Commonwealth of Virginia Emergency Operations Plan
Standard Hazard Mitigation Support Annex 3
(Volume II)

CHAPTER 3

Hazard Identification and Risk Assessment (HIRA)

Section 3.8a:
Non-Rotational Wind

2010

SECTION 3.8a

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Section 3.8a: Non-Rotational Winds

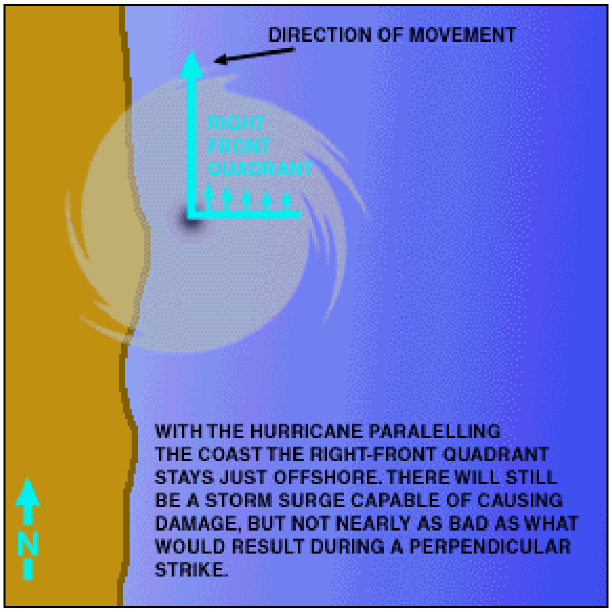
Description

Hurricane Isabel, City of Richmond
2003
Source: Bill Hark, www.harkphoto.com/isabel.html

Tropical cyclones involve both atmospheric and hydrologic characteristics, such as severe winds, storm surge flooding, high waves, coastal erosion, extreme rainfall, thunderstorms, lightning, and, in some cases, tornadoes. Storm surge flooding can push inland, and riverine flooding associated with heavy inland rains can be extensive. Many areas of the Tidewater region are flat, and intense prolonged rainfall tends to accumulate without ready drainage paths. Of particular concern with extreme rainfall is the Chowan River Basin which has relatively no elevation and results in flood events like back-to-back Hurricanes Dennis and Floyd which devastated the City of Franklin and other communities along the Blackwater River. Extreme rainfall in the higher elevations can also result in secondary hazards such as landslides and debris flows as witnessed during Hurricane Camille in Nelson County. High winds are also associated with hurricanes, with two significant effects: widespread debris due to damaged and downed trees and building debris; and power outages. The Tidewater region, including areas on tidal-influenced tributaries, is vulnerable to hurricanes and their effects.

As a storm moves into more shallow waters, the waves lessen, but water levels rise, bulging up on the storm's Right-Front Quadrant (RFQ) in what is called the "storm surge", as shown in Figure 3.8a-1. This is the deadliest part of a hurricane. The storm surge and wind driven waves can devastate a coastline and bring ocean water several miles inland. Once inland, the hurricane's band of thunderstorms produces torrential rains and sometimes tornadoes. A foot or more of rain may fall in less than a day causing flash floods and mudslides. The rain eventually drains into the large rivers, which may still be flooding days after the storm has passed. The storm's driving winds can topple trees, utility poles, and damage buildings. Communication and electricity is lost for days and roads are impassable due to fallen trees and debris.

Figure 3.8a- 1: Right-Front Quadrant (RFQ) of a hurricane is the stronger side of the storm and creates the highest storm surge.



Source: www.HurricaneTrack.com

The hurricanes that affect Virginia typically form in the Atlantic or Gulf of Mexico during the months of June through November. These storms form from strong low-pressure systems originating in the tropics, which cause the updraft of warm ocean water. Typically, these systems result in strong damaging winds and high seas that can cause flooding. A storm originating in the Atlantic is defined as a hurricane when the maximum sustained winds reach 74 miles per hour. Below this level, it is defined as either a tropical storm or tropical depression.

The Saffir-Simpson Hurricane Scale is a 1-5 rating based on the hurricane's present intensity. This 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 and the shape of the coastline in the landfall region. Note that all winds are using the U.S. 1-minute average.[1]

Hurricanes are categorized by the Safer-Simpson Hurricane Damage Scale listed below. Table 3.8a-1 provides a detailed description of each hurricane category, potential damage caused, and the name and strength of hurricanes as they passed near or through Virginia.

[1] National Weather Service National Hurricane Center. The Saffir-Simpson Hurricane Scale descriptions http://www.nhc.noaa.gov/aboutsshs.shtml

Table 3.8a- 1: Saffir-Simpson Hurricane Damage Scale. From National Weather Service National Hurricane Center and Virginia's Warning Coordination Meteorologist. Historical events from FEMA and VDEM.

Category	**Wind Speeds** (US 1-min average.)	**Damage Potential**	**Damage Description pertaining to the effects of wind only** Heavy rains can occur at any level	**Historical Hurricane Category in Virginia** (* indicates a Federally Declared Disaster)
Tropical Depression Tropical Storm	<38 mph (TD) <33 kt <62 kh/hr 39-73 mph (TS) 34-63 kt 63 – 118 km/hr	Negligible	Wind Effects: Scattered trees down, scattered power outages, some roads blocked due to downed trees and power lines. For example. Neighborhoods could lose power for several days. *This damage description is more likely associated with a tropical storm than a tropical depression.*	Hurricane Diane (8/17/1955) Hurricane Camille (8/20/1969) Tropical Storm Doria (8/27/1971) Tropical Storm Agnes (6/21/1972)* Hurricane Hugo (9/9/1989) Hurricane Bertha (7/12-13/1996) Hurricane Fran (9/5-6/1996)* Hurricane Danny (7/24/1997) Hurricane Dennis (9/4-5/1999)* Hurricane Floyd (9/15-16/1999)* Hurricane Isabel (9/18/2003)* Hurricane Charley (8/14/2004) Hurricane Gaston (8/29/2004) Hurricane Frances (9/8/2004) Hurricane Ivan (9/17/2004) Hurricane Jeanne (9/28/2004) Tropical Storm Ernesto (9/1/2006)*
1	74 – 95 mph 64-82 kt 119-153 km/hr	Minimal	Wind Effects: Damage to mobile homes and some homes of frame construction. Numerous trees down and widespread power outages. Roads blocked due to downed trees and power lines. Loose outdoor items will become airborne projectiles. For example. An area as large as a county could experience near total power loss.	Chesapeake-Potomac Hurricane of 1933 Hurricane Hazel (10/15/1954) Hurricane Charley (9/17/1986 Hurricane Bonnie (8/27/1998)*
2	96 – 110 83-95 kt 154-177 km/hr	Moderate	Wind Effects: Severe damage to the majority of mobile homes and homes of frame construction. Many trees down. Well-constructed homes will have damage to shingles, siding and gutters. Extensive damage to power lines and widespread power outages. Airborne debris could injure or kill. Damage could extend well inland. For example, multiple localities could experience near total loss of power and water from several days to weeks.	The Great Hurricane (9/14/1944) Hurricane Donna (9/12/1960) Hurricane Gloria (9/27/1985)
3	111 – 130 mph 96 - 113 kt 178 - 209 km/hr	Extensive	Wind Effects: Nearly all mobile homes destroyed. Severe damage to most homes, including structural collapse. Airborne debris will injure or kill. Severe damage to most low-rise apartment buildings with partial roof and wall failure. Damage could extend well inland. For example, large portions of the affected area could experience total power and water loss for more than a week.	
4	131 – 155 mph 114-135 kt 210-249 km/hr	Extreme	Wind Effects: Catastrophic damage to residential structures. Most of the affected area will be uninhabitable for weeks or longer. Nearly all industrial building and low-rise apartment buildings severely damaged or destroyed. Nearly all trees and power poles downed. Damage could extend well inland. For example, large portions of the affected area will experience total power and water loss for weeks and possible months.	
5	> 155 mph > 135 kt >249 km/hr	Catastrophic	Wind Effects: Similar to Category 4.	*Meteorologists consider the water off the Virginia coast too cool to support a Category 5 storm.*

Historic Occurrence

As expected, most hurricanes affect the eastern Virginia due to its proximity to the coast. However, it is not uncommon for hurricanes and tropical storms to track through the state and impact non-coastal jurisdictions. NCDC includes information on hurricane events and their effects. The events included in Table 3.8a-2 summarize some of the major hurricane events that have historically affected Virginia. Federally declared hurricane related events are listed in Section 3.3. Figure 3.8a-2 shows the paths of some of the major hurricanes that have passed through Virginia.

Virginia has experienced several lulls in hurricane activity since reliable records began. One possibility for these peaceful periods is the phenomenon called El Nino. El Nino causes stronger westerly winds in the atmosphere over the southeastern United States. These winds tend to shear hurricanes apart and help steer them away from the mainland. La Nina, the opposite for El Nino, brings cold waters over the equatorial Pacific, and there tends to be a dramatic increase in hurricane activity. Between 1951 and 1960, Virginia was affected by 16 storms, including Hazel, Connie, Diane and Flossy.[2]

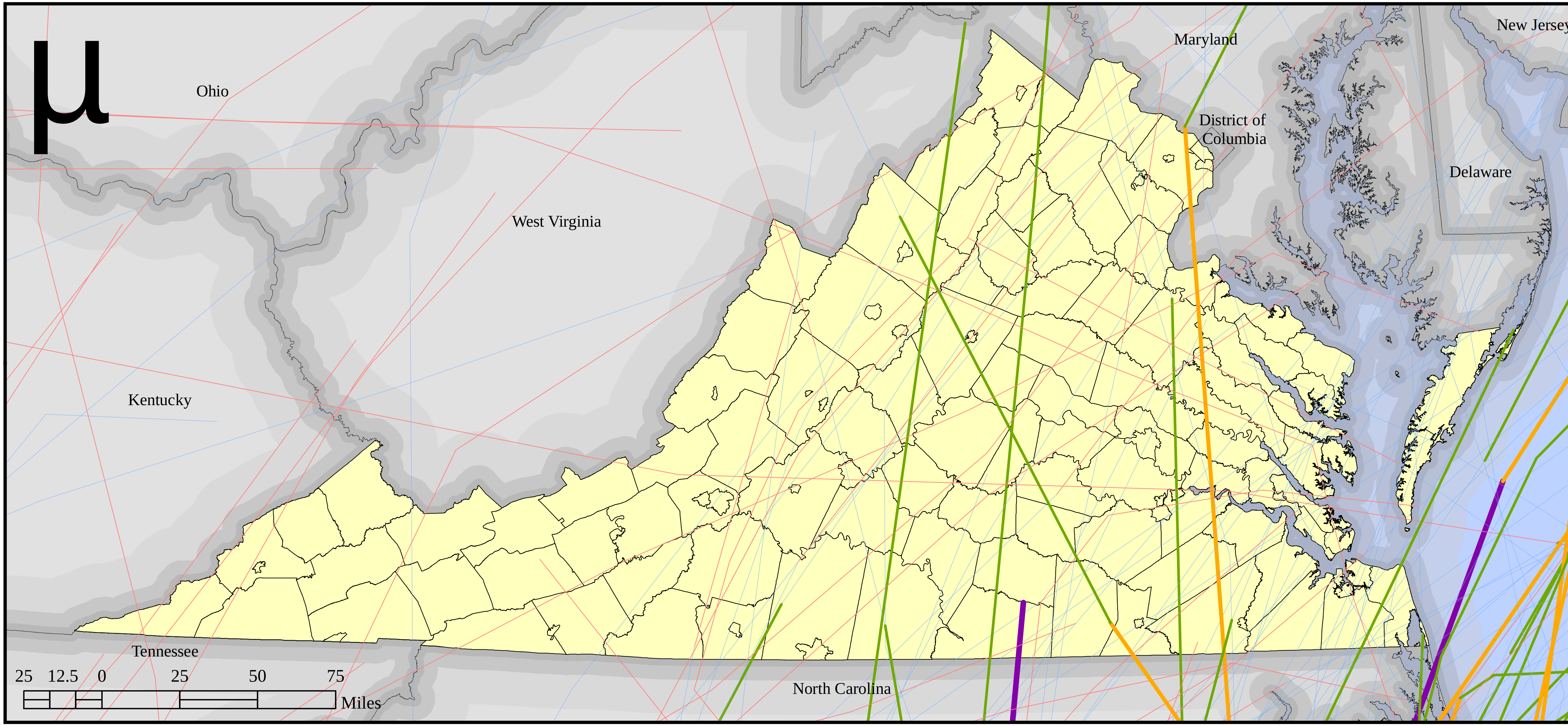
Table 3.8a- 2: Historical Hurricanes (1749 – 2008).

Year	System Name	Description
1749	None	A tremendous hurricane created Willoughby Spit, south of Hampton. The Bay rose 15 feet above normal. In Williamsburg, a family drowned as floodwaters carried their house away. At Hampton, water rose to four feet deep in the streets; many trees were uprooted or snapped in two. Bodies washed ashore from shipwrecks for days afterward.
1769	None	A strong hurricane struck near Williamsburg causing "inconceivable" damages to homes and crops. Many ships on the Chesapeake were damaged by storm winds and waves.
1806	Great Hurricane of 1806	A slow moving storm completed the creation of Willoughby Spit, damaged warships, and damaged a seawall.
1878	Gale of '78	A strong hurricane moved quickly from the Bahamas up the North Carolina Coast through the eastern portion of the state, completely submerging Cobb and Smith Islands in the Chesapeake Bay. (Middle Peninsula).
1933	Chesapeake-Potomac	Record high tides in many locations; approximately 9.8 feet above mean lower low water. There were four casualties on the Peninsula: two in Hampton, one in James City County, and one in York County. At Buckroe Beach in Hampton, and at Yorktown, martial law was declared and National Guard troops were brought in to prevent looting. Flooding was severe in low-lying parts of Hampton (Fox Hill and Buckroe), York County (Goodwin Neck), and Newport News (Small Boat Basin). Jamestown Island was severely damaged.
1933	Storm of '33	A strong storm struck the Chesapeake with a storm surge of 10 feet. Only 3 weeks later another storm struck with 88 mph winds and an 8.3 foot storm

[2] Virginia's Hurricane History. Virginia Department of Emergency Management. http://www.vaemergency.com/newsroom/history/hurricane.cfm

Year	System Name	Description
1954	Hurricane Hazel	Hurricane Hazel inflicted 130 mph winds on Hampton and blew apart at least one anemometer there. There was one casualty on the Peninsula in the Dare section of York County.
1955	Hurricanes Connie &Diane	Five days after Hurricane Connie, Diane made landfall in North Carolina as a Category 1 and moved North across Central Virginia. Five to ten inches of rain fell along the Blue Ridge Mountains. Hurricane Connie and Diane are attributed to the record rainfall in August of that year. Statewide damages totaled $1.5 million. Flooding impacts of Hurricane Diane are described in flooding (section 3.7).
1957	Nor'Easter	A Nor'easter brought extremely high tides to the Town of Wachapreague on the Eastern Shore up to four feet above normal. (Eastern Shore PDC
1969	Hurricane Camille	Hurricane Camille described earlier in the discussion on federally declared disasters (section 3.3) and in flooding (section 3.7).
1972	Tropical Storm Agnes	Tropical Storm Agnes is described earlier in the discussion on federally declared disasters (section 3.3) and in flooding (section 3.7).
1996	Hurricane Fran	Hurricane Fran described earlier in the discussion on federally declared disasters (section 3.3).
1998	Nor'easter	Much of the eastern portion of the state was affected by a slow moving Nor'easter. This storm caused severe coastal flooding in the Hampton Roads area and on the Eastern Shore. The causeway to Chincoteague Island was closed and the entire island was submerged under floodwaters. Several streets in Norfolk were closed due to over three feet of water, and at least one family in Gloucester County was rescued by rowboat. There were no reported injuries or fatalities, but damages were estimated at $75 million. (Eastern Shore HMP)
1999	Hurricane Floyd	Hurricane Floyd described earlier in the discussion on federally declared disasters (section 3.3).
2003	Hurricane Isabel	Hurricane Isabel described earlier in the discussion on federally declared disasters (section 3.3).
2004	Tropical Depression Gaston	Tropical Depression Gaston described earlier in the discussion on federally declared disasters (section 3.3).
2006	Nor'easter	A Nor'easter impacted the southeastern portion of the state causing minor flooding in the City of Chesapeake and the City of Hampton. The City of Franklin along the Blackwater River experienced their 2nd flood of record at 22.77 feet. This happened only 7 years after the city experienced their flood of record during Hurricane Floyd which crested at 26.27 feet, flood state is 12 feet.
2006	Tropical Storm Ernesto	Tropical Storm Ernesto described in the discussion of federally declared disasters (section 3.3).

Figure 3.8a-2: Tropical Cyclone Activity in Virginia 1851-2008



CGIT Center for Geospatial Information Technology

VIRGINIA DEPARTMENT OF EMERGENCY MANAGEMENT

DATA SOURCES:

NOAA Hurricane Tracks
VGIN Jurisdicational Boundaries
ESRI State Boundaries

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.

LEGEND:

Saffir-Simpson Hurricane Categories
- Tropical Depression (17-38 mph)
- Tropical Storm (39-73 mph)
- Category 1 (74-95 mph)
- Category 2 (96-110 mph)
- Category 3 (111-130 mph)

HAZARD IDENTIFICATION:

Map shows all the hurricane tracks in or around Virginia from 1851-2008.

NOAA provided the locations and categories of all hurricanes from 1851-2007. Data for 2008 is approximate and was obtained from Stormpulse.

Risk Assessment

FEMA's HAZUS hurricane model has been used to estimate annualized losses for the Commonwealth. The hurricane model was released in 2003 as part of a multi-hazard version of HAZUS. It allows users to estimate hurricane winds and potential damage and loss to residential, commercial, and industrial buildings. The model makes use of state of the art wind field models, calibrated and validated using full-scale hurricane data. Wind speed has been calculated as a function of central pressure, translation speed, and surface roughness. This revision of the Hazard Mitigation Plan utilizes only Level 1 analysis for the hurricane wind module. Level 1 analysis involves using the provided hazard and inventory data with no outside data collection. This is an acceptable level of information for mitigation planning; future versions of this plan can be enhanced with Level 2 and 3 analysis.

Development is continuing on the HAZUS hurricane model to add capability for estimating losses from storm surge, impacts to lifelines and agriculture, indirect economic losses, and improved performance in terms of speed and accuracy.[3]

Probability

Most office buildings are designed for a 50-year mean recurrence interval wind event (2% annual probability). Figure 3.8a-3 shows the basic design wind speed for the 50-year recurrence interval used for design and construction in Virginia, as defined by the American Society of Civil Engineers (ASCE). This map not only applies to windstorms, but also hurricane winds and tornado winds, as a basis for structural design based on potential wind loads.

ASCE 7 requires office buildings where more than 300 people congregate in one area to be designed for a 100-year mean recurrence interval wind event; therefore, these particular office buildings are designed to resist stronger, rarer storms than most office buildings.[4] Other office buildings that must be designed for a 100-year mean recurrence interval wind event include:

1. Buildings that will be used for hurricane or other emergency shelter
2. Buildings housing a day care center with capacity greater than 150 occupants
3. Buildings designated for emergency preparedness, communication, or emergency operation center or response

[3] National Institute of Building Sciences (NIBS) HAZUS Wind Methodology www.nibs.org/hazusweb/methodology/wind.php

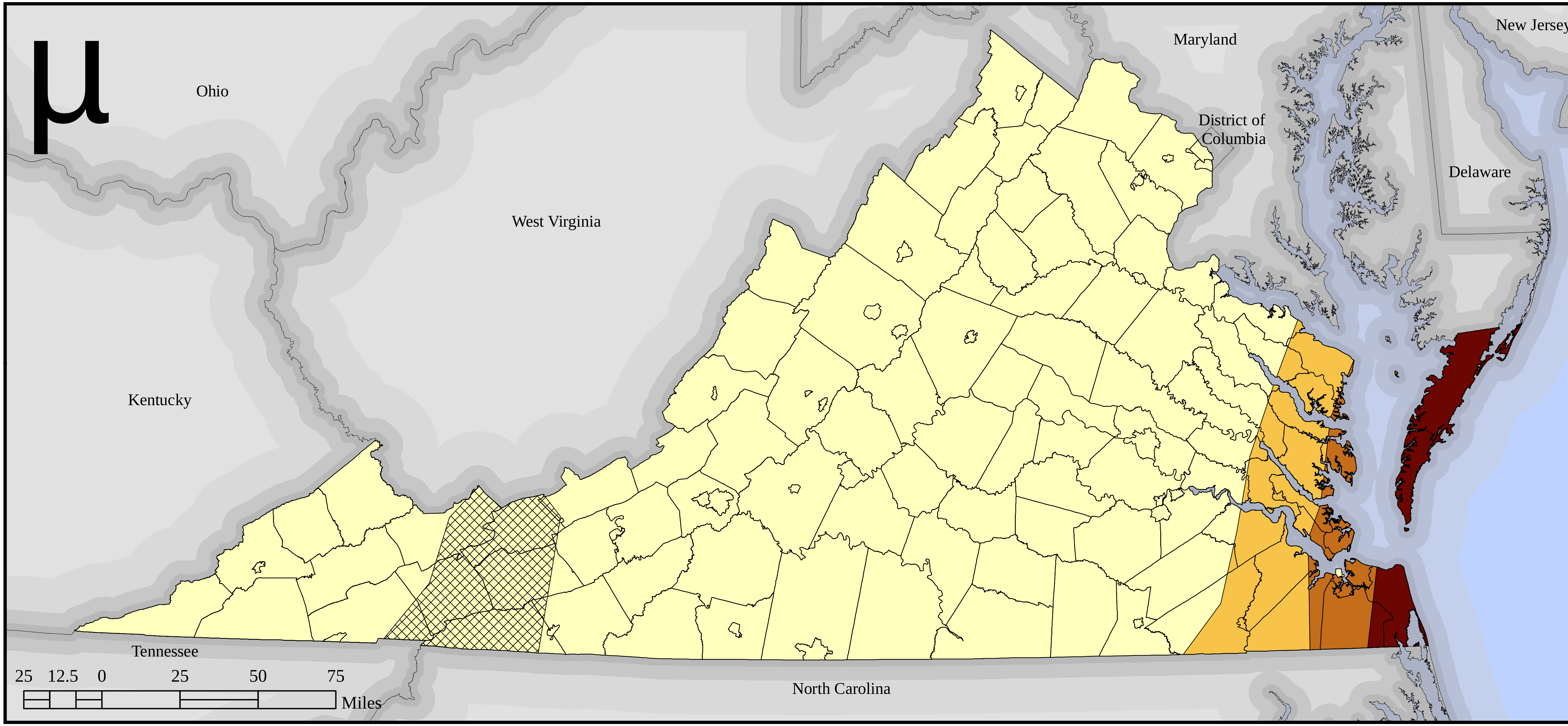
[4] Whole Building Design Guide (WBDG) Wind Safety of the Building Envelop by Tom Smith 5/26/2008

4. Buildings housing critical national defense functions

5. Buildings containing sufficient quantities of hazardous materials

In the 2003 version of the HMP, the wind design map from *ASCE 7-98* (Figure 3-8a-3) was used to determine the maximum 50-yr wind speed for each jurisdiction. Analysis for this revision of the HMP uses the HAZUS 100-year recurrence interval for peak wind gust. Geographic extent has been based off of these values for determining risk and ranking. This represents the wind peak gusts that have a 1% annual probability of occurrence. The 1% annual probability wind speeds is the estimated 3-second gusts in open terrain at 10m above ground at the centroid of each census tract.

Figure 3.8a-3 ASCE Design Wind Speeds



DATA SOURCES:

ASCE 7-98 Design Wind Speeds
VGIN Jurisdictional Boundaries
ESRI State Boundaries

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

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LEGEND:

Wind Speeds for 3-Second Gust

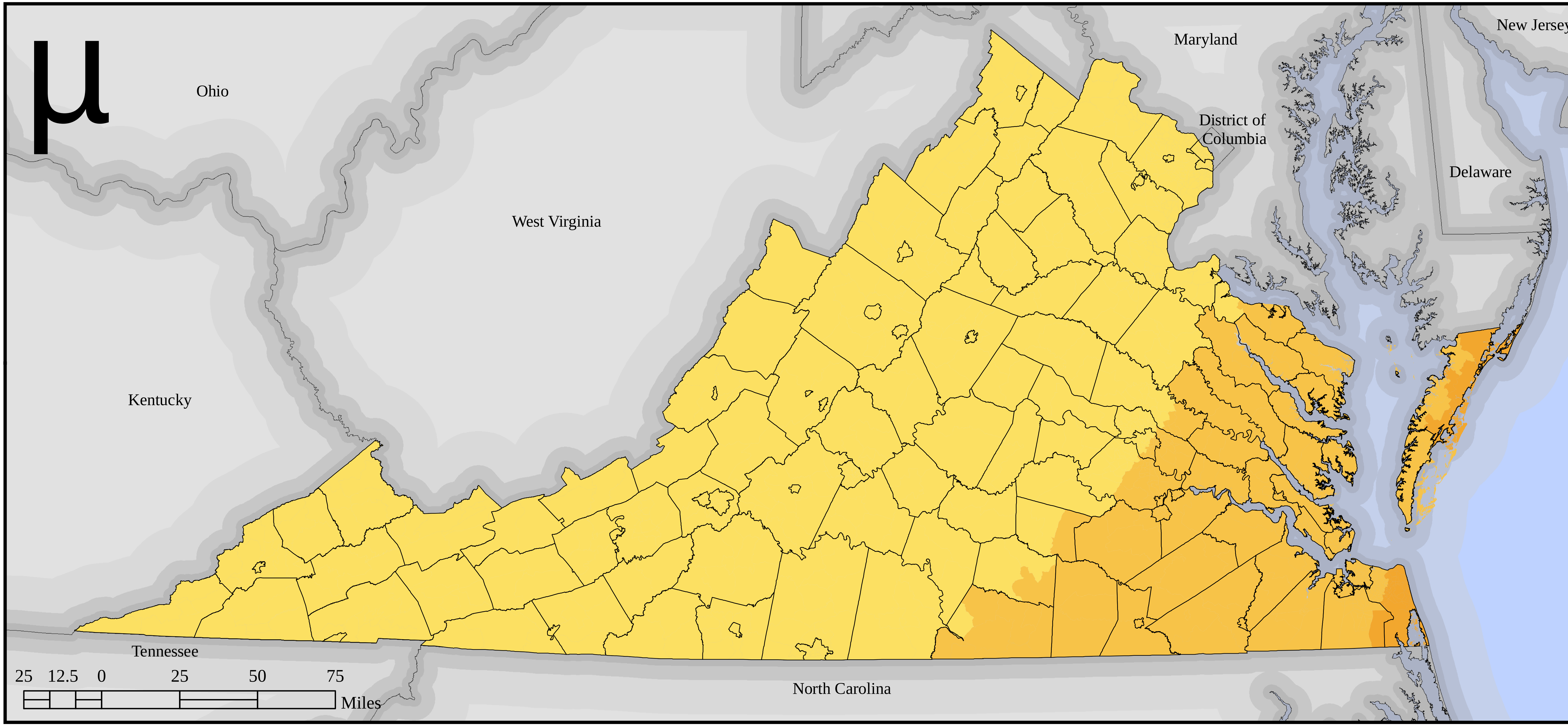
- < 90 mph
- 90-100
- 100-120
- > 120 mph
- Special Wind Region

HAZARD IDENTIFICATION:

ASCE basic wind speeds are based on nominal design 3-second gust wind speeds in miles per hour (m/s) at 33 feet (10m) above ground for the 50-year recurrence interval (2% annual probability). Values have been determined by localized research using approved probabilistic methods.

Special Wind Regions are areas of unusual wind conditions.

Figure 3.8a-4: HAZUS 100-Year Wind Speeds



DATA SOURCES:

HAZUS-MH MR3 Wind Model
VGIN Jurisdictional Boundaries
ESRI State Boundaries

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.

LEGEND:

3-Second Peak Gust Wind Speed (mph)

- 0 - 38 (Tropical Depression)
- 39 - 73 (Tropical Storm)
- 74 - 95 (Category 1)
- 96 - 110 (Category 2)
- 111 - 130 (Category 3)
- 131 - 155 (Category 4)
- > 156 (Category 5)

HAZARD IDENTIFICATION:

HAZUS-MH Hurricane Wind Model makes use of an existing state-of-the-art windfield model, which has been calibrated and validated using full-scale hurricane data. The model calculates wind speed as a function of central pressure, translation speed, and surface roughness.

Impact & Vulnerability

Vulnerability and impact have been measured in terms of population and property for hurricane winds using 2000 Census Tract information. Table 3.8a-1 in the Hurricane Description section illustrates the potential injuries and damages to property based on different hurricane category events.

The flooding and high winds associated with hurricanes may also disrupt the distribution of gasoline, kerosene, diesel fuel, fuel oils, propane and other petroleum products. This disruption could cause major problems for organizations and businesses that rely on such supplies. Additionally, such a disruption could affect backup power generation.

Risk

Hurricane risk to state facilities and critical facilities is based on the wind speed values from the HAZUS 100-year peak gust wind speeds. All of the wind speeds are sustained wind speeds over land at a height of 10 meters above the ground surface. After the average wind speed was calculated for each state facility and critical facility, they were assigned a value of 1 through 4 based on the Storm Class values used in the Benefit Cost Analysis (BCA) toolkit (Table 3.8a-3). Each storm class corresponds to a designated wind speed in miles per hour. The windstorm classes are defined in accordance with the National Weather Service hurricane Storm Classes 1 through 5 with the addition of Storm Class 0 for tropical storm wind speeds. Storm class values 0 through 4 were used to represent risk in Virginia; jurisdictions likely to experience a Category 2 or greater were assigned a high risk. Table 3.8a-4 shows the four risk categories and associated wind speeds used for the analysis in this plan.

Table 3.8a- 3: BCA storm class values for hurricane module.

Storm Class	Wind Speed (mph)
0	60-73
1	74-95
2	96-110
3	111-130
4	131-155
5	>155

Table 3.8a- 4: Wind risk categories used for determining risk and ranking hazards.

Hurricane Risk	Wind Speed (mph)	Category
Low	≤ 59.9	High Wind
Medium-Low	60.0-73.9	Tropical Storm
Medium- High	74.0-94.9	Category 1 Hurricane
High	≥ 95.0	Category 2+

State Facility Risk

Approximately 60% of the mapped state facility locations are in a medium-low risk zone which is equivalent to experiencing 60.0-73.9 mph winds. Only 2.6% of the state facilities are located in the high hurricane risk category, which accounts for less than 1% of the total building value for all state facilities. Table 3.8a-5 shows the distribution of state facilities and building value by hurricane risk zone. The count in each risk zone is a result of the GIS intersection of the wind categories with the state facilities. Risk from non-rotational wind should be examined cumulatively since the areas that experience the category 2+ events can also experience all of the other events (high wind, tropical storm, and category 1). Annualized loss estimates were not calculated for individual structures as a result of the lack of detailed facilities information available. Building value at risk has been provided for reference.

Table 3.8a- 5: Non-rotational wind risk to state facilities.

Hurricane Risk	Number of State Facilities		Building Value at Risk*	
	Count in Risk Zone	Cumulative Count in Risk Zone	Value in Risk Zone	Cumulative Value in Risk Zone
Low	1,096	1,096	$1,624,510,108	$1,624,510,108
Medium-Low	5,367	6,463	$10,169,791,325	$11,794,301,433
Medium-High	2,252	8,715	$3,929,957,059	$15,724,258,492
High	236	8,951	$136,542,955	$15,860,801,447
Total	**8,951**		**$15,860,801,447**	
**Building values for all facilities not available. Building values at risk is based on what was available from VAPS.*				

The 236 buildings that were considered to be at high risk for wind can be broken up into 23 state agencies. All of the agencies in high wind risk are listed below in Table 3.8a-6. These state facilities are in wind speeds zone greater than 95 mph; hurricane risk is cumulative and therefore these structures are vulnerable to all of the categories that are outlined in Table 3.4a-4.

Table 3.8a- 6: State facilities in located in high wind risk by building value.

Agency Name	Number of Buildings in High Hazard	Building Value in High Hazard*
St. Brides Correctional Center	14	$43,045,939
Tidewater Community College	13	$35,480,716
Indian Creek Correctional Center	31	$21,004,136
Old Dominion University	1	$17,550,320
Department of Conservation and Recreation	79	$6,044,925
Department of Military Affairs	1	$3,927,859
Department of Motor Vehicles	5	$2,700,272
VA Institute of Marine Science	19	$2,500,563
Virginia Polytechnic Inst. and State University	11	$1,743,862
Department of Transportation	24	$905,079
Department of Health	4	$564,578
Environmental Service Unity	5	$371,584
Department of Game and Inland Fisheries	7	$316,663
Public Defender Commission	1	$214,624
Department of Agriculture & Consumer Services	1	$129,813
P & P District 004	2	$42,022
Court of Appeals of Virginia	1	Not Available
Department of Alcoholic Beverage Control	11	Not Available
Department of Correctional Education	1	Not Available
Department of Rehabilitative Service	1	Not Available
Department of Veterans Services	1	Not Available
Marine Resources Commission	2	Not Available
Norfolk State University	1	Not Available
Total	**236**	**$136,542,955**
**Building values for all facilities not available. Building values at risk is based on what was available from VAPS.*		

Critical Facility Risk

Similar to state facilities, the majority of critical facilities are located in the medium-low risk zone which is equivalent to experiencing 60.0 – 73.9 mph winds. Approximately three-quarters of the critical facilities are located within low or medium-low hazard risk areas. Table 3.8a-7 below shows the distribution of critical facilities in the four wind risk areas. Similar to state facility risk, critical facility building counts in each of the hazard zones is shown as a cumulative risk. Annualized loss estimates were not calculated for individual structures as a result of the lack of detailed facilities information available. Building value at risk has been provided for reference.

Table 3.8a- 7: Critical facility locations within mapped surge zones.

Wind Risk	Law Enforcement	Fire Station	Hospital	Nursing Home	School	EOC
Low	111	104	22	40	1,009	30
Medium-Low	390	335	94	196	3,469	107
Medium-High	534	425	129	271	4,424	144
High	542	437	130	279	4,475	147

Jurisdictional Risk

Annualized loss was calculated using HAZUS-MH in September 2005 for a special VDEM initiative. Separate runs were conducted for each jurisdiction in the Commonwealth. These results have been included as part of this report.

Probabilistic results represent a range of probable losses estimated from a 100,000-year simulation of expected hurricane activity. The results are based solely on the total direct losses for the entire study region. This ensures that all of the results for a given period come from the same simulated event. Annualized losses are simply the total losses summed over the entire simulation period divided by 100,000 years. Annualized losses are very useful for comparing loss estimates from different locations or comparing the risks posed by different hazards at a single location.

The Commonwealth can expect **$85,434,542** in total annualized damages estimated in HAZUS-MH. The coastal cities of Virginia Beach, Norfolk, Chesapeake, and Hampton all can expect $5 million to $24 million in annualized damages. Damages range dramatically by jurisdiction. Communities in Southwest Virginia can expect less than $15,000 in annualized damages due to hurricane winds and Coastal Virginia can expect millions of dollars in annualized damages (Figure 3.8a-4). Table 3.8a-8 shows the jurisdiction specific annualized loss results.

Table 3.8a- 8: HAZUS-MH hurricane wind annualized loss.

Hurricane Wind Annualized Loss Brackets			
> $5 Million			
City of Virginia Beach	$24,102,248	City of Chesapeake	$7,410,421
City of Norfolk	$10,362,739	City of Hampton	$5,569,092
$1 Million - $4.9 Million			
City of Newport News	$4,733,236	Chesterfield County	$1,449,077
Accomack County	$4,659,599	Henrico County	$1,434,764
City of Portsmouth	$3,644,431	Northampton County	$1,080,411
Fairfax County	$3,638,641	City of Richmond	$1,067,476
York County	$1,593,685	James City County	$1,051,364
City of Suffolk	$1,462,958		
$150,000 - $999,999			
Arlington County	$924,216	Prince George County	$265,861
Prince William County	$818,986	City of Petersburg	$262,710
Gloucester County	$682,146	Lancaster County	$256,976
City of Alexandria	$612,862	Middlesex County	$248,023
Isle of Wight County	$582,251	Spotsylvania County	$221,430
City of Poquoson	$442,115	Westmoreland County	$208,536
Hanover County	$397,627	City of Hopewell	$187,701
Loudoun County	$348,012	Mecklenburg County	$174,552
Stafford County	$337,110	City of Williamsburg	$170,995
Mathews County	$291,515	Southampton County	$170,082
Northumberland County	$285,958	City of Colonial Heights	$169,757
$50, 000 - $149,999			
Pittsylvania County	$139,921	Charles City County	$77,257
Dinwiddie County	$138,195	Roanoke County	$75,743
City of Danville	$134,397	Henry County	$71,692
King William County	$133,582	King and Queen County	$69,912
New Kent County	$130,226	Bedford County	$69,883
Albemarle County	$123,300	Campbell County	$68,706
King George County	$116,866	Powhatan County	$61,760
Essex County	$115,349	City of Fredericksburg	$61,168
Halifax County	$110,409	Carroll County	$59,637
City of Franklin	$104,897	Nottoway County	$59,214
Fauquier County	$104,851	City of Fairfax	$59,069
Richmond County	$96,934	Franklin County	$56,149
City of Manassas	$95,223	Goochland County	$56,055
Surry County	$89,689	Greensville County	$54,545
Sussex County	$88,211	City of Falls Church	$53,826
City of Lynchburg	$88,011	City of Charlottesville	$51,908

Hurricane Wind Annualized Loss Brackets			
$50, 000 - $149,999			
City of Roanoke	$84,723	Lunenburg County	$50,981
Brunswick County	$81,568		

$20,000 - $49,999			
Culpeper County	$48,869	Amherst County	$31,405
Orange County	$46,852	Washington County	$28,206
Amelia County	$41,947	Fluvanna County	$27,355
Prince Edward County	$39,644	Cumberland County	$24,302
Caroline County	$39,104	Buckingham County	$23,423
Louisa County	$38,923	City of Martinsville	$22,620
Montgomery County	$36,751	Floyd County	$22,171
Augusta County	$35,881	Frederick County	$21,690
Charlotte County	$34,668	Appomattox County	$20,543
Rockingham County	$32,805	City of Manassas Park	$20,534
City of Emporia	$32,263		

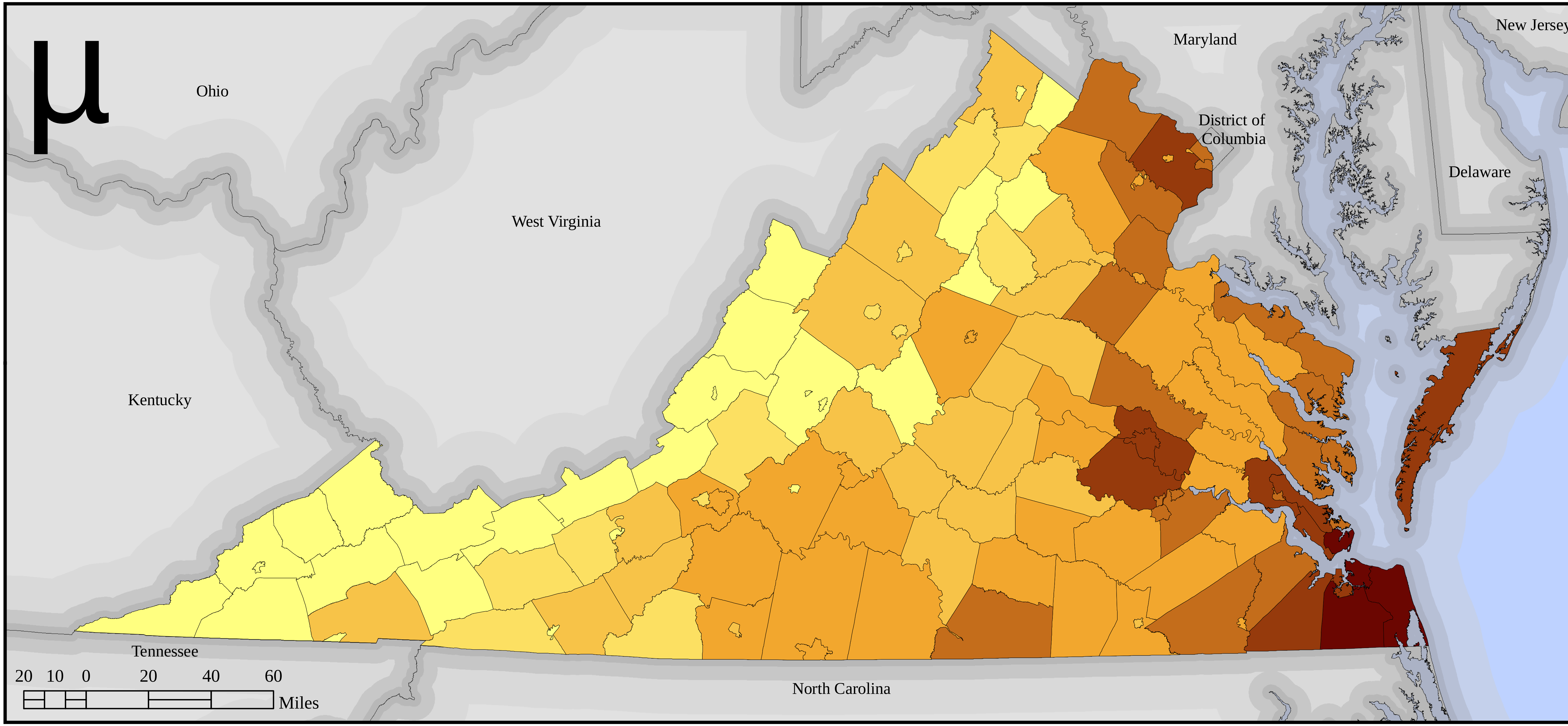
$15,000 - $19,999			
Pulaski County	$19,757	City of Salem	$17,421
Warren County	$19,179	Wythe County	$16,887
Botetourt County	$18,761	Shenandoah County	$16,229
Patrick County	$18,296	City of Staunton	$16,124
City of Harrisonburg	$17,794	City of Waynesboro	$15,724
Grayson County	$17,758	Madison County	$15,167

> $14,999			
City of Winchester	$13,581	Lee County	$5,578
Tazewell County	$13,554	Scott County	$5,550
Greene County	$13,509	City of Bristol	$5,491
Nelson County	$13,428	Alleghany County	$5,367
Smyth County	$12,219	City of Lexington	$5,364
Rockbridge County	$11,373	Buchanan County	$4,414
Page County	$10,132	City of Covington	$3,378
Rappahannock County	$9,890	City of Buena Vista	$3,078
Clarke County	$9,383	Bland County	$2,636
Giles County	$8,889	Bath County	$2,523
City of Bedford	$8,232	Dickenson County	$2,377
City of Galax	$8,154	Craig County	$2,114
Wise County	$6,375	Highland County	$1,041
Russell County	$6,308	City of Norton	$597
City of Radford	$5,689		

Annualized damages were also calculated based on NCDC crop and property damages; the Commonwealth can expect approximately **$55,390,380** in damages per year from non-rotational wind events. NCDC annualized damages have been calculated by taking the total damages per jurisdiction and dividing by the period of record. Multiple factors account for the differences in the two annualized loss values. While NCDC's data is based on reported estimates, the HAZUS results are based on a highly developed model using census tract data and estimates of hurricane winds to come up with potential damage. HAZUS total direct economic loss includes damage to structural, non-structural, building contents, inventory loss, relocation, income loss, rental loss and wage loss.

Figure 3.8a-5 shows the hazard rank for non-rotational winds (primarily hurricane and tropical weather patterns, although thunderstorm winds are also included). Most of the state is at high risk for non-rotational winds, although the extreme western part of the state is at relatively lower risk. High wind events before 1989 have not been included as they would skew the record due to reasons described in Section 3.5. This ranking, based on NCDC records, does not distinguish winds resulting from tropical and non-tropical weather systems. In addition, some of the impacts in the NCDC records may have been coded as hurricane (and included in this wind section), but may be more directly related to secondary impacts of hurricanes (such as flooding). However, sorting these damages out would be very difficult given the available information.

Figure 3.8a-5: Hurricane Probabilistic Annualized Loss (HAZUS)



DATA SOURCES:

CGIT 2005 HAZUS-MH runs
VGIN Jurisdictional Boundaries
ESRI State Boundaries

LEGEND:

Annualized Loss by County

- < $15,000
- $15,000 - $20,000
- $20,000 - $50,000
- $50,000 - $150,000
- $150,000 - $1 Million
- $1 Million - $5 Million
- > $5 Million

RISK ASSESSMENT:

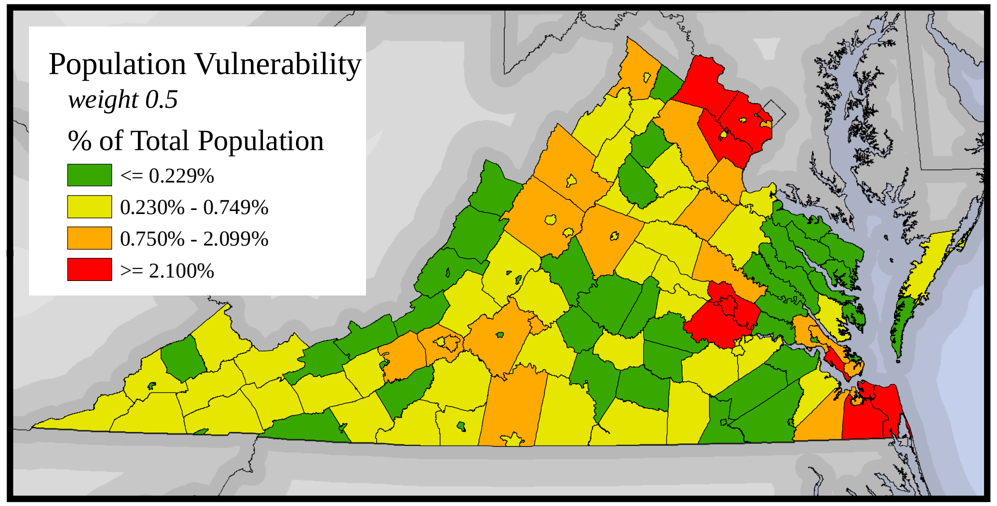
Probabilistic Annualized Loss was calculated by HAZUS-MH using the probabilistic s enario. Annualized loss is defined as the expected value of loss in any one year, and is developed by aggregating the losses and their exceedance probabilities.

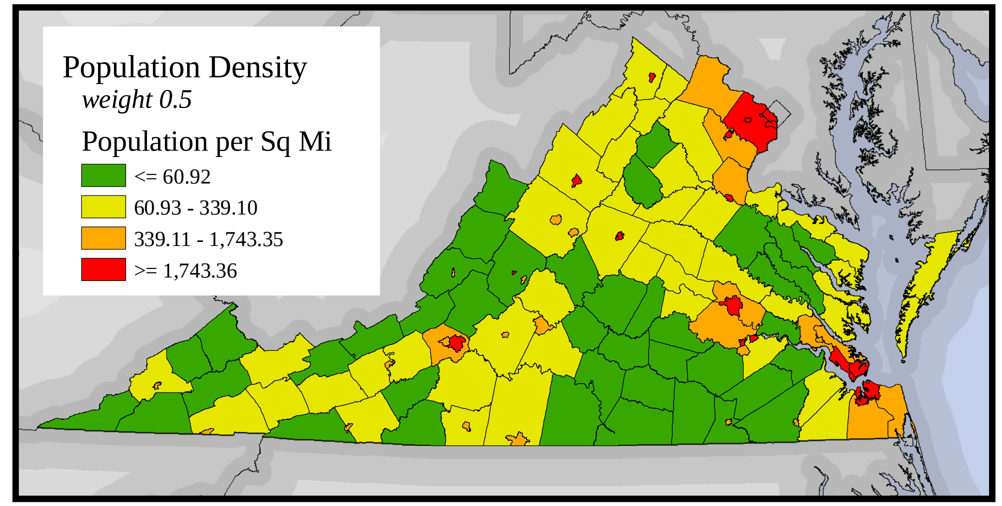
Total Direct Economic Loss includes: Damage to Structural , Non-Structural, Building, Contents, Inventory Loss, Relocation, Income Loss, Rental Loss and Wage Loss.

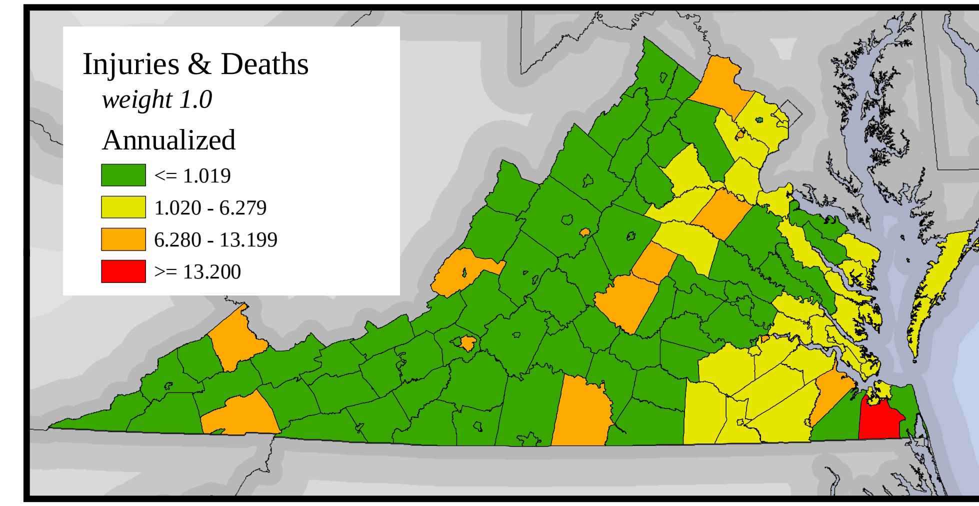
PROJECTION: *VA Lambert Conformal Conic*
North American Datum 1983

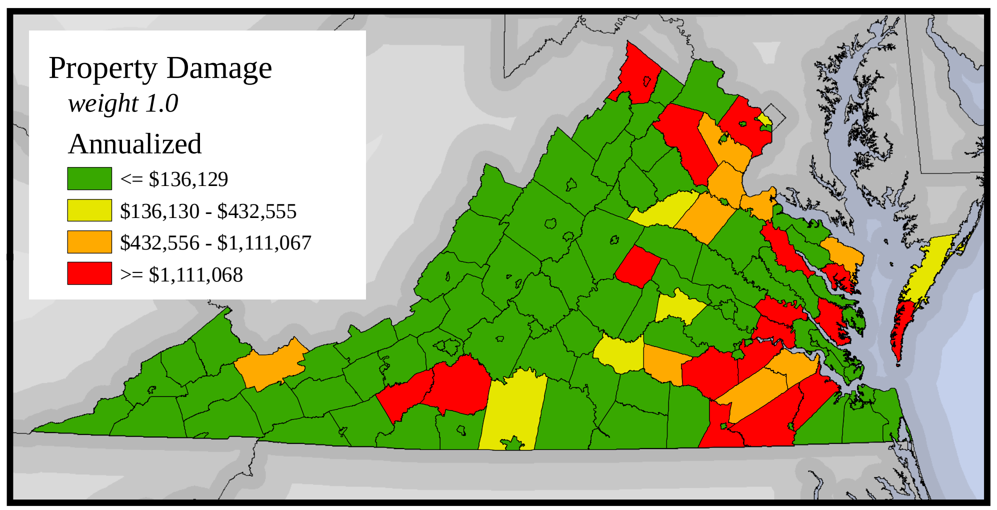
DISCLAIMER: Majority of available hazard data is intended to be used at national or regional scales. The purpose of the data sets are to give general indication of areas that may be susceptible to hazards. In order to identify potential risk in the Commonwealth available data has been used beyond the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

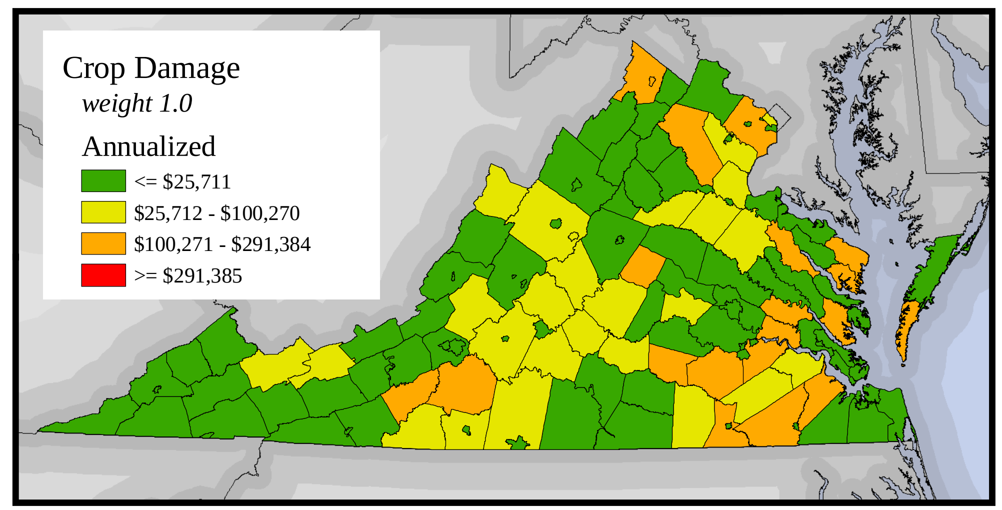
Figure 3.8a-6: Non-Rot Wind Hazard Ranking Parameters and Risk Map

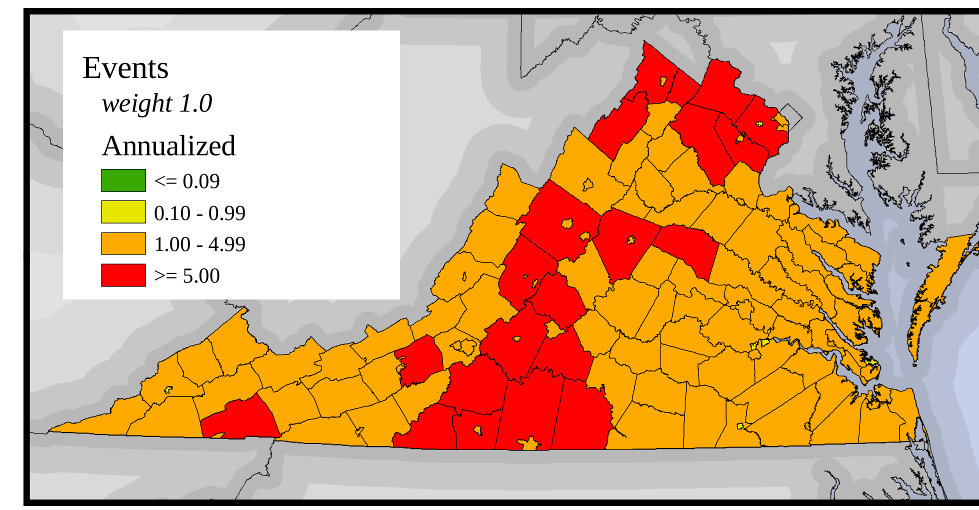


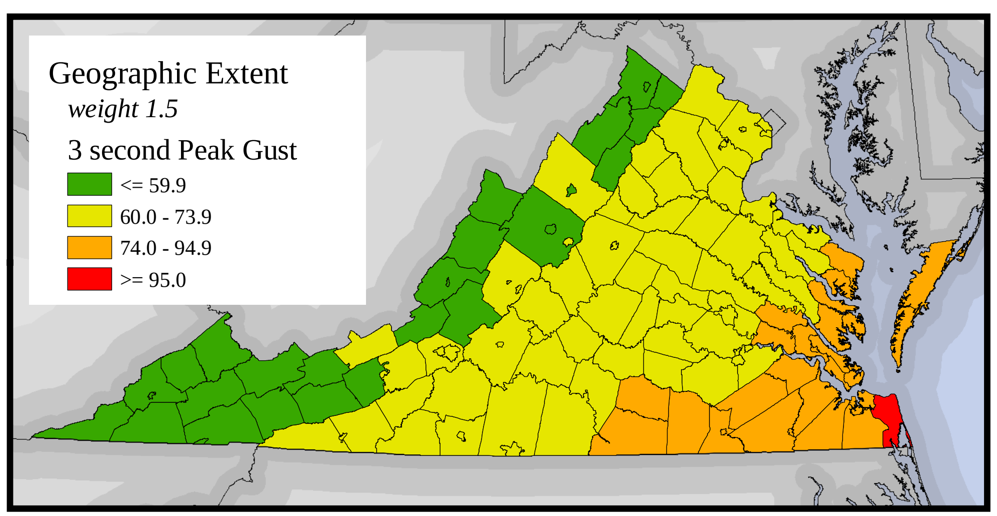


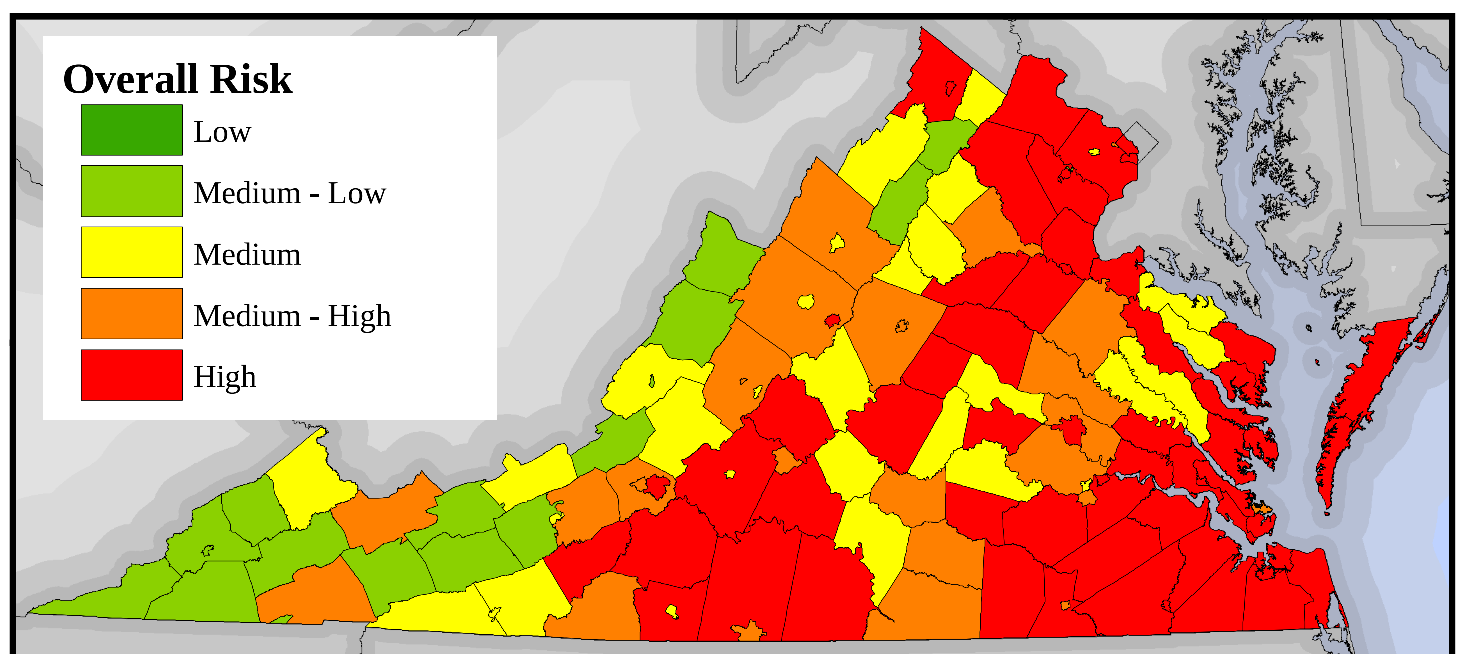












HAZARD RANKING:

A number of factors have been considered in this risk assessment to be able to compare between jurisdictions and hazards. The factors have been added together to come up with the overall total ranking for each hazard.
Some factors were weighted based on imput from the HIRA sub-committee.

Section 3.5 explains each of the factors in detail.

Factors & Weighting Include:

- Population Vulnerability & Density 0.5 weighting
- Injuries & Deaths 1.0 weighting
- Crop & Property Damage 1.0 weighting
- Annualized Events 1.0 weighting
- Geographic Extent 1.5 weighting

DATA SOURCES:

CGIT Ranking Methodology
VGIN Jurisdictional Boundaries
ESRI State Boundaries

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

μ

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.

Local Plan Risk Assessment

Each of the twenty-seven local plans were reviewed and summarized based on methodology and results for their non-rotational wind analysis. Each plan varied based on the type of data available and analysis methodology. Techniques for assessing wind risk in the local plans included one or more of the following methods:

- FEMA HAZUS-MH
- NCDC statistics
- FEMA Wind Benefit-Coast Module to determine percent of buildings constructed before and after adoption of local building codes
- ASCE Wind Design Speeds
- Referenced Virginia Hurricane Evacuation Study

Nineteen of the twenty-seven local plans utilized HAZUS-MH for hurricane wind analysis in some fashion. Three of the nineteen plans did not complete probabilistic runs to develop annualized loss estimates. One of the three plans used the tools to determine present day losses based on several historical hurricane tracks that had significant damage in their region. Two of the three plans provided tables for the value of exposed structures and the number of structures in each of the damage classifications, by return period.

Eight plans did not use HAZUS-MH for hurricane wind analysis. A couple of these plans developed specific return-period estimates using the FEMA Coastal Construction Manual or the BCA toolkit. The analysis of these results is quite varied and has not been annualized. Six of these eight plans did not complete hurricane specific analysis for their regions.

As discussed in section 3.6 and above, local plan hazard analysis and loss estimations vary considerably. The definition of what is considered a wind hazard also varies and should be evaluated for consistencies in future plans. Table 3.8a-9 and Figure 3.6-2 (section 3.6) shows the summary of the local plans that provided annualized flood losses. None of the annualized loss values for the local plan are the same as the values calculated for this revision. The difference can result from different types of HAZUS-MH scenarios completed and study area selected for the model run. In most cases, the statewide methodology (completed in 2005) resulted in conservative annualized loss estimates when compared to the local plan estimates.

Table 3.8a- 9: Comparison of local and statewide annualized loss.

PDC/Jurisdiction	Annualized Hurricane Wind	
	Local Plan	2009 Statewide
Southside Hampton Roads	$33,546,000	$53,272,999
Northern Virginia RC	$33,723,000	$6,571,369
Richmond Regional PDC	$13,889,700	$3,225,165
Crater PDC	$27,093,020	$2,738,009
Northern Neck PDC	$4,820,740	$848,404
West Piedmont PDC	$4,835,928	$443,075
Region 2000 LGC	$1,421,500	$286,780
Commonwealth RC (Virginia's Heartland)	$698,000	$232,232
Rappahannock-Rapidan RC	$1,050,000	$225,629
Southampton County	$480,390	$170,082
Central Shenandoah PDC	$1,095,990	$141,707
City of Franklin	$341,000	$104,897
Northern Shenandoah Valley RC	$815,887	$90,194

Comparison with Local Ranking

Eleven of the twenty-seven regional and local hazard mitigation plans ranked hurricane related winds as a high hazard; ten of those plans also ranked general wind as high. Only four localities ranked general wind as low and five as low for hurricane wind, resulting in a local plan average of medium for general wind and medium-high for hurricane wind. The 2010 statewide analysis has ranked non-rotational wind as a medium-high hazard. Section 3.6 (Table 3.6-2) includes the complete ranking of all the local plans.

Changes in Development

The majority of local plans did not specifically address changes in development for each hazard or the effects of changes in development on loss estimates. In most cases overall development patterns were discussed in general. Seventeen of the twenty-seven local plans cite their comprehensive plans for current and future land use changes (section 3.2). Some of the coastal communities discussed development of residential structures in high hazard areas and the need to evaluate engineering practices before development or elevation occurs.

Table 3.8a-10: EMAP Analysis

Subject	Detrimental Impacts
Health and Safety of Public	Localized impact expected to be severe to extensive for event areas and minor for other adversely affected areas.
Health and Safety of Response Personnel	Localized impacts expected to be minor unless the response personnel live within the impacted area.
Continuity of Operations	Damage to facilities/personnel in the area of the event may require temporary relocation of some operations.
Property, Facilities, and Infrastructure	Depending on the magnitude of the event, localized impact to facilities, residential properties, and infrastructure in the area of the event could be extensive.
Delivery of Services	Localized disruption of roads, facilities, communications and/or utilities caused by the event may postpone the delivery of some services.
The Environment	Localized impacts expected to be moderate, including uprooted trees and widespread debris which may include HAZMAT.
Economic and Financial Condition	Local economy and finances adversely impacted, possibly for a prolonged period of time.
Public Confidence in the Jurisdiction's Governance	Ability to respond and recover may be questioned and challenged if planning, response, and recovery time is not sufficient.

**Table was modeled from the Missouri State Hazard Mitigation Plan*