4.6 Tornado

4.6.1 Hazard Profile

Damaging winds typically are associated with tornadoes or landfalling hurricanes. Isolated "downburst" or "straight-line" winds associated with any common thunderstorm can also cause extensive property damage. Tornadoes are classified as a rotating column of wind that extends between a thunderstorm cloud and the earth's surface. Tornadoes are classified by their wind speed, which can range between 100 and 250 miles per hour. Tornadoes typically measure less than 200 feet wide, but in rare circumstances can be over a mile wide, and have wind speeds between 65 and 250 miles per hour. The rotating column of air often resembles a funnel-shaped cloud.

4.6.1.1 Geographical Location and Extent

The United States averages 1,200 tornadoes per year, and 80% of those are either an F0/EF0 or F1/EF1 (see Table 4-117 for definition). In 2017, 25 tornadoes struck Virginia and caused $10M in damage, but no deaths or injuries. In Virginia, most tornadoes are low-intensity, and tornadoes rated F2 or higher are rare. While tornadoes are most common in the central part of the US, Virginia has averaged 17.7 tornadoes per year during the 24 years between 1991 and 2015 (Figure 4-99), and increased to 24 tornadoes per year over the last decade. The total number may be higher, as incidents may occur over areas with sparse populations, or may not cause any property damage.

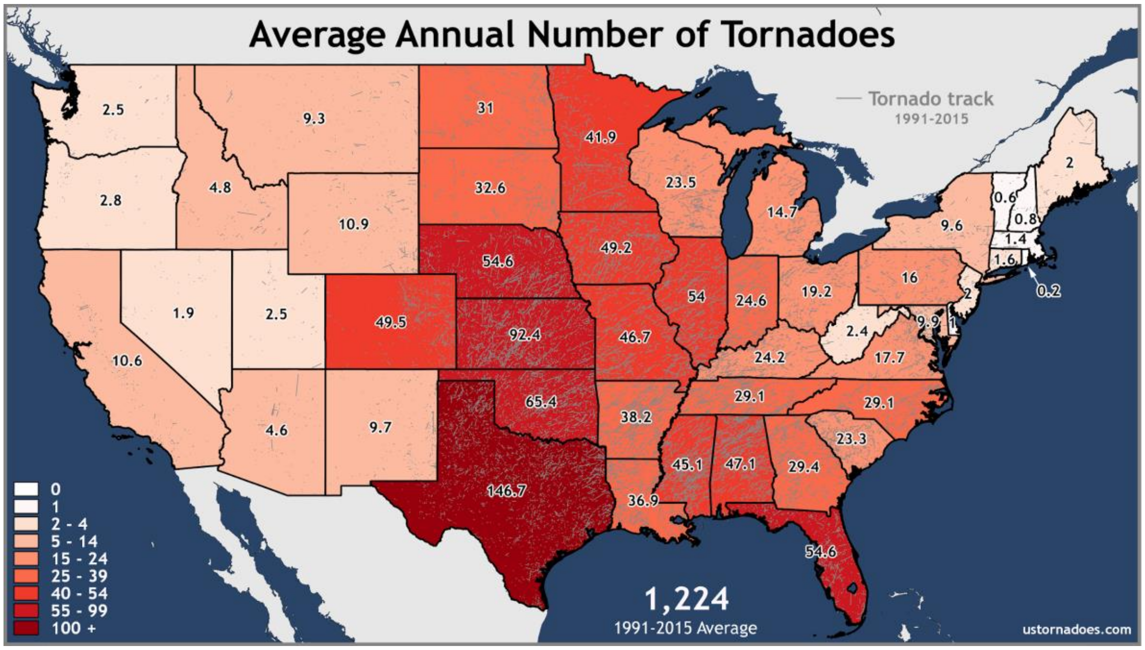
The Virginia Department of Emergency Management (VDEM) documents statewide annual tornado hazard frequency in the Commonwealth of Virginia Hazard Mitigation Plan. Annual tornado hazard frequency is an estimate of the frequency with which a point will experience a tornado. It is interpolated from neighboring tornado impact areas over a historical period.

The CVPDC area, as seen in Figure 4-100, is located in an area of low to medium risk for tornado strikes of magnitude F2 or larger. Please note that this map is Virginia-specific and "high frequency" in the Commonwealth is still relatively low frequency compared to the Midwest and Southern United States.

4.6.1.2 Magnitude or Severity

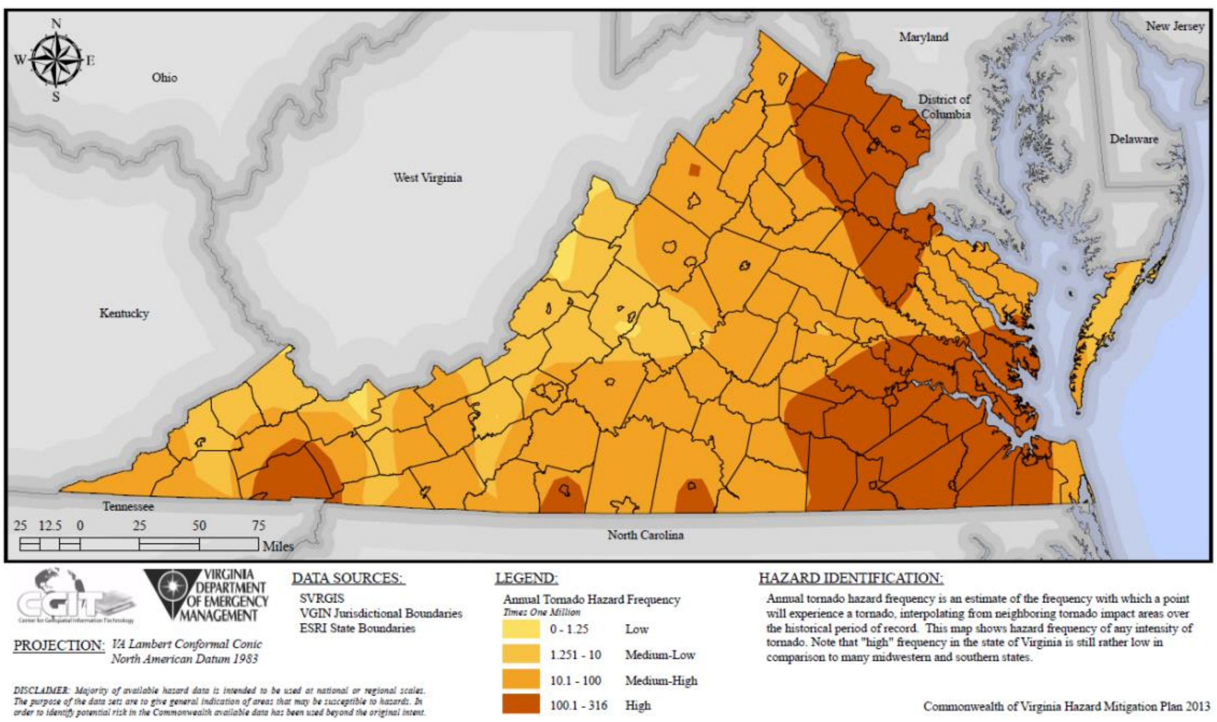
Tornadoes and their resultant damage can be classified into six categories using the Fujita Scale (see Table 4-117). This scale assigns numerical values (from zero to five) for wind speeds inside the tornado, according to the type of damage and intensity of the tornado. Starting in 2007, the original Fujita Scale was replaced with the Enhanced Fujita Scale (EF-Scale) to better align wind speeds more closely with associated storm damage. Most modern structures are designed to withstand tornadoes using the Enhanced Fujita Scale as reference. [35]

[35] NWS. The Enhanced Fujita Scale (EF Scale). https://www.weather.gov/oun/efscale



(Source: USTornadoes.com) [36]

Figure 4-99 Average annual number of tornadoes



(Source: Commonwealth of Virginia Hazard Mitigation Plan 2013)

Figure 4-100 Annual Tornado Hazard Frequency

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[36] https://www.ustornadoes.com/2016/04/06/annual-and-monthly-tornado-averages-across-the-united-states/

Table 4-117 Fujita and Enhanced Fujita Scale

F-Scale	3-sec. gust speed (mph)	EF-Scale	3-sec. gust speed (mph)	Typical Damage
F0	45-78	EF0	65-86	Light damage. Some damage to chimneys. Branches broken off trees. Shallow-rooted trees pushed over; signboards damaged.
F1	79-117	EF1	86-109	Moderate damage. Peels surface off roofs. Mobile homes pushed off foundations or overturned. Moving autos blown off roads.
F2	118-161	EF2	110-137	Considerable damage. Roofs torn off frame houses. Mobile homes demolished. Boxcars overturned. Large trees snapped or uprooted. Light-object missiles generated. Cars lifted off ground.
F3	162-209	EF3	138-167	Severe damage. Roofs and some walls torn off well-constructed houses. Trains overturned. Most trees in forest uprooted. Heavy cars lifted off the ground and thrown.
F4	210-261	EF4	168-199	Devastating damage. Well-constructed houses leveled. Structures with weak foundations blown away some distance. Cars thrown and large missiles generated.
F5	262-317	EF5	200-234	Incredible damage. Strong frame houses leveled off foundations and swept away. Automobile-sized missiles fly through the air in excess of 100 meters (109 yards). Trees debarked. Incredible phenomena will occur

The classification of the tornado provides an approximation of the corresponding damage.

4.6.1.3 Previous Occurrences

Over the last decade, tornadoes have primarily occurred in May through September in Virginia, with peak activity in July. [37] However, a tornado can occur at any time throughout the year. Hot and humid conditions stimulate the tornado's frequency and growth. Strong tornadoes may be produced by thunderstorms and often associated with the passage of hurricanes.

[37] VDEM. 2018. Tornado preparedness. https://www.vaemergency.gov/wp-content/uploads/2019/05/tornado-one-sheet-in-house-printing-and-digital-download.pdf

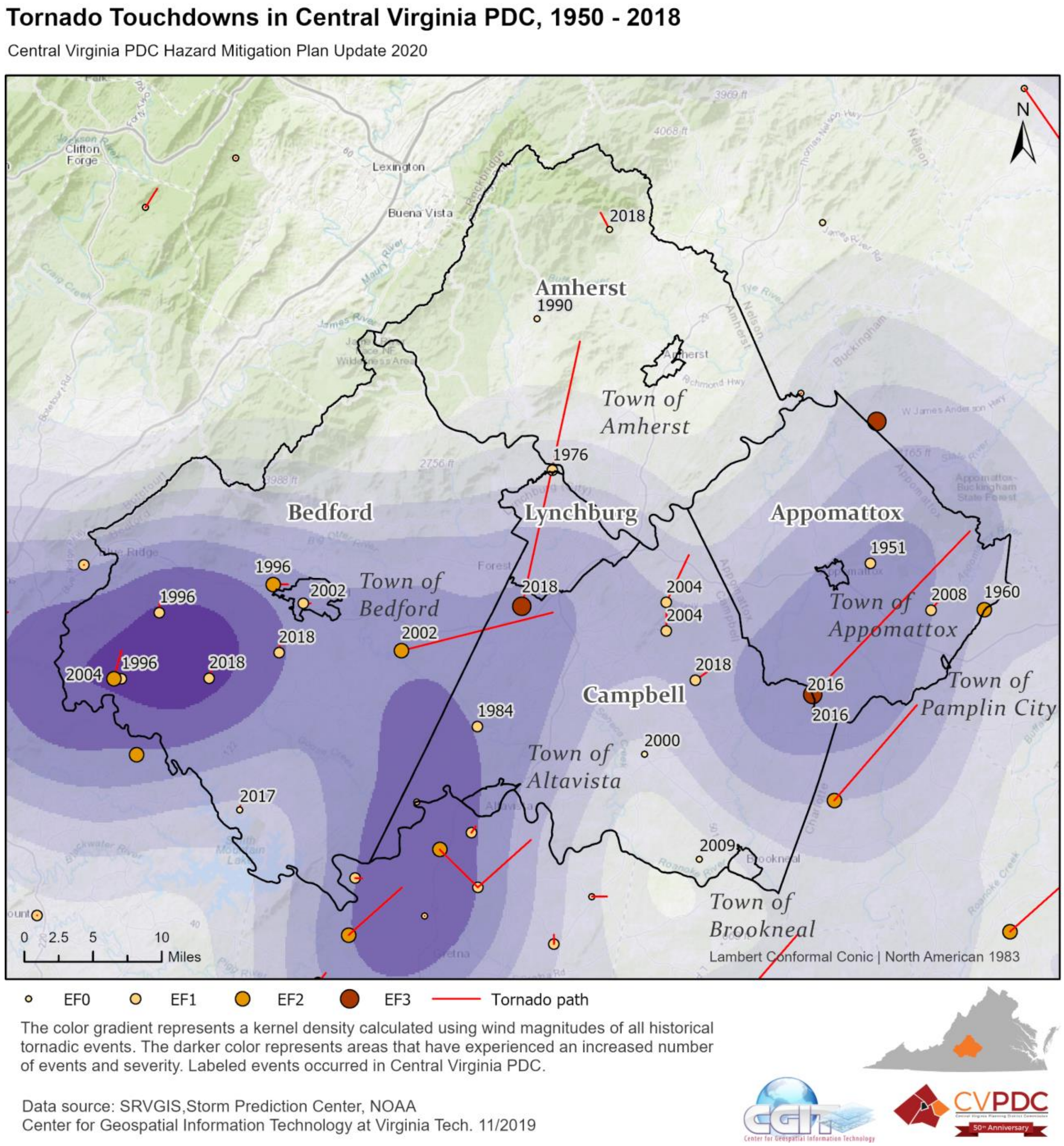
The NCEI Storm Event Database records tornado occurrences when the storm has sufficient intensity to cause loss of life, injuries, significant property damage, and/or disruption to commerce. According to the database, 29 tornado events occurred between 1950 and 2019 in the CVPDC area, including two severe tornado touchdowns rated EF3. Both touchdowns occurred after the last hazard mitigation plan update in 2012. On February 24, 2016, an EF3 tornado spanning a 16 mile stretch caused damage in Campbell and Appomattox counties (Figure 4-101). The tornado caused seven reported injuries and one fatality. On April 15, 2018, an EF3 tornado hit the community of Elon northwest of Lynchburg. It caused 12 injuries and damaged or destroyed dozens of homes. This is the first touchdown occurred within Lynchburg city limits, and the first EF3 tornado impact Amherst County. [38]

Reporting of severe weather events (storms, tornado, hurricane, etc.) relies upon human observation, and therefore the NCEI storm event database, which is the best available data, exhibits a population bias. The degree of bias is related to the population density of a region, the terrain (i.e., observation distance; terrain blockage of the radar beam in mountainous areas), the existence or absence of organized storm-spotting organizations, and the road network of the region. Consequently, rural areas may be underrepresented in the data of spatial and temporal distributions of severe weather presented here.

Figure 4-101 Damage from tornado in Appomattox County, 2016

The NOAA National Centers for Environmental Prediction publish Storm Prediction Center Severe Weather GIS (SVRGIS) data, including path and initial point of each tornado event between 1950 and 2018 (events in 2019 are currently unavailable). Figure 4-102 shows the historic tornado touchdowns and paths that have been published in the SVRGIS.

[38] National Weather Service. The April 15th, 2018 Tornadoes Event Summary. https://www.weather.gov/rnk/2018_04_15_Tornado



(Source: SRVGIS,Storm Prediction Center, NOAA, 2019)

Figure 4-102 Tornado touchdowns in CVPDC Area, 1950 - 2018

4.6.1.4 Relationship to Other Hazards

The following figure (Figure 4-103) shows the interrelationship (causation, concurrence, *etc.*) between this hazard and other hazards discussed in this plan update.

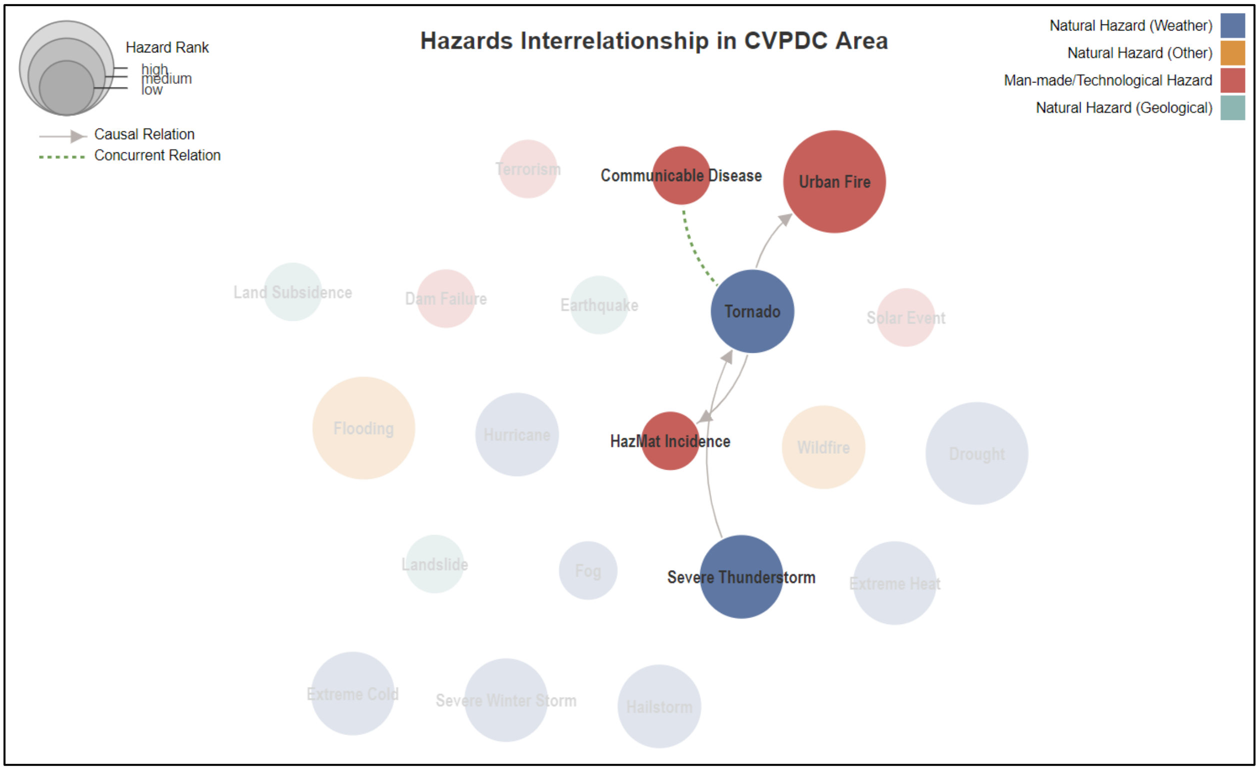


Figure 4-103 Hazards interrelationship

4.6.2 Impact and Vulnerability

Tornadoes are high-impact, low-probability hazards. The net impact of a tornado depends on the storm intensity and the vulnerability of development in its path. Tornado vulnerability is based on various factors, including building construction standards, availability of shelters or safe rooms, advanced warning capabilities, etc. Many variables need to be considered to establish an intensity-damage relationship.

Tornadoes with winds greater than 75 mph can cause significant structural damage to most buildings, but tornadoes with lower wind speeds can also cause damage, for example, by causing a tree to fall into a house. Most historical tornadoes in the CVPDC area are F0 and F1 on the Enhanced Fujita Scale. These cause minor to moderate damage. Damage that is likely to occur would be damage to trees, shrubbery, signs, antennas, with some damage to roofs and unanchored trailers. Higher wind events can pose a serious threat to people and infrastructure. The urban environment provides numerous objects that can become flying debris and severely injure people and damage structures.

Numerous wind damage investigations have revealed that the building elements most commonly damaged by tornadoes or other high winds are: [39]

- Roof structure blow-off or collapse. This type of failure typically occurs in buildings constructed before approximately 1990 or in buildings struck by a tornado.
- Collapse of fire station apparatus bay doors in fire stations constructed before approximately 2000.
- Glazing breakage from wind-borne debris generated by hurricanes or tornadoes.
- Roof coverings. Roof coverings are the most commonly damaged building element.
- Rooftop equipment. Equipment that is blown off frequently leaves openings in the roof and often punctures the roof covering.

4.6.3 Risk Assessment and Jurisdictional Analysis

The tornado risk cannot be fully estimated due to lack of intensity-damage models for this hazard. Instead, estimates of the financial impacts of tornadoes can be developed based on historical data contained within the NCEI storm event data. Table 4-118 presents the tornado touchdown information acquired from the NOAA storm event database and breaks down by jurisdiction. It shows the total of 29 events in the CVPDC area caused 31 injuries and 1 death and brought property damages of about 39.5 million dollars. While Campbell County has experienced the most tornado events, Appomattox County has recorded more tornado damage than other jurisdictions. However, the normalized data by land area of jurisdiction indicates Lynchburg is also at higher risk.

Table 4-118 Tornado touchdowns in CVPDC Area by jurisdiction, 1950 - 2019

Jurisdiction	Number of events	Number of Deaths	Number of Injuries	Property damage ($K)	Jurisdiction Size (Square Miles)	Events per Square Mile	Damage per Square Mile($K/mi^2)
Amherst County	4	0	7	4,355.0	479	0.008	9.092
Appomattox County	3	1	7	11,227.5	334	0.009	33.615
Bedford County	10	0	1	4,745.0	769	0.013	6.170
Campbell County	11	0	14	9,545.0	507	0.022	18.826
Lynchburg City	1	0	2	9,600.0	50	0.020	192.000

Note: If the path of a tornado on the ground occurred across jurisdictional boundaries, its occurrence could be counted in multiple jurisdictions. The tornado touchdowns for the Towns of Amherst, Appomattox, Altavista, and Brookneal are found in their respective county's totals.

The type and age of construction plays a role in vulnerability of structures to tornadoes. Risk to existing structures is largely determined by building construction type: construction methods, materials, and roof span. In terms of building types, older wood-frame and manufactured housing are generally more vulnerable than concrete, brick, and steel-framed structures. In terms of occupancy types, mobile homes are at a higher risk than any others. According to a recent study, 39 percent of people killed by tornadoes

[39] Guidelines for Wind Vulnerability Assessments of Existing Critical Facilities. FEMA. 2019

from 1985 to 2017 died in mobile homes.[40] That is especially significant considering only 6 percent lived in mobile homes during that period. Because mobile homes have no foundation or basement, they are more easily destroyed in a tornado. The risk increases when the mobile home isn't securely anchored to concrete slabs. Given the vulnerability of people living in mobile homes (including trailers and RVs), the owners of mobile home parks, trailer parks, RV parks, and campgrounds should strongly consider building storm shelters for their residents and campers.

Areas with tall buildings, such as downtown Lynchburg, are at a higher risk because of increased wind pressures at greater heights. A list of tall buildings in the CVPDC area can be found in the Earthquake hazard chapter. Open-air venues, including D-Day Memorial and Lynchburg City Stadium, are also particularly susceptible (Table 4-119).

Figure 4-104, Figure 4-105, Figure 4-106, Figure 4-107, and Figure 4-108 describe maps of geographic concentrations of mobile homes and wood structures for each jurisdiction. The building statistics derive from the building stock inventory data in the Hazus software (Version 4.2). [41] Table 4-120 lists RV parks and campgrounds in the CVPDC area by jurisdiction.

Table 4-119 Open-air venues in CVPDC Area

Facility Name	Location	Coordinates
National D-Day Memorial	3 Overlord Cir, Bedford	37.3305, -79.5360
City Stadium	3176 Fort Ave, Lynchburg	37.3924, -79.1664

Table 4-120 RV parks and campground in CVPDC Area

Locality	Facility Name	Location	Coordinates
Amherst	Otter Creek Campground	60851 Blue Ridge Pkwy, Monroe	37.5760, -79.3379
Amherst	Lynchburg/Blue Ridge Parkway KOA	6252 Elon Rd, Monroe	37.5744, -79.3247
Amherst	Shady Mountain Campground	Panther Falls Rd, Vesuvius	37.7170, -79.2893
Amherst	Oronoco Campground	Jordan Rd, Vesuvius	37.7488, -79.2653
Appomattox	Paradise Lake Family Campground	1105 W Lake Rd, Spout Spring	37.3372, -78.9372
Appomattox	Holliday Lake State Park Campground	2759 State Park Rd, Appomattox	37.3945, -78.6395
Bedford	Eagles Roost Campground	15335 Smith Mountain Lake Pkwy, Huddleston	37.0699, -79.5819
Bedford	Peaks of Otter Campground	10454 Peaks Rd, Bedford	37.4428, -79.6045
Bedford	Smith Mountain Lake State Park	1619 Overnight Rd, Huddleston	37.0834, -79.5951
Bedford	Mitchell's Point Marina & Campground	3553 Trading Post Rd, Huddleston	37.0622, -79.5601
Bedford	Moorman Marina	1510 Moorman Rd, Goodview	37.2232, -79.7753
Bedford	Waterfront Park Campground	1000 Waterfront Dr, Moneta	37.1397, -79.6464
Bedford	Hannabass-Crouch Campground	1241 Hannabass Dr, Goodview	37.1548, -79.6994

[40] Strader, *et al*. https://doi.org/10.1175/WCAS-D-18-0060.1

[41] In Hazus software, Mobile Home is coded as "RES2" occupancy class in building stock data.

Locality	Facility Name	Location	Coordinates
Bedford	Tri-County Marina	1261 Sunrise Loop, Lynch Station	37.0595, -79.4468
Bedford	Isle of Pines Subdivision Campground	Across From 3930 Isle Of Pines Drive	37.0998, -79.6246
Bedford	Spring Valley Farm Campground	2077 Meadors Spur Rd, Moneta	37.2234, -79.6669
Bedford	Camp Lowman	11738 Leesville Rd, Lynch Station	37.1569, -79.4332
Bedford	Camp Sacajawea--Girl Scouts	2124 Fox Hill Rd, Lynchburg	37.4704, -79.1918
Bedford	Legacy International-Global Youth Village	1020 Legacy Dr, Bedford	37.2370, -79.4137
Bedford	The Woods Adventure & Conference Retreat (Leased)	1336 Simmons Mill Rd, Thaxton	37.3073, -79.6844
Bedford	Camp Karma	2058 Stone Mountain Rd, Bedford	37.1944, -79.5664
Bedford	Church of God In Virginia--Bedford Camp	1032 Cider Mill Rd, Bedford	37.2147, -79.4621
Bedford	Halesford Harbour RV Park Resort	1336 Campers Paradise Trl, Moneta	37.1583, -79.6617
Bedford	Sweetwater RV Park	4474 White House Road, Moneta	37.1417, -79.5865
Bedford	Thomas Road Outpost	7794 Sheep Creek Rd, Bedford	37.4505, -79.6346
Bedford	Tuck-A-Way Campground	1312 Sunrise Loop, Lynch Station	37.0605, -79.4484
Campbell	Lynchburg RV Resort	405 Mollies Creek Rd, Gladys	37.2108, -79.0496
Campbell	Hat Creek Camp	7145 Hat Creek Rd, Brookneal	37.1116, -78.9304

4.6.4 Probability of Future Occurrences

The probability of future occurrences of tornadoes is definite; predicting the potential locations and costs for such events is nonviable given the scope of this analysis. According to the historic occurrence map, some areas in the CVPDC area appear to be slightly more prone to tornadoes than others, especially central Bedford County. This is caused by topographical influences on thunderstorms, such as the change in low-level wind flow and humidity caused by the orientation of the mountains.

Geographic Concentrations of Wood Structure and Mobile Home by Census Block in Amherst County, Virginia

Central Virginia PDC Hazard Mitigation Plan Update 2020

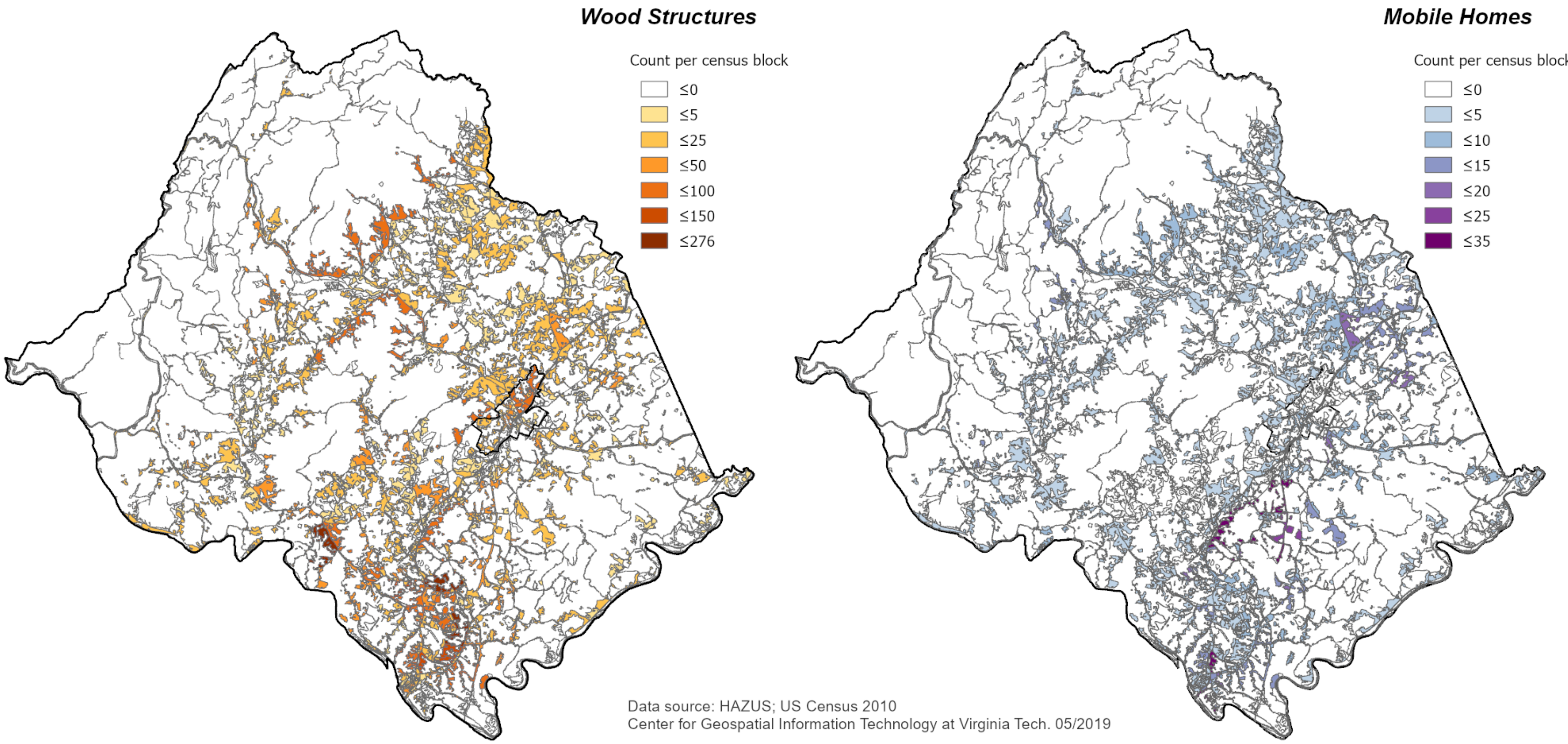


Figure 4-104 Geographic concentrations of wood structures and mobile home by census block in Amherst County, Virginia

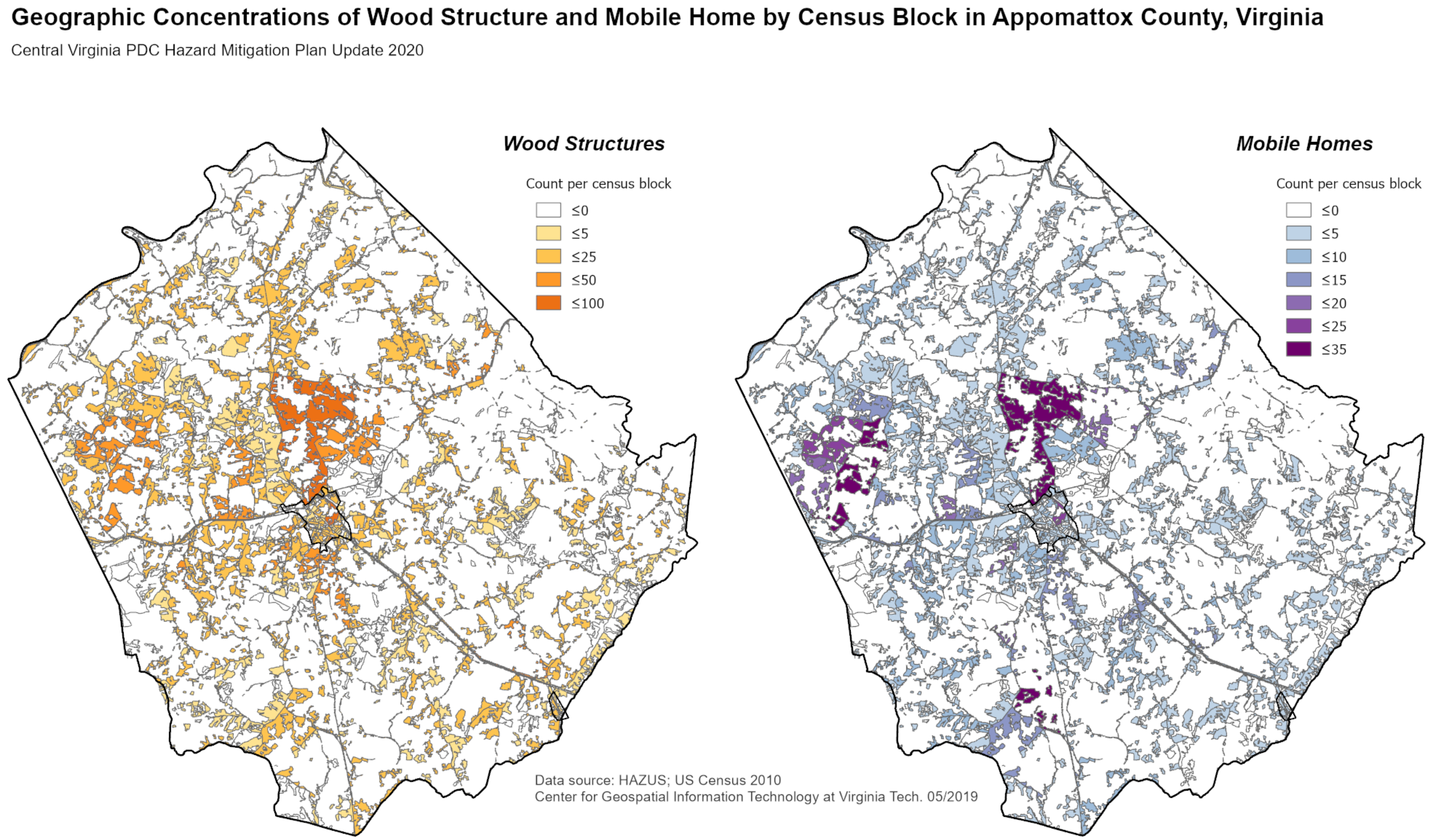


Figure 4-105 Geographic concentrations of wood structures and mobile home by census block in Appomattox County, Virginia

Geographic Concentrations of Wood Structure and Mobile Home by Census Block in Bedford County, Virginia

Central Virginia PDC Hazard Mitigation Plan Update 2020

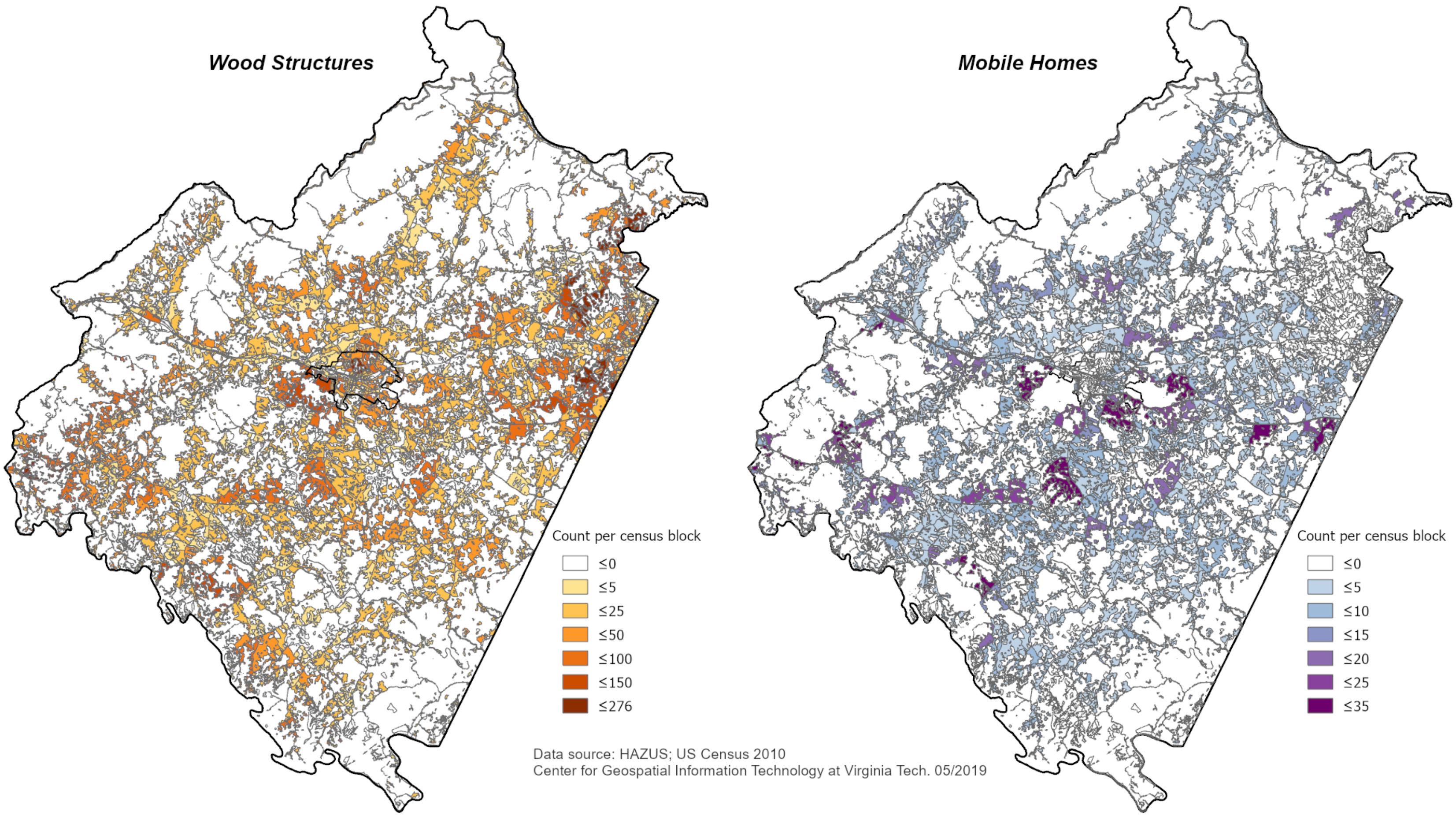


Figure 4-106 Geographic concentrations of wood structures and mobile home by census block in Bedford County, Virginia

Geographic Concentrations of Wood Structure and Mobile Home by Census Block in Campbell County, Virginia

Central Virginia PDC Hazard Mitigation Plan Update 2020

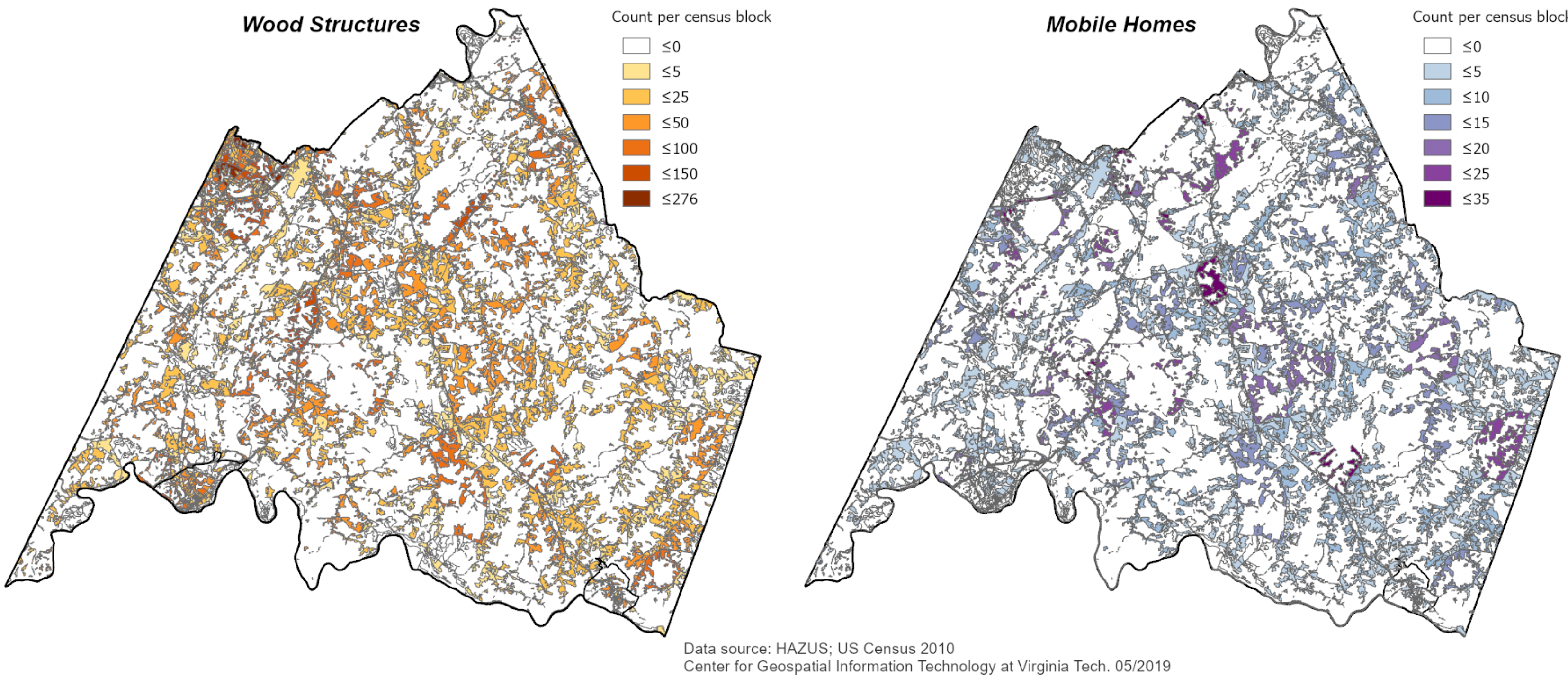


Figure 4-107 Geographic concentrations of wood structures and mobile home by census block in Campbell County, Virginia

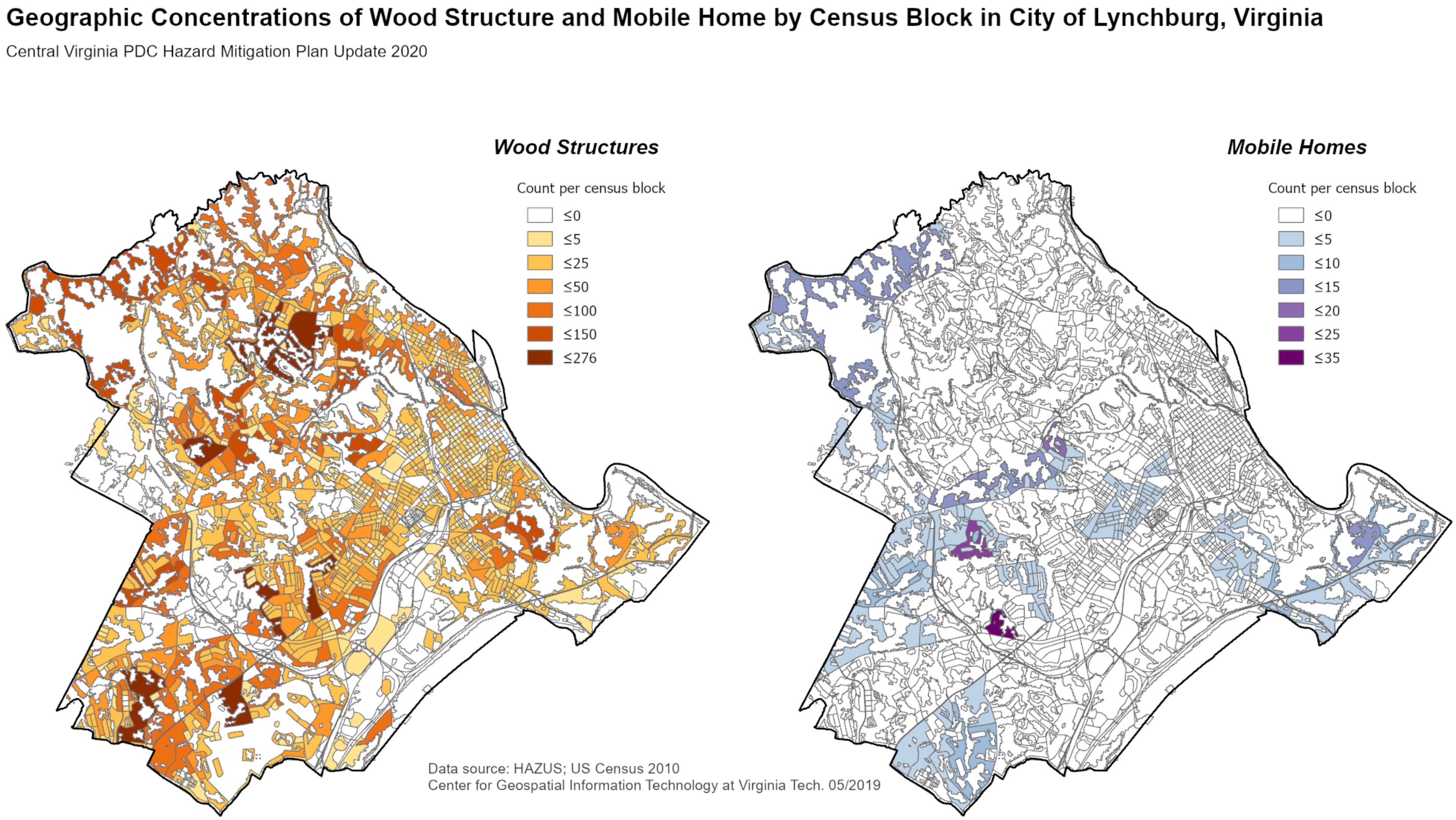


Figure 4-108 Geographic concentrations of wood structures and mobile home by census block in City of Lynchburg, Virginia

4.6.5 References

- Federal Emergency Management Agency. *Guidelines for Wind Vulnerability Assessments of Existing Critical Facilities*. September 2019. https://www.fema.gov/sites/default/files/2020-07/guidelines-wind-vulnerability.pdf.
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- Strader, Stephen M., and Walker S. Ashley. *Finescale Assessment of Mobile Home Tornado Vulnerability in the Central and Southeast United States*. Weather, Climate, and Society 10, no. 4 (October 2018): 797–812. https://doi.org/10.1175/WCAS-D-18-0060.1.
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