



## 4.3.19 Winter Storm

This section provides a profile and vulnerability assessment of the winter storm hazard for the Chester County Hazard Mitigation Plan (HMP).

### 4.3.19.1 Description

Winter storms occur, on average, approximately five times each year in Pennsylvania. From November through March, Pennsylvania is exposed to winter storms that move up the Atlantic coast or sweep in from the west. Every county in the Commonwealth is vulnerable to severe winter storms; however, the northern tier, western counties, and mountainous regions tend to experience winter weather more frequently and with greater severity.

Winter storms can produce more damage than any other severe weather event, including tornadoes. Complications caused by winter storms can lead to road closures (especially secondary and farm roads); business losses to commercial centers built in outlying areas because of supply interruption and loss of customers; property losses and roof damages from snow and ice loading and fallen trees; utility interruptions; and loss of water supplies. Flooding can result from winter storm events as well.

Most severe winter storm hazards include heavy snow (snowstorms), blizzards, sleet or freezing rain, ice storms, and mid-Atlantic cyclones locally known as Northeasters or Nor'easters. Because most Nor'easters generally occur during winter weather months, these hazards have also been grouped as a type of severe winter weather storm. Types of severe winter weather events or conditions are further defined as follows:

- **Heavy Snow:** According to the National Weather Service (NWS), heavy snow is generally considered snowfall accumulating to depth of 4 inches or more within 12 hours or less or snowfall accumulating to depth of 6 inches or more within 24 hours or less. A snow squall is an intense but limited-duration period of moderate to heavy snowfall, also known as a snowstorm, accompanied by strong, gusty surface winds and possibly lightning (generally moderate to heavy snow showers) (NWS 2009). Snowstorms are complex phenomena involving heavy snow and winds whose impact can be affected by a great many factors, including a region's climatological susceptibility to snowstorms, snowfall amounts, snowfall rates, wind speeds, temperatures, visibility, storm duration, topography, and occurrence during the course of the day, weekday versus weekend, and time of season (Kocin and Uccellini 2013).
- **Blizzard:** Blizzards are characterized by low temperatures, wind gusts of 35 miles per hour (mph) or more and falling and/or blowing snow that reduces visibility to 0.25 mile or less for an extended period (3 or more hours) (NWS 2009). A severe blizzard is defined as having a wind velocity of 45 mph, temperatures of 10 °F or lower, and a high density of blowing snow with visibility frequently measured in feet over an extended period.
- **Sleet or Freezing Rain:** Sleet is defined as pellets of ice composed of frozen or mostly frozen raindrops or refrozen, partially melted snowflakes. These pellets of ice usually bounce after hitting the ground or other hard surfaces. Freezing rain is rain that falls as a liquid but freezes into glaze upon contact with the ground. Both types of precipitation, even in small accumulations, can cause significant hazards to a community (NWS 2009).
- **Ice Storm:** An ice storm is described as an occasion when damaging volumes of ice are expected to accumulate during freezing rain situations. Significant accumulations of ice pull down trees and utility lines, resulting in loss of power and means of communication. These accumulations of ice render walking and driving extremely dangerous and can create extreme hazards to motorists and pedestrians (NWS 2009).
- **Nor'easter:** Nor'easters are macro-scale, extra-tropical storms named for the strong northeasterly winds that blow in from the Atlantic Ocean ahead of the storm and over coastal areas of the northeastern United States and Atlantic Canada. They are also referred to as a type of extra-tropical cyclone (mid-latitude



storms, or Great Lake storms). Wind gusts associated with Nor’easters can exceed hurricane forces in intensity. Unlike tropical cyclones that form in the tropics and have warm cores (including tropical depressions, tropical storms, and hurricanes), Nor’easters contain a cold core of low barometric pressure that forms in the mid-latitudes. Their strongest winds are close to the earth’s surface and often extend several hundred miles across. Nor’easters may occur at any time of the year but are more common during fall and winter months (September through April) (New York City Office of Emergency Management [NYCOEM] n.d.).

Nor’easters can induce heavy snow, rain, and gale-force winds, that can cause structural damage, power outages, and unsafe human conditions. If a Nor’easter cyclone stays just offshore, the results are much more devastating than if the cyclone travels up the coast on an inland track. Nor’easters that stay inland are generally weaker and usually cause strong winds and rain. Those that stay offshore can bring heavy snow, blizzards, ice, and strong winds. In these storms, the warmer air is aloft. Precipitation falling from this warm air moves into the colder air at the surface, causing crippling sleet or freezing rain (McNoldy Multi-Community Environmental Storm Observatory [MESO] n.d.). While some of the most devastating effects of Nor’easters occur in coastal areas (e.g., beach erosion, coastal flooding), effects on inland areas, like Chester County, may include heavy snow, strong winds, and blizzards.

**4.3.19.2 Location and Extent**

Winter storms are regional events, most of which impact a large area of the entire Commonwealth. In many cases, surrounding states and even the northeast region of the United States is affected by a single winter storm incident.

The magnitude or severity of a severe winter storm depends on several factors, including a region’s climatological susceptibility to snowstorms, snowfall amounts, snowfall rates, wind speeds, temperatures, visibility, storm duration, topography, time of occurrence during the day (e.g., weekday versus weekend), and time of season.

The extent of a severe winter storm can be classified by meteorological measurements and by evaluating its societal impacts. National Oceanic and Atmospheric Administration’s (NOAA) National Centers for Environmental Information (NCEI) is currently producing the Regional Snowfall Index (RSI) for significant snowstorms that affect the eastern two-thirds of the United States. The RSI ranks snowstorm impacts on a scale from 1 to 5. The index is based on spatial extent of the storm, amount of snowfall, and interaction of the extent and snowfall totals with population (based on the 2000 U.S. Census). NCEI has analyzed and assigned RSI values to over 500 storms since 1900 (NCEI 2011). Table 4.3.19-1 lists the five RSI ranking categories.

**Table 4.3.19-1. RSI Ranking Categories**

Category	Description	Regional Snowfall Index (RSI)
1	Notable	1-3
2	Significant	3-6
3	Major	6-10
4	Crippling	10-18
5	Extreme	18.0+

Source: NCEI 2011



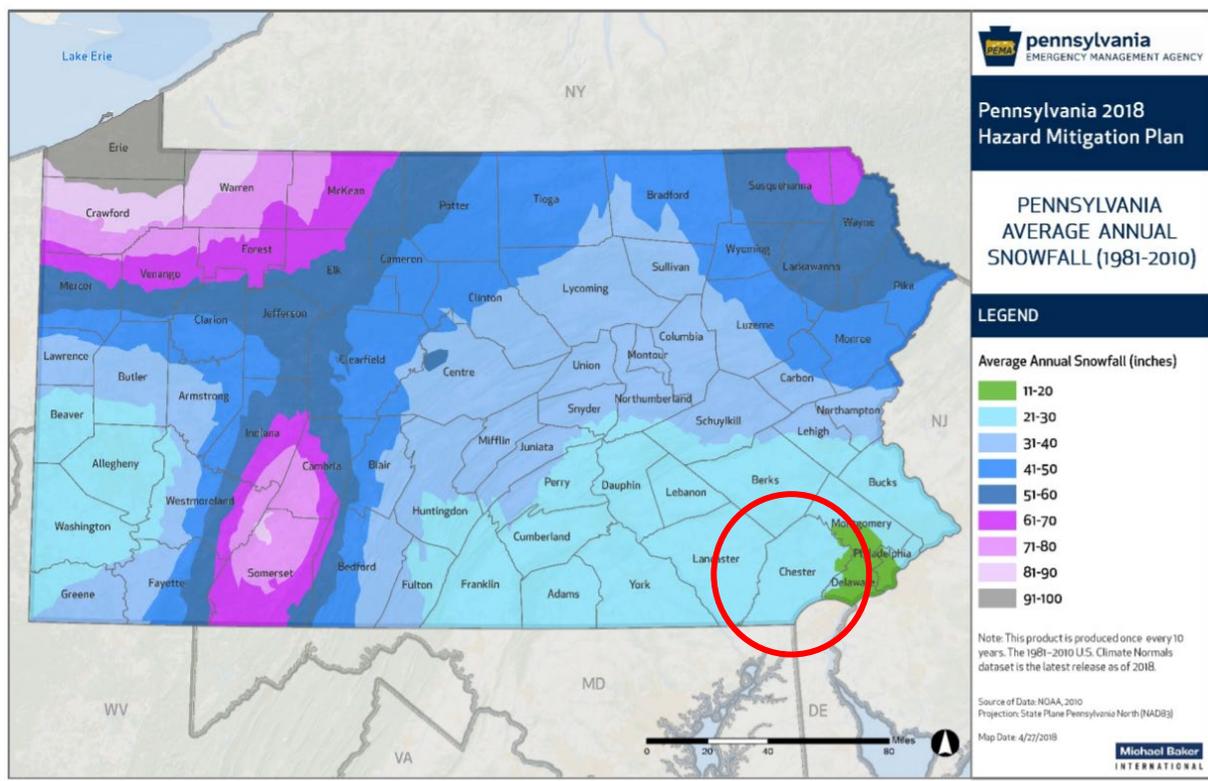
### 4.3.19.3 Range in Magnitude

A winter storm can adversely affect roadways, utilities, and businesses and can cause loss of life, frostbite, and freezing conditions. These storms typically fall into one of the following categories, defined in the previous section:

- Heavy snow
- Sleet or freezing rain
- Ice storm
- Blizzard
- Nor'easter

All of Chester County is susceptible to winter storms. Based on annual snowfall averages according to the 2018 State HMP, snowfall accumulation during the winter season in Chester County ranges from 30 or less inches, as shown on Figure 4.3.19-1.

Figure 4.3.19-1. Annual Snowfall



Source: Pennsylvania Emergency Management Agency (PEMA) 2018  
Note: The red circle surrounds Chester County.

The March 1993 snowstorm has been referred to as the “storm of the century,” but the worst-case scenario of a winter storm in Chester County occurred in January 1996. A blizzard dropped 26 inches of snow on the county with significant drifting, causing many primary and secondary road closures. There were 154 fatalities total, 80 of which were in Pennsylvania and an estimated \$600 million to \$3 billion in property damage on the east coast (reflects 1996 dollars). The federal government was shut down for a week because of the storm and D.C. and nine states were declared disaster areas (History 2009).



#### 4.3.19.4 Past Occurrence

Many sources provided historical information regarding previous occurrences and losses associated with winter storm events throughout the Commonwealth of Pennsylvania and Chester County. With so many sources reviewed for the purpose of this plan, loss and impact information for many events varied depending on the source. Therefore, accuracy of monetary figures discussed is based only on available information identified during research for this plan. Monetary figures may also have been calculated for the region, based on entire storm damage, and include damage from other counties.

Between 1954 and 2020, the Federal Emergency Management Agency (FEMA) declared that the Commonwealth of Pennsylvania experienced eight winter storm-related disasters (DR) or emergencies (EM) classified as one or a combination of the following disaster types: severe winter storms, snowstorms, blizzards, winter storms, severe storms, and snowfalls. Generally, these disasters covered a wide region of the Commonwealth, and therefore may have impacted many counties. However, not all counties were included in the disaster declarations. Pennsylvania Emergency Management Agency (PEMA) and other sources indicate that Chester County has been declared as a disaster area as a result of seven of the declarations for winter storm events (FEMA 2020).

According to the NOAA-NCEI storm events database, Chester County experienced 22 major winter storm events between March 1993 and March 2019. Based on all sources researched, known winter storm events that have affected Chester County are listed in Table 4.3.19-2. Because winter storm documentation for the Commonwealth of Pennsylvania is so extensive, not all sources have been identified or researched. Therefore, Table 4.3.19-2 may not include all events that have occurred throughout the county.

**Table 4.3.19-2. Major Winter Storm Events in Chester County between 1993 and 2020**

Dates of Event	Event Type	FEMA Declaration Number	County Designated?	Losses / Impacts
March 13-17, 1993	Severe Snowfall and Winter Storm	EM-3105	Yes	A winter storm with heavy snowfall occurred in Chester County and other counties through Pennsylvania. Nearly three feet fell within the county.
January 4-February 25, 1994	Winter Storm, Severe Storm	DR-1015	Yes	A winter storm affected several counties in Pennsylvania including Chester with freezing temperatures and more than 15 inches of snow.
January 6-12, 1996	Blizzard	DR-1085	Yes	Blizzard affected several counties in Pennsylvania including Chester. Parts of the county saw 26 inches of snow. There were 80 fatalities in the state. \$600 million - \$3 billion in damages throughout the east coast were reported.
February 14-19, 2003	Snowstorm	EM-3180	Yes	A snowstorm affected several counties in Pennsylvania including Chester. A major accident closed the eastbound lanes of the PA turnpike between Morgantown and Downingtown for 3 hours.
February 5-11, 2010	Severe Winter Storms and Snowstorms	DR-1898	Yes	Several Pennsylvania counties were affected by severe winter storms that caused major damage. 60,500 people experienced power outages in Chester County.
December 8-9, 2013	Winter Storm	N/A	N/A	5-8 inches of snow fell throughout the county causing numerous accidents and road closures.
December 14-15, 2013	Winter Storm	N/A	N/A	Snow, sleet, and freezing rain fell within the county causing difficult traveling conditions as well as isolated power outages.
January 2-3, 2014	Heavy Snow	N/A	N/A	5-8 inches of snow fell throughout Chester County.
January 21, 2014	Heavy Snow	N/A	N/A	8-9 inches of heavy snow fell in Chester County causing accidents and traffic tie-ups as well as flight cancellations.



Dates of Event	Event Type	FEMA Declaration Number	County Designated?	Losses / Impacts
February 3, 2014	Heavy Snow	N/A	N/A	8 inches of snow fell throughout the county. Schools were delayed and flights were cancelled, and some homes and businesses lost power.
February 4-20, 2014	Severe Winter Storm	EM-3367	Yes	A mix of heavy snow and ice storms happened throughout the county. In Chester County, whole municipalities lost power as did 87 percent of the county overall. There were about 400 tree blocked roadways in the county. Hardest hit municipalities included Highland, Charlestown, East Nantmeal, Parkesburg, and West Vincent. West Chester University was used as a shelter. About 265 Verizon telephone customers lost service in West Fallowfield Township. In Montgomery County, there were 340 calls for electrical fires, 1,001 road obstructions, 153 crashes, and more than 4,000 calls for police assistance. Fifty major roadways were blocked by fallen trees.
February 21, 2015	Winter Storm	N/A	N/A	Snow, sleet, and freezing rain fell across the county. No reported losses.
March 1, 2015	Winter Storm	N/A	N/A	Snowfall averaged one to four inches, but ice accumulations on exposed surfaces reached as high as around one-quarter of an inch in southeastern Pennsylvania. This caused widely scattered power outages
March 5, 2015	Heavy Snow	N/A	N/A	8-11 inches fell in the county. Pennsylvania Turnpike (Interstate 76) was closed for more than 4 hours due to a multiple tractor trailer accident in West Pikeland Township and many people lost power.
January 22-23, 2016	Severe Winter Storm and Snowstorm	DR-4267	Yes	Winds gusting over 35 mph reduced visibilities to under one-quarter mile at times. Some representative snowfall totals include 26.2 inches in East Vincent Township, 26.0 inches in Phoenixville, 26.0 inches in East Nantmeal, 25.5 inches in Caln, and 25.0 inches in East Coventry Township.
February 9-10, 2016	Heavy Snow	N/A	N/A	Some snowfall totals from eastern Chester County include 4.7 inches in West Chester, and 4.7 inches near Chadds Ford. Slippery conditions on untreated roads were problematic during the afternoon commute on the 9th, with numerous automobile accidents reported.
March 14, 2017	Winter Storm	N/A	N/A	Snowfall ranged from 5 to 8 inches across the county. Some sleet and freezing rain mixed in as well
March 6-7, 2018	Winter Storm	N/A	N/A	Over a foot of snow fell in a very short period across the eastern portions of the county. Area roadways were impassable. Some reported snowfall totals: 8.1 inches in Glenmoore, 8.0 inches in Coatesville, 6.8 inches in Exton, and 4.8 inches in Chester Springs.
March 21, 2018	Winter Storm	N/A	N/A	A mix of wet and dry snow fell throughout the county. The highest snowfall totals from the event occurred along and north of I-276. Some reported snowfall amounts include: 10.3 inches in Uwchlan Township, 10.0 inches in Elverson, and 8.6 inches in Glenmoore.
November 15, 2018	Winter Storm	N/A	N/A	An early season winter storm total snowfall ranged from 7.3 in East Nantmeal Township to 3.7 in Atglen.
February 20, 2019	Winer Storm	N/A	N/A	3.8 inches of snow and 0.15 inch of ice accumulated in the county.
March 3-4, 2019	Winter Storm	N/A	N/A	6.0 inches of snow in East Nantmeal Twp. and 5.2 inches in East Coventry Twp. were reported.



Source: NCEI 2020

Notes:

Monetary figures within this table were U.S. Dollar (USD) figures calculated during or within the approximate time of the event. If such an event would occur in the present day, many monetary losses earlier than 2017 would be considerably higher in USDs as a result of increased U.S. Inflation Rates.

DR	Federal Disaster Declaration	NCEI	National Centers for Environmental Information
FEMA	Federal Emergency Management Agency	NOAA	National Oceanic Atmospheric Administration
N/A	Not applicable/available		

### 4.3.19.5 Future Occurrence

Apparently, given the history of winter storm events that have impacted Chester County, future winter storm events of varying degrees will occur every year, and thus many people and properties are at risk from the winter storm hazard in the future.

Based on available historical data, future occurrences of winter storm events are considered *likely*, according to Risk Factor Methodology probability criteria further discussed in Section 4.4.

### 4.3.19.6 Vulnerability Assessment

To understand risk, a community must evaluate that assets that are exposed or vulnerable within the identified hazard area. Regarding winter storm events, all of Chester County has been identified as the hazard area. Therefore, all assets (population, structures, critical facilities and lifelines), as described in the Section 2, County Profile, are potentially vulnerable. The following section includes an evaluation and estimation of potential winter storm impacts on the county, including:

- Data and methodology used for the evaluation
- Impacts on life, health, and safety; general building stock; critical facilities; economy; environment; and future growth and development
- Effect of climate change on vulnerability
- Further data collections that will increase understanding of this hazard over time

### Impact on Life, Health, and Safety

According to the NOAA National Severe Storms Laboratory (NSSL), winter weather indirectly and deceptively kills hundreds of people in the United States every year, primarily from automobile accidents, overexertion, and exposure. Winter storms are often accompanied by strong winds creating blizzard conditions with blinding wind-driven snow, drifting snow, extreme cold temperatures, and dangerous wind chill. Winter storms are considered deceptive killers because most deaths and other impacts or losses are indirectly related to the storm. People can die in traffic accidents on icy roads, of heart attacks while shoveling snow, or of hypothermia from prolonged exposure to cold.

Heavy snow can immobilize a region and paralyze a city, shutting down air and rail transportation, stopping flow of supplies, and disrupting medical and emergency services. First responders will have to take on additionally responsibilities during winter storm events such as controlling traffic, debris removal from roads, answering to a higher than normal call volume and demand, and responding to weather related traffic accidents. First responders' safety may be at risk during on scene operations and limited access to roads due to damaged infrastructure and debris may hinder their ability to respond to accidents in a timely manner. Accumulations of snow can collapse buildings and knock down trees and power lines. In rural areas, homes and farms may be isolated for days, and unprotected livestock may be lost. In the mountains, heavy snow can lead to avalanches (NSSL 2015c).

Heavy accumulations of ice can bring down trees, electrical wires, telephone poles and lines, and communication towers. Communications and power can be disrupted for days while utility companies work to repair the





extensive damage. Even small accumulations of ice may cause extreme hazards to motorists and pedestrians. Bridges and overpasses are particularly dangerous because they freeze before other surfaces (NSSL 2015c).

For the purposes of this HMP, the entire population of Chester County is considered exposed to winter storm events (U.S. Census 2010). The elderly is considered most susceptible to this hazard because of their increased risk of injuries and death from falls and overexertion, and/or hypothermia from exposure while attempting to clear snow and ice. In addition, winter storm events can reduce ability of these populations to access emergency services. Residents with low incomes may not have access to housing, or their housing may be less able to withstand cold temperatures (e.g., homes with poor insulation and heating supply). Section 2, County Profile, of this HMP provides population statistics regarding each participating municipality and a summary of the more vulnerable populations (over the age of 65 and individuals living below the U.S. Census poverty threshold).

### Impact on General Building Stock

The entire general building stock inventory in Chester County is exposed and vulnerable to the winter storm hazard. In general, structural impacts include damage to roofs and building frames rather than building content. Current modeling tools are not available to estimate specific losses from this hazard. As an alternate approach, this plan considers percentage damages that could result from winter storm conditions. Table 4.3.19-3 below summarizes percent damages from winter storm conditions on Chester County’s total general building stock. Given professional knowledge and currently available information, potential losses from this hazard are considered overestimated; hence, the listed values in Table 4.3.19-3 represent conservative estimates of losses associated with severe winter storm events.

**Table 4.3.19-3. General Building Stock Exposure and Estimated Losses from Winter Storm Events in Chester County**

Jurisdiction	Total Replacement Cost Value (RCV)	1-Percent Exposure/Loss	5-Percent Exposure/Loss	10%-Percent Exposure/Loss
Atglen (B)	\$300,171,233	\$3,001,712	\$15,008,562	\$30,017,123
Avondale (B)	\$275,491,131	\$2,754,911	\$13,774,557	\$27,549,113
Birmingham (Twp.)	\$1,521,752,088	\$15,217,521	\$76,087,604	\$152,175,209
Caln (Twp.)	\$4,389,258,174	\$43,892,582	\$219,462,909	\$438,925,817
Charlestown (Twp.)	\$2,334,124,537	\$23,341,245	\$116,706,227	\$233,412,454
Coatesville (C)	\$2,658,702,748	\$26,587,027	\$132,935,137	\$265,870,275
Downingtown (B)	\$2,678,308,815	\$26,783,088	\$133,915,441	\$267,830,881
East Bradford (Twp.)	\$3,166,888,223	\$31,668,882	\$158,344,411	\$316,688,822
East Brandywine (Twp.)	\$2,499,920,165	\$24,999,202	\$124,996,008	\$249,992,017
East Caln (Twp.)	\$1,864,909,402	\$18,649,094	\$93,245,470	\$186,490,940
East Coventry (Twp.)	\$2,200,926,728	\$22,009,267	\$110,046,336	\$220,092,673
East Fallowfield (Twp.)	\$1,984,687,476	\$19,846,875	\$99,234,374	\$198,468,748
East Goshen (Twp.)	\$5,680,635,001	\$56,806,350	\$284,031,750	\$568,063,500
East Marlborough (Twp.)	\$3,646,563,821	\$36,465,638	\$182,328,191	\$364,656,382
East Nantmeal (Twp.)	\$1,131,945,456	\$11,319,455	\$56,597,273	\$113,194,546
East Nottingham (Twp.)	\$3,185,167,607	\$31,851,676	\$159,258,380	\$318,516,761
East Pikeland (Twp.)	\$2,751,413,608	\$27,514,136	\$137,570,680	\$275,141,361
East Vincent (Twp.)	\$2,764,012,516	\$27,640,125	\$138,200,626	\$276,401,252



Section 4.3.19: Risk Assessment – Winter Storm

Jurisdiction	Total Replacement Cost Value (RCV)	1-Percent Exposure/Loss	5-Percent Exposure/Loss	10%-Percent Exposure/Loss
East Whiteland (Twp.)	\$8,143,686,632	\$81,436,866	\$407,184,332	\$814,368,663
Easttown (Twp.)	\$3,998,338,009	\$39,983,380	\$199,916,900	\$399,833,801
Elk (Twp.)	\$754,193,647	\$7,541,936	\$37,709,682	\$75,419,365
Elverson (B)	\$516,332,051	\$5,163,321	\$25,816,603	\$51,633,205
Franklin (Twp.)	\$1,537,535,450	\$15,375,354	\$76,876,772	\$153,753,545
Highland (Twp.)	\$1,067,555,265	\$10,675,553	\$53,377,763	\$106,755,526
Honey Brook (B)	\$446,825,932	\$4,468,259	\$22,341,297	\$44,682,593
Honey Brook (Twp.)	\$3,389,705,910	\$33,897,059	\$169,485,296	\$338,970,591
Kennett (Twp.)	\$4,134,894,338	\$41,348,943	\$206,744,717	\$413,489,434
Kennett Square (B)	\$1,600,982,472	\$16,009,825	\$80,049,124	\$160,098,247
London Britain (Twp.)	\$1,064,040,035	\$10,640,400	\$53,202,002	\$106,404,003
London Grove (Twp.)	\$3,148,102,405	\$31,481,024	\$157,405,120	\$314,810,241
Londonderry (Twp.)	\$1,034,199,367	\$10,341,994	\$51,709,968	\$103,419,937
Lower Oxford (Twp.)	\$2,325,017,464	\$23,250,175	\$116,250,873	\$232,501,746
Malvern (B)	\$1,256,307,741	\$12,563,077	\$62,815,387	\$125,630,774
Modena (B)	\$143,886,459	\$1,438,865	\$7,194,323	\$14,388,646
New Garden (Twp.)	\$5,996,313,471	\$59,963,135	\$299,815,674	\$599,631,347
New London (Twp.)	\$1,850,994,293	\$18,509,943	\$92,549,715	\$185,099,429
Newlin (Twp.)	\$767,919,221	\$7,679,192	\$38,395,961	\$76,791,922
North Coventry (Twp.)	\$2,814,129,243	\$28,141,292	\$140,706,462	\$281,412,924
Oxford (B)	\$1,620,222,123	\$16,202,221	\$81,011,106	\$162,022,212
Parkesburg (B)	\$791,790,495	\$7,917,905	\$39,589,525	\$79,179,050
Penn (Twp.)	\$3,335,917,017	\$33,359,170	\$166,795,851	\$333,591,702
Pennsbury (Twp.)	\$1,741,030,601	\$17,410,306	\$87,051,530	\$174,103,060
Phoenixville (B)	\$4,404,373,172	\$44,043,732	\$220,218,659	\$440,437,317
Pocopson (Twp.)	\$1,616,048,060	\$16,160,481	\$80,802,403	\$161,604,806
Sadsbury (Twp.)	\$1,514,078,865	\$15,140,789	\$75,703,943	\$151,407,886
Schuylkill (Twp.)	\$3,296,773,180	\$32,967,732	\$164,838,659	\$329,677,318
South Coatesville (B)	\$656,482,254	\$6,564,823	\$32,824,113	\$65,648,225
South Coventry (Twp.)	\$1,175,837,157	\$11,758,372	\$58,791,858	\$117,583,716
Spring City (B)	\$913,935,869	\$9,139,359	\$45,696,793	\$91,393,587
Thornbury (Twp.)	\$1,249,939,720	\$12,499,397	\$62,496,986	\$124,993,972
Tredyffrin (Twp.)	\$13,427,976,905	\$134,279,769	\$671,398,845	\$1,342,797,691
Upper Oxford (Twp.)	\$1,327,197,078	\$13,271,971	\$66,359,854	\$132,719,708
Upper Uwchlan (Twp.)	\$3,757,709,779	\$37,577,098	\$187,885,489	\$375,770,978
Uwchlan (Twp.)	\$7,025,589,763	\$70,255,898	\$351,279,488	\$702,558,976



Jurisdiction	Total Replacement Cost Value (RCV)	1-Percent Exposure/Loss	5-Percent Exposure/Loss	10%-Percent Exposure/Loss
Valley (Twp.)	\$2,597,377,442	\$25,973,774	\$129,868,872	\$259,737,744
Wallace (Twp.)	\$1,322,743,721	\$13,227,437	\$66,137,186	\$132,274,372
Warwick (Twp.)	\$1,133,542,100	\$11,335,421	\$56,677,105	\$113,354,210
West Bradford (Twp.)	\$3,995,074,181	\$39,950,742	\$199,753,709	\$399,507,418
West Brandywine (Twp.)	\$2,231,906,820	\$22,319,068	\$111,595,341	\$223,190,682
West Caln (Twp.)	\$2,765,167,902	\$27,651,679	\$138,258,395	\$276,516,790
West Chester (B)	\$5,374,643,016	\$53,746,430	\$268,732,151	\$537,464,302
West Fallowfield (Twp.)	\$1,743,066,295	\$17,430,663	\$87,153,315	\$174,306,629
West Goshen (Twp.)	\$9,444,801,871	\$94,448,019	\$472,240,094	\$944,480,187
West Grove (B)	\$499,625,186	\$4,996,252	\$24,981,259	\$49,962,519
West Marlborough (Twp.)	\$997,081,475	\$9,970,815	\$49,854,074	\$99,708,147
West Nantmeal (Twp.)	\$1,139,858,316	\$11,398,583	\$56,992,916	\$113,985,832
West Nottingham (Twp.)	\$1,196,217,005	\$11,962,170	\$59,810,850	\$119,621,701
West Pikeland (Twp.)	\$1,506,034,830	\$15,060,348	\$75,301,741	\$150,603,483
West Sadsbury (Twp.)	\$1,651,357,888	\$16,513,579	\$82,567,894	\$165,135,789
West Vincent (Twp.)	\$2,587,356,437	\$25,873,564	\$129,367,822	\$258,735,644
West Whiteland (Twp.)	\$7,660,221,171	\$76,602,212	\$383,011,059	\$766,022,117
Westtown (Twp.)	\$3,282,102,771	\$32,821,028	\$164,105,139	\$328,210,277
Willistown (Twp.)	\$4,727,817,226	\$47,278,172	\$236,390,861	\$472,781,723
<b>Chester County (Total)</b>	<b>\$194,736,735,824</b>	<b>\$1,947,367,358</b>	<b>\$9,736,836,791</b>	<b>\$19,473,673,582</b>

Source: Chester County GIS 2020; RSMeans 2019

Notes: % - Percent; B = Borough; C = City; Twp. = Township

An area especially vulnerable to the winter storm hazard is the floodplain. At-risk building stock and infrastructure in floodplains are presented in the flood hazard profile in Section 4.3.6. Generally, losses from flooding associated with winter storms should be less than those associated with a 1-percent or 0.2-percent flood. Snow and ice melt can cause both riverine and urban flooding. Estimated losses caused by riverine flooding in the county are discussed in Section 4.3.6.

### Impact on Critical Facilities

Full functionality of critical facilities such as police, fire, and emergency medical services is essential for response during and after a winter storm event. These critical facility structures are largely constructed of concrete and masonry; therefore, these should undergo only minimal structural damage from severe winter storm events. Because power interruption can occur, backup power is recommended for critical facilities and infrastructure.

### Impact on the Economy

Infrastructure at risk from the winter storm hazard includes roadways that could be damaged by application of salt and intermittent freezing and warming conditions that can damage roads over time. Costs of snow and ice removals, as well as repairs of roads undergoing freeze/thaw cycles, can drain local financial resources. Potential



secondary impacts from winter storms also impact the local economy, including loss of utilities, interruption of transportation corridors, and loss of business function.

### Impact on the Environment

Environmental impacts often include damage to trees and shrubs caused by heavy snow loading, ice build-up, and/or high winds, which can break limbs and down large trees. Indirect effects of winter storms include possible damage to surfaces and contamination of groundwater adjacent to roadway surfaces treated with salt, chemicals, and other de-icing materials (PEMA 2013).

Winter storms have a positive environmental impact; gradual melting of snow and ice recharges groundwater. However, abrupt high temperatures following a heavy snowfall can accelerate snowmelt, leading to rapid surface water runoff and severe flooding (PEMA 2013).

### Future Changes That May Impact Vulnerability

Understanding future changes that impact vulnerability in the county can assist in planning for future development and ensure that appropriate mitigation, planning, and preparedness measures are in place. The county considered the following factors to examine potential conditions that can affect hazard vulnerability:

- Potential or projected development
- Projected changes in population
- Other identified conditions as relevant and appropriate, including the impacts of climate change

### Projected Development

Areas targeted for potential future growth and development within the next 5 to 10 years have been identified across the county at the municipal level and are further discussed in Section 2.4 of this HMP. Because Chester County in its entirety has been identified as the hazard area vulnerable to the winter storm hazard, any new development will be exposed to associated risks. However, because of increased standards and codes, new development may be less vulnerable to the severe winter weather hazard compared with the aging building stock in the county.

### Projected Changes in Population

As discussed in Section 2, County Profile, the Chester County population has been increasing and is projected to continue to increase in coming decades. In addition, the population is aging. As the aging population grows, so too will the number of persons vulnerable to severe winter weather and extreme cold temperatures.

### Climate Change

Climate is defined not simply as average temperature and precipitation, but also by the type, frequency, and intensity of weather events. Both globally and at the local scale, climate change has the potential to alter the prevalence and severity of extreme events such as winter storms. While predicting changes of winter storm events under a changing climate is difficult, understanding vulnerabilities to potential changes is a critical part of estimating future climate change impacts on human health, society and the environment (U.S. Environmental Protection Agency [EPA] 2006).

In terms of snowfall and ice storms in Chester County, the lack of quantitative data makes it difficult to predict the ways in which future climate change will affect this hazard. It is likely that the number of winter weather events may decrease, and the winter weather season may shorten; however, it is also possible that the intensity of winter storms may increase. An increase in the frequency and severity of severe winter storms could result in an increase of snow loads on the county's building stock and infrastructure, putting each building at risk to structural damage. More frequent and severe events also will result in increased resources spent to prepare for and clean-up after an event. However, as winter temperatures continue to rise, climate projections indicate the increase in precipitation is likely to occur during the winter months as rain. Increased rain on snowpack or frozen or saturated soils can lead to increased flooding and related impacts on the county's assets.



### **Vulnerability Change Since the 2015 HMP**

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Overall, the county’s exposure and vulnerability have not changed, and the entire county will continue to be exposed and vulnerable to severe winter storm events.

### **Effect of Climate Change on Vulnerability**

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Climate is defined not just as average temperature and precipitation, but also by type, frequency, and intensity of weather events. Both globally and at the local level, climate change potentially can alter prevalence and severity of weather extremes such as winter storms. While predicting changes in winter storm events under a changing climate is difficult, understanding vulnerabilities to potential changes is a critical part of estimating future climate change impacts on human health, society, and the environment.

The climate of Pennsylvania has changed in several ways. Over the past 100 years, annual average temperatures have been rising across the Commonwealth. Warmer winters have led to decrease in snow cover and earlier arrival of spring. Recent analyses based on the Intergovernmental Panel on Climate Change models suggest a decrease in frequency and an increase in intensity of extra-tropical winter cyclones. However, based on the methodology applied, some models show no significant change in the storm track whereas others indicate a northward displacement of the storm track in the North Atlantic. For the mid-Atlantic region, there is little indication of a change in storm activity or track over Pennsylvania. An overall increase in winter precipitation is anticipated, with decrease in snow and increase in rain during the winter months. Projections regarding future occurrences of extra-tropical cyclones in Pennsylvania are substantially uncertain. Based on available information and projections, winter storms are anticipated to continue to affect Pennsylvania in the future. Future improvements in modeling smaller-scale climatic processes can be expected and will lead to improved understanding of ways in which changing climate will alter temperature, precipitation, and storm events in Pennsylvania (Shortle and others 2009).

### **Additional Data and Next Steps**

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The assessment above identifies vulnerable populations and economic losses associated with the winter storm hazard of concern. Historical data on structural losses to general building stock are not adequate to predict specific losses to this inventory; therefore, the percent of damage assumption methodology was applied. This methodology is based on FEMA How-to Series (FEMA 386-2), Understanding Your Risks, Identifying and Estimating Losses (FEMA 2001), and FEMA’s Using HAZUS-MH for Risk Assessment (FEMA 433) (FEMA 2015a). Acquisition of additional and actual valuation data regarding general building stock and critical infrastructure losses would further support future estimates of potential exposure of and damage to the general building stock inventory.