4.7 Severe Thunderstorm

4.7.1 Hazard Profile

Thunderstorms are caused when air masses of varying temperatures and moisture content meet. Rapidly rising warm moist air serves as the driving force for thunderstorms. These storms can occur singularly, in lines, or in clusters. They can move through an area very quickly or linger for several hours.

Some storms produce a particular type of high wind called a *derecho*. Derechos are widespread, long-lived, straight-line wind storms associated with severe thunderstorms. They can cause hurricane-force winds, tornadoes, heavy rains, and flooding. Derechos travel quickly, with sustained winds that often exceed hurricane-force. They typically occur in the summer months, though they can occur any time of year and at any time of the day or night.

Although thunderstorms generally affect a small area when they occur, they can be very dangerous as, by definition, they contain lightning, and can also produce heavy rain, flash flooding, strong straight-line winds, large hail, and tornadoes.

4.7.1.1 Magnitude / Severity

The National Weather Service (NWS) estimates that more than 100,000 thunderstorms occur each year across the United States, though only about 10 percent of these storms are classified as "severe". According to NWS, a typical thunderstorm is 15 miles in diameter and lasts an average of 30 minutes. To be classified as a "severe thunderstorms", the storm must be capable of producing either a tornado, straight-line winds gust greater than 58 mph (50 knots)[42], or hail greater than one inch in diameter.

The severity of a thunderstorm is usually measured based on the strength of the wind speeds or significant winds associated with the thunderstorm event. Table 4-121 depicts intensity for thunderstorms according to wind magnitude published by the World Meteorological Organization (WMO).

Table 4-121 Beaufort Wind Scale

Force	Wind (kts)*	Wind classification	Appearance of wind effects
0	Less than 1	Calm	Calm, smoke rises vertically
1	1-3	Light Air	Smoke drift indicates wind direction, still wind vanes
2	4-7	Light Breeze	Wind felt on face, leaves rustle, vanes begin to move
3	8-12	Gentle Breeze	Leaves and small twigs constantly moving, light flags extended
4	13-18	Moderate Breeze	Dust, leaves, and loose paper lifted, small tree branches move
5	19-24	Fresh Breeze	Small trees in leaf begin to sway
6	25-31	Strong Breeze	Larger tree branches moving, whistling in wires
7	32-38	Near Gale	Whole trees moving, resistance felt walking against wind
8	39-46	Gale	Whole trees in motion, resistance felt walking against wind
9	47-54	Strong Gale	Slight structural damage occurs, slate blows off roofs
10	55-63	Storm	Seldom experienced on land, trees broken or uprooted, “considerable structural damage”

[42] https://www.weather.gov/safety/thunderstorm

Force	Wind (kts)*	Wind classification	Appearance of wind effects
11	64-72	Violent Storm	If experienced on land, widespread damage
12	73+	Hurricane	Violence and destruction

** 1 Knot (kts) = 1 Nautical Mile per hour, or approximately 1.15 miles per hour. Source: World Meteorological Organization*

Figure 4-109 illustrates the typical distribution and frequency of derecho occurrence in the United States, as determined by the NWS.[43] Based on this data, the CVPDC area could expect to experience at least one derecho every 2-4 years, on average, especially during spring and early summer seasons.

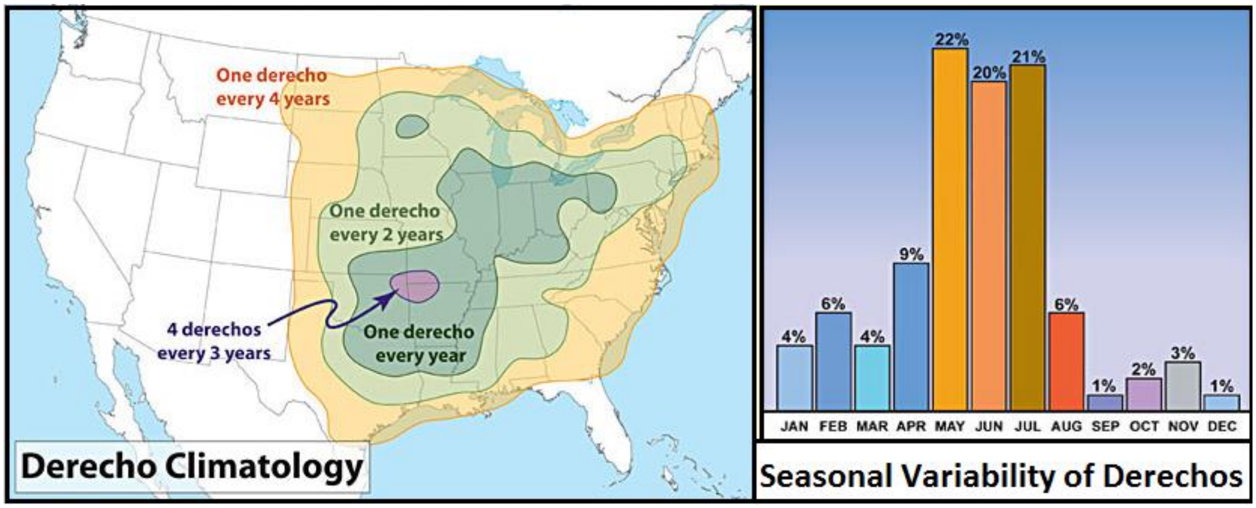

Figure 4-109 Derecho climatology and seasonal variability in the United States

4.7.1.2 Previous Occurrences

Although most frequent in the Southeast and parts of the Midwest, thunderstorms are a relatively common occurrence across Virginia. The CVPDC area is affected by thunderstorms each year, in almost all calendar months, and suffers damages caused by heavy rainfalls, lightning strikes or high winds. These severe weather reports associated with thunderstorms are recorded in the Storm Events Database at the National Center for Environmental Information (NCEI). Data has been collected in a consistent manner since 1996. It is important to note that this database covers only "reported" severe weather, and does not provide information on all the severe weather that may have occurred in a particular storm. The NOAA National Centers for Environmental Prediction (NCEP) publish Storm Prediction Center Severe Weather GIS (SVRGIS) data, including paths and initial points of thunderstorm wind events. Some historical events before 1996 may not have available wind paths information.

4.7.1.3 Thunderstorm Wind

NCEI Storm Events Database records 883 severe thunderstorm wind events between 1958 and 2019 for the CVPDC area. There are 507 recorded events that occurred in the past decade (2010 - 2019), most of them reaching 50 - 70 kts in magnitude (*i.e.* storm and violent storm conditions) and causing damages or injuries. Severe thunderstorm wind occurred every year, for example:

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[43] https://www.spc.noaa.gov/misc/AbtDerechos/derechofacts.htm

- On September 22, 2010, a very unstable atmosphere with plenty of potential for strong downdrafts of wind existed across the CVPDC region. Strong thunderstorms formed during the late afternoon and lasted into the early evening. Several of these storms realized the potential for damaging winds and resulted in the downing of numerous trees. In Bedford County, a severe thunderstorm uprooted many large trees, toppling them on lakefront homes, outbuildings, vehicles, and boats at Smith Mountain Lake. Also, the Smith Mountain Eagle reported numerous trees blown down at the Waterfront Park campground. Severe damage occurred to numerous recreational vehicles and campers at the park. In Campbell County, thunderstorm winds blew a tree down on a vehicle; one person in the vehicle was injured. In the City of Lynchburg, damaging winds blew multiple trees and power lines down. Some roads were blocked by debris.
- On June 29, 2012, a derecho of historic proportion rolled through the entire CVPDC region and caused widespread, significant damage. In Amherst County and Bedford County, severe thunderstorm winds that measured 66 mph blew several hundreds of trees down. Some of these trees brought down power lines and also fell onto houses. Many roads were blocked due to the downed trees. In Campbell County, hundreds of trees were blown down. The greatest concentration was over the northern half of the county. In the City of Lynchburg, over 1,000 trees were knocked down (Figure 4-110). Many power lines also came down as a direct result of the wind or trees and limbs falling on them. The winds damaged eight homes to the point of being deemed uninhabitable or destroyed. In Appomattox County, the thunderstorm winds brought down approximately 100 trees and many power lines across the county.

Figure 4-110 Wind Damages in City of Lynchburg

Figure 4-111 shows the initial points and paths of the damaging wind associated with thunderstorm events between 1958 and 2018 provided by SVRGIS (events in 2019 are currently unavailable in GIS data format). The color gradient represents a kernel density calculated using wind magnitudes of occurrence points of all historical wind events. The darker color represents areas that have experienced an increased number of reported events and severity. Highlighted points represent occurrence initiated within the PDC area. According to the map, many damaging winds occurred in and around the City of Lynchburg. Please note that the more rural parts of the CVPDC area may be underrepresented due to how the data is collected (using observations).

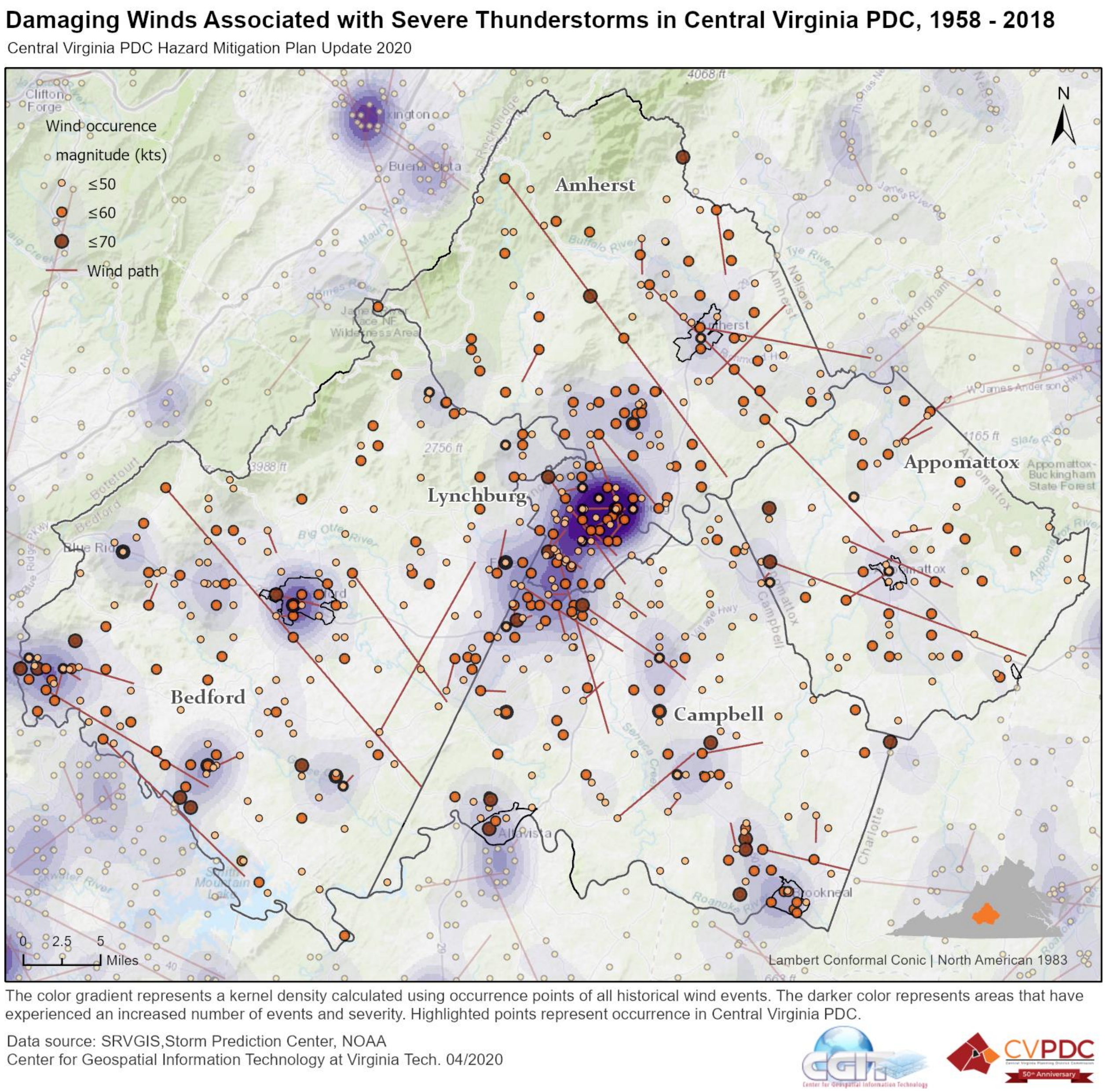

Figure 4-111 Damaging Winds Associated with Severe Thunderstorms in CVPDC Area, 1958 - 2018

4.7.1.4 Heavy Rain

There are 62 heavy rain events recorded in the NCEI Storm Events Database between 1996 and 2019 for the CVPDC area, including 26 events that occurred in the past decade (2010 - 2019). The events brought damages but no injuries or deaths. The following are most recent heavy rain occurrences:

- On May 2, 2019, a few severe thunderstorms developed over the CVPDC area. The storms produced hail up to the size of quarters, damaging winds that blew down several trees, and lightning that set a house on fire and destroyed a transformer. Local, heavy rainfall caused some flooding in Bedford County.
- On August 1, 2019, very heavy rainfall occurred especially in parts of northeast Bedford County and the City of Lynchburg, where 3 to 4 inches of rain fell in several hours causing some flash flooding. It was estimated as roughly a 200-year rain event (0.5% annual chance occurrence).

4.7.1.5 Lightning

All thunderstorms contain lightning. A lightning strike is an electrical current between the cloud and ground. Each spark of lightning can reach over five miles in length, hit temperatures of approximately 50,000 degrees Fahrenheit, and contain 100 million electrical volts. There are about 25 million cloud-to-ground lightning flashes in the United States per year. According to the VAISALA Global Lightning Dataset, Virginia gets an average of 280,000 cloud-to-ground lightning flashes annually, and 6.9 flashes per square miles.[44] According to the National Weather Service, an average of 300 people are injured and 80 people are killed each year by lightning in the United States.[45]

According to the NCEI Storm Event database, there are 49 documented damaging lightning events for the CVPDC area between 1996 and 2019 which caused property damage, deaths, or injuries. In the past decade (2010 - 2019), 26 events have been reported. The PDC area experiences damaging lightning events every year. In the most recent events, lightning strikes from thunderstorms caused barns, outbuildings, homes, and a church to catch fire, brought down trees on homes and vehicles, and took down power lines across the CVPDC area.

4.7.1.6 1.4 Relationship to Other Hazards

Figure 4-112 shows the interrelationship (causation, concurrence, *etc.*) between this hazard and other hazards discussed in this plan update.

4.7.2 Impact and Vulnerability

Thunderstorms are one of the most common and most noticeable weather events of our atmosphere. Compared to other natural hazards, thunderstorms pose hazards and hazardous effects that most concern people throughout the CVPDC area. Severe thunderstorms contain multiple dangers that can threaten safety and personal property in any part of the region and at any time of the year, including flooding, tornadoes, high wind, hail, lightning, and lightning-induced fire (urban fires and wildfires). The impacts of severe thunderstorms would have many of the same impacts as hurricane, tornado, and flooding. For more information concerning those hazards, please refer to the corresponding chapters in this plan. Thunderstorms associated with large hail are discussed separately in the Hailstorm chapter.

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[44] Vaisala Global Lightning Dataset GLD360, 2018. https://www.vaisala.com/en/products/data-subscriptions-and-reports/data-sets/gld360

[45] https://www.weather.gov/phi/ThunderstormDefinition

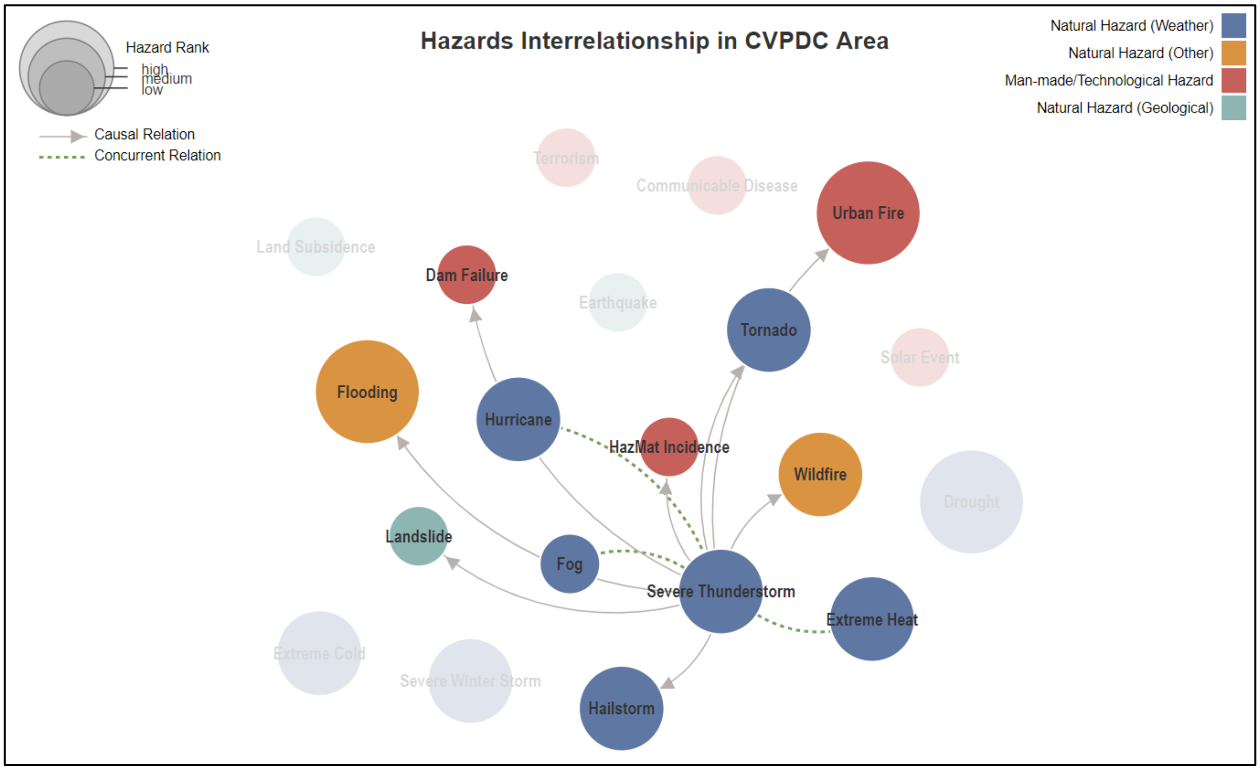


Figure 4-112 Hazards interrelationship

4.7.2.1 Thunderstorm Wind

According to NOAA National Severe Storms Laboratory, damage from severe thunderstorm winds account for half of all severe reports and is more common than damage from tornadoes.[46] The strong straight-line winds or derechos associated with thunderstorms knock down trees, power lines, and mobile homes.

4.7.2.2 Heavy Rainfall

Heavy rainfalls coupled with extreme temperatures or other severe weather conditions can result in increases in traffic accidents and disruptions in transportation, commerce, government, and education. Such severe weather incidents can also cause utility outages and injuries due to falling trees or other debris and flooding.

4.7.2.3 Flash Flooding

An associated danger of heavy rainfalls during the passage of thunderstorms is flash flooding. The NWS classifies flooding into two types: those that develop and crest over a period of approximately six hours (flooding) or more, and those that crest more quickly (flash flooding). Flash flooding is typically the result of intense rainfalls, possibly in conjunction with already saturated soils, though very sudden snow melts can also contribute to flash flooding. Flash flooding is difficult to distinguish and can be either riverine or stormwater flooding (overland flooding). Stormwater flooding events tend to strike and end swiftly. They occur when stormwater pools in normally dry depressions in the land. For more details, please refer to the Flood and Landslides chapters.

[46] https://www.nssl.noaa.gov/education/svrwx101/wind/

4.7.2.4 Stormwater Runoff

Stormwater runoff is one of the largest sources of water pollution in urban and suburban areas. It presents many environmental, social, and economic challenges. Rainwater that flows over land or impervious surfaces, such as paved streets, parking lots, and building rooftops, does not soak into the ground, resulting in stormwater runoff. The runoff picks up pollutants such as trash, chemicals, oils, and dirt/sediment that can harm rivers, streams, lakes, and coastal waters. These pollutants directly impact water quality. Increases in stormwater runoff are not only a concern for water quality, but also directly contribute to urban flooding. As high volumes of runoff enter local streams, there is also a rapid increase in the water levels in those streams. This increases the impacts of localized flooding, streambank erosion, destruction of property, and, in some cases, flash flooding.

Green infrastructure is a cost-effective, resilient approach to mitigate stormwater impacts and provide many community benefits. [47] See Mitigation chapter about examples of green infrastructure practices.

4.7.2.5 Lightning

Lightning has the ability to create wildfires as well as local and large-scale power outages that can be damaging to communication systems and electrical systems including computers. According to NWS, lightning kills an average of 47 people in the United States each year, and hundreds more are severely injured. Early detection, monitoring, and warning of lightning hazards, combined with prudent protective actions, can greatly reduce the likelihood of lightning injuries and deaths.

4.7.3 Risk Assessment and Jurisdictional Analysis

Although the thunderstorm risk cannot be fully estimated due to lack of intensity-damage models for this hazard, economic losses from historical events contained within the NCEI storm event data could provide insights.

4.7.3.1 Thunderstorm Wind

According to the NCEI Storm Events Database, the 883 severe thunderstorm wind events in the CVPDC area during 1958 and 2019 resulted in $15,091,460 loss in property damage, $40,500 loss in crop damage (mainly in Campbell County), and 4 injuries (Table 4-122). According to the data, over 80% of the thunderstorm wind occurred between May and August in the region. Bedford County and Campbell County experienced more than 60% of the total events. The City of Lynchburg had more economic losses than any other jurisdictions (Table 4-122 and Table 4-123).

Anyone living in thunderstorm-prone areas is at risk for experiencing this hazard. People living in mobile homes are especially at risk for injury and death. Even anchored mobile homes can be seriously damaged when high winds gust over 80 mph. Please refer to the Hurricane hazard chapter for more information.

Table 4-122 Occurrence of Thunderstorm Wind Events by Jurisdiction in CVPDC area, 1958 - 2019

Jurisdiction	Number of Events	Number of Deaths	Number of Injuries	Property damage ($K)	Crop damage ($K)
Amherst County	161	0	0	642.64	0
Appomattox County	98	0	0	405.20	0

[47] https://www.epa.gov/green-infrastructure/what-green-infrastructure

Jurisdiction	Number of Events	Number of Deaths	Number of Injuries	Property damage ($K)	Crop damage ($K)
Bedford County	307	0	1	4,321.80	0
Campbell County	237	0	3	1,789.12	40.50
Lynchburg City	80	0	0	7,932.70	0
Total	**883**	**0**	**4**	**15,091.46**	**40.50**

Table 4-123 Occurrence of Thunderstorm Wind Events by Month in CVPDC Area, 1959 - 2019

Month	Number of Events	Number of Deaths	Number of Injuries	Property damage ($K)	Crop damage ($K)
January	5	0	0	7.00	0
February	6	0	0	9.50	0
March	14	0	0	108.10	0
April	51	0	0	437.90	0
May	132	0	2	378.46	0
June	223	0	1	10,086.40	0
July	218	0	0	984.90	0.50
August	158	0	0	312.70	40.00
September	50	0	1	2,633.20	0
October	6	0	0	43.50	0
November	17	0	0	28.00	0
December	3	0	0	61.80	0
Total	883	0	4	15,091.46	40.50

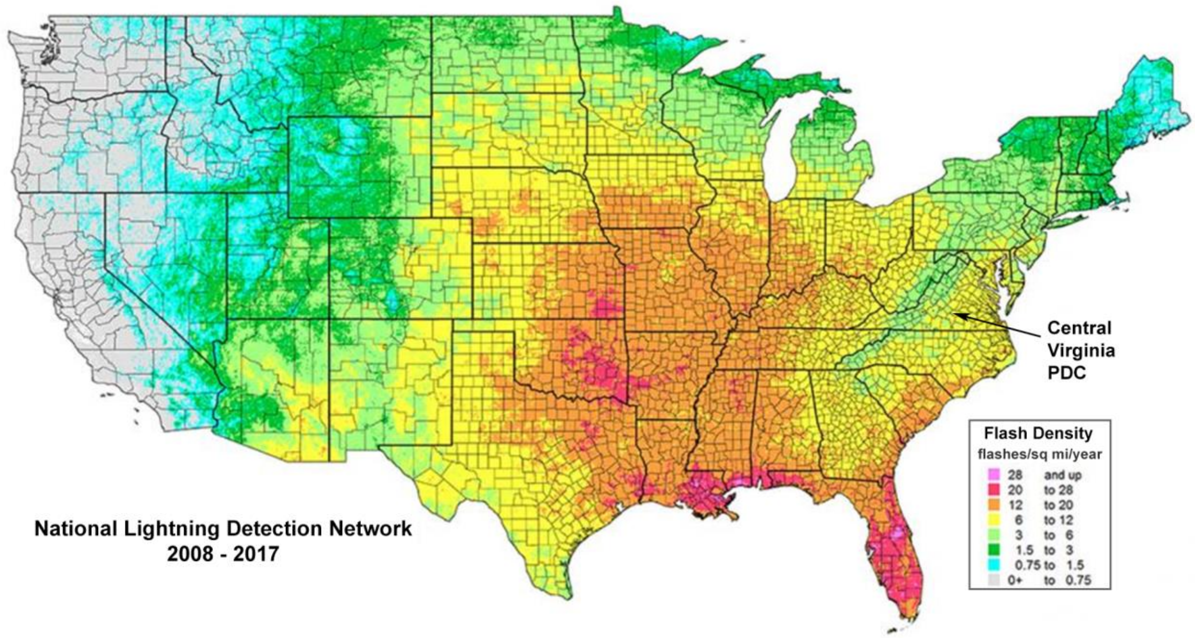
4.7.3.2 Heavy Rain

The NCEI Storm Events Database only recorded two damages associated with heavy rain events in the CVPDC area: one heavy rain in March 2010 caused about $3000 damages in the Town of Brookneal; another event in June 2018 brought about one million dollars of loss in the City of Lynchburg.

4.7.3.3 Lightning

According to the NCEI Storm Events Database, during the period 1996 through 2019, there were 49 reported structural damage reports or injuries associated with lightning strikes across the CVPDC area. These events resulted in a reported loss of $1,254,550 in property damage, 2 deaths, and 2 injuries during the 23-year period (Table 4-124). Bedford County and Campbell County experienced the most damaging lightning events. A majority of the events are concentrated in June and July for the CVPDC area (Table 4-125).

As indicated by Figure 4-113, the CVPDC area averages between 3 and 6 flashes of cloud-to-ground lightning per square mile per year. That equals a 0.8% to 1.6% chance of a cloud-to-ground lightning strike on any given day. This shows a much higher indication of lightning occurrences than has been reported to the NCEI Storm Database, which only records lightning events causing damage.



(Source: VAISALA, 2018)

Figure 4-113 Occurrences density of cloud-to-ground lightning flashes in the United States.

Table 4-124 Occurrence of Damaging Lightning Events by Jurisdiction in CVPDC Area, 1996 - 2019

Jurisdiction	Number of Events	Number of Deaths	Number of Injuries	Property Damage ($K)
Amherst County	6	0	1	320.40
Appomattox County	3	0	0	17.50
Bedford County	14	1	0	283.00
Campbell County	17	1	1	322.55
Lynchburg City	9	0	0	311.10
Total	**1**	**2**	**2**	**1,254.55**

Table 4-125 Occurrence of Damaging Lightning Events by Month in CVPDC Area, 1996 - 2019

Month	Number of Events	Number of Deaths	Number of Injuries	Property Damage ($K)
April	3	0	0	83.00
May	5	0	0	222.50
June	13	1	0	401.20
July	17	1	1	250.25
August	9	0	1	242.60
Sep	2	0	0	55.00
Total	**49**	**2**	**2**	**1,254.55**

4.7.4 Probability of Future of Occurrences

Since severe storms are difficult to predict, it is extremely difficult to determine the probability of future occurrence with any degree of accuracy. Based on historical record, the CVPDC area is projected to continue to experience severe thunderstorms with great frequency; several times a year, in most cases.

Thunderstorms can be detected using a variety of tools. Radars depict where rain and hail are located in the storm. Doppler radars also allow us to visualize how the wind is blowing within and near the storm. Some features of thunderstorms, such as the anvil that spreads out at the top of the storm, can be seen from satellites. Flash flooding may be predicted with reasonable notice using meteorological techniques to determine likely rainfall, intensity, and duration.

Climate change is projected to increase the frequency and intensity of extreme weather events, including severe thunderstorms. Using global climate models and a high-resolution regional climate model, one study by Stanford University in 2013 that investigated the link between severe thunderstorms and global warming found a net increase in the number of days with environmental conditions that foster the development of severe thunderstorms.[48] This was true for much of the United States, including the CVPDC area.

4.7.5 References

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[48] https://www.sciencedaily.com/releases/2013/09/130923155542.htm

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