until it reaches the surface. Freezing rain, on the other hand, may have started in the clouds as either rain or snow, but reaches the surface as liquid that freezes on contact with surfaces (power lines, tree limbs, the ground) with temperatures below freezing. Freezing rain can accrete on these surfaces resulting in an ice coating. Sleet reaches the surface in the form of clear pellets of ice that bounce upon contact.



### 5.10.2 Magnitude or Severity

The impacts of winter storms are usually minimal in terms of property damage and long-term effects. The most notable impact from winter storms is damage to power distribution networks and utilities. Severe winter storms have the potential to inhibit normal functions of the community. Government costs for these events include overtime personnel wages and equipment or contractors for road clearing. Private-sector losses are attributed to time lost when employees are unable to travel. Homes and businesses suffer damage when electric service is interrupted for long periods of time. Several utility companies and cooperatives provide service to the region, which can make power restoration complicated.

Health threats can become severe when frozen precipitation makes roadways and walkways very slippery, when prolonged power outages occur, and when fuel supplies are jeopardized. Occasionally, buildings may be damaged when snow loads exceed the design capacity of their roofs or when trees fall due to excessive ice accumulation on branches. The water content of snow can vary significantly from one storm to another and can drastically impact the degree to which damage might occur. In snow events that occur at temperatures at or even above freezing, the water content of the snowfall is generally higher. Higher water content translates into a heavier, “wet” snowfall that more readily adheres to power lines and trees, increasing the risk of their failure. Roof collapse is also more of a concern with wetter, heavier snowfall. Clearing of roadways and sidewalks is usually easier with a drier, more powdery snow which is also less likely to accumulate on power lines and trees. This type of snow generally occurs in temperatures below freezing, as water content decreases with temperature. The primary impact of excessive cold is increased risk for frostbite, and potentially death as a result of over-exposure to extreme cold.

Secondary effects of extreme/excessive cold include danger to livestock and pets as well as frozen water pipes in homes and businesses.

### 5.10.3 Hazard History

Table 5-27 includes descriptions of major winter storm events in the region. Events have been broken down by the date of occurrence and, when available, by individual community descriptions. When no community description is available, the general description applies to the entire region. All descriptions are based on NCDC and VDEM data unless otherwise noted. Although very limited in terms of winter weather-related fatalities and injuries, the NCDC database indicates that since 1993 there has been one death and five injuries in the region due to winter storm events.

**Table 5-27. History of Winter Storm Events and Damages, 2010–2016**

Date	Damages
December 25, 2010	A 4- to 10-inch snowfall blanketed the region with the heaviest amounts falling over the south and eastern sections. Amounts ranged from 4 inches northwest of the City of Richmond, 6 to 7 inches in the Cities of Petersburg and Emporia, and around a foot near the Town of Wakefield.
February 10, 2014	This was a major ice and snow storm that affected the entire region and elsewhere in the Eastern United States. This event produced devastating amounts of freezing rain and snow along and east of Interstate 95 all the way down to the coast. Overall temperatures throughout the winter were much colder in 2014. This was rated as 3 (Major) on the NESIS scale. A Presidential Disaster event was declared in Chesterfield. (Source: <a href="http://www.weather.gov/phi/02132014">http://www.weather.gov/phi/02132014</a> )
January 22, 2016	What transpired was reasonably close to what was forecast, with a major snowstorm for our entire region, which also included a mix of some sleet across portions of the area as well as small amounts of freezing rain. NOAA ranks Northeast U.S. storms according to overall impact, part of which is dependent on societal and economic factors, thus population density is a key component. This particular storm was ranked as a 4 on the “NESIS” scale of 1-5, or “crippling”. It is now 4th on the list of historic storms that have been ranked on the NESIS scale, with only two storms ever ranked as a 5 (“extreme”). Presidential Disasters for this study region were declared for Sussex and Henrico Counties. (Source: <a href="http://www.weather.gov/media/rnk/past_events/2017_01_2223_Winter.pdf">http://www.weather.gov/media/rnk/past_events/2017_01_2223_Winter.pdf</a> )
*History from 1940-2010 in Appendix B-3	

As part of the 2006 analysis, gridded climate data was obtained from the Climate Source and through the Virginia View program. This data was developed by the Oregon State University Spatial Climate Analysis Service using PRISM (Parameter-elevation Regressions on Independent Slopes Model). This climate mapping system is an analytical tool that uses point weather station observation data, a digital elevation model, and other spatial datasets to generate gridded estimates of monthly, yearly, and event-based climatic parameters.

The mean annual days map reveals the 30-year average of the number of days that a location will receive greater than 1 inch of snowfall in a 24-hour period in a given year.

A criterion of greater than 1 inch was selected for winter snowfall severity assessment because this depth will result in complete road coverage that can create extremely dangerous driving conditions and will require removal by the local community. This amount of snowfall in a 24-hour period can also lead to business closures and school delays or cancellation.

Figure 5-21 shows the average number of days with snowfall greater than 1 inch for the state. The analysis shows that the highest frequency of days with greater than 1 inch of snow is found in the higher elevations of western portions of the commonwealth. On the flip side, southern and southeastern portions of the commonwealth typically only experience one day or fewer where snowfall accumulates to more than an inch. Availability of new data through PRISM is now somewhat restricted due to that program's limited remaining funding. This circumstance prevented a similar or updated analysis for this plan's update. Even so, the previous analysis is based on long-term records and is still considered valid.

The Virginia Tech Center for Geospatial Information and Technology performed analyses of weather station daily snowfall data for the Commonwealth of Virginia's Hazard Mitigation Plan in 2013. Station-specific statistics were used as the basis for a seamless statewide estimate based on multiple linear regressions between the weather statistics (dependent variable) and elevation and latitude (independent variables). Figure 5-22 shows that the average number of days with at least 3 inches of snowfall ranges from 1.51 to 2 days over northwestern portions of the region, including portions of Hanover, Goochland, Powhatan, and Henrico Counties to 1.5 days or fewer over the remainder of the area.

Figure 3.9-2: Average number of days with at least 3 inches of snow

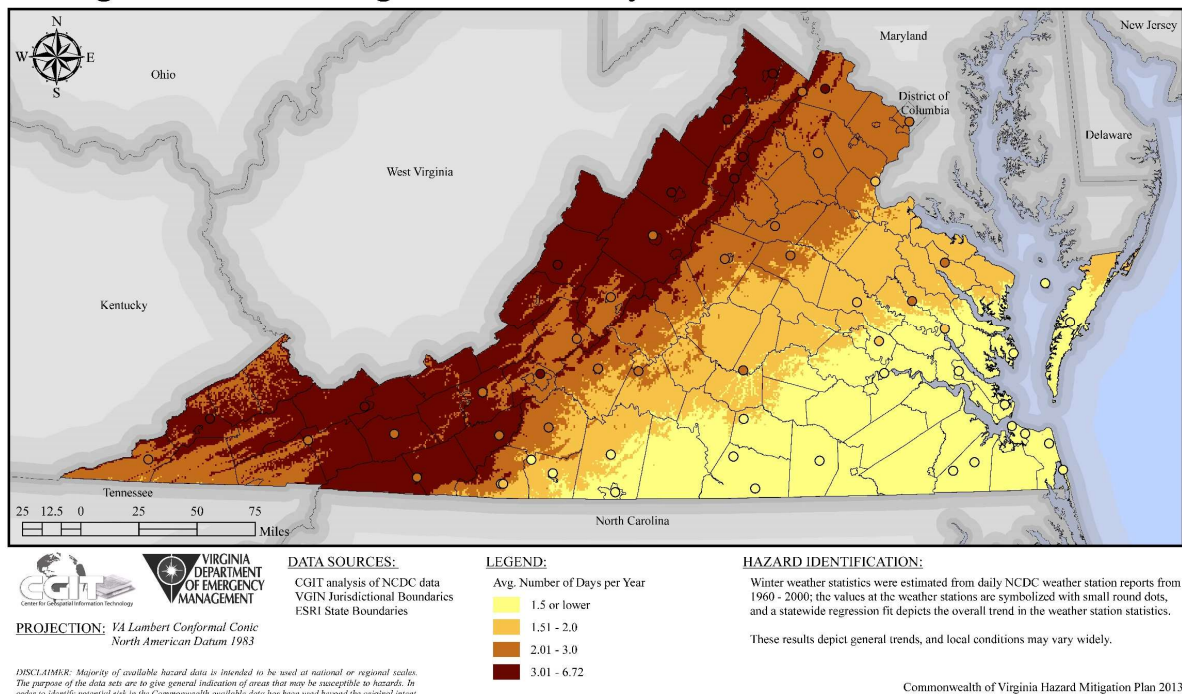


Figure 5-21. Virginia Average Number of Days with Snowfall > 3 Inches

**Figure 5-22. Average Number of Days with at Least 3 Inches of Snowfall**  
Source: 2010 Virginia State Hazard Mitigation Plan



#### **5.10.4 Ice Potential**

Another challenge with winter weather in the region is the amount of ice that often accompanies the winter season. Ice in winter storms takes two primary forms:

**Sleet** is rain that freezes into ice pellets before it reaches the ground. Sleet usually bounces when hitting a surface and does not stick to objects; however, it can accumulate like snow and cause roads and walkways to become hazardous.

**Freezing rain** (also known as an ice storm) is rain that falls onto a surface that has a temperature below freezing. The cold surface causes the rain to freeze, so surfaces such as tree branches, utility wires, vehicles, and roads become glazed with ice. Even small accumulations of ice can cause significant hazards to people, especially to pedestrians and motorists, as well as to property.<sup>8</sup>

Ice from freezing rain can accumulate on trees, power lines, and communication towers causing damage and leading to power and communication outages that can last for days, and in the most severe cases, for weeks. Even small accumulations of ice can be severely dangerous to motorists and pedestrians. Bridges and overpasses are particularly dangerous because they freeze before other surfaces.

The debris created by the trees can also block roadways and impact emergency services. Clean-up of the debris is often complicated because responsibility is shared by the Virginia Department of Transportation (VDOT) and private utility companies.

#### **5.10.5 Vulnerability Analysis**

##### *Probability*

Winter storms can be a combination of heavy snowfall, high winds, ice, and extreme cold. Winter weather typically impacts the state of Virginia between the months of October and April, with varied intensities.

To determine the geographic distribution and frequency with which major snow or ice events impact the region, the Iowa Environmental Mesonet (IEM) obtains data from cooperating members that have observing networks. Watch, Warning, and Advisory events were collected and examined between 1986 and 2017 (see Table 5-28 and 5-29). The events were sorted into the following categories: Freeze, Freezing Fog, Freezing Rain, Frost, Heavy Snow, Snow, Winter Storm, and Winter Weather. (Data was collected from: <http://mesonet.agron.iastate.edu/vtec/search.php> )

The most alerts between 1986 and 2016 were for Goochland County, followed next by Hanover and Powhatan Counties. The fewest alerts were given for Charles City, Sussex, and Prince George Counties. The most common type of events for all counties were the Winter Weather, Winter Storm, Freeze, and Frost type events.

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<sup>8</sup> *Talking About Disaster.*

It should be noted that the number of reported events from the IEM and NCDC collections were slightly different. With the number of annual IEM events being 49.3 and the NCDC annual winter events being around 45.9. Because of the difference in collection criteria, agencies, and time frames of the reported events, the 7% difference between the two annualized events reported was not significant.

**Table 5-28. National Weather Service Winter Alerts, 1986 - 2016**

<b>Jurisdiction</b>	<b>Watch Events</b>	<b>Warning Events</b>	<b>Advisory Events</b>	<b>Total Events</b>	<b>Annualized Events</b>
Charles City County	20	36	59	<b>115</b>	<b>3.71</b>
Chesterfield County	21	38	63	<b>122</b>	<b>3.94</b>
City of Colonial Heights	-	-	-	-	-
Dinwiddie County	22	39	66	<b>127</b>	<b>4.10</b>
City of Emporia	-	-	-	-	-
Goochland County	33	45	73	<b>151</b>	<b>4.87</b>
Greensville County	21	37	62	<b>120</b>	<b>3.87</b>
Hanover County	26	41	77	<b>144</b>	<b>4.65</b>
Henrico County	22	38	64	<b>124</b>	<b>4.00</b>
City of Hopewell	-	-	-	-	-
New Kent County	22	34	65	<b>121</b>	<b>3.90</b>
City of Petersburg	-	-	-	-	-
Powhatan County	32	46	65	<b>143</b>	<b>4.61</b>
Prince George County	19	38	62	<b>119</b>	<b>3.84</b>
City of Richmond	-	-	-	-	-
Surry County (Incl. Towns of Claremont, Dendron, Surry)	22	34	62	<b>118</b>	<b>3.81</b>
Sussex County (Incl. Towns of Stony Creek, Wakefield, Waverly)	22	37	65	<b>124</b>	<b>4.00</b>
<b>Totals</b>	<b>282</b>	<b>463</b>	<b>783</b>	<b>1528</b>	<b>49.3</b>

**Table 5-29 Annualized Winter Alert Types, 1986 - 2016**

<b>Jurisdiction</b>	<b>Freeze</b>	<b>Freezing Fog</b>	<b>Freezing Rain</b>	<b>Frost</b>	<b>Heavy Snow</b>	<b>Snow</b>	<b>Winter Storm</b>	<b>Winter Weather</b>	<b>Total Annualized Events</b>
Charles City County	0.87	0.03	-	0.48	-	0.06	0.94	1.32	<b>3.7</b>
Chesterfield County	0.77	0.03	0.03	0.48	0.03	0.03	1.1	1.45	<b>3.92</b>
City of Colonial Heights	-	-	-	-	-	-	-	-	
Dinwiddie County	0.97	0.03	0.03	0.48	-	0.06	1	1.52	<b>4.09</b>
City of Emporia	-	-	-	-	-	-	-	-	
Goochland County	0.94	0.03	0.19	0.35	0.03	0.03	1.55	1.74	<b>4.86</b>

**Table 5-29 Annualized Winter Alert Types, 1986 - 2016**

<b>Jurisdiction</b>	<b>Freeze</b>	<b>Freezing Fog</b>	<b>Freezing Rain</b>	<b>Frost</b>	<b>Heavy Snow</b>	<b>Snow</b>	<b>Winter Storm</b>	<b>Winter Weather</b>	<b>Total Annualized Events</b>
Greensville County	0.97	0.03	-	0.48	-	0.06	0.9	1.42	<b>3.86</b>
Hanover County	0.81	0.03	0.13	0.45	0.03	0.06	1.32	1.81	<b>4.64</b>
Henrico County	0.77	0.03	0.03	0.52	0.03	0.03	1.13	1.45	<b>3.99</b>
City of Hopewell	-	-	-	-	-	-	-	-	
New Kent County	0.84	0.03	-	0.48	-	0.06	0.97	1.52	<b>3.9</b>
City of Petersburg	-	-	-	-	-	-	-	-	
Powhatan County	0.94	0.03	0.16	0.39	0.03	0.03	1.55	1.48	<b>4.61</b>
Prince George County	0.94	0.03	-	0.52	-	0.06	0.9	1.39	<b>3.84</b>
City of Richmond	-	-	-	-	-	-	-	-	
Surry County (Incl. Towns of Claremont, Dendron, Surry)	0.94	0.03	-	0.52	-	0.1	0.87	1.35	<b>3.81</b>
Sussex County (Incl. Towns of Stony Creek, Wakefield, Waverly)	0.97	0.03	-	0.52	-	0.06	0.94	1.48	<b>4</b>
<b>Totals</b>	<b>10.73</b>	<b>0.36</b>	<b>0.57</b>	<b>5.67</b>	<b>0.15</b>	<b>0.64</b>	<b>13.17</b>	<b>17.93</b>	<b>49.22</b>

### Impact and Vulnerability

Winter storm vulnerability can be expressed by impacts to people, property, and societal function. For example, exposure of individuals to extreme cold, falls on ice-covered walkways, carbon monoxide poisoning from generators and automobile accidents is heightened during winter weather events. According to NCDC records dating back to 1993, at least one fatality was officially recorded resulting from a winter storm event in the area. NCDC storm event records typically do not contain traffic fatalities blamed on wintry weather, and although details were not provided, the fatality took place during a severe snow storm on January 25, 2000.

Property damage due to winter storms includes damage done by and to trees, water pipe breakage, structural failure due to snow loads, and injury to livestock and other animals. The average amount of total damages due to winter events is \$40,000 per year (1993-2017) for the region (adjusted for inflation to 2017 dollars). The counties most affected from winter events over the years are Prince George (\$9,089/yr.), Henrico (\$8,948/yr.), and Chesterfield (\$7,962/yr.). Disruption of utilities and transportation systems, as well as lost business and decreased productivity represent societal vulnerability.

Vulnerability to winter storm damages varies due to specific factors; for example, proactive measures such as regular tree maintenance and utility system winterization can minimize property vulnerability. Localities accustomed to winter weather events or with resources to

take proactive preventive measures are typically more prepared to deal with them and therefore less vulnerable than localities that rarely experience winter weather.

### *Risk and Loss Estimation*

A quantitative assessment of critical facilities for winter storm risk was not feasible for this plan update. Even so, it is apparent that transportation structures are at great risk from winter storms. In addition, building construction variables – particularly roof span and construction method, are factors that determine the ability of a building to perform under severe stress weights from snow. Finally, not all critical facilities have redundant power sources and many are not wired to accept a generator for auxiliary power. Future plan updates should consider including a more comprehensive examination of critical facility vulnerability to winter storms.

Table 5-30 summarizes NCDC historical data for winter weather events since 1993. Based on this information, on average, the region experiences approximately two winter weather events annually, of which some rare winter storms have historically included significant accumulations of ice (due to freezing rain). In terms of annualized damages, roughly \$40,411 per year in losses is attributed to winter weather events, 57% of which is attributed to ice storms.

**Table 5-30. NCDC Annualized Winter Weather Events, 1993 - 2016**

<b>Jurisdiction</b>	<b>Number of Winter Weather Events</b>	<b>Annualized Property Damages</b>	<b>Annualized Crop Damages</b>	<b>Annualized Total Losses</b>
Charles City County	2.38	\$1,444	-	\$1,444
Chesterfield County	6	\$7,962	-	\$7,962
City of Colonial Heights	-	-	-	-
City of Emporia	-	-	-	-
City of Hopewell	-	-	-	-
City of Petersburg	-	-	-	-
City of Richmond	-	-	-	-
Dinwiddie County	2.42	\$2,600	-	\$2,600
Goochland County	3.5	\$3,004	-	\$3,004
Greensville County	4.17	-	-	-
Hanover County	3.54	\$3,030	-	\$3,030
Henrico County	6.08	\$8,948	-	\$8,948
New Kent County	2.5	\$1,444	-	\$1,444
Powhatan County	3.04	\$2,889	-	\$2,889
Prince George County	7.88	\$9,089	-	\$9,089

**Table 5-30. NCDC Annualized Winter Weather Events, 1993 - 2016**

Jurisdiction	Number of Winter Weather Events	Annualized Property Damages	Annualized Crop Damages	Annualized Total Losses
Surry County	2.08	-	-	-
Sussex County	2.29	-	-	-
<b>Total</b>	<b>45.88</b>	<b>\$40,411</b>	<b>\$0</b>	<b>\$40,411</b>

Source: National Climatic Data Center.

The jurisdictional executive summaries highlight hazards and vulnerability within the community.

## 5.11 Droughts and Extreme Heat

### 5.11.1 Hazard Profile

A drought can be characterized in several different ways depending on the impact. The most common form of drought is agricultural. Agricultural droughts are characterized by unusually dry conditions during the growing season. Meteorological drought is an extended period of time (six or more months) with precipitation of less than 75% of normal precipitation. Severity of droughts often depends on the community's reliance on a specific water source. The probability of a drought is difficult to predict given the number of variables involved. As seen in the Table 5-32, drought conditions appear to make an appearance at least once a decade.

### 5.11.2 Magnitude or Severity

Many problems can arise at the onset of a drought, some of which include diminished water supplies and quality, undernourishment of livestock and wildlife, crop damage, and possible wildfires. Secondary impacts from droughts pose problems to farmers with reductions in income, while food prices and lumber prices could drastically increase.

High summer temperatures can exacerbate the severity of a drought. When soils are wet, a significant portion of the sun's energy goes toward evaporation of the ground moisture. However, when drought conditions eliminate soil moisture, the sun's energy heats the ground surface and temperatures can soar, further drying the soil. The impact of excessive heat is most prevalent in urban areas, where urban heat-island effects prevent inner-city buildings from releasing heat built up during the daylight hours. Secondary impacts of excessive heat are severe strain on the electrical power system and potential brownouts or blackouts.

Extreme heat combined with high relative humidity slows evaporation, limiting the body's ability to efficiently cool itself. Overexposure may result in heat exhaustion or stroke, which could lead to death. The Centers for Disease Control and Prevention state that



excessive heat exposure caused 8,015 deaths in the United States between 1979 and 1999.<sup>9</sup> The Virginia Department of Health reports that between 1999 and 2004 there were three deaths from extreme heat in the Richmond region. All three deaths occurred in Hanover County. Newer data is not available while central Virginia record high seasonal and annual temperatures have been set during the past five years quantitative impacts have not been recorded.

Table 5-31 provides a summary of drought categories and impacts produced by the U.S. Drought Monitor. The U.S. Drought Monitor classification used both science and subjectivity, the result of which is a drought severity classification table for each dryness level. Notice that water restrictions are usually initiated as “voluntary” and can evolve to “mandatory.”

**Table 5-31. Drought Severity Classification and Possible Impacts**

Category	Description	Possible Impacts
D0	Abnormally dry	Going into a drought: short-term dryness slows planting, growth of crops or pastures; fire risk above average. Coming out of a drought: some lingering water deficits; pastures or crops not fully recovered.
D1	Moderate drought	Some damage to crops, pastures; fire risk high; streams, reservoirs, or wells low; some water shortages develop or are imminent; voluntary water use restrictions requested.
D2	Severe drought	Crop or pasture losses likely; fire risk very high; water shortages common; water restrictions imposed.
D3	Extreme drought	Major crop/pasture losses; extreme fire danger; widespread water shortages or restrictions.

Source: U.S. Drought Monitor.

For excessive heat, the NWS uses heat index thresholds as criteria for the issuance of heat advisories and excessive heat warnings. NWS heat advisory bulletins inform citizens of forecasted extreme heat conditions. The bulletins are based on projected or observed heat index values and include:

- Excessive Heat Outlook when there is a potential for an excessive heat event within three to seven days.
- Excessive Heat Watch when conditions are favorable for an excessive heat event within 12 to 48 hours but some uncertainty exists regarding occurrence and timing.
- Excessive Heat Warning/Advisory when an excessive heat event is expected within 36 hours.

These products are usually issued when confidence is high that the event will occur. A warning implies that conditions could pose a threat to life or property, while an advisory is

<sup>9</sup> National Center for Environmental Health, Centers for Disease Control. *About Extreme Heat*. Retrieved from <http://www.cdc.gov/nceh/hsb/extremeheat/>

issued for less serious conditions that may cause discomfort or inconvenience, but could still lead to threat to life and property if caution is not taken.

### 5.11.3 Hazard History

There have been a number of significant droughts recorded in Virginia since 1900. An extended period of abnormally dry weather occurred during a period of four years, from 1998 to 2002. This period saw rainfall levels well below normal and caused many communities throughout the state to institute water restrictions. In the most recent planning cycle, periods of dry weather have mostly had superficial landscaping impacts rather than impacts to crops and water supplies.

Table 5-32 includes descriptions of major droughts that have occurred in the Crater region. Drought conditions generally occur over a region or larger area rather than in a single jurisdiction.

**Table 5-32. History of Drought Events and Damages, Richmond-Crater Region, 1976–2016**

Date	Damages
November 1976 – September 1977	The region experienced ten months of below average precipitation. The drought began in November 1976 when rainfall totaled only 50% to 75% of normal. During the rest of the winter, storms tracked across the Gulf. During the spring and summer storms tracked across the Great Lakes. These weather patterns created significant droughts throughout most of Virginia.
June – November 1998	A heat wave over the Southeast produced warm and dry conditions over much of Virginia. Unusually dry conditions persisted through much of the fall. The drought produced approximately \$38.8 million in crop damages over portions of central and south-central Virginia.
December 2001 – November 2004	Beginning in the winter of 2001, the Mid-Atlantic began to show long-term drought conditions. The NWS issued reports of moisture-starved cold fronts that would continue throughout the winter. Stream levels were below normal with record lows observed at gauges for the York, James, and Roanoke River basins. By November 2002, the U.S. Secretary of Agriculture had approved 45 counties for primary disaster designation, while 36 requests remained pending.
2007	Unusually dry conditions persisted through a significant portion of the year through much of southern and central Virginia. Virginia as a whole experienced its tenth driest year on record.
July 21, 2011	This was one of the hottest July's in the last 75 years, breaking records for multiple. According to the NCDC data, all counties were recorded as having excessive heat waves and drought throughout the entire month. (Source: <a href="https://www.ncdc.noaa.gov/sotc/national/201107">https://www.ncdc.noaa.gov/sotc/national/201107</a> )
July 5, 2012	Another year of record setting highs and ties throughout the states. These high were accompanied with droughts and heat waves. (Source: <a href="https://en.wikipedia.org/wiki/Summer_2012_North_American_heat_wave">https://en.wikipedia.org/wiki/Summer_2012_North_American_heat_wave</a> )

### 5.11.4 Vulnerability Analysis

#### Probability

Based on historical frequency of occurrence using NCDC, an annual determination of probability of future drought events can be made. Table 5-33 indicates that drought events of some significance affect any jurisdiction in the region from the NCDC database. The annualized event occurrence and damages are shown for the study area.

**Table 5-33. Annualized Drought Events and Losses, 1993 - 2016**

Jurisdiction	Annualized Number of Events	Annualized Property Losses	Annualized Crop Losses	Annualized Total Losses
Charles City County	0.17	-	\$131,417	\$131,417
Chesterfield County	0.25	-	-	-
City of Colonial Heights	-	-	-	-
Dinwiddie County (incl. Town of McKenney)	-	-	-	-
City of Emporia	-	-	-	-
Goochland County	-	-	-	-
Greensville County (incl. Town of Jarratt)	-	-	-	-
Hanover County (incl. Town of Ashland)	0.25	-	\$402,556	\$402,556
Henrico County	0.21	-	\$122,077	\$122,077
City of Hopewell	0.25	-	-	-
New Kent County	0.25	-	\$500,830	\$500,830
City of Petersburg	0.5	-	\$244,153	\$244,153
Powhatan County	0.13	-	\$69,428	\$69,428
Prince George County	0.25	-	\$378,381	\$378,381
City of Richmond	0.5	-	\$223,161	\$223,161
Surry County (incl. Towns of Claremont, Dendron, Surry)	0.13	-	-	-
Sussex County (incl. Towns of Stony Creek, Wakefield, Waverly)	0.13	-	-	-
<b>Total</b>	<b>3.02</b>	<b>\$0</b>	<b>\$2,739,683</b>	<b>\$2,739,683</b>

Source: National Climatic Data Center.

#### Impact and Vulnerability

If a significant drought event were to occur, it could bring economic, social, and environmental impacts to the study area. Commonly, one of the most significant economic effects to a community is agricultural impact. Other economic effects could be felt by businesses that rely on adequate water levels for their day-to-day business, such as carwashes and laundromats.

Droughts can also create conditions that enable the occurrence of other natural hazard events such as wildfires or wind erosion. The likelihood of flash flooding is increased if a period of severe drought is followed by a period of extreme precipitation. Low-flow conditions also decrease the quantity and pressure of water available to fight fires, while the dry conditions increase the likelihood that fires will occur.

Environmental drought impacts include those on both human and animal habitats and hydrologic units. During periods of drought, the amount of available water decreases in lakes, streams, aquifers, soil, wetlands, springs, and other surface and subsurface water sources. This decrease in water availability can affect water quality such as oxygen levels, bacteria, turbidity, temperature increase, and pH changes. Changes in any of these levels can have a significant effect on the aquatic habitat of numerous plants and animals found throughout the study area.

Low water flow can result in decreased sewage flows and subsequent increases in contaminants in the water supply. Decrease in the availability of water also decreases drinking water supply and the food supply as food sources become scarcer. This disruption can work its way up the food chain within a habitat. Loss of biodiversity and increases in mortality can lead to increases in disease and endangered species.

Table 5-34 provides an overview of the agricultural products that could be affected by a drought. These numbers are based on the 2007 Census of Agriculture conducted by the U.S. Department of Agriculture. The numbers show all of the counties with significant agricultural sectors that could be impacted by droughts. Hanover County, in particular, had approximately \$43 million in products sold, most of which were crops.

**Table 5-34. Value of Agricultural Products Potentially Affected by Drought**

<b>Jurisdiction</b>	<b>Number of Farms 2012 (% change from 2007)</b>	<b>Total Value of Agricultural Products Sold</b>
Charles City County	79 (-1.3%)	\$23,680,000
Chesterfield County	197 (-11.7%)	\$6,400,000
Dinwiddie County	383 (2.3%)	\$24,798,000
Goochland County	315 (-20.3%)	\$16,562,000
Greensville County	151 (5.3%)	\$9,884,000
Hanover County	600 (-4.2%)	\$55,272,000
Henrico County	117 (-52.1%)	\$9,371,000
New Kent County	137 (11.7%)	\$7,003,000
Powhatan County	250 (8.8%)	\$10,009,000
Prince George County	167 (-11.4%)	\$10,763,000
Surry County	127 (4.7%)	\$27,723,000
Sussex County	123 (-22.8%)	\$37,277,000
Total	2646 (-6%)	\$238,742,000

Source: United States Department of Agriculture, Virginia Agricultural Statistics Service. 2007 Census of Agriculture. County Profiles.

The elderly, small children, the chronically ill, livestock and pets are most vulnerable to extreme heat.

### *Risk and Loss Estimation*

Except for potential water supply issues associated with a prolonged drought, droughts have little impact on critical facilities.

The data shows recurrence of drought conditions, of varying magnitude, on a relatively regular basis. With records dating back to 1993, the NCDC database indicates that drought events of some significance occur roughly three times annually in the region (see Table 5-33). Based on historical data, it is reasonable to assume that drought events will continue to impact the region with some regularity and may even increase with climate change into the future. Annual regional crop losses associated with drought events are more than \$2.7M.

## **5.12 Mass Evacuation**

### **5.12.1 Hazard Profile**

Mass evacuations from urban areas can strain a community's resources and cause gridlock on major transportation routes, overcrowding of hospitals and shelters, and increased load on local utilities' infrastructures leading to potential failure.

VDOT has worked with the localities to develop incident plans that include evacuation routes. When an event occurs, the Emergency Alert System (EAS) provides the latest information on evacuation. The majority of the Richmond and Crater regions are within the Richmond Extended EAS area. Surry County is an exception and is part of the Eastern Virginia EAS area.

Many of the region's community emergency operations plans outline the concerns surrounding mass evacuation, in terms of jurisdictional evacuation, evacuation of other areas in which the locality acts as a "host," or as a transit route locale.

### **5.12.2 Hazard History**

A mass evacuation of significant proportions has not impacted the area in the past decade. In anticipation of Hurricane Floyd in September 1999, more than three million people were evacuated from Florida to the North Carolina coastline, and to a lesser extent from the Virginia coast. Although the majority of these evacuations were from North and South Carolina coasts to inland areas of those states, some limited impact was likely experienced in the planning region.



### **5.12.3 Vulnerability Analysis**

#### *Probability*

The probability of a mass evacuation impacting the planning region includes factors such as the probability and location of the hazard (e.g., terrorist incident, hurricane, etc.) that would make such an evacuation necessary, as well as sociological considerations.

Determining the probability of a mass evacuation was not quantified for this plan update. Future plan updates should consider potential methods and data that might allow such an analysis.

#### *Impact and Vulnerability*

An influx of evacuees as a result of a mass evacuation has the potential to overload infrastructure and support systems. Impacted segments might include transportation, public safety, medical facilities and shelters, utilities, and depending on the duration of the evacuation, potentially the education sector. Although vulnerability is difficult to quantify, jurisdictions located along major evacuation routes (interstates and major highways) are more likely to be impacted than those away from such routes.

#### *Risk and Loss Estimation*

Mass evacuations do not necessarily pose a structural risk to critical facilities, but rather have the potential to strain critical services and resources by overwhelming response systems. Such risks were not quantified in terms of dollar losses for this plan update.

A major concern for the region is the possibility of a mass evacuation of the coastal areas of Virginia and North Carolina due to a hurricane threat, or from the Northern Virginia/Washington, D.C. metro area due to a potential or actual terrorist attack.

A project termed the U.S. Route 460 Corridor Improvements Project is proposed to create a four-lane divided limited access highway between the Cities of Petersburg and Suffolk in Virginia. The highway could potentially serve as a route for those evacuating the coast due to a hurricane threat.

Researchers at the Institute for Infrastructure and Information Assurance, which is part of James Madison University, have conducted preliminary studies to determine the possible number of displaced residents that may need to be temporarily housed in the region, and the impact resulting from the increased traffic flow on Interstates 64, 66, and 81. The Institute has developed a Rural Citizen's Guide for Emergency Preparedness that provides citizens with information on threats facing rural areas and ways to prepare for emergencies (natural and human-made). Terrorism-related issues for Northern Virginia and adjacent regions will require extensive intra-regional planning and cooperation in the future.

Some localities have detailed evacuation routes in the Warning, Evacuation, and Emergency Transportation Annex of their emergency operations plans. These jurisdictions have established traffic control measures and routes to enhance the rate of evacuation and

to provide security for evacuated areas, critical facilities, and resources. The emergency operations plans address evacuation from the locality, and touch on the potential impacts caused by a mass evacuation. The type and scale of event that warrants evacuation will drive the type of response the localities will implement. To assist and mitigate against mass evacuation, jurisdictions should include additional detail in their plans regarding secondary evacuation routes, coordination between and among neighboring jurisdictions, the number and location of potential shelters, and what needs the communities foresee in their capacity as “host” communities.

## 5.13 Wildfires

### 5.13.1 Hazard Profile

Wildfires can be classified as either wildland fires or urban-wildland interface (UWI) fires. The former involves situations where a wildfire occurs in an area that is relatively undeveloped except for the possible existence of basic infrastructure such as roads and power lines. An urban-wildland interface fire includes situations in which a wildfire enters an area that is developed with structures and other human developments. In UWI fires, the fire is fueled by both naturally occurring vegetation and the urban structural elements themselves. According to the National Fire Plan issued by the U.S. Departments of Agriculture and Interior, the urban-wildland interface is defined as “...the line, area, or zone where structures and other human development meet or intermingle with undeveloped wildlands or vegetative fuels.”

A wildfire hazard profile is necessary to assess the probability of risk for specific areas. Certain conditions must be present for a wildfire hazard to occur. A large source of fuel must be present; the weather must be conducive (generally hot, dry, and windy); and fire suppression sources must not be able to easily suppress and control the fire. After a fire starts, topography, fuel, and weather are the principal factors that influence wildfire behavior. According to the Virginia Department of Forestry (VDOT), there are several factors that influence an area’s risk to the occurrence of wildfires. These include, but are not limited to:

- Historical wildfire data
- Land cover
- Percent slope of topography
- Slope orientation
- Population density
- Distance to roads
- Railroad buffer
- Road density and developed areas

### 5.13.2 Severity or Magnitude

A wildfire can range from a very localized and containable burn to an out-of-control blaze that can spread quickly and is capable of scorching thousands of acres of land over many days. The Virginia wildfire season is normally in the spring (March and April) and then again in the fall (October and November). During these months, the relative humidity is

usually lower and the winds tend to be higher. In addition, the hardwood leaves are on the ground, providing more fuel and allowing the sunlight to directly reach the forest floor, warming and drying the surface fuels.

As fire activity fluctuates during the year from month to month, it also varies from year to year. Historically, extended periods of drought and hot weather can increase the risk of wildfires. Some years with adequate rain and snowfall amounts keep fire occurrences low; while other years with extended periods of warm, dry, and windy days exhibit increased fire activity.

Long-term climate trends as well as short-term weather patterns play a major role in the risk of wildfires occurring. For instance, short-term heat waves along with periods of low humidity can increase the risk of fire, while high winds directed toward a fire can cause it to spread rapidly.

There are numerous secondary effects that could impact the study area due to wildfires. Areas that have been burned due to wildfires have an increased risk of flooding and landslides in the event of heavy rains. Additional secondary impacts due to wildfires include a degradation of air and water quality, as well as a threat to wildlife habitat including endangered species.

### **5.13.3 Hazard History**

Most of Virginia's wildfires were caused by humans either intentionally or unintentionally. Due to the growth of the population of the commonwealth, there has been an increase in people living in the urban-wildland interface, as well as an increase in use of the forest for recreational purposes. Historical records of wildfire events specific to the study area are limited, and not all wildfires are reported.

The VDOF website provided fire incidence data for the years between 2002 and 2017. The fire incidence data provided from 1995 to 2001 came from the 2011 Hazard Mitigation study that used VDOF data for those years. The data provided by VDOF was summarized into the following tables. Table 5-35 shows the number of wildfires per jurisdiction per year from VDOF. Tables 5-36 and 5-37 provide a summary of the number of acres burned and total damages associated with wildfires in the region. According to VDOF records from 1995 to 2008, there were 1,849 wildfires that burned approximately 24,800 acres and caused nearly \$3.9 million in damages in the region during the period. Another 435 fires occurred in the region from 2010 to 2017, averaging to 72 fires per year. Dinwiddie County experienced the most occurrences and acres burned. The City of Richmond has the highest dollar amount of damages due to the hazard.

**Table 5-35. Number of Wildfires by Fire Year, 1995–2016**

<b>Jurisdiction Name</b>	<b>1995</b>	<b>1996</b>	<b>1997</b>	<b>1998</b>	<b>1999</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>2010-2017</b>	<b>Total</b>
Charles City County	12	2	17	8	10	7	20	24	5	6	15	9	11	18	7	71	<b>242</b>
Chesterfield County	33	18	28	22	29	11	22	3			1	2		3	11	37	<b>220</b>
City of Colonial Heights							1										<b>1</b>
Dinwiddie County	14	11	6	11	12	10	31	33	3	16	15	26	25	23	2	56	<b>294</b>
<i>Town of McKenney</i>																	
City of Emporia					1		1									3	<b>5</b>
Goochland County	21	15	15	14	11	8	18	6	2	6	5	10	7	7	2	42	<b>189</b>
Greensville County	6	4	11	3	6	4	16								3	42	<b>95</b>
<i>Town of Jarratt</i>						1											<b>1</b>
Hanover County	19	6	4	11	16	8	11	7	2	7	6	17	15	21	10	43	<b>203</b>
<i>Town of Ashland</i>																	
Henrico County	13	4	13	4	5	8	8	8	2	5	6	2	3	5		11	<b>97</b>
City of Hopewell							1										<b>1</b>
New Kent County	14	8	13	5	7	4	15								8	65	<b>139</b>
City of Petersburg							1	39	5	26	28	35	26	33			<b>193</b>
Powhatan County	26	16	24	14	19	5	27									13	<b>144</b>
Prince George County	12	4	9	7	8	6	17								11	11	<b>85</b>
City of Richmond			1			1		28	11	20	19	27	29	19			<b>155</b>
Surry County	11	3	6	5	7	2	4	9	1	3	4	4	5	7	3	14	<b>88</b>
<i>Town of Claremont</i>																	
<i>Town of Dendron</i>																	
<i>Town of Surry</i>																	
Sussex County	22	9	11	13	12	2	21	9	4	8	13	10	13	12	3	27	<b>189</b>
<i>Town of Jarratt</i>						1											<b>1</b>

**Table 5-35. Number of Wildfires by Fire Year, 1995–2016**

<b>Jurisdiction Name</b>	<b>1995</b>	<b>1996</b>	<b>1997</b>	<b>1998</b>	<b>1999</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>2010- 2017</b>	<b>Total</b>
<i>Town of Stony Creek</i>																	
<i>Town of Wakefield</i>																	
<i>Town of Waverly</i>					1		1										2
<b>Total</b>	<b>203</b>	<b>100</b>	<b>158</b>	<b>117</b>	<b>144</b>	<b>78</b>	<b>215</b>	<b>166</b>	<b>35</b>	<b>97</b>	<b>112</b>	<b>142</b>	<b>134</b>	<b>148</b>	<b>60</b>	<b>435</b>	<b>2344</b>



Table 5-36. Wildfire Damage Summary, 1995–2001

Fire Year	1995		1996		1997		1998		1999		2000		2001	
Jurisdiction Name	Total Acres	Total Damage	Total Acres	Total Damage	Total Acres	Total Damage	Total Acres	Total Damage	Total Acres	Total Damage	Total Acres	Total Damage	Total Acres	Total Damage
Charles City County	120.8	\$600	1.2	\$0	9.3	\$1,300	4.6		7.3		8.2	\$100	53.20	\$1,400
Chesterfield County	50.6	\$600	32.1	\$1,275	83.9	\$1,920	64	\$1,610	42.5	\$3,400	19.7	\$1,675	60.40	\$4,200
City of Colonial Heights													3.00	\$500
Dinwiddie County	36.4	\$1,800	8.95	\$500	12.8	\$1,500	9.9	\$10,500	72.4	\$17,200	35.6		9,895.40	\$52,600
<i>Town of McKenney</i>														
City of Emporia									1				0.25	\$100
Goochland County	33	\$50,200	23.2	\$0	17	\$300	16.8	\$1,300	22		14.4	\$3,300	52.90	\$65,000
Greensville County	6	\$2,000	12.1	\$400	17.9	\$15,275	6	\$100	14	\$400	5.1	\$2,500	71.10	\$4,700
<i>**Town of Jarratt</i>											0.5			
Hanover County	69.6	\$1,050	8.3	\$400	5	\$350	63.1	\$1,775	24.9	\$2,030	37.4	\$425	13.10	\$1,000
<i>Town of Ashland</i>														
Henrico County	27.2	\$1,050	5	\$400	70.7	\$1,240	11.6	\$50	18.2	\$800	60.4	\$600	26.20	\$600
City of Hopewell													0.10	
New Kent County	37.5	\$100	5.7	\$0	22.2	\$650	54.1		14.2	\$250	6.4	\$100	7.90	\$100
City of Petersburg													0.30	
Powhatan County	25.2	\$34,500	13	\$10,500	24.7	\$63,250	22.1	\$20,000	11.1	\$2,600	6.8	\$4,800	31.90	\$31,450
Prince George County	92.05	\$1,350	1.55	\$100	64.95	\$7,000	54.05	\$3,000	77	\$1,500	1.4	\$3,190	26.00	\$1,400
City of Richmond					3	\$100					3			
Surry County	14.6	\$1,600	21.25	\$200	11.2	\$0	34.75	\$2,700	12.2	\$11,350	1.1	\$500	9.00	\$1,000
<i>Town of Claremont</i>														

Table 5-36. Wildfire Damage Summary, 1995–2001

Fire Year	1995		1996		1997		1998		1999		2000		2001	
Jurisdiction Name	Total Acres	Total Damage	Total Acres	Total Damage	Total Acres	Total Damage	Total Acres	Total Damage	Total Acres	Total Damage	Total Acres	Total Damage	Total Acres	Total Damage
<i>Town of Dendron</i>														
<i>Town of Surry</i>														
Sussex County	157.45	\$17,775	15.6	\$710	7.85	\$685	94.1	\$6,650	153.6	\$15,600	39		267.60	\$34,150
<i>**Town of Jarratt</i>											0.5			
<i>Town of Stony Creek</i>														
<i>Town of Wakefield</i>														
<i>Town of Waverly</i>									0.1	\$75			0.10	
<b>Total</b>	<b>670.4</b>	<b>\$112,625</b>	<b>147.95</b>	<b>\$14,485</b>	<b>350.5</b>	<b>\$93,570</b>	<b>435.1</b>	<b>\$47,685</b>	<b>470.5</b>	<b>\$55,205</b>	<b>239.5</b>	<b>\$17,190</b>	<b>10,515.45</b>	<b>\$197,700</b>

Source: Virginia Department of Forestry.

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Table 5-37. Wildfire Damage Summary, 2002–2008

Fire Year	2002		2003		2004		2005		2006		2007		2008	
Jurisdiction Name	Total Acres	Total Damage	Total Acres	Total Damage	Total Acres	Total Damage	Total Acres	Total Damage	Total Acres	Total Damage	Total Acres	Total Damage	Total Acres	Total Damage
Charles City County	134.2	\$88,884	11	\$18,590	6	\$22,341	34	\$57,022	54	\$33,707	33.2	\$73,220	15.6	\$94,164
Chesterfield County	169	\$13,842					113	\$4,616	2	\$9,235			4	\$14,777
City of Colonial Heights														
Dinwiddie County	34.2	\$135,727	6	\$12,267	21.8	\$65,576	25	\$61,710	116.1	\$107,497	122.3	\$163,769	2,800.2	\$112,990
<i>Town of McKenney</i>														
City of Emporia														
Goochland County	6.1	\$21,219	1	\$7,081	1	\$21,267	1.2	\$17,674	37.3	\$35,535	10	\$47,193	104.7	\$36,648
Greensville County														
<i>**Town of Jarratt</i>														
Hanover County	46.1	\$23,814	4.1	\$6,906	27.6	\$24,528	7.5	\$21,063	24.8	\$61,086	14.2	\$103,840	106.7	\$106,473
<i>Town of Ashland</i>														
Henrico County	16	\$28,500	2	\$7,135	4	\$17,855	18.3	\$21,459	0.1	\$7,161	1.3	\$19,321	73.5	\$25,028
City of Hopewell														
New Kent County														
City of Petersburg	89.9	\$2,400	16.7	\$300	78.3	\$670	33.2	\$1,850	67.6	\$2,250	14.5	\$1,150	165.6	\$5,900
Powhatan County														
Prince George County														
City of Richmond	1340.7	\$259,000	17.7	\$0	11.3	\$3,650	22.5	\$2,000	151.3	\$1,900	579.1	\$1,400	4069.8	\$1,999,400
Surry County	180.9	\$40,077	0.5	\$4,458	7.5	\$13,380	61.2	\$17,854	15.5	\$17,870	195	\$31,017	187	\$34,884
<i>Town of Claremont</i>														
<i>Town of Dendron</i>														

Table 5-37. Wildfire Damage Summary, 2002–2008

Fire Year	2002		2003		2004		2005		2006		2007		2008	
Jurisdiction Name	Total Acres	Total Damage	Total Acres	Total Damage	Total Acres	Total Damage	Total Acres	Total Damage	Total Acres	Total Damage	Total Acres	Total Damage	Total Acres	Total Damage
<i>Town of Surry</i>														
Sussex County	63.9	\$3,800	44.4	\$2,020	18.5	\$6,500	19.5	\$4,150	39.2	\$2,600	52.3	\$1,200	257.3	\$13,200
<i>**Town of Jarratt</i>														
<i>Town of Stony Creek</i>														
<i>Town of Wakefield</i>														
<i>Town of Waverly</i>														
<b>Total</b>	<b>2081</b>	<b>\$617,263</b>	<b>103.4</b>	<b>\$58,757</b>	<b>176</b>	<b>\$175,767</b>	<b>335.4</b>	<b>\$209,398</b>	<b>507.9</b>	<b>\$278,841</b>	<b>1021.9</b>	<b>\$442,110</b>	<b>7,784.4</b>	<b>\$2,443,464</b>

Source: Virginia Department of Forestry.

### 5.13.4 Vulnerability Analysis

#### Probability

The probability of wildfires is difficult to predict and is dependent on many things, including the types of vegetative cover in a particular area, and weather conditions, including humidity, wind, and temperature. Analysis of VDOF data indicates that on an annual basis, roughly 132 wildfires impact the region.

#### Impact and Vulnerability

VDOF used a Geographic Information System (GIS) to develop a statewide spatial Wildfire Risk Assessment model to identify areas where conditions are more conducive and favorable for wildfires to occur and advance. This model incorporated the factors listed in the Hazard Profile section and weighted them on a scale of 0 to 10, with 10 representing the characteristic of each factor that has the highest wildfire risk. With this model VDOF identified areas of the study area as having a wildfire risk level of High, Medium, or Low. The results are shown on the maps included at the end of this section (Figure 5-24). New Kent and Charles City Counties have the largest proportion of high risk areas while Henrico County and the City of Richmond have the least amount.

Hurricanes Isabel and Irene downed thousands of trees in both New Kent and Charles City Counties in 2003 and 2011, respectively. While the counties removed the most hazardous trees from public facilities and many homeowners have removed trees from their property, thousands still remain. These trees provide an easy source of fuel for wildfires and create a high risk across these counties.

Goochland County has been working with VDOF to promote best management practices among landowners in the county. The department and the county have offered joint courses on forestry management and wetlands protection. In addition, the county has thinned more than 160 acres as part of instituting best management practices on county-owned property.

#### Risk and Loss Estimation

Table 5-38 (redacted Appendix I) shows the percentages of critical facilities in fire risk zones, with 44.33% in the high-risk category. This was based on the VDOF Burn Probability analysis for the Richmond and Crater Regions. The burn probability data has categories 1-10, with 1 being the lowest risk and 10 being the highest. Because all critical facilities were only within the 1-3 range, 1 was set as low, 2 as medium, and 3 as high risk. Facilities not in a burn probability zone were assumed to be zero, or have no risk. The structures that had the highest risk were 8 cell towers (Dinwiddie, Goochland, Henrico, and



Powhatan Counties), 2 combined Fire/EMS facilities (Town of McKenney and Hanover County), and 1 Fire Facility (Prince George County).

### Jurisdictional Risk

VDOF defines woodland home communities as clusters of homes located along forested areas at the wildland-urban interface that could possibly be damaged during a nearby wildfire incident. Table 5-39 illustrates the number of woodland communities while Table 5-40 illustrates the number of homes in woodland communities, as designated by the Virginia Department of Forestry. The data indicates that approximately 46% of woodland home communities in the region are located in a high-fire-risk area. Of the 132,218 homes in woodland home communities, approximately 33% are located in a high-fire-risk area.

The jurisdictional executive summaries highlight hazards and vulnerability within the community.

**Table 5-39. Number of Woodland Communities by Fire Risk**

<b>Jurisdiction Name</b>	<b>Low</b>	<b>Moderate</b>	<b>High</b>	<b>Total</b>	<b>% High Risk</b>
Charles City County	0	6	36	42	86%
Chesterfield County	82	140	189	411	46%
City of Colonial Heights	0	0	1	1	100%
Dinwiddie County	1	5	4	10	40%
<i>Town of McKenney</i>	1	0	0	1	0%
City of Emporia	5	0	0	5	0%
Goochland County	4	93	79	176	45%
Greensville County	1	5	0	6	0%
<i>Town of Jarratt</i>	0	0	2	2	100%
Hanover County	10	184	79	273	29%
<i>Town of Ashland</i>	2	3	1	6	17%
Henrico County	54	67	74	195	38%
City of Hopewell	1	0	0	1	0%
New Kent County	0	8	47	55	85%
City of Petersburg	5	2	4	11	36%
Powhatan County	0	31	73	104	70%
Prince George County	2	7	24	33	73%
City of Richmond	23	2	4	29	14%
Surry County	0	0	1	1	100%
<i>Town of Claremont</i>	0	0	1	1	100%

**Table 5-39. Number of Woodland Communities by Fire Risk**

<b>Jurisdiction Name</b>	<b>Low</b>	<b>Moderate</b>	<b>High</b>	<b>Total</b>	<b>% High Risk</b>
<i>Town of Dendron</i>	0	0	0	0	0%
<i>Town of Surry</i>	0	0	0	0	0%
Sussex County	0	0	1	1	100%
<i>Town of Jarratt</i>	0	0	2	2	100%
<i>Town of Stony Creek</i>	0	0	0	0	0%
<i>Town of Wakefield</i>	0	0	0	0	0%
<i>Town of Waverly</i>	0	0	0	0	0%
<b>Totals</b>	<b>191</b>	<b>553</b>	<b>622</b>	<b>1,366</b>	<b>46%</b>

**Table 5-40. Number of Homes in Woodland Communities by Fire Risk**

<b>Jurisdiction Name</b>	<b>Low</b>	<b>Moderate</b>	<b>High</b>	<b>Total</b>	<b>% High Risk</b>
Charles City County	0	136	855	991	86%
Chesterfield County	20,697	27,146	25,142	72,985	34%
City of Colonial Heights	0	0	75	75	100%
Dinwiddie County	135	144	253	532	48%
<i>Town of McKenney</i>	31	0	0	31	0%
City of Emporia	240	0	0	240	0%
Goochland County	138	3,099	2,720	5,957	46%
Greensville County	85	149	0	234	0%
<i>Town of Jarratt</i>	0	0	76	76	100%
Hanover County	981	7,278	3,342	11,601	29%
<i>Town of Ashland</i>	255	312	14	581	2%
Henrico County	13,700	4,409	3,761	21,870	17%
City of Hopewell	65	0	0	65	0%
New Kent County	0	293	1,829	2,122	86%
City of Petersburg	555	104	271	930	29%
Powhatan County	0	713	3,204	3,917	82%
Prince George County	415	199	1,397	2,011	69%
City of Richmond	7,595	65	185	7,845	2%
Surry County	0	0	15	15	100%

**Table 5-40. Number of Homes in Woodland Communities by Fire Risk**

<b>Jurisdiction Name</b>	<b>Low</b>	<b>Moderate</b>	<b>High</b>	<b>Total</b>	<b>% High Risk</b>
<i>Town of Claremont</i>	0	0	21	21	100%
<i>Town of Dendron</i>	0	0	0	0	0%
<i>Town of Surry</i>	0	0	0	0	0%
Sussex County	0	0	43	43	100%
<i>Town of Jarratt</i>	0	0	76	76	100%
<i>Town of Stony Creek</i>	0	0	0	0	0%
<i>Town of Wakefield</i>	0	0	0	0	0%
<i>Town of Waverly</i>	0	0	0	0	0%
<b>Totals</b>	<b>44,892</b>	<b>44,047</b>	<b>43,279</b>	<b>132,218</b>	<b>33%</b>

**Figure 5-24. Wildfire Vulnerability**

Source: Virginia Department of Forestry

In summary, based on the VDOF historical record (1995–2008; refer to Table 5-41), the region experiences approximately 132 fires per year that result in approximately \$152,941 in damages. The past is a reasonable predictor of the future. It should be expected that the region will continue to battle wildfires from time to time, particularly during extended periods of dry and windy weather.

**Table 5-41. Wildfire Events and Losses, 1995–2008**

Jurisdiction Name	Total		Annualized	
	Total Acres	Total Damage	Number of Events	Losses
Charles City County	392.5	\$71,100	10.31	\$5,469
Chesterfield County	631.2	\$53,675	18.92	\$4,129
City of Colonial Heights	3	\$500	0.08	\$38
Dinwiddie County	13,227.05	\$868,350	17.38	\$66,796
<i>Town of McKenney</i>	0		0.00	\$0
City of Emporia	2.25	\$100	0.23	\$8
Goochland County	232.1	\$120,100	10.15	\$9,238
Greensville County	1,758.3	\$359,175	6.54	\$27,629
<i>Town of Jarratt</i>	0.5		0.08	\$0
Hanover County	432.8	\$133,840	10.92	\$10,295
<i>Town of Ashland</i>	7.5	\$1,200	0.31	\$92
Henrico County	328.5	\$28,040	6.46	\$2,157
City of Hopewell	0.1		0.08	\$0
New Kent County	199.1	\$11,150	11.69	\$858
City of Petersburg	26.4		0.31	\$0
Powhatan County	167.4	\$167,100	11.92	\$12,854
Prince George County	533.6	\$22,990	9.62	\$1,768
City of Richmond	6	\$100	0.15	\$8
Surry County	656.7	\$45,700	5.15	\$3,515
<i>Town of Claremont</i>	0		0.00	\$0
<i>Town of Dendron</i>	0		0.00	\$0
<i>Town of Surry</i>	0		0.00	\$0
Sussex County	1,175.1	\$104,040	11.85	\$8,003
<i>Town of Jarratt</i>	0.5		0.08	\$0
<i>Town of Stony Creek</i>	0		0.00	\$0
<i>Town of Wakefield</i>	1.5	\$1,000	0.08	\$77
<i>Town of Waverly</i>	0.2	\$75	0.15	\$6
<b>Total</b>	<b>19,781</b>	<b>\$1,988,235</b>	<b>132.46</b>	<b>\$152,941</b>

Source: Virginia Department of Forestry.



## 5.14 Landslide and Shoreline/Coastal Erosion

### 5.14.1 Hazard Profile

#### Landslides

The term “landslide” describes many types of downhill earth movements ranging from rapidly moving catastrophic rock avalanches and debris flows in mountainous regions to more slowly moving earth slides.<sup>10</sup>

#### Shoreline/Coastal Erosion

NOAA describes shoreline/coastal erosion as a process whereby large storms, flooding, strong wave action, sea level rise, and human activities, such as inappropriate land use, alterations, and shore protection structures, wear away beaches and bluffs. Erosion undermines and often destroys homes, businesses, and public infrastructure.<sup>11</sup>

### 5.14.2 Magnitude or Severity

The severity of a landslide is dependent on many factors including the slope and width of the area involved and any structures or infrastructure directly in the path of the slide. Impacts of a landslide can range from a minor inconvenience to a life-threatening situation when automobiles and buildings are involved. The extent or severity of erosion is related to a number of factors: composition of the shoreline (rock, sand, clay, marsh, or human-made structures), fetch, orientation to prevailing wind direction, and relative sea level rise.<sup>12</sup>

### 5.14.3 Hazard History

#### Landslides

The greatest landslide hazards are found in the higher elevations of western and southwestern Virginia. Analysis of the hazards here is limited by the availability of data. There is no comprehensive database documenting all landslide occurrences within the commonwealth.

Local officials from the City of Richmond reported that a number of areas in the city were affected by landslides triggered by the rains of Tropical Storm Gaston in August 2004. The Church Hill and Riverside Drive sections of Richmond experienced 14 inches of rain in eight hours.

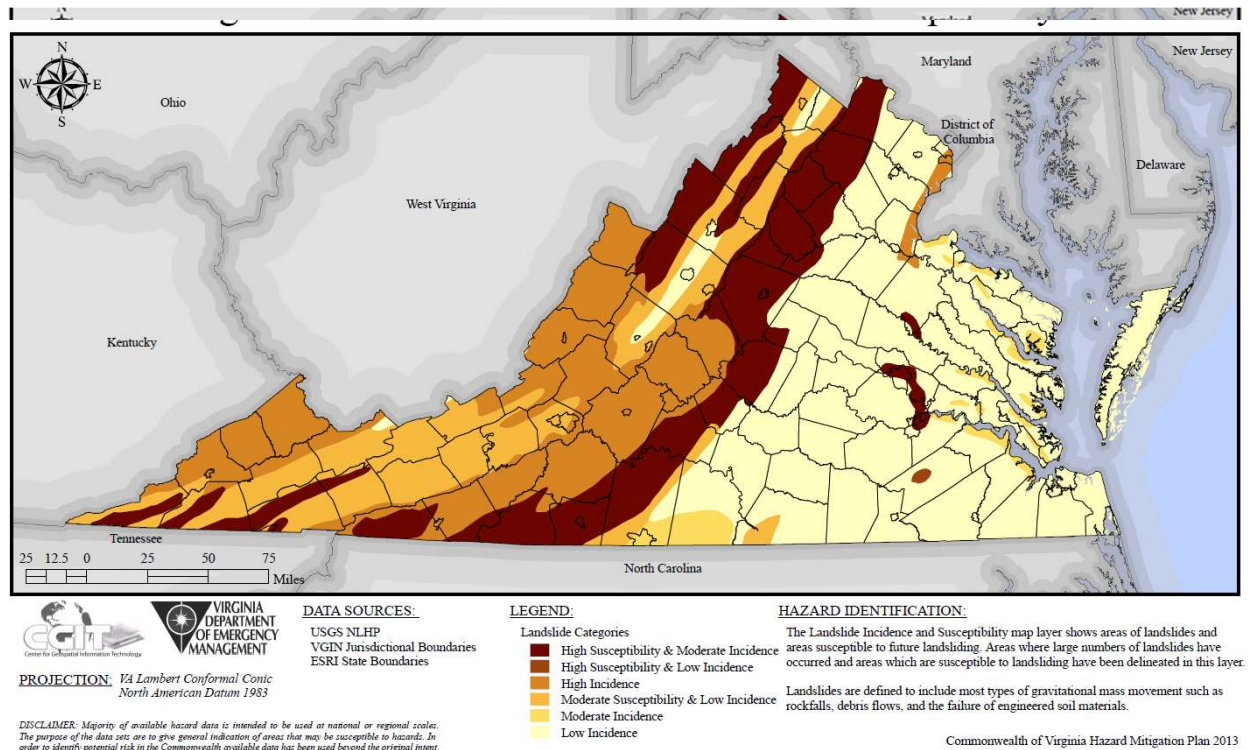
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<sup>10</sup> National Disaster Education Coalition. Talking About Disaster: Guide for Standard Messages. Washington, D.C., 2004.

<sup>11</sup> NOAA. (2011) <http://coastalmanagement.noaa.gov/hazards.html#erosion>

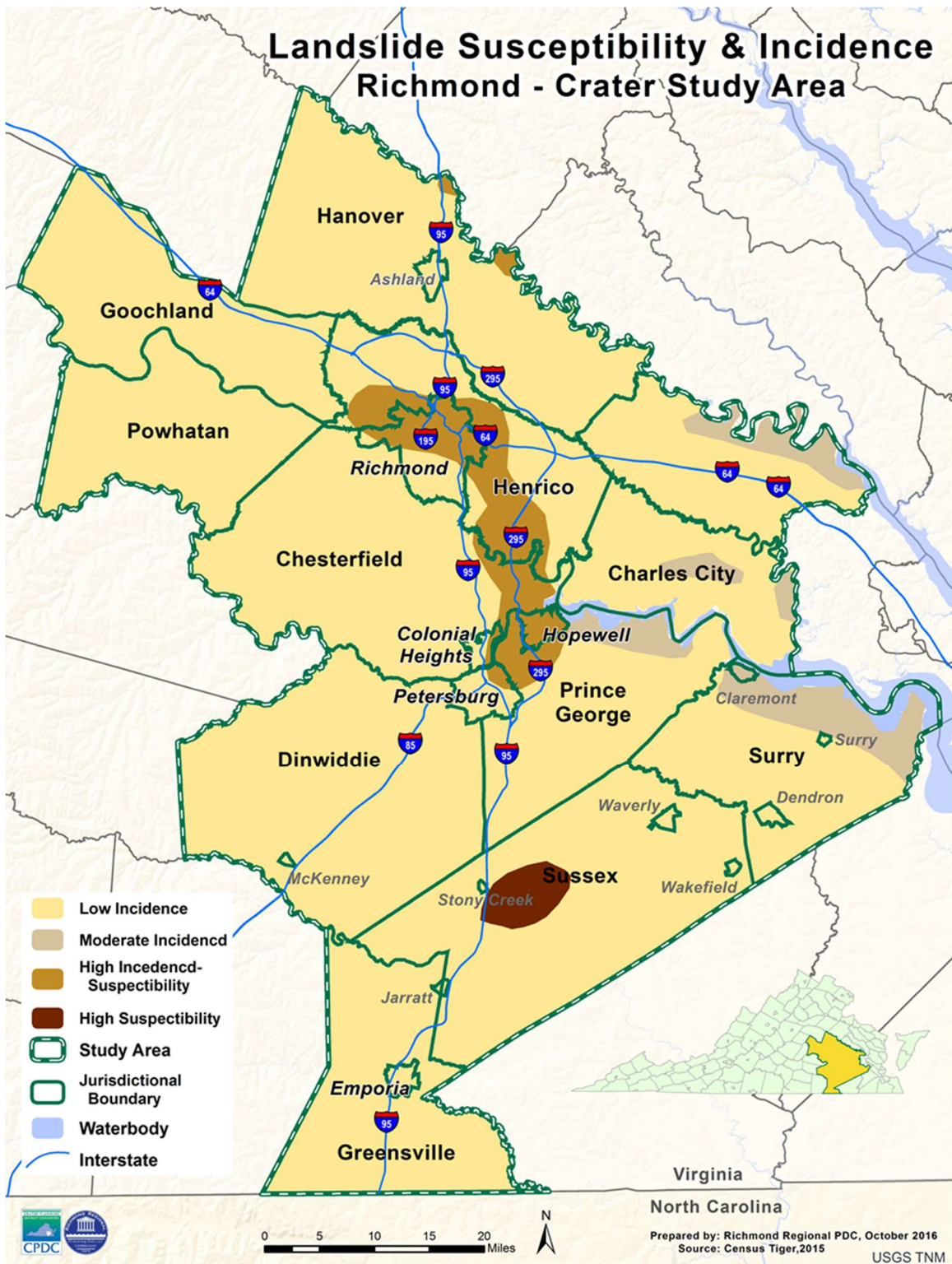
<sup>12</sup> Virginia Department of Mine Minerals and Energy. (2011) <http://www.dmme.virginia.gov/DMR3/coastalerosion.shtml>

Although no significant landslide occurrences have been reported for the rest of the region, the following map from the 2010 Virginia State Hazard Mitigation Plan (Figure 5-25) shows landslide susceptibility and incidence for the region based on U.S. Geological Survey (USGS) analysis and data. A strip of High Susceptibility and Moderate Incidence runs through portions of Henrico County and the City of Richmond and touches portions of Chesterfield and Prince George Counties and the Cities of Hopewell, Petersburg, and Colonial Heights (Figure 5-26).



**Figure 5-25. U.S. Geological Survey Landslide Susceptibility and Incidence**

Source: 2013 Virginia State Hazard Mitigation Plan



**Figure 5-26. U.S. Geological Survey Landslide Susceptibility and Incidence for Region**

### Shoreline/Coastal Erosion

The shoreline areas of the region are consistently undergoing coastal erosion. However, severe storms that increase wave activity, such as hurricanes, tropical storms, and nor'easters, sea level rise, and shoreline development can increase occurrences of erosion. The banks of the James River have historically experienced substantial erosion (varying rates) from storm events. However, data regarding specific events that resulted in substantial erosion is lacking.

#### **5.14.4 Vulnerability Analysis**

##### Landslides

The probability of a landslide is difficult to ascertain given the lack of data available to perform such an analysis. Even so, landslide events in the region are considered to be a low-probability event, but with the potential to have a significant impact when and where they do occur.

The USGS first developed a national landslide incidence map in 1982. This national map was used as a basis for the maps in this analysis. The map shows areas where large numbers of landslides have been recorded (incidence) and areas that may be susceptible to landslides because of their geologic composition (susceptibility). According to the report that accompanies the incidence map, "susceptibility is not shown where it is comparable to incidence – for example, where areas of the highest category of incidence are assumed to have high susceptibility and where areas of the lowest category are assumed to have low susceptibility."<sup>13</sup>

The report goes on to state, "The map was prepared by evaluating formations or groups of formations shown on the geologic map of the United States and classifying them as having high, medium, or low landslide incidence (number of landslides) and being of high, medium, or low susceptibility to landslides. Those map units or parts of units with more than 15 percent of their area involved in landslides were classified as having high incidence; those with 1.5 to 15 percent of their area involved in landslides, as having medium incidence; and those with less than 1.5 percent of their area involved, as having low incidence. This classification scheme was modified where particular lithofacies are known to have variable landslide incidence or susceptibility."

The susceptibility categories are largely subjective because insufficient data was available for precise determinations. Because the map is highly generalized, was created at a national scale, and is based on relatively old and imprecise data, it should not be taken as an absolute guide to landslide incidence and susceptibility and should not be used for site selection purposes.

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<sup>13</sup> Radbruch-Hall, Dorothy H. et al. United States Geologic Survey. *Landslide Overview Map of the Conterminous United States*. U.S. Geological Survey Professional Paper 1183. 1982.



While the majority of the region has low landslide incidence, high susceptibility and moderate incidence is located in portions of Prince George County, City of Hopewell, City of Colonial Heights, City of Petersburg, Chesterfield County, City of Richmond, Henrico County, and Hanover County. High susceptibility and low incidence is located in Sussex County. Moderate incidence is located in New Kent County, Charles City County, Prince George County, and Surry County.

As noted in the previous section, landslides have occurred in the City of Richmond following high rainfall but have generally been limited in scope and/or extent. The primary area of concern noted by city officials is Government Road. At the time of this report, this is the best available data; no other historical data is available.

The impact of landslides on jurisdictions in the region has historically been that of inconvenience resulting from partially blocked roadways. Data regarding landslide risk in the region is limited. Depending on the scale of a landslide event and the damage it inflicts, losses could potentially range into the thousands or perhaps millions of dollars in an extreme event. The jurisdictional executive summaries highlight hazards and vulnerability within the community.

### *Shoreline/Coastal Erosion*

The probability of shoreline erosion is difficult to quantify, but is a near-certainty along the region's shorelines. The Harrison Point subdivision, along the James River, experiences recurrent flooding. In addition, the river banks experience substantial erosion from storm events and are considered to be vulnerable for ongoing erosion.

The coastal portion of the region is protected by the Virginia Coastal Zone Management Program. Surry, Prince George, Chesterfield, Henrico, New Kent, Hanover, and Charles City Counties, and the Cities of Richmond, Colonial Heights, Hopewell, and Petersburg are all part of Virginia's Coastal Management Program. The program aims to reduce the likelihood of erosion and the effects of erosion on Virginia's shoreline by emphasizing land use best practices. Figure 5-27 shows the boundary of Virginia's Coastal Zone.<sup>14</sup>

The jurisdictional executive summaries highlight hazards and vulnerability within the community.

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<sup>1414</sup> Virginia Department of Environmental Quality. (2011)  
<http://www.deq.virginia.gov/coastal/coastmap.html>

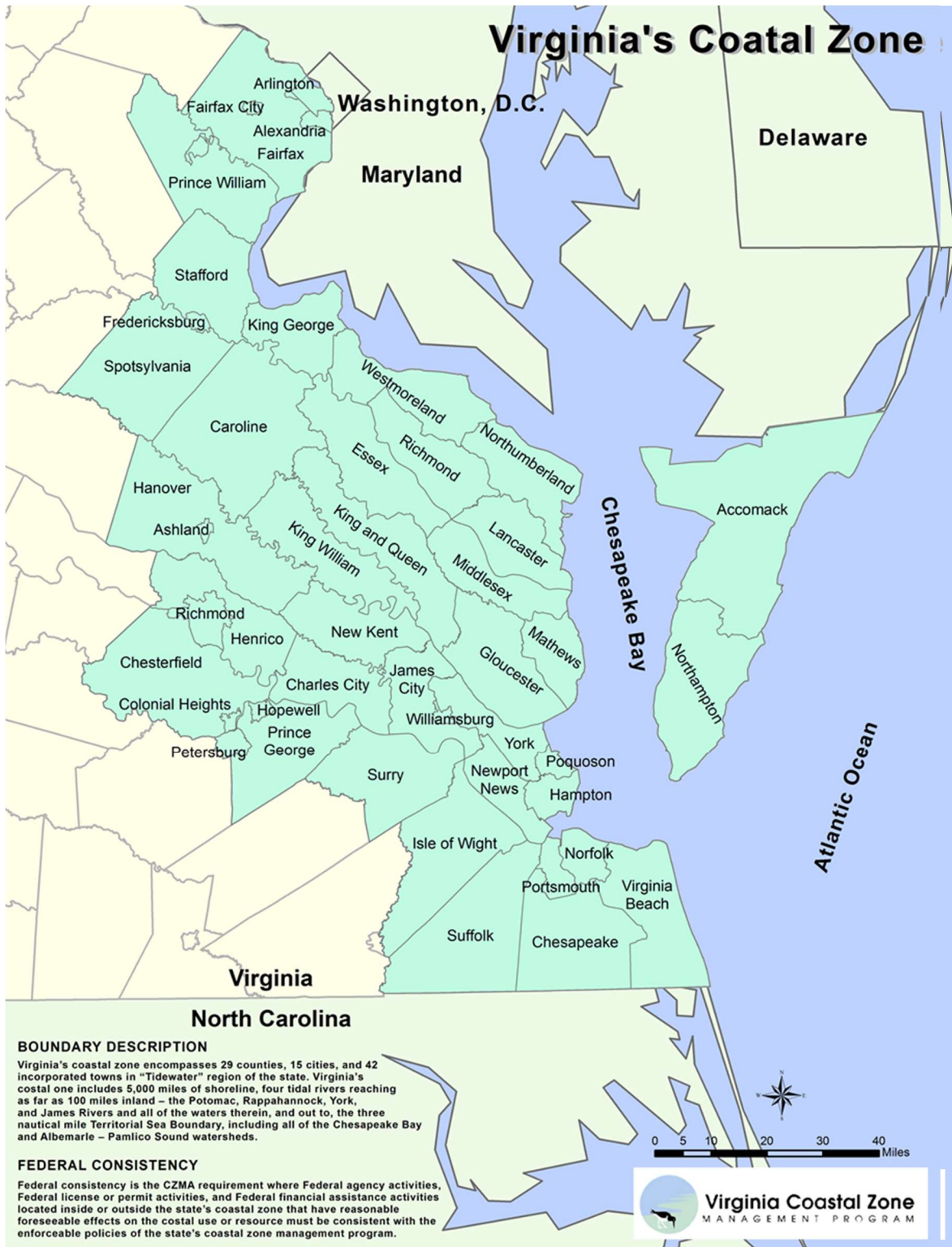


Figure 5-27. Jurisdictions included in the Virginia Coastal Zone Management Program



## 5.15 Land Subsidence/Karst/Sinkholes

### 5.15.1 Hazard Profile

Karst topography can be described as a landscape formed over limestone, dolomite, or gypsum, and is characterized by sinkholes, caves, and underground drainage. The collapse of land in the karst topography creates sinkholes.

Sinkholes are classified as natural depressions of the land surface and are caused when the acidic groundwater dissolves the surrounding geology. Most of these events are triggered by human activity in the karst environment. Excessive pumping of groundwater from karst aquifers may rapidly lower the water table and cause a sudden loss of buoyant forces that stabilize the roofs of cavernous openings. Human-induced changes in surface water flow and infiltration also may cause collapse. Most sinkholes that form suddenly occur where soil that overlies bedrock collapses into the pre-existing void.

### 5.15.2 Magnitude or Severity

Depending on its size, sinkholes can cause damage to bridges, roads, railroads, storm drains, sanitary sewers, canals, levees, and private and public buildings. Another problem associated with karst topography is its impact on aquifers and potential for groundwater contamination. The greatest impact occurs when polluted surface waters enter karst aquifers. This problem is universal among all populated areas located in areas of karst. The groundwater problems associated with karst are accelerated with the advent of (1) expanding urbanization, (2) misuse and improper disposal of environmentally hazardous chemicals, (3) shortage of suitable repositories for toxic waste (both household and industrial), and (4) ineffective public education on waste disposal and the sensitivity of the karstic groundwater system.

Areas over underground mine workings are also susceptible to subsidence. Mine collapses have resulted in losses of homes, roadways, utilities, and other infrastructure. Subsidence is often exacerbated by the extensive pumping of groundwater associated with underground mining. Abandoned coal mines occur in Henrico, Chesterfield, and Goochland Counties in the Richmond coal basin and Buchanan, Dickenson, Lee, Scott, Russell, Tazewell, Wise, Montgomery, and Pulaski Counties in southwest Virginia.

In addition to areas of karst and underground or abandoned mine sites, aging or crumbling infrastructure is another potential source of sudden sinkholes. This can occur anywhere and is difficult to predict.

### 5.15.3 Hazard History

Dramatic collapses of land that swallow homes or persons have happened in Virginia, but generally are rare. Although there have been a few in the region, the most notable incidents occurred in western Virginia in the City of Staunton. On August 11, 1911, parts of several homes and the firehouse were lost in a series of sinkholes on Baldwin Street and

Central Avenue, and on October 28, 2001, a 45-foot-deep chasm opened up on Lewis Street.<sup>15</sup>

According to the 2013 Virginia State Hazard Mitigation Plan, there have been no Federal Declared Disasters or NCDC recorded events for karst-related events in the commonwealth. Land subsidence is very site-specific. There is no comprehensive long-term record of past events in Virginia. Several documented occurrences have been included in Table 5-42. Future plan updates and/or mitigation strategies might include working with VDOT to determine those roadways and areas most susceptible to sinkholes.

**Table 5-42. History of Sinkhole Damages, January 2010 – March 2011**

Date	Damages
January 4, 2010	<b>City of Richmond:</b> The ramp from I-95 North to Broad Street in downtown Richmond was closed because of a sinkhole. Reports say that what started as a pothole quickly became a gaping hole in which the ground collapsed, with about 5 feet of earth underneath it washed away. (Source: WWBT-TV NBC 12 Richmond, VA; <a href="http://www.nbc12.com/story/11763653/update-sinkhole-closes-i-95-downtown-exit?redirected=true">http://www.nbc12.com/story/11763653/update-sinkhole-closes-i-95-downtown-exit?redirected=true</a> )
August 2010	<b>Chesterfield County:</b> Sinkholes in the Scottingham neighborhood were reported around storm drain infrastructure. (Source: WWBT-TV NBC 12 Richmond, VA)
March 2011	<b>City of Richmond:</b> A sinkhole closed the intersection of Grove and Stafford Avenues in Richmond. (Source: Richmond Times-Dispatch)

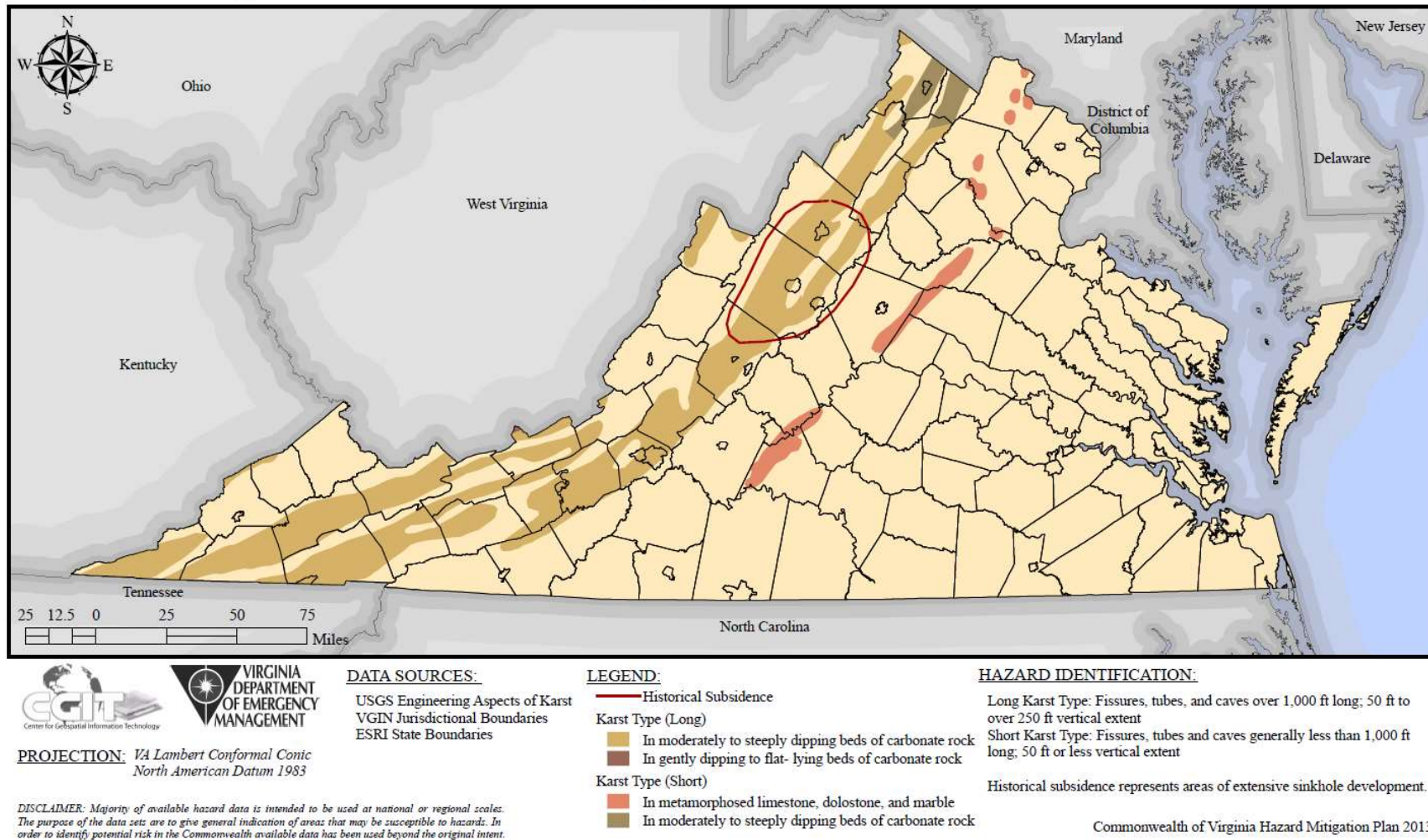
#### 5.15.4 Risk Assessment

In Virginia, the principal area affected by sinkholes is the Valley and Ridge province, an extensive karst terrain underlain by limestone and dolomite, but the narrow marble belts in the Piedmont and some shelly beds in the Coastal Plain are also pocked with sinkholes. A majority of the karst regions in Virginia follow I-81, as seen in Figure 28. These areas are broadly defined and mapped with a general understanding of karst hazard risks.

The jurisdictional executive summaries highlight hazards and vulnerability within the community.

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<sup>15</sup> Virginia Department of Mines Minerals and Energy; <http://www.dmme.virginia.gov/DMR3/sinkholes.shtml>.



**Figure 5-28. Karst Areas in the Commonwealth of Virginia**

Source: 2013 Virginia State Hazard Mitigation Plan

Based on the previous maps, the region does not have a karst-like environment. However, abandoned coal mines do exist in the region and, as stated previously, areas over underground mine workings are also susceptible to subsidence. Maps of historic mining activities are available for a majority of the region, including Powhatan, Goochland, Hanover, New Kent, Charles City, Chesterfield, and Henrico Counties, as well as the Cities of Richmond and Hopewell. The maps can be found at the following website: <http://www.dmme.virginia.gov/DMR3/abandonedmines.shtml>.

As discussed previously, sinkholes are relatively uncommon events in the region. The existing soil types are not conducive to creating natural sinkholes. There are no known sources of data for determining sinkhole probability for the region. Based on previous instances, likely the result of aging infrastructure, and the fact that abandoned mines exist, there is at least a low probability of future sinkhole occurrences in the region.

Limited data prevents a detailed vulnerability analysis at the jurisdictional level. Those jurisdictions with underground infrastructure in need of replacement or repair and those sitting on top of abandon mine locations are at an elevated risk from sinkholes as compared to those without such risk factors.

The potential impacts of land subsidence depend on the type of subsidence that occurs (regional or localized, gradual or sudden) and the location in which the subsidence occurs. The impacts of subsidence occurring in non-urban areas are likely to be less damaging than subsidence that occurs in heavily populated locations. The amount of structural damage depends on the type of construction, the structure location and orientation with respect to the subsidence location, and the characteristics of the subsidence event (sag or pit).

Potential impacts from land subsidence could include damage to residential, commercial, and industrial structures; damage to underground and above-ground utilities; damage to transportation infrastructure, including roads, bridges, and railroad tracks; as well as damage to or loss of crops. Potential damage and loss due to sinkholes or land subsidence is nearly impossible to assess because the nature of the damage is site- and event-specific.

## 5.16 Earthquakes

### 5.16.1 Hazard Profile

The earth's outer surface is broken into pieces called tectonic plates, which move away from, toward, or past each other. Because the continents are part of these plates, they also move. An earthquake occurs when the stresses caused by plate movements are released. The abrupt release of stored energy in the rocks beneath the earth's surface results in a sudden motion or trembling of the earth. The epicenter is the point on the Earth's surface directly above the source of the earthquake.

### 5.16.2 Magnitude or Severity

Smaller earthquakes occur much more frequently than larger earthquakes. These smaller earthquakes generally cause little or no damage. However, very large earthquakes can

cause tremendous damage and are often followed by a series of smaller aftershocks lasting for weeks after the event. This phenomenon, referred to as “minor faulting,” occurs during an adjustment period that may last for several months.

Earthquakes are measured in terms of their magnitude and intensity. Magnitude is measured using the Richter Scale (Table 5-43). The Richter magnitude scale was developed in 1935 by Charles F. Richter of the California Institute of Technology, as a mathematical device to compare the size of earthquakes. The magnitude of an earthquake is determined from the logarithm of the amplitude of waves recorded by seismographs. Adjustments are included for the variation in the distance between the various seismographs and the epicenter of the earthquakes. On the Richter Scale, magnitude is expressed in whole numbers and decimal fractions. For example, a magnitude 5.3 might be computed for a moderate earthquake, and a strong earthquake might be rated as magnitude 6.3. Because of the logarithmic basis of the scale, each whole number increase in magnitude represents a tenfold increase in measured amplitude; as an estimate of energy, each whole number step in the magnitude scale corresponds to the release of about 31 times more energy than the amount associated with the preceding whole number value.

**Table 5-43. The Richter Scale**

<b>Richter Magnitudes</b>	<b>Earthquake Effects</b>
Less than 3.5	Generally not felt, but recorded.
3.5–5.4	Often felt, but rarely causes damage.
Under 6.0	At most, slight damage to well-designed buildings. Can cause major damage to poorly constructed buildings over small regions.
6.1–6.9	Can be destructive in areas up to about 100 kilometers across where people live.
7.0–7.9	Major earthquake. Can cause serious damage over larger areas.
8 or greater	Great earthquake. Can cause serious damage in areas several hundred kilometers across.

The effect of an earthquake on the Earth's surface is called the intensity. The intensity scale consists of a series of certain key responses such as people awakening, movement of furniture, damage to chimneys, and finally, total destruction. Although numerous intensity scales have been developed in the last several hundred years to evaluate the effects of earthquakes, the one currently used in the United States is the Modified Mercalli Intensity Scale. It was developed in 1931 by American seismologists Harry Wood and Frank Neumann. This scale, composed of 12 increasing levels of intensity that range from imperceptible shaking to catastrophic destruction, is designated by Roman numerals as shown in Table 5-44. It does not have a mathematical basis; instead it is an arbitrary ranking based on observed effects.



The Modified Mercalli Intensity value assigned to a specific site after an earthquake has a more meaningful measure of severity to the nonscientist than the magnitude because intensity refers to the effects actually experienced at a particular place.

The lower numbers of the intensity scale deal with the manner in which people feel the earthquake. The higher numbers of the scale are based on observed structural damage. Structural engineers usually contribute information for assigning intensity values of VIII or above.

**Table 5-44. Modified Mercalli Intensity Scale for Earthquakes**

Scale	Intensity	Earthquake Effects	Corresponding Richter Scale Magnitude
I	Instrumental	Detected only on seismographs	
II	Feeble	Some people feel it	<4.2
III	Slight	Felt by people resting; like a truck rumbling by	
IV	Moderate	Felt by people walking	
V	Slightly Strong	Sleepers awake; church bells ring	<4.8
VI	Strong	Trees sway; suspended objects swing; objects fall off shelves	<5.4
VII	Very Strong	Mild alarm; walls crack; plaster falls	<6.1
VIII	Destructive	Moving cars uncontrollable; masonry fractures; poorly constructed buildings damaged	
IX	Ruinous	Some houses collapse; ground cracks; pipes break open	<6.9
X	Disastrous	Ground cracks profusely; many buildings destroyed; liquefaction and landslides widespread	<7.3
XI	Very Disastrous	Most buildings and bridges collapse; roads, railways, pipes and cables destroyed; general triggering of other hazards	<8.1
XII	Catastrophic	Total destruction; trees fall; ground rises and falls in waves	>8.1

### 5.16.3 Hazard History

Significant earthquakes were first recorded in Virginia in 1774. Virginia has had more than 160 earthquakes since 1977, of which 16% were felt. This averages to approximately one earthquake every month, with two felt each year.<sup>16</sup> Figure 5-29, from the 2010 Virginia State Hazard Mitigation Plan, shows the significant earthquakes that have impacted Virginia from 1568 to 2009. There have been four significant earthquakes centered in the region (Figure 5-30). The figure also shows quaternary faulting in the Central Virginia Seismic Zone, running through Powhatan, Goochland, Fluvanna, and Cumberland Counties. Quaternary faults and folds are believed to be sources of earthquakes greater than magnitude 6 in the past 1,600,000 years; however, the USGS reports that only

<sup>16</sup> Virginia Tech Seismological Observatory. (2010) <http://www.geol.vt.edu/outreach/vtso/quake.html>



liquefaction features are evidence of strong shaking and that individual faults in the Central Virginia Seismic Zone remain unidentified.<sup>17</sup>

Of the four significant earthquakes that have been recorded in the region, one was centered near the City of Petersburg, two near Goochland County, and one near Powhatan County. Historical earthquake occurrences, which have affected the region and are summarized in the following paragraphs, are based on available records from the Virginia Tech Seismological Observatory, Seismicity of the United States (USGS Paper 1527), and Earthquakes in Virginia and Vicinity 1774 – 2004 (USGS Paper 2006 1017).

The first earthquake (4.5 on the Richter Scale) occurred on February 21, 1774, near the City of Petersburg and Prince George County. The earthquake was felt in much of Virginia and southward into North Carolina. Many houses were moved considerably off their foundations in the cities of Petersburg and Blandford. The shock was described as "severe" in Richmond and terrified residents about 50 miles north in the City of Fredericksburg, but caused no damage in those areas. The total felt area covered about 57,900 square miles.

On August 27, 1833, an earthquake near Goochland County (4.5 on the Richter Scale) was felt from Norfolk to Lexington and from Baltimore, Maryland, to Raleigh, North Carolina – about 52,110 square miles. In Charlottesville, Fredericksburg, Lynchburg, and Norfolk, windows rattled violently, loose objects shook, and walls of buildings were visibly agitated.

Although it did not occur within the region, an earthquake (4.3 on the Richter Scale) was observed on November 2, 1852, with the epicenter in Buckingham County, Virginia. Chimney damage was reported in Buckingham and the earthquake was reported to be the strongest in Fredericksburg and Richmond, and the Town of Scottsville.

Centered near Goochland County, a series of shocks (4.8 on the Richter Scale) in quick succession were felt throughout the eastern two-thirds of Virginia and a portion of North Carolina on December 23, 1875. The highest intensities from this earthquake occurred mainly in towns near the James River shoreline in Goochland and Powhatan Counties, and in Louisa County. In Richmond and Henrico Counties, the most severe damage was sustained in the downtown business and residential areas adjacent to the James River. Damage included bricks knocked from chimneys, fallen plaster, an overturned stove, and several broken windows. Waves "suddenly rose several feet" at the James River dock in Richmond, causing boats to "part their cables" and drift below the wharf. At Manakin, about 20 kilometers west of Richmond, shingles were shaken from a roof and many lamps and chimneys were broken. The total felt area was about 50,180 square miles.

On February 11, 1907, an earthquake reaching 4 on the Richter Scale affected the Town of Arvon and Buckingham County. The earthquake was also felt strongly from Powhatan to Albemarle Counties.

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<sup>17</sup>USGS. (2011)

[http://geohazards.usgs.gov/cfusion/qfault/qf\\_web\\_disp.cfm?qfault\\_or=1235&qfault\\_id=2653](http://geohazards.usgs.gov/cfusion/qfault/qf_web_disp.cfm?qfault_or=1235&qfault_id=2653)

The December 9, 2003, Powhatan County earthquake (4.5 on the Richter Scale) was a complex event consisting of two sub-events occurring 12 seconds apart and causing slight damage nearest the epicenter. The quakes were felt in much of Maryland and Virginia; in north-central North Carolina; and in a few areas of Delaware, New Jersey, New York, Pennsylvania, and West Virginia.

A 5.8 magnitude quake centered near Mineral, VA occurred at 1:51 pm EDT on August 23, 2011. The earthquake was reportedly felt as far north as Boston, as far south as Georgia and as far west as Chicago. Effects of the earthquake were reported to the USGS through its online survey from over 8,434 zip codes, and ranged from weak intensity to very strong. In terms of damage, particularly hard-hit were brick and unreinforced structures and infrastructure near the quake's epicenter. In addition to cracks and buckling, some buildings were knocked off of their foundations. Minor injuries were reported as a result of the damage and debris. The earthquake forced the North Anna Power Station nuclear power plant offline pending an all-clear from a Nuclear Regulatory Commission review. Aftershocks of a lesser magnitude continued to plague the area for several weeks after the event. The strongest aftershock measured 4.5 and occurred on August 25 at 1:08 am EDT.

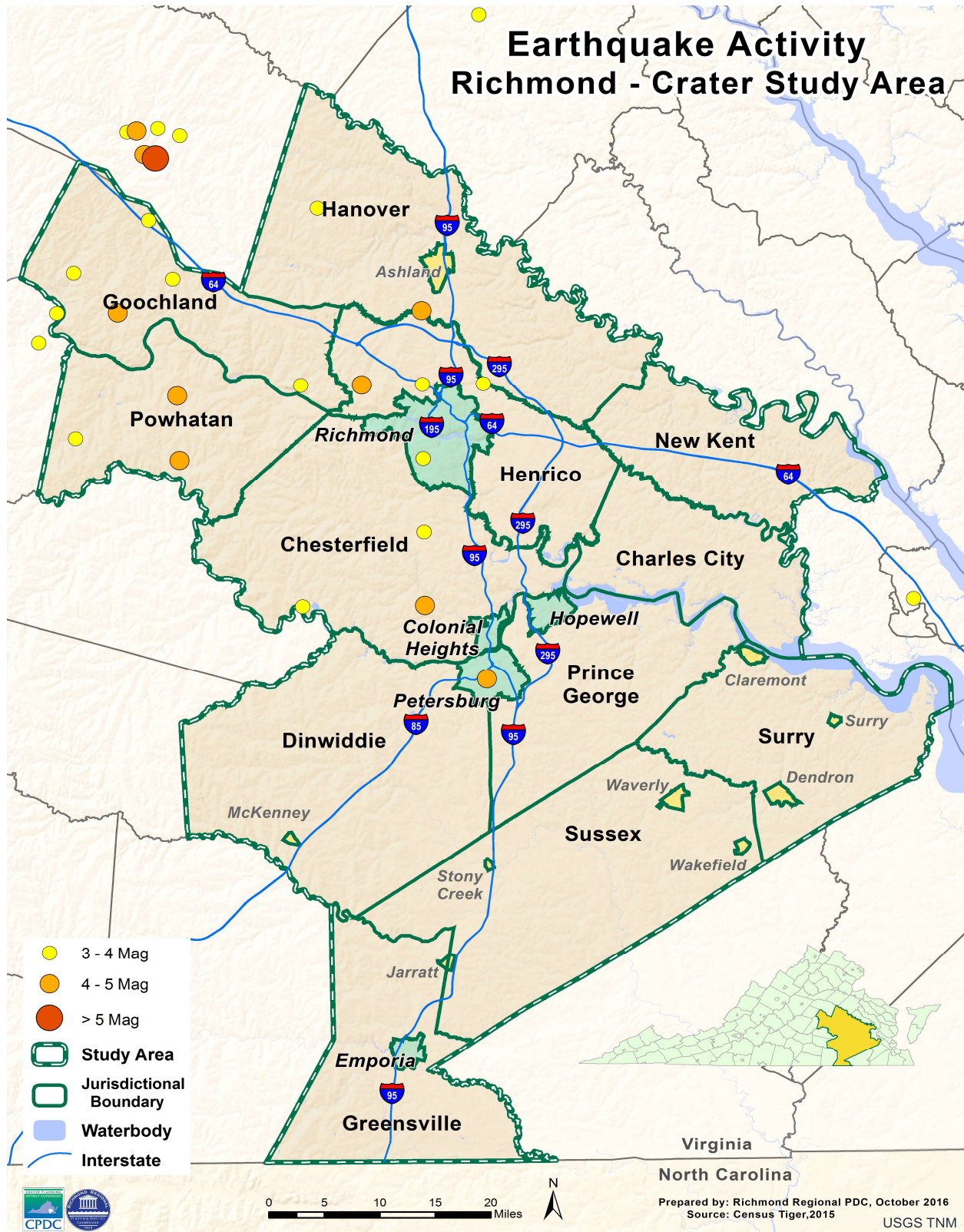


Figure 5-30. Earthquake Activity and Seismic Hazard Map

## **5.16.4 Vulnerability Analysis**

### *Probability*

Because earthquakes have a limited ranking for the region, calculation of probability was not performed for this analysis. Earthquakes are high-impact, low-probability events. With the few historical incidents throughout the region and limited data, the probability is low.

### *Impact and Vulnerability*

Impacts from earthquakes can be severe and cause significant damage. Ground shaking can lead to the collapse of buildings and bridges, and disrupt gas, lifelines, electric, and phone service. Death, injuries, and extensive property damage are possible vulnerabilities from this hazard. Some secondary hazards caused by earthquakes may include fire, hazardous material release, landslides, flash flooding, avalanches, tsunamis, and dam failure.

### *Risk and Loss Estimation*

Because earthquakes have a limited ranking for the region, analysis for critical facilities was not performed. The HAZUS-MH earthquake model estimates damages and loss to buildings, lifelines, and essential facilities from scenario and probabilistic earthquakes.

For the 2013 Virginia State Hazard Mitigation Plan, probabilistic earthquake events were modeled using HAZUS-MH MR3. HAZUS-MH was used to generate damage and loss estimates for the probabilistic ground motions associated with each of eight return periods (100-, 250-, 500-, 750-, 1,000-, 2,000-, and 2,500-year return periods). The building damage estimates were then used as the basis for computing direct economic losses. These include building repair costs, contents and business inventories losses, costs of relocation, and capital-related wage and rental losses.

Annualized loss was computed in the 2011 update in HAZUS, by multiplying losses from eight potential ground motions by their respective annual frequencies of occurrence, and then summing the values. Table 5-45 shows the HAZUS results for the jurisdictions in the region. These results were extracted directly from the 2013 Virginia State Hazard Mitigation Plan. Based on this analysis, Henrico County would be expected to see the greatest losses on an annual basis in the region, followed closely by the City of Richmond and Chesterfield County.

The jurisdictional executive summaries highlight hazards and vulnerability within the community.

**Table 5-45. Annualized Earthquake Losses (Hazus 2011)**

<b>Jurisdiction</b>	<b>Annualized Losses</b>
15 Charles City County	\$7,849
2 Chesterfield County	\$596,915
8 City of Colonial Heights	\$42,257
11 Dinwiddie County (incl. Town of McKenney)	\$35,223
14 City of Emporia	\$11,286
6 Goochland County	\$58,031
Greensville County (incl. Town of Jarratt)	\$10,862
4 Hanover County (incl. Town of Ashland)	\$215,922
1 Henrico County	\$726,316
10 City of Hopewell	\$35,637
12 New Kent County	\$16,193
5 City of Petersburg	\$78,970
7 Powhatan County	\$55,723
9 Prince George County	\$42,008
3 City of Richmond	\$591,619
Surry County (incl. Towns of Claremont, Dendron, Surry)	\$5,523
13 Sussex County (incl. Towns of Stony Creek, Wakefield, Waverly)	\$11,465
<b>Total</b>	<b>\$2,541,799</b>

Source: [http://www.vaemergency.gov/webfm\\_send/865/Section3-9-WinterWeather.pdf](http://www.vaemergency.gov/webfm_send/865/Section3-9-WinterWeather.pdf)

## 5.17 Hazard Identification and Risk Assessment Summary

A variety of hazards, both natural and human caused, have the potential to impact the region. Data analysis presented in the preceding sections and input from the MAC indicate that flooding has the most significant and frequent impacts on the region and its citizens.

In addition to the potential for injury or loss of life and damage to property and crops, hazards have the potential to cause disruption of utilities, communication and transportation systems, which can contribute to lost business and decreased productivity. Table 5-46 provides a summary of potential annualized losses by hazard for which losses could be determined. Tables 5-47 and 5-48 are summarized annual total damages and events for each county. Tables 5-49, 5-50, and 5-51 show the individual scores and ranks of each of the hazards analyzed for each of the Jurisdictions. The scores were based on a similar analysis shown in Section 5.4.3, except for being compared as totals for the study area, hazards were compared within each jurisdiction to determine the ranks for each hazard.

It is important to point out that data limitations prevent a full accounting of past or potential future losses. This is particularly true in the case of the wildfire, earthquake, landslides, and karst hazards, as there was no applicable data found from the NCDC and historical data may have been supplemented. Also, the NCDC database recognizes that it may not contain every event or damages and should only be considered as estimates.

The jurisdictional executive summaries in Appendix G highlight hazards and vulnerability within each community.



NOTES: \*Data for some hazards is only available at the city and/or county level.

\*\*Loss data for the Towns are incorporated into their larger counties for consistency with the NCDC dataset.

**Table 5-46. Potential Annualized Losses**

<b>Jurisdiction</b>	<b>Total Annualized Losses</b>	<b>Largest Event Property Damages</b>	<b>Largest Property Damages Event Type</b>	<b>Largest Event Crop Damages</b>	<b>Largest Crop Damages Event Type</b>
Charles City County	\$180,743.34	\$13,987.96	Tornado	\$131,416.88	Drought
Chesterfield County	\$2,479,939.80	\$1,951,015.48	Hurricanes	\$10,694.79	Hurricanes
City of Colonial Heights	\$109,139.03	\$71,663.27	Flood	-	N/A
City of Emporia	\$20,252.60	\$12,223.05	Flood	\$3,284.57	Flood
<i>City of Hopewell</i>	\$87,141.27	\$85,942.05	Tornado	-	N/A
City of Petersburg	\$946,015.13	\$891,490.10	Tornado	\$11,943.88	Flood
City of Richmond	\$1,142,827.00	\$1,065,174.56	Flood	-	N/A
Dinwiddie County	\$2,295,987.73	\$1,272,732.68	Tornado	\$402,556.43	Drought
Goochland County	\$167,949.85	\$24,560.15	Tornado	\$122,076.69	Drought
Greensville County	\$163,994.86	\$71,663.27	Flood	\$47,775.51	Flood
<i>Hanover County</i>	\$677,733.31	\$109,340.00	Flood	\$500,830.07	Drought
Henrico County	\$1,571,013.91	\$982,142.37	Hurricanes	\$244,153.37	Drought
New Kent County	\$139,018.00	\$38,965.66	Flood	\$69,427.79	Drought
Powhatan County	\$621,507.27	\$216,288.04	Hurricanes	\$378,380.68	Drought
Prince George County	\$2,654,799.45	\$1,305,027.80	Hurricanes	\$931,930.92	Hurricanes
Surry County	\$608,554.11	\$367,251.73	Hurricanes	\$115,894.15	Hurricanes
Sussex County	\$455,933.42	\$265,726.39	Flood	\$62,186.96	Flood

Table 5-47. Summary of Annualized Total Damages for each HIRA Category

Jurisdiction	Flood	Thunderstorm	Wind	Winter	Tornado	Drought	Hurricanes	Wildfires*	Earthquake*
Charles City County	\$0	\$1,535	\$70	\$1,444	\$13,988	\$131,417	\$32,289	\$5,469	\$7,849
Chesterfield County	\$290,444	\$15,640	\$2,545	\$7,962	\$201,639	\$0	\$1,961,710	\$4,129	\$596,915
City of Colonial Heights	\$71,663	\$4,370	\$0	\$0	\$33,106	\$0	\$0	\$38	\$42,257
City of Emporia	\$15,508	\$1,408	\$0	\$0	\$3,337	\$0	\$0	\$8	\$11,286
City of Hopewell	\$0	\$1,199	\$0	\$0	\$85,942	\$0	\$0	\$0	\$35,637
City of Petersburg	\$50,761	\$3,764	\$0	\$0	\$891,490	\$0	\$0	\$0	\$78,970
City of Richmond	\$1,065,175	\$3,673	\$0	\$0	\$73,980	\$0	\$0	\$8	\$591,619
Dinwiddie County	\$184,075	\$10,714	\$154	\$2,600	\$1,272,733	\$402,556	\$423,155	\$66,796	\$35,223
Goochland County	\$0	\$2,972	\$34	\$3,004	\$24,560	\$122,077	\$15,302	\$9,238	\$58,031
Greensville County	\$119,439	\$2,513	\$214	\$0	\$18,033	\$0	\$23,796	\$27,629	\$10,862
Hanover County	\$109,340	\$15,037	\$102	\$3,030	\$27,280	\$500,830	\$22,115	\$10,387	\$215,922
Henrico County	\$141,487	\$36,087	\$508	\$8,948	\$114,430	\$244,153	\$1,025,400	\$2,157	\$726,316
New Kent County	\$38,966	\$5,979	\$117	\$1,444	\$16,581	\$69,428	\$6,502	\$858	\$16,193
Powhatan County	\$0	\$4,538	\$0	\$2,889	\$0	\$378,381	\$235,700	\$12,854	\$55,723
Prince George County	\$158,329	\$6,247	\$469	\$9,089	\$20,546	\$223,161	\$2,236,959	\$1,768	\$42,008
Surry County	\$101,548	\$2,224	\$0	\$0	\$21,636	\$0	\$483,146	\$3,515	\$5,523
Sussex County	\$327,913	\$3,418	\$190	\$0	\$75,448	\$0	\$48,964	\$8,086	\$11,465
Totals	\$2,674,649	\$121,317	\$4,403	\$40,411	\$2,894,729	\$2,072,003	\$6,515,038	\$6,515,038	\$6,515,038

\*Data used from 2011 Plan Update and were not from NCDC dataset

Table 5-48. Summary of Annualized Events for each HIRA Category

Jurisdiction	Flood	Thunderstorm	Wind	Winter	Tornado	Drought	Hurricanes	Mass Evacuation	Wildfires*	Earthquake	Landslide	Karst
Charles City County	0.29	0.95	0.02	2.38	0.03	0.17	0.08	-	10.31	-	-	-
Chesterfield County	0.92	3.98	0.10	6.00	0.25	0.25	0.17	-	18.92	-	-	-
City of Colonial Heights	0.21	0.59	0.00	0.00	0.01	0.00	0.00	-	0.08	-	-	-
City of Emporia	0.33	0.54	0.00	0.00	0.03	0.00	0.00	-	0.23	-	-	-
City of Hopewell	0.13	0.70	0.00	0.00	0.06	0.00	0.00	-	0.08	-	-	-
City of Petersburg	0.21	0.82	0.00	0.00	0.07	0.00	0.00	-	0.31	-	-	-
City of Richmond	0.54	1.41	0.00	0.00	0.13	0.00	0.00	-	0.15	-	-	-
Dinwiddie County	0.38	2.03	0.05	2.42	0.13	0.25	0.08	-	17.38	-	-	-
Goochland County	0.13	2.03	0.02	3.50	0.13	0.21	0.04	-	10.15	-	-	-
Greensville County	0.25	1.13	0.07	4.17	0.09	0.25	0.17	-	6.62	-	-	-
Hanover County	0.58	3.16	0.07	3.54	0.28	0.25	0.08	-	11.23	-	-	-
Henrico County	0.58	4.26	0.26	6.08	0.18	0.50	0.17	-	6.46	-	-	-
New Kent County	0.42	1.54	0.02	2.50	0.07	0.13	0.08	-	11.69	-	-	-
Powhatan County	0.42	1.80	0.00	3.04	0.04	0.25	0.04	-	11.92	-	-	-
Prince George County	0.58	2.74	0.20	7.88	0.15	0.50	0.25	-	9.62	-	-	-
Surry County	0.67	1.38	0.00	2.08	0.12	0.13	0.17	-	5.15	-	-	-
Sussex County	0.63	1.80	0.07	2.29	0.13	0.13	0.13	-	12.16	-	-	-
Totals	7.27	30.86	0.88	45.88	1.90	3.02	1.46	-	0.00	-	-	-

\*Data used from 2011 Plan Update and were not from NCDC dataset

Table 5-49. HIRA Analysis Scores for Ranking

Jurisdiction	Flood	Thunderstorm	Wind	Winter	Tornado	Drought	Hurricanes	Mass Evacuation	Wildfires	Earthquake	Landslide	Karst
Charles City County	0.75	1.08	0.88	1.58	1.08	1.88	1.20	0.19	1.45	0.33	0.31	0.31
Chesterfield County	1.13	1.64	0.88	1.57	1.07	0.57	2.19	0.19	1.44	0.41	0.31	0.31
City of Colonial Heights	2.06	1.14	0.69	0.63	1.36	0.38	0.69	0.19	0.69	0.51	0.31	0.31
City of Emporia	2.06	1.18	0.69	0.63	1.22	0.38	0.69	0.19	0.69	0.55	0.31	0.31
City of Hopewell	0.75	1.08	0.69	0.63	2.25	0.38	0.69	0.19	0.69	0.45	0.31	0.31
City of Petersburg	0.82	1.07	0.69	0.63	2.25	0.38	0.69	0.19	0.69	0.34	0.31	0.31
City of Richmond	2.25	1.63	0.69	0.63	1.03	0.38	0.69	0.19	0.69	0.49	0.31	0.31
Dinwiddie County	0.94	1.64	0.88	1.57	2.25	0.98	1.31	0.19	1.45	0.32	0.31	0.31
Goochland County	0.75	1.66	0.88	1.59	1.20	1.88	1.04	0.19	1.46	0.47	0.31	0.31
Greensville County	2.06	1.65	0.88	1.57	1.14	0.57	1.14	0.19	1.51	0.34	0.31	0.31
Hanover County	1.22	1.66	0.88	1.57	1.01	1.88	0.93	0.19	1.44	0.45	0.31	0.31
Henrico County	1.12	1.67	0.88	1.57	1.08	0.88	2.19	0.19	1.44	0.54	0.31	0.31
New Kent County	1.49	1.74	0.88	1.59	1.25	1.88	1.00	0.19	1.44	0.39	0.31	0.31
Powhatan County	0.75	1.64	0.69	1.57	0.94	1.88	1.69	0.19	1.45	0.36	0.31	0.31
Prince George County	1.03	1.63	0.88	1.57	0.95	0.69	2.19	0.19	1.44	0.32	0.31	0.31
Surry County	1.21	1.63	0.69	1.57	1.00	0.57	2.19	0.19	1.44	0.32	0.31	0.31
Sussex County	2.25	1.64	0.88	1.57	1.24	0.57	1.07	0.19	1.45	0.32	0.31	0.31

Table 5-50. Individual County HIRA Analysis Ranking (High, Moderate, or Low)

Jurisdiction	Flood	Thunderstorm	Wind	Winter	Tornado	Drought	Hurricanes	Mass Evacuation	Wildfires	Earthquake	Landslide	Karst
Charles City County	Low	Moderate	Low	High	Moderate	High	Moderate	Low	High	Low	Low	Low
Chesterfield County	Moderate	High	Low	Moderate	Moderate	Low	High	Low	Moderate	Low	Low	Low
City of Colonial Heights	High	Moderate	Low	Low	Moderate	Low	Low	Low	Low	Low	Low	Low
City of Emporia	High	Moderate	Low	Low	Moderate	Low	Low	Low	Low	Low	Low	Low
City of Hopewell	Moderate	Moderate	Low	Low	High	Low	Low	Low	Low	Low	Low	Low
City of Petersburg	Moderate	Moderate	Low	Low	High	Low	Low	Low	Low	Low	Low	Low
City of Richmond	High	Moderate	Low	Low	Moderate	Low	Low	Low	Low	Low	Low	Low
Dinwiddie County	Low	High	Low	Moderate	High	Low	Moderate	Low	Moderate	Low	Low	Low
Goochland County	Low	High	Low	High	Moderate	High	Moderate	Low	High	Low	Low	Low
Greensville County	High	High	Low	High	Moderate	Low	Moderate	Low	High	Low	Low	Low
Hanover County	Moderate	High	Low	High	Moderate	High	Low	Low	High	Low	Low	Low
Henrico County	Moderate	High	Low	Moderate	Moderate	Low	High	Low	Moderate	Low	Low	Low
New Kent County	High	High	Low	High	Moderate	High	Low	Low	High	Low	Low	Low
Powhatan County	Low	High	Low	High	Low	High	High	Low	High	Low	Low	Low
Prince George County	Moderate	High	Low	Moderate	Low	Low	High	Low	Moderate	Low	Low	Low
Surry County	Moderate	High	Low	High	Moderate	Low	High	Low	Moderate	Low	Low	Low
Sussex County	High	High	Low	Moderate	Moderate	Low	Moderate	Low	Moderate	Low	Low	Low

Table 5-51. Individual County HIRA Analysis Ranking (1 Highest - 12 Lowest)

Jurisdiction	Flood	Thunderstorm	Wind	Winter	Tornado	Drought	Hurricanes	Mass Evacuation	Wildfires	Earthquake	Landslide	Karst
Charles City County	8	5	7	2	6	1	4	12	3	9	10	10
Chesterfield County	5	2	7	3	6	8	1	12	4	9	10	10
City of Colonial Heights	1	3	4	7	2	9	4	12	6	8	10	10
City of Emporia	1	3	4	7	2	9	4	12	6	8	10	10
City of Hopewell	3	2	4	7	1	9	4	12	6	8	10	10
City of Petersburg	3	2	4	7	1	8	4	12	6	9	10	10
City of Richmond	1	2	4	7	3	9	4	12	6	8	10	10
Dinwiddie County	7	2	8	3	1	6	5	12	4	9	10	10
Goochland County	8	2	7	3	5	1	6	12	4	9	10	10
Greensville County	1	2	7	3	6	8	5	12	4	9	10	10
Hanover County	5	2	8	3	6	1	7	12	4	9	10	10
Henrico County	5	2	7	3	6	8	1	12	4	9	10	10
New Kent County	4	2	8	3	6	1	7	12	5	9	10	10
Powhatan County	7	3	8	4	6	1	2	12	5	9	10	10
Prince George County	5	2	7	3	6	8	1	12	4	9	10	10
Surry County	5	2	7	3	6	8	1	12	4	9	10	10
Sussex County	1	2	7	3	5	8	6	12	4	9	10	10