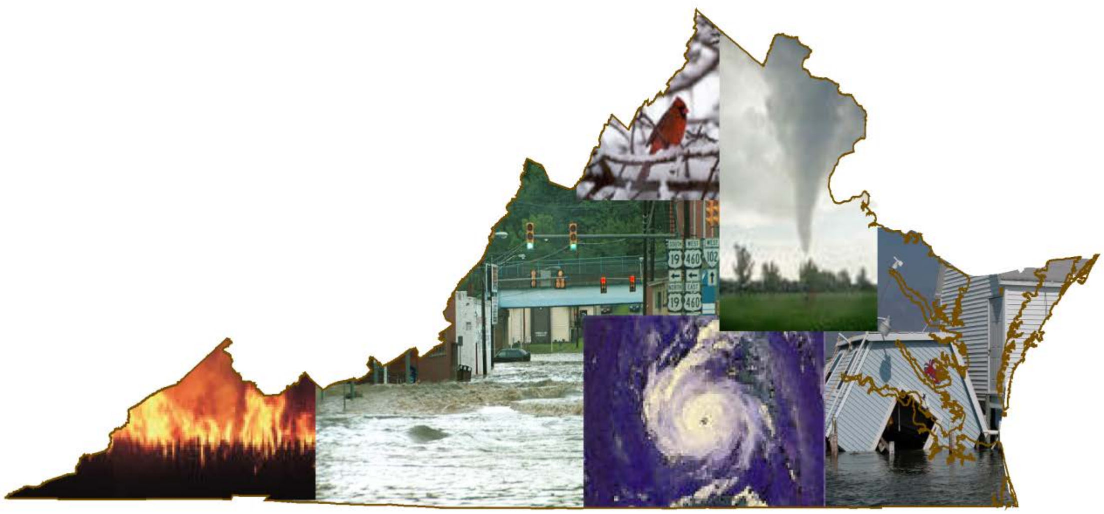
COMMONWEALTH OF VIRGINIA

Hazard Mitigation Plan



Chapter 3
Hazard Identification and Risk Assessment (HIRA)

Appendix 3.8a – Non-Rotational Winds

SECTION 3.8a

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Section 3.8a: Non-Rotational Winds

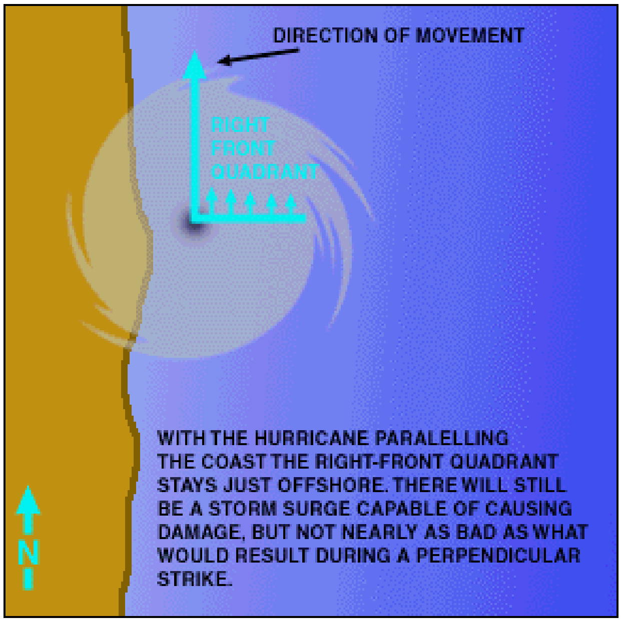
Description

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 as it contains the strongest winds. 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	Very dangerous winds will produce some damage: Well-constructed frame homes could have damage to roof, shingles, vinyl siding and gutters. Large branches of trees will snap and shallowly rooted trees may be toppled. Extensive damage to power lines and poles likely will result in power outages that could last a few to several days.	Chesapeake-Potomac Hurricane of 1933 Hurricane Hazel (10/15/1954) Hurricane Charley (9/17/1986 Hurricane Bonnie (8/27/1998)* Hurricane Irene (8/27/2011)*
2	96 – 110 83-95 kt 154-177 km/hr	Moderate	Extremely dangerous winds will cause extensive damage: Well-constructed frame homes could sustain major roof and siding damage. Many shallowly rooted trees will be snapped or uprooted and block numerous roads. Near-total power loss is expected with outages that could last from several days to weeks.	The Great Hurricane (9/14/1944) Hurricane Donna (9/12/1960) Hurricane Gloria (9/27/1985)
3 (major)	111 – 129 mph 96 - 112 kt 178 - 208 km/hr	Extensive	Devastating damage will occur: Well-built framed homes may incur major damage or removal of roof decking and gable ends. Many trees will be snapped or uprooted, blocking numerous roads. Electricity and water will be unavailable for several days to weeks after the storm passes.	
4 (major)	130 – 156 mph 113-136 kt 209-251 km/hr	Extreme	Catastrophic damage will occur: Well-built framed homes can sustain severe damage with loss of most of the roof structure and/or some exterior walls. Most trees will be snapped or uprooted and power poles downed. Fallen trees and power poles will isolate residential areas. Power outages will last weeks to possibly months. Most of the area will be uninhabitable for weeks or months.	
5 (major)	> 157 mph > 137 kt >252 km/hr	Catastrophic	Catastrophic damage will occur: A high percentage of framed homes will be destroyed, with total roof failure and wall collapse. Fallen trees and power poles will isolate residential areas. Power outages will last for weeks to possibly months. Most of the area will be uninhabitable for weeks or months.	*Meteorologists consider the water off the Virginia coast too cool to support a Category 5 storm.*

Other non-rotational wind events include severe thunderstorms, wind storms, and derechos. A derecho is a widespread straight-line windstorm linked to a band of severe thunderstorms. Derechos are mainly a warm-weather phenomenon, occurring mostly in June and July in the Northern Hemisphere. Derechos are a thunderstorm complex, producing a band of winds at least 240 miles in length with wind speeds of at least 58 mph or greater along most of its length[2]. Derechos can produce damage comparable to tornados.

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 non-rotational wind events that have historically affected Virginia. Federally declared hurricane and other non-rotational wind 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.

Figure 3.8a-3 shows Hurricane Hazel and Figure 3.8a-4 shows Hurricane Camille to provide examples of historical hurricane events that affected Virginia. These figures identify the main path of the storms and the peak windspeeds that jurisdictions may have experienced at that time. Hazus MH-2.1 was used to simulate this historical occurrence.

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.[3]

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[2] National Weather Service. Storm Prediction Center. "About Derechos." http://www.spc.noaa.gov/misc/AbtDerechos/derechofacts.htm

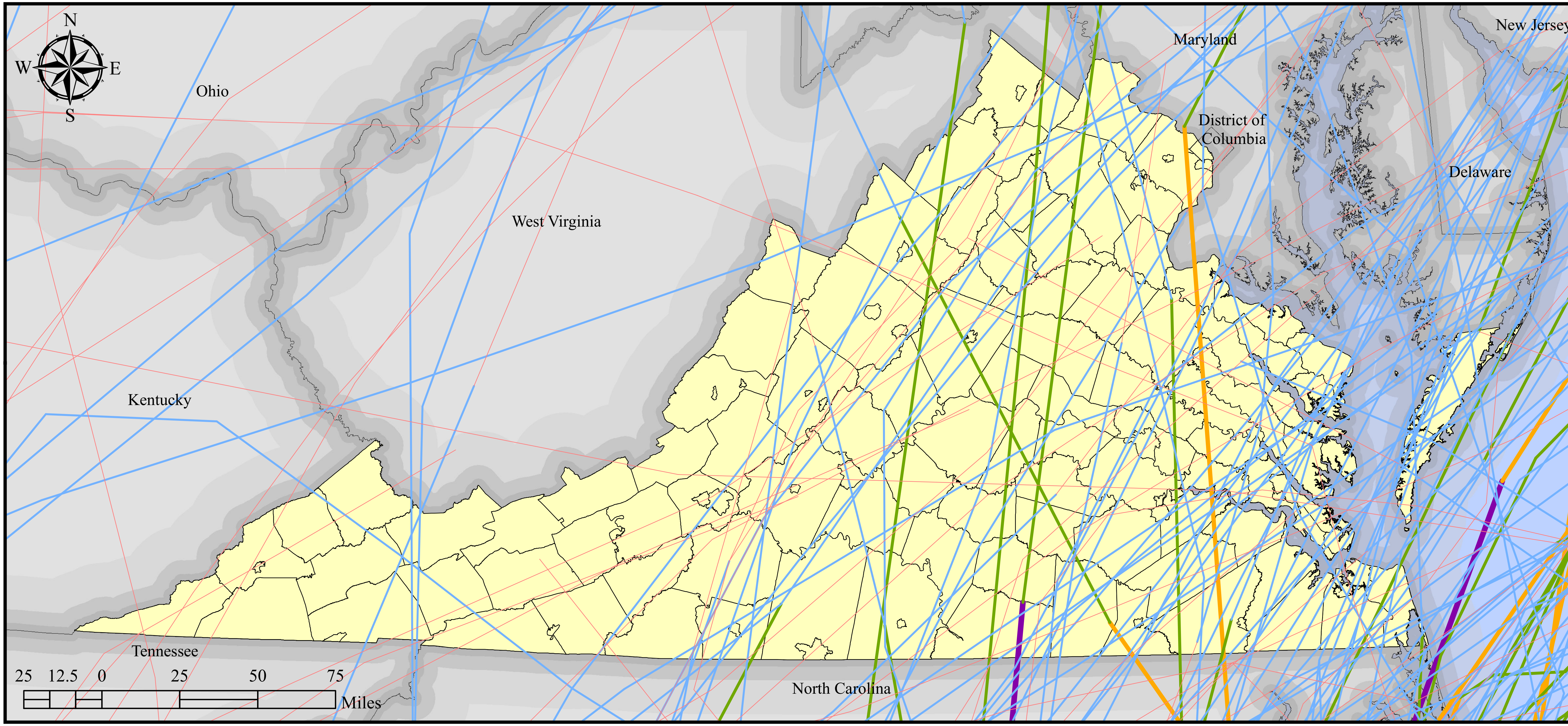
[3] Virginia's Hurricane History. Virginia Department of Emergency Management. http://www.vaemergency.com/newsroom/history/hurricane.cfm

Table 3.8a-2: Historical Hurricanes and other Non-Rotational Wind Events (1749-2012)

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 Storm of ‘33	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.
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. (See Figure 3.8a-3)
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). (See Figure 3.8a-4)
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)

Year	System Name	Description
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).
2009	Nor'easter and Remnants of Tropical Depression Ida	Nor'easter and remnants of Tropical Depression Ida described in the discussion of federally declared disasters (section 3.3).
2011	Hurricane Irene	Hurricane Irene described in the discussion of federally declared disasters (section 3.3).
2011	Remnants of Tropical Storm Lee	Tropical Storm Lee described in the discussion of federally declared disasters (section 3.3).
2012	Derecho	Derecho described in the discussion of federally declared disasters (section 3.3).

Figure 3.8a-2: Tropical Cyclone Activity in Virginia 1851-2010



CGIT Center for Geospatial Information Technology

VIRGINIA DEPARTMENT OF EMERGENCY MANAGEMENT

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

DATA SOURCES:

NOAA Hurricane Tracks
VGIN Jurisdictional Boundaries
ESRI State Boundaries

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)

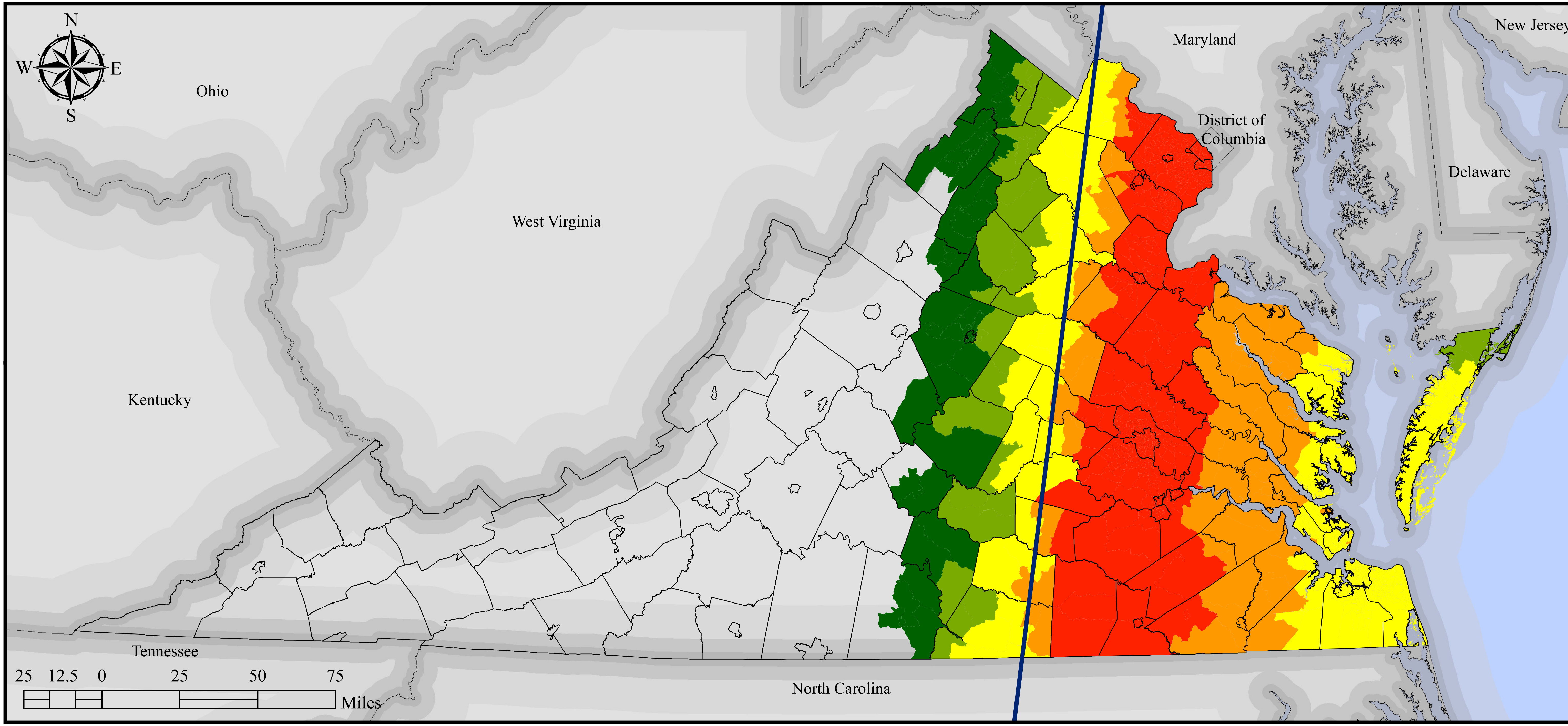
HAZARD IDENTIFICATION:

Map shows all the hurricane tracks in or around Virginia from 1851-2010.

NOAA provided the locations and categories of all hurricanes from 1851-2010. Data for 2008 is approximate and was obtained from Stormpulse.

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-3: Historical Occurrence: Hurricane Hazel (1954)



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VIRGINIA DEPARTMENT OF EMERGENCY MANAGEMENT

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

DATA SOURCES:

HAZUS-MH 2.1 Wind Model
VGIN Jurisdictional Boundaries
ESRI State Boundaries

LEGEND:

Hazel StormTrack

Peak Gust Windspeeds

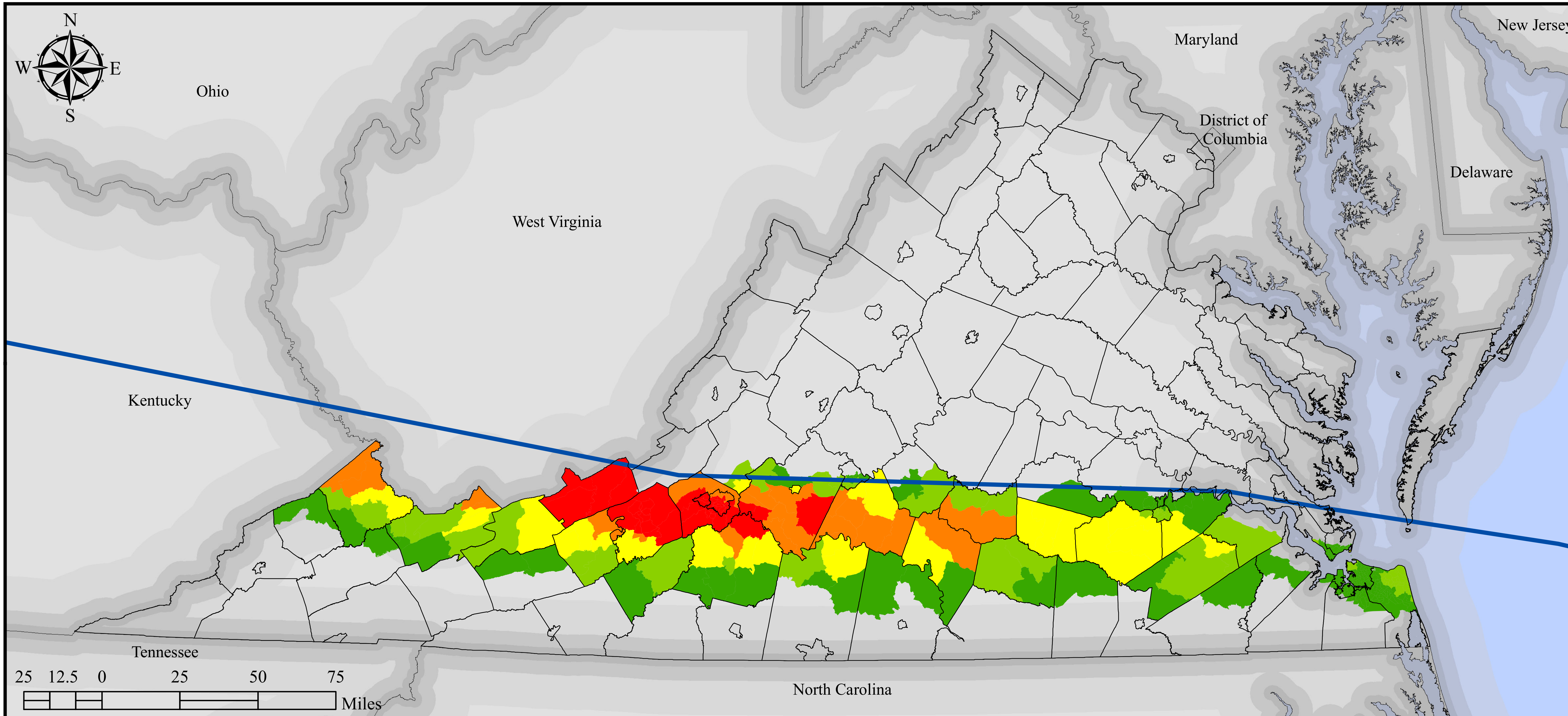
- 50 - 61
- 62 - 70
- 71 - 80
- 81 - 91
- 92 - 104

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.

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-4: Historical Occurrence: Hurricane Camille (1969)



DATA SOURCES:

HAZUS-MH 2.1 Wind Model
VGIN Jurisdictional Boundaries
ESRI State Boundaries

LEGEND:

Camille_StormTrack

PeakGust Windspeeds

- 50 - 53
- 54 - 56
- 57 - 58
- 59 - 61
- 62 - 64

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.

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

Risk Assessment

FEMA's HAZUS MH 2.1 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 state hazard mitigation planning.

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.[4]

Probability

Most office buildings are designed for a 50-year mean recurrence interval wind event (2% annual probability). Figure 3.8a-5 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.[5] Other office buildings that must be designed for a 100-year mean recurrence interval wind event include:

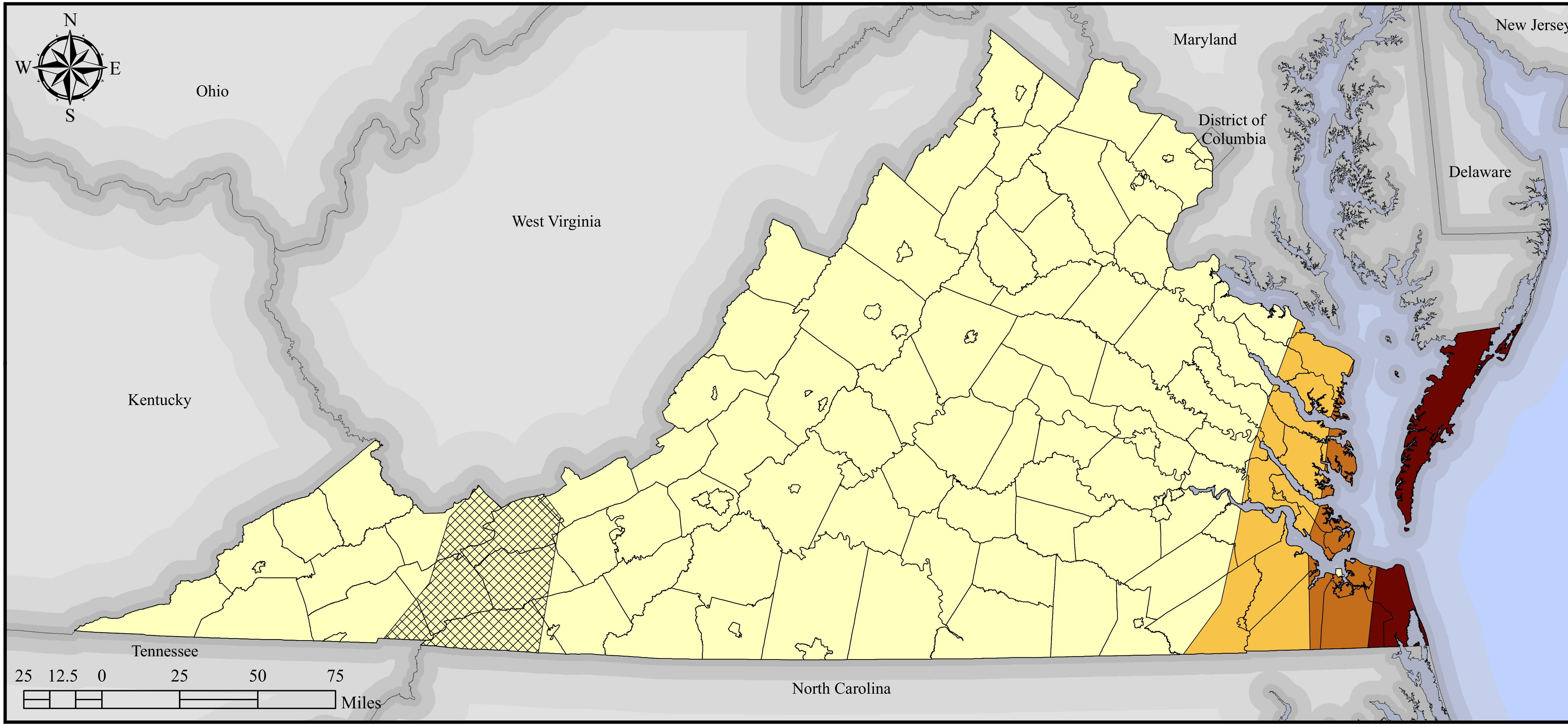
1. Buildings that will be used for hurricane or other emergency shelter
2. Buildings housing a day care center with capacity greater than 150 occupants
3. Buildings designated for emergency preparedness, communication, or emergency operation center or response

[4] National Institute of Building Sciences (NIBS) HAZUS Wind Methodology www.nibs.org/hazusweb/methodology/wind.php
[5] 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

Similar to the 2010 version of the HMP, HAZUS 100-year recurrence interval for peak wind gust was used to determine the maximum 100-yr wind speed for each jurisdiction. 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-5: ASCE Design Wind Speeds



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DATA SOURCES:

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

LEGEND:

Wind Speeds for 3-Second Gust
- < 90 mph
- 90-100
- 100-120
- > 120 mph
- Special Wind Region

HAZARD IDENTIFICATION:

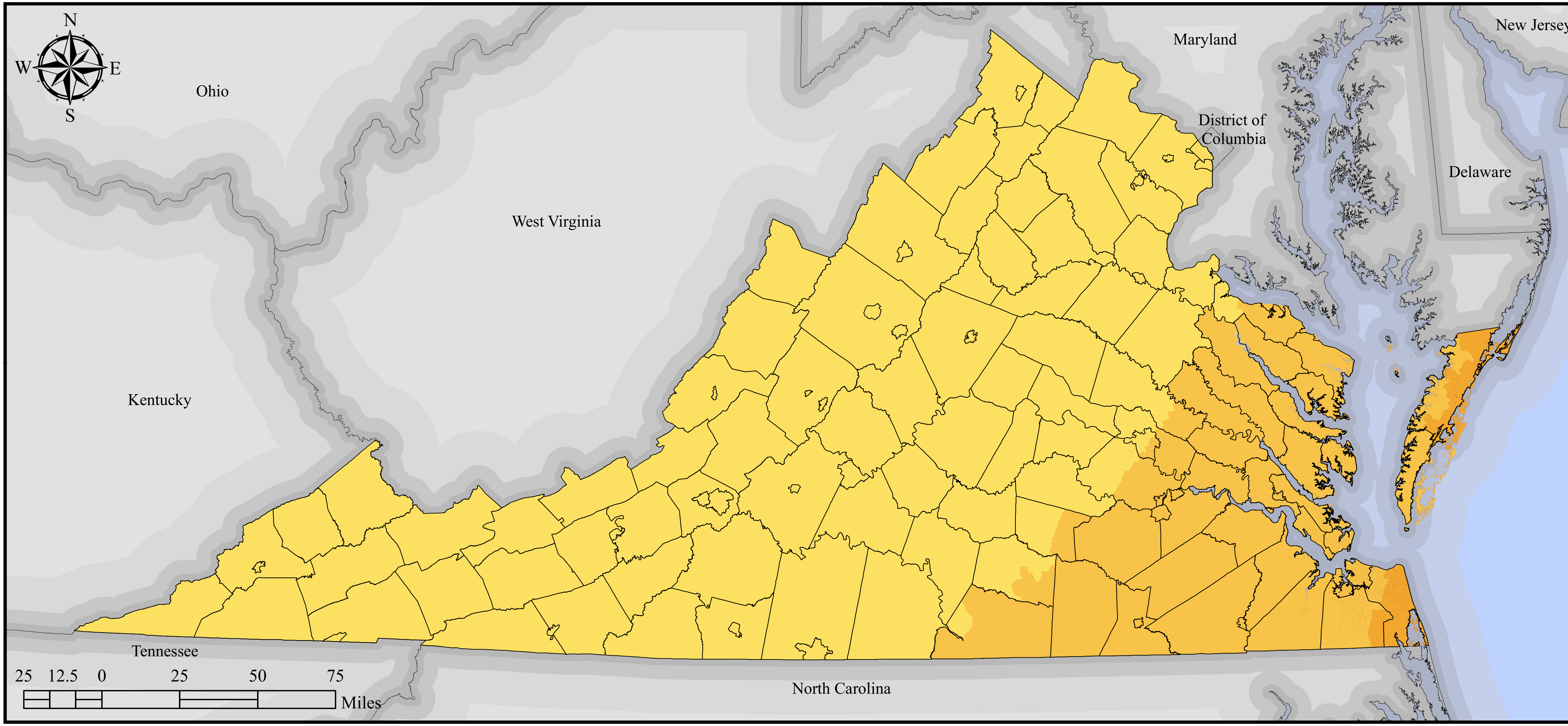
ASCE basic wind speeds are based on nominal design 3-second gust wind speeds in miles per hour (m/s) at 33 feet (10m) above ground for the 50-year recurrence interval (2% annual probability). Values have been determined by localized research using approved probabilistic methods.

Special Wind Regions are areas of unusual wind conditions.

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: HAZUS 100-Year Wind Speeds



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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:

HAZUS-MH 2.1 Wind Model
VGIN Jurisdictional Boundaries
ESRI State Boundaries

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 2010 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 55% of the mapped state facility locations are in a medium-low risk zone which is equivalent to experiencing 60.0-73.9 mph winds. Approximately 2% of the state facilities are located in the high wind 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	Cumulative Count	Value in Risk Zone	Cumulative Value
High	313	313	$209,600,771	$209,600,771
Medium-High	3,264	3,577	$5,346,635,740	$5,556,236,511
Medium-Low	7,204	10,781	$14,529,961,903	$20,086,198,414
Low	2,212	12,993	$2,543,170,461	$22,629,368,875
Total	**12,993**		**$22,629,368,875**	
**Building values for all facilities not available. Building values at risk is based on what was available from VAPS.*				

The 313 buildings that were considered to be at high risk for wind can be broken up into 27 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	23	$62,837,833
Tidewater Community College	14	$52,268,716
Indian Creek Correctional Center	21	$44,995,680
Old Dominion University	1	$17,902,450
Department of Conservation & Recreation	76	$10,823,356
VA Institute of Marine Science	24	$6,694,082
Department of Transportation	39	$4,504,097
Department of Military Affairs	44	$4,007,927
Department of Motor Vehicles	6	$2,821,275
Virginia Polytechnic Inst. and State University	13	$17,72,679
Department of Forestry	9	$502,931
Department of Game and Inland Fisheries	7	$318,245
P & P Dist. 004	1	$151,500
Court of Appeals of Virginia	2	Not Available
Department for the Blind & Vision Impaired	1	Not Available
Department of Alcoholic Beverage Control	14	Not Available
Department of Corrections	1	Not Available
Department of Environmental Quality	1	Not Available
Department of Health	7	Not Available
Department of Juvenile Justice	2	Not Available
Department of Veterans Services	1	Not Available
Environmental Service Unit	1	Not Available
Norfolk State University	1	Not Available
P & P Dist. 023	1	Not Available
University of Virginia- Academic Division	1	Not Available
Virginia Employment Commission	1	Not Available
Virginia Indigent Defense Commission	1	Not Available
Total	**313**	**$209,600,771**
**Building values for all facilities not available. Building values at risk is based on what was available from VAPS.*		

Critical Facility Risk

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	Transportation	Public Health	Emergency Response	Education
Low	129	10	144	444	354
Medium-Low	341	28	647	1,665	1,886
Medium-High	171	16	230	631	641
High	21	2	54	99	160
Total	**662**	**56**	**1,075**	**2,839**	**3,041**

Hurricane Risk to Energy Pipelines

Strong wind associated with hurricanes can affect pipelines by damaging the infrastructure that supports pipeline operations such as power and telephone and satellite communications. Some pipelines require above ground facilities for their operations, like pump stations. Wind can damage these facilities, causing pipelines to be shutdown. In addition, severe wind events can make pipeline operation sites inaccessible, making it more difficult to fix the damaged equipment and restore operations. In some cases, pipeline operators may proactively shutdown pipeline operations prior to the onset of severe weather, to mitigate potential damages; this may cause supply interruptions. Flooding associated with hurricanes can also negatively impact pipeline infrastructure (See Section 3.7).

Jurisdictional Risk

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 **$96,155,812** in total annualized damages estimated in HAZUS-MH 2.1. The coastal cities of Virginia Beach, Norfolk, Chesapeake, and Hampton all can expect $5 million to $27.5 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-7). 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	$27,449,218	City of Norfolk	$10,321,408
City of Chesapeake	$11,438,490	City of Hampton	$5,872,665

$1 Million - $4.9 Million			
City of Newport News	$4,958,778	Chesterfield County	$1,917,763
City of Portsmouth	$4,354,219	York County	$1,858,560
Accomack County	$3,461,693	Henrico County	$1,688,479
Fairfax County	$3,331,739	James City County	$1,118,063
City of Suffolk	$2,087,032	City of Richmond	$1,077,318

$150,000 - $999,999			
Northampton County	$985,650	Lancaster County	$259,150
Gloucester County	$814,673	Stafford County	$259,079
Prince William County	$779,932	Mecklenburg County	$241,605
Isle of Wight County	$776,389	City of Petersburg	$230,089
Hanover County	$713,783	Westmoreland County	$185,204
Arlington County	$708,067	City of Franklin	$169,933
City of Alexandria	$528,449	Dinwiddie County	$168,561
Loudoun County	$511,653	Pittsylvania County	$167,520
City of Poquoson	$341,385	City of Hopewell	$165,483
Southampton County	$337,168	City of Danville	$165,258
Spotsylvania County	$333,369	City of Williamsburg	$162,502
Northumberland County	$332,129	New Kent County	$159,299
Mathews County	$328,704	City of Roanoke	$154,910
Middlesex County	$292,160	City of Colonial Heights	$153,427
Prince George County	$267,323	Albemarle County	$151,884

$50,000 - $149,000			
Roanoke County	$142,353	Powhatan County	$85,738
Halifax County	$141,225	Franklin County	$82,095
Brunswick County	$128,417	Rockingham County	$81,994
King William County	$127,315	Richmond County	$79,406
Bedford County	$113,454	Goochland County	$79,360

$50,000 - $149,000			
Fauquier County	$112,640	City of Emporia	$71,286
City of Lynchburg	$112,366	City of Fairfax	$69,436
Henry County	$110,571	Nottoway County	$68,697
Sussex County	$107,867	King George County	$68,687
Montgomery County	$101,587	Charles City County	$66,258
Surry County	$100,362	City of Charlottesville	$61,055
Augusta County	$99,353	King and Queen County	$59,274
Greensville County	$97,443	Culpeper County	$58,534
Caroline County	$96,228	Orange County	$58,466
Campbell County	$93,826	Pulaski County	$54,601
City of Manassas	$92,066	Frederick County	$53,979
Louisa County	$91,436	Lunenburg County	$53,757
Essex County	$91,382	City of Fredericksburg	$50,725

$20,000 - $49,999			
Amelia County	$46,225	Wythe County	$33,244
Charlotte County	$46,056	Appomattox County	$32,636
City of Falls Church	$45,594	Patrick County	$31,768
Washington County	$45,381	Cumberland County	$30,933
City of Martinsville	$41,014	City of Harrisonburg	$28,662
Botetourt County	$40,666	City of Staunton	$27,548
Fluvanna County	$39,694	Buckingham County	$26,361
Amherst County	$39,052	City of Waynesboro	$26,318
Carroll County	$38,858	City of Manassas Park	$24,779
Prince Edward County	$38,618	Warren County	$22,448
Salem	$38,466	Nelson County	$21,986
Smyth	$37,911	Rockbridge County	$21,937
Tazewell	$34,510	Grayson County	$20,155
Shenandoah	$33,899		

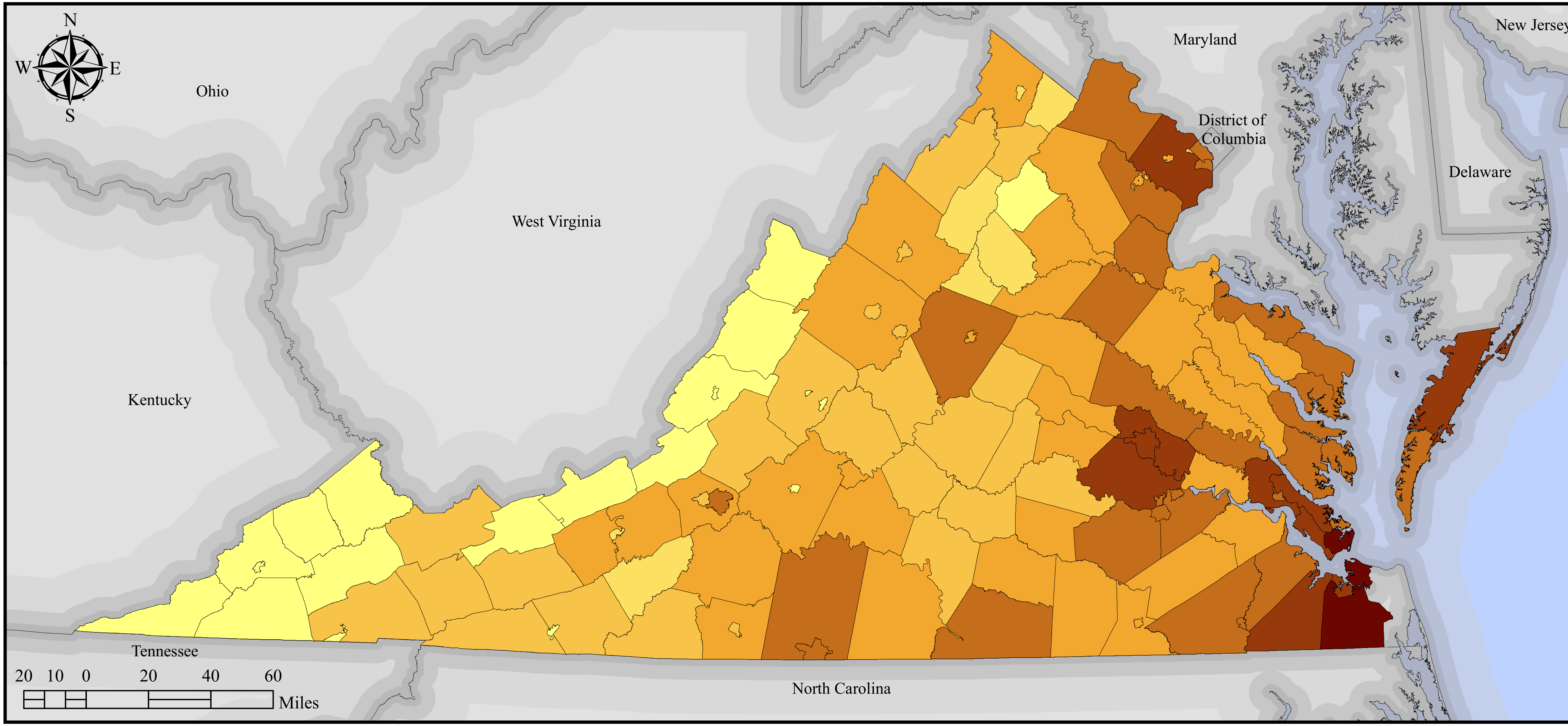
$15,000 - $19,999			
Floyd County	$19,996	Clarke County	$17,662
Greene County	$19,244	Page County	$17,550
City of Winchester	$18,871	Madison County	$16,314
City of Radford	$18,441		

< 14,999			
Russell County	$14,234	Alleghany County	$8,140
Giles County	$13,893	City of Buena Vista	$8,126
City of Bristol	$13,316	Rappahannock County	$7,542
Wise County	$13,225	City of Covington	$5,236
City of Galax	$12,055	Bland County	$4,120
City of Bedford	$11,600	Dickenson County	$3,981
Scott County	$11,275	Bath County	$3,952
Lee County	$11,208	Craig County	$3,406
Buchanan County	$8,630	Highland County	$2,323
City of Lexington	$8,595	City of Norton	$1,717

Annualized damages were also calculated based on NCDC crop and property damages; the Commonwealth can expect approximately **$63,363,748** 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-8 shows the hazard rank for non-rotational winds (primarily hurricane and tropical weather patterns, although thunderstorm winds are also included). Relative to the rest of Virginia, the eastern jurisdictions have the highest risk for non-rotational wind. 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-7: Hurricane Probabilistic Annualized Loss (HAZUS)



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:

CGIT 2012 HAZUS-MH 2.1 runs
VGIN Jurisdictional Boundaries
ESRI State Boundaries

LEGEND:

Annualized Loss by County

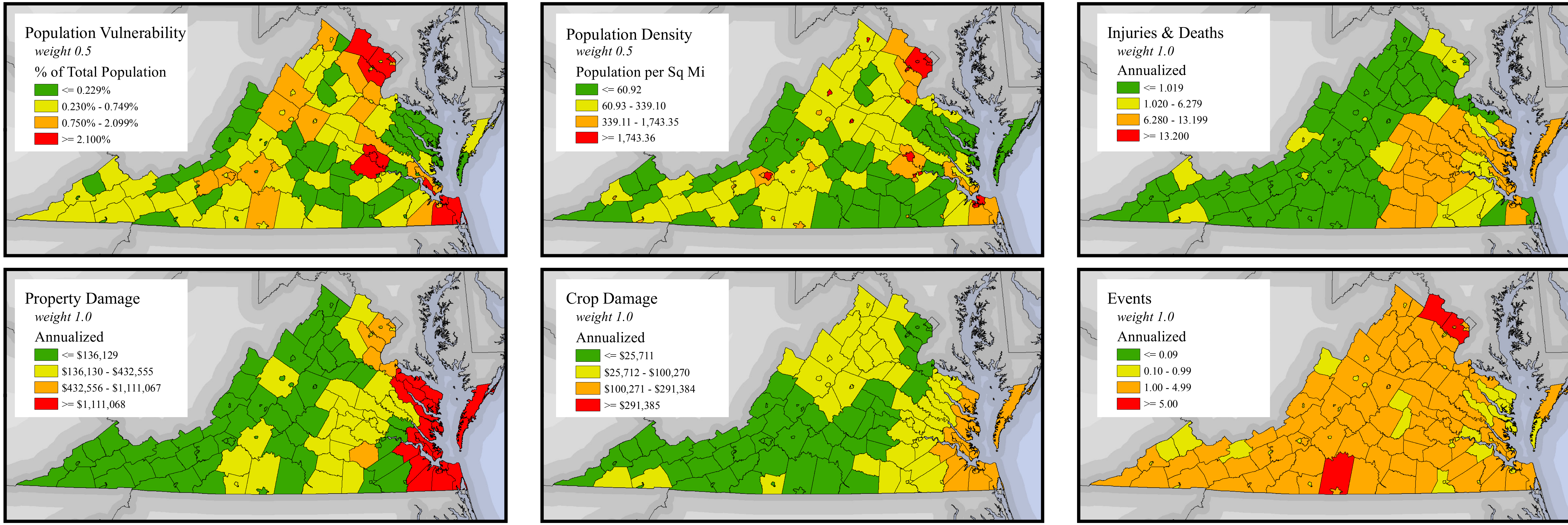
- < $15,000
- $15,000 - $20,000
- $20,000 - $50,000
- $50,000 - $150,000
- $150,000 - $1 Million
- $1 Million - $5 Million
- > $5 Million

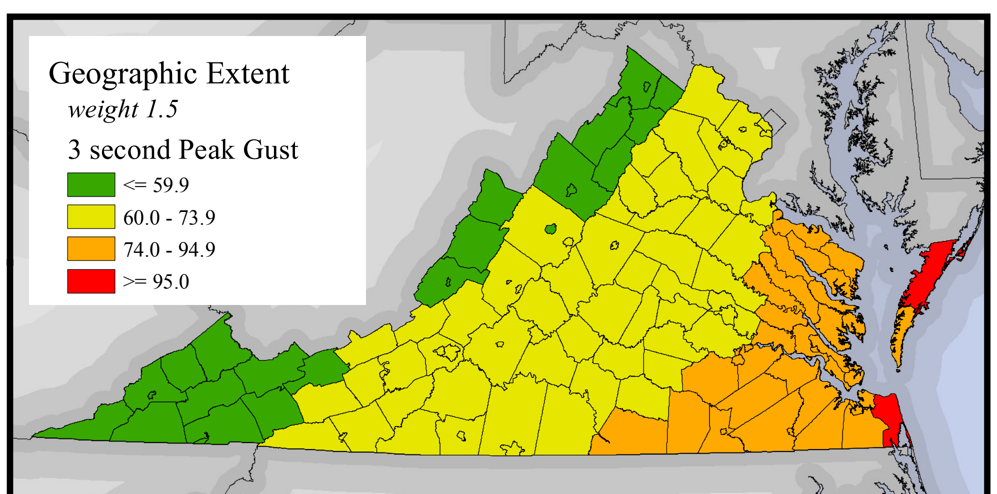
RISK ASSESSMENT:

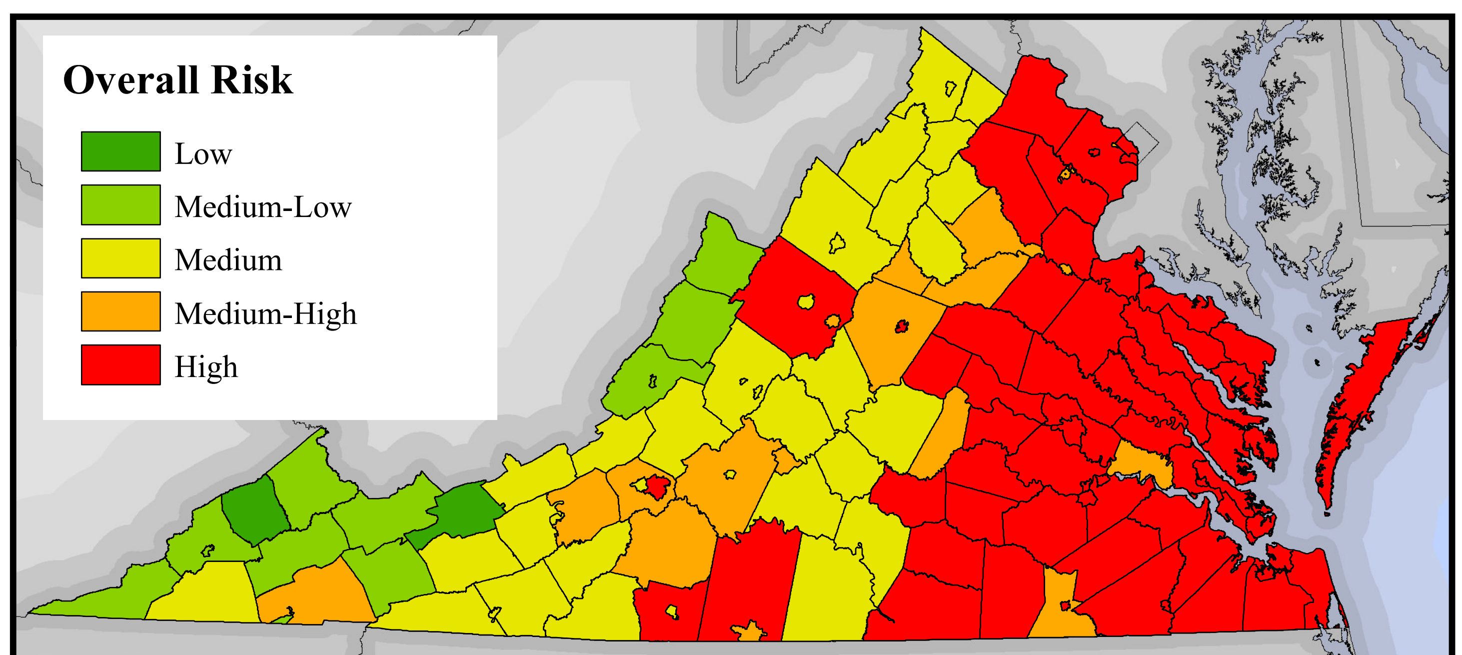
Probabilistic Annualized Loss was calculated by HAZUS-MH using the probabilistic scenario. Annualized loss is defined as the expected value of loss in any one year, and is developed by aggregating the losses and their exceedance probabilities.

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

Figure 3.8a-8: Non-Rot Wind Hazard Ranking Parameters and Risk Map







HAZARD RANKING:

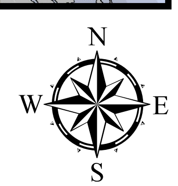
A number of factors have been considered in this risk assessment to be able to compare between jurisdictions and hazards. The factors have been added together to come up with the overall total ranking for each hazard.
Some factors were weighted based on imput from the HIRA sub-committee.
Section 3.5 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



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-five 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

Sixteen of the twenty-five local plans utilized HAZUS-MH for hurricane wind analysis in some fashion. Three of the sixteen plans did not complete probabilistic runs to develop annualized loss estimates.

Nine 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. Seven of the nine plans did not calculate annualized loss for hurricane.

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.

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

PDC/Jurisdiction	Annualized Hurricane Wind Loss	
	Local Plan	2013 Statewide
Southside Hampton Roads PDC	$30,443,000	$44,988,266
Lower Peninsula	$9,666,524	$13,970,568
Northern Virginia RC	$4,800,000	$6,091,715
Richmond and Crater PDCs	$4,399,829	$7,149,839
Middle Peninsula	$959,258	$1,713,508
New River Valley	$563,000	$208,518
Southside PDC	$482,000	$511,247
Southampton County	$480,390	$337,168
West Piedmont	$463,930	$598,226
Thomas Jefferson	$385,000	$385,299
City of Franklin	$291,000	$169,933
Commonwealth RC (Virginia's Heartland)	$274,179	$310,647
Rapahannock-Rapidan	$139,000	$253,496

Comparison with Local Ranking

Fourteen of the twenty-five regional and local hazard mitigation plans ranked hurricane related winds as a high hazard; Three of those plans also ranked general wind as high. No localities ranked general wind as low and only one locality ranked hurricane wind as low, resulting in a local plan average of medium-high for general wind and medium-high for hurricane wind. The 2013 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. Sixteen of the twenty-five 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