



5.4.5 LANDSLIDE

The following section provides the hazard profile (hazard description, location, extent, previous occurrences and losses, probability of future occurrences, and impact of climate change) and vulnerability assessment for the landslide hazard in Burlington County.

2019 HMP UPDATE CHANGES

- The hazard profile has been significantly enhanced to include a detailed hazard description, location, extent, previous occurrences, probability of future occurrence, and potential change in climate and its impacts on the landslide hazard is discussed. Additionally, it includes information regarding sinkholes.
- New and updated figures from federal and state agencies are incorporated. U.S. 2010 Census data was incorporated, where appropriate.
- Previous occurrences were updated with events that occurred between 2013 and 2018.
- A vulnerability assessment was conducted for the geological hazards; it now directly follows the hazard profile.

5.4.5.1 PROFILE

Hazard Description

Geologic hazards are any geological or hydrological processes that pose a threat to humans and natural properties. Every year, severe natural events destroy infrastructure and cause injuries and deaths. Geologic hazards may include volcanic eruptions and other geothermal related features, earthquakes, landslides and other slope failures, mudflows, sinkhole collapses, snow avalanches, flooding, glacial surges and outburst floods, tsunamis, and shoreline movements. For the purpose of this HMP update, only landslides and land subsidence/sinkholes will be discussed.

Landslides

According to the U.S. Geological Survey (USGS), the term landslide includes a wide range of ground movement, such as rock falls, deep failure of slopes, and shallow debris flows. Although gravity acting on an over steepened slope is the primary reason for a landslide, there are other contributing factors (NJGWS 2013). Among the contributing factors are: (1) erosion by rivers, glaciers, or ocean waves which create over-steepened slopes; (2) rock and soil slopes weakened through saturation by snowmelt or heavy rains; (3) earthquakes which create stresses making weak slopes fail; and (4) excess weight from rain/snow accumulation, rock/ore stockpiling, waste piles, or man-made structures. Scientists from the USGS also monitor stream flow, noting changes in sediment load in rivers and streams that may result from landslides. All of these types of landslides are considered aggregately in USGS landslide mapping.

In New Jersey, there are four main types of landslides: slumps, debris flows, rockfalls, and rockslides. Slumps are coherent masses that move downslope by rotational slip on surfaces that underlie and penetrate the landslide deposit (Briggs et al 1975). A debris flow, also known as a mudslide, is a form of rapid mass movement in which loose soil, rock, organic matter, air, and water mobilize as slurry that flows downslope. Debris flows are often caused by intense surface water from heavy precipitation or rapid snow melt. This precipitation loosens surface matter, thus triggering the slide. Rockfalls are common on roadway cuts and steep cliffs. These landslides are abrupt movements of geological material such as rocks and boulders. Rockfalls happen when these materials become detached. Rockslides are the movement of newly detached segments of bedrock sliding on bedrock, joint, or fault surfaces (Delano and Wilshusen 2001).



Subsidence/Sinkholes

Land subsidence can be defined as the sudden sinking or gradual downward settling of the earth's surface with little or no horizontal motion, owing to the subsurface movement of earth materials (USGS 2000). Subsidence often occurs through the loss of subsurface support in karst terrain, which may result from a number of natural- and human-caused occurrences. Karst describes a distinctive topography that indicates dissolution of underlying carbonate rocks (limestone and dolomite) by surface water or groundwater over time. The dissolution process causes surface depressions and the development of sinkholes, sinking stream, enlarged bedrock fractures, caves, and underground streams (New Jersey State HMP 2014).

Sinkholes, the type of subsidence most frequently seen in New Jersey, are a natural and common geologic feature in areas with underlying limestone, carbonate rock, salt beds, or other rocks that are soluble in water. Over periods of time, measured in thousands of years, the carbonate bedrock can be dissolved through acidic rain water moving in fractures or cracks in the bedrock. This creates larger openings in the rock through which water and overlying soil materials will travel. Over time the voids will enlarge until the roof over the void is unable to support the land above at which time it will collapse, forming a sinkhole. In this example the sinkhole occurs naturally, but in other cases the root causes of a sinkhole are anthropogenic. These anthropogenic causes can include changes to the water balance of an area such as: over-withdrawal of groundwater; diverting surface water from a large area and concentrating it in a single point; artificially creating ponds of surface water; and drilling new water wells. These actions can accelerate the natural processes of creation of soil voids, which can have a direct impact on sinkhole creation (New Jersey State HMP 2014).

Both natural and man-made sinkholes can occur without warning. Slumping or falling fence posts, trees, or foundations, sudden formation of small ponds, wilting vegetation, discolored well water, and/or structural cracks in walls and floors, are all specific signs that a sinkhole is forming. Sinkholes can range in form from steep-walled holes, to bowl, or cone-shaped depressions. When sinkholes occur in developed areas they can cause severe property damage, disruption of utilities, damage to roadways, injury, and loss of life (New Jersey State HMP 2014).

Location

Table 5.4.5-1 summarizes the land area within the 'Low Incidence and 'Moderate Susceptibility/Low Incidence' landslide hazard areas and the areas underlain by carbonate bedrock by municipality.

Table 5.4.5-1. Estimated Area Exposed to the Hazard Areas in Burlington County

Municipality	Total Area in Acres	Landslide Incidence		Landslide Susceptibility/Incidence		Carbonate Formations	
		Low		Moderate/Low			
		Acres	% of Total	Acres	% of Total	Acres	% of Total
Bass River Township	50,140	50,140	100%	0	0%	0	0%
Beverly City	486	0	0%	486	100%	0	0%
Bordentown City	618	36	6%	581	94%	0	0%
Bordentown Township	5,926	3,295	56%	2,632	44%	0	0%
Burlington City	2,426	147	6%	2,272	94%	0	0%
Burlington Township	8,992	5,532	62%	3,477	39%	0	0%
Chesterfield Township	13,736	13,736	100%	0	0%	4	0%
Cinnaminson Township	5,099	51	1%	5,040	99%	0	0%



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Municipality	Total Area in Acres	Landslide Incidence		Landslide Susceptibility/Incidence		Carbonate Formations	
		Low		Moderate/Low			
		Acres	% of Total	Acres	% of Total	Acres	% of Total
Delanco Township	2,190	0	0%	2,190	100%	0	0%
Delran Township	4,654	872	19%	3,772	81%	0	0%
Eastampton Township	3,723	3,723	100%	0	0%	0	0%
Edgewater Park Township	1,976	0	0%	1,976	100%	0	0%
Evesham Township	18,943	18,932	100%	0	0%	1,349	7%
Fieldsboro Borough	224	0	0%	224	100%	0	0%
Florence Township	6,559	3,411	52%	3,137	48%	0	0%
Hainesport Township	4,344	4,343	100%	0	0%	0	0%
Lumberton Township	8,327	8,327	100%	0	0%	71	1%
Mansfield Township	14,010	13,576	97%	446	3%	0	0%
Maple Shade Township	2,451	2,244	92%	207	8%	0	0%
Medford Lakes Borough	812	812	100%	0	0%	0	0%
Medford Township	25,474	25,475	100%	0	0%	3,754	15%
Moorestown Township	9,585	9,415	98%	164	2%	0	0%
Mount Holly Township	1,837	1,837	100%	0	0%	0	0%
Mount Laurel Township	14,066	14,073	100%	0	0%	0	0%
New Hanover Township	14,483	14,483	100%	0	0%	382	3%
North Hanover Township	11,203	11,203	100%	0	0%	2,025	18%
Palmyra Borough	1,673	0	0%	1,673	100%	0	0%
Pemberton Borough	403	403	100%	0	0%	38	9%
Pemberton Township	40,171	40,164	100%	0	0%	3,146	8%
Riverside Township	1,048	0	0%	1,047	100%	0	0%
Riverton Borough	614	0	0%	614	100%	0	0%
Shamong Township	28,791	28,824	100%	0	0%	0	0%
Southampton Township	28,446	28,422	100%	0	0%	2,910	10%
Springfield Township	18,924	18,920	100%	0	0%	761	4%
Tabernacle Township	31,688	31,725	100%	0	0%	0	0%
Washington Township	66,539	67,067	101%	0	0%	0	0%
Westampton Township	7,104	7,101	100%	0	0%	0	0%
Willingboro Township	5,175	3,540	68%	1,654	32%	0	0%
Woodland Township	61,001	60,439	99%	0	0%	0	0%
Wrightstown Borough	1,146	1,146	100%	0	0%	223	19%
Burlington County	525,009	493,412	94%	31,592	6%	14,664	3%

Source: USGS, 2011; NJGS 2008



Landslides

Landslides are common in New Jersey, primarily in the northern region of the state. According to the USGS and the landslide susceptibility map in the 2014 New Jersey State HMP, Burlington County has moderate susceptibility/low incidence landslide potential in the northwestern region of the County. For a figure displaying the landslide potential of the conterminous United States, please refer to <http://pubs.usgs.gov/fs/2005/3156/2005-3156.pdf> (USGS 2005).

According to the NJGWS, the entire county has a low susceptibility to landslides. Figure 5.4.5-1 illustrates the historic landslide locations overlaid by areas of steep slopes (greater than 15%) in Burlington County. A majority of occurrences have been concentrated in the northern portion of the County, in the municipalities of Bordentown Township, Burlington Township, and Florence Township; most of these events occurred on or at the base of steep slopes (greater than 15%). This correlates with the location of moderate landslide susceptibility areas found along the northern border of Burlington County.

Subsidence/Sinkholes

New Jersey is susceptible to the effects of subsidence and sinkholes, primarily in the northwestern section of the State. Land subsidence and sinkholes have been known to occur as a result of natural geologic phenomenon or as a result of human alteration of surface and underground geology. The only spatial coverage for historic sinkholes in the State of New Jersey is in Warren County; however, limiting analysis of past occurrences for other counties in the state.

Naturally occurring subsidence and sinkholes in New Jersey occur within bands of carbonate bedrock. In northern New Jersey, there are more than 225 square miles that are underlain by limestone, dolomite, and marble. In some areas, no sinkholes have appeared, while in others, sinkholes are common. In southern New Jersey, there are approximately 100 miles which are locally underlain by a lime sand with thin limestone layers. No collapse sinkholes have been identified; however, there are some features which could be either very shallow solution depressions or wind blowout features. Burlington County has a lower occurrence rate of carbonate bedrock than other counties in the northwestern part of the state. The County has a thin strip of carbonate bedrock that runs from New Hanover to Evesham. Overall, approximately 3-percent (22.9 square miles) of the county has carbonate rock formation (NJGS 2008).



Figure 5.4.5-1. Historic Landslide Locations in Burlington County, 1869 –2018

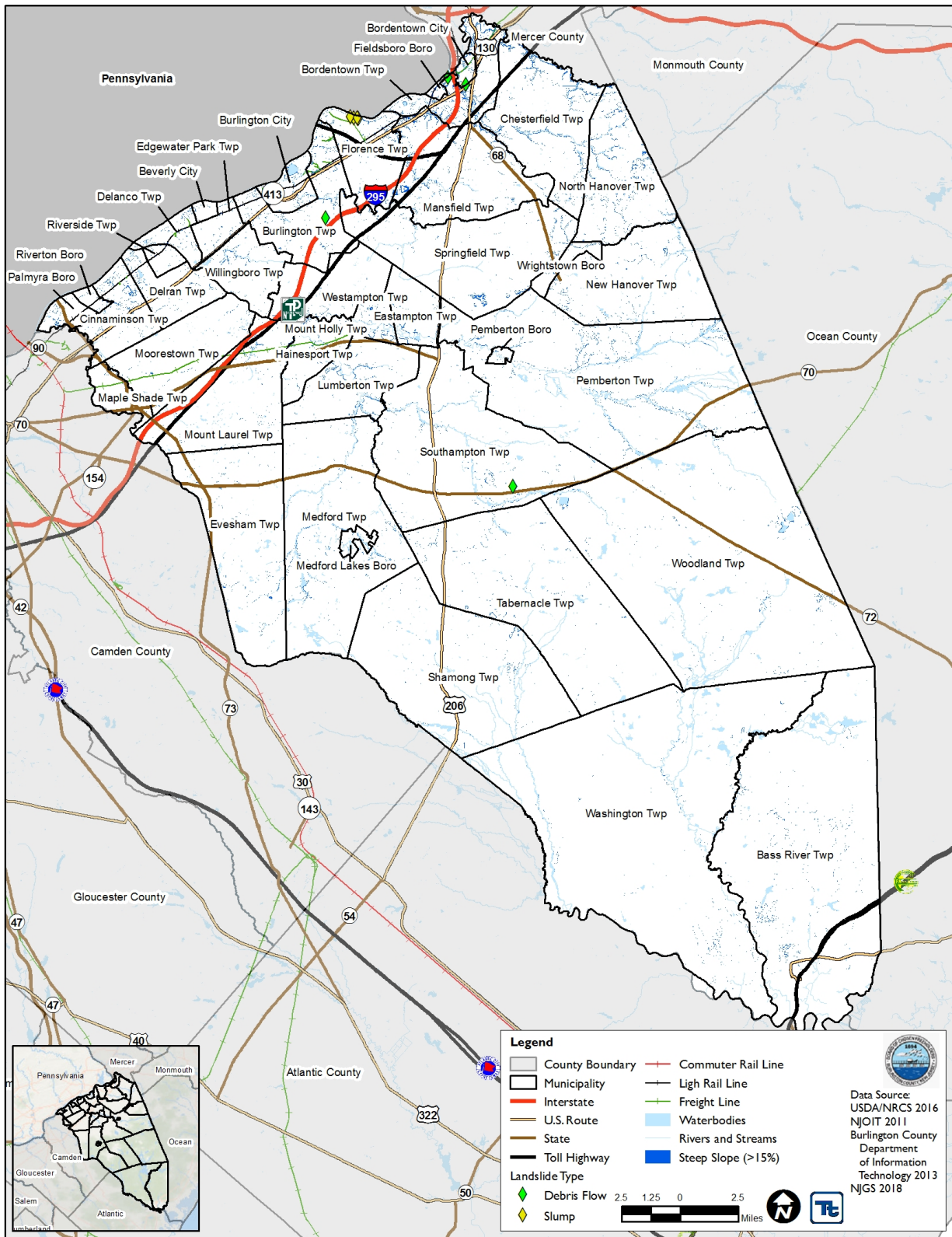
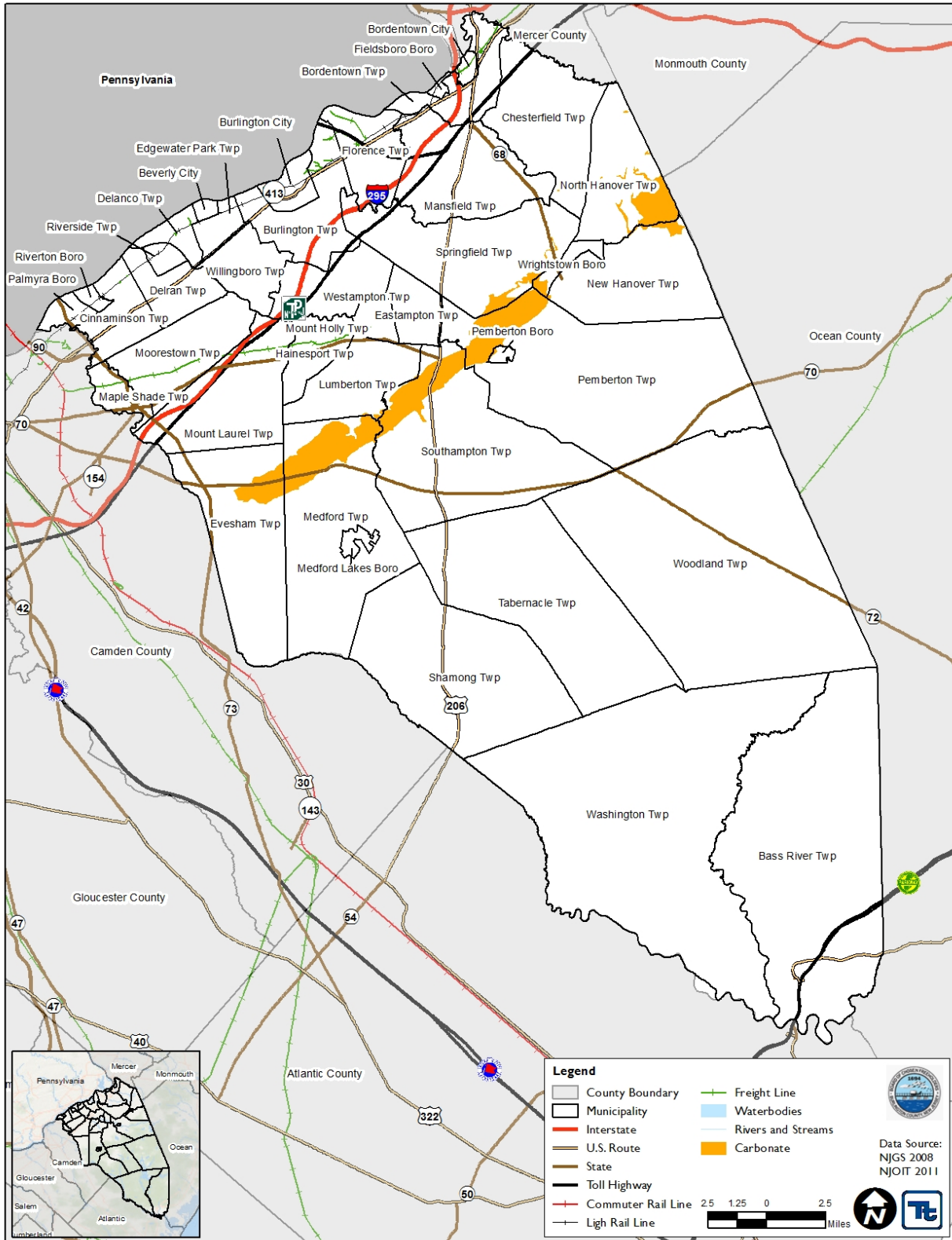




Figure 5.4.5-2. Carbonate Formations in Burlington County





Extent

Landslide

To determine the extent of a landslide hazard, the affected areas need to be identified and the probability of the landslide occurring within some time period needs to be assessed. Natural variables that contribute to the overall extent of potential landslide activity in any particular area include soil properties, topographic position and slope, and historical incidence. Predicting a landslide is difficult, even under ideal conditions and with reliable information. As a result, the landslide hazard is often represented by landslide incidence and/or susceptibility, as defined below:

- Landslide incidence is the number of landslides that have occurred in a given geographic area. High incidence means greater than 15-percent of a given area has been involved in landsliding; medium incidence means that 1.5- to 15-percent of an area has been involved; and low incidence means that less than 1.5-percent of an area has been involved (State of Alabama Date Unknown).
- Landslide susceptibility is defined as the probable degree of response of geologic formations to natural or artificial cutting, to loading of slopes, or to unusually high precipitation. It can be assumed that unusually high precipitation or changes in existing conditions can initiate landslide movement in areas where rocks and soils have experienced numerous landslides in the past. Landslide susceptibility depends on slope angle and the geologic material underlying the slope. Landslide susceptibility only identifies areas potentially affected and does not imply a time frame when a landslide might occur. High, medium, and low susceptibility are delimited by the same percentages used for classifying the incidence of landsliding (USGS 1997).

Subsidence/Sinkhole

Landslide subsidence occurs slowly and continuously over time or abruptly for various reasons. Subsidence and sinkholes can occur due to either natural processes (karst sinkholes in areas underlain by soluble bedrock) or as a result of human activities. Subsidence in the U.S. has directly affected more than 17,000 square miles in 45 states, and associated annual costs are estimated to be approximately \$125 million. The principal causes of subsidence are aquifer-system compaction, drainage of organic soils, underground mining, hydrocompaction, natural compaction, sinkholes, and thawing permafrost (Galloway et al. 1999). There are several methods used to measure land subsidence. Global Positioning System (GPS) is a method used to monitor subsidence on a regional scale. Benchmarks (geodetic stations) are commonly space around four miles apart (State of California 2009).

Another method which is becoming increasingly popular is Interferometric Synthetic Aperture Radar (InSAR). InSAR is a remote sensing technique that uses radar signals to interpolate land surface elevation changes. It is a cost-effective solution for measuring land surface deformation for a region while offering a high degree of spatial detail and resolution (State of California 2015).

Previous Occurrences and Losses

Numerous sources provided historical information regarding previous occurrences and losses associated with geological hazard events throughout Burlington County. Burlington County has experienced 6 landslide events between 1782 and 2017; however, sinkhole/subsidence history could not be determined due to limited historical records. Many sources were reviewed for the purpose of this HMP and loss and impact information could vary depending on the source. Therefore, the accuracy of monetary figures, if any, is based only on the available information identified during research for this HMP.



Between 1954 and 2015, FEMA issued a disaster (DR) or emergency (EM) declaration for the State of New Jersey for one geological hazard-related event, classified as severe storms, flooding and mudslide. This declaration did not include Burlington County (FEMA 2018).

For this HMP, known landslide and sinkhole events that have occurred in Burlington County between 2013 and 2018 are identified in Table 5.4.5-2. For events prior to 2013, refer to Appendix G (Supplementary Data). Please note that many sources were researched for historical information regarding landslide and sinkhole events in Burlington County; therefore, Table 5.4.5-2 may not include all landslide and sinkhole events that have impacted the County. Additionally, not all sources may have been identified or researched. Loss and impact information could vary depending on the source. Therefore, the accuracy of monetary figures discussed is based only on the available information identified during research for this HMP Update.



Table 5.4.5-2. Landslide and Sinkhole Events Impacting Burlington County, 2013 to 2018

Dates of Event	Event Type	Location	FEMA Declaration Number (if applicable)	County Designated?	Losses / Impacts
April 20, 2015	Slump	Florence Township	N/A	No	Portions of two properties developed a sinkhole in the backyard and forced evacuations of two homes. The homes were purchased by the county and a stabilization project has been planned.
2017	Slump	Florence Township	N/A	No	Heavy rain caused a washout and a 15-foot tall caved bank on the bluff, above a steel culvert, broke and caused a piping failure that led to the original slump and caving of the bank. Smaller slumps occurred in Florence Township as well. A smaller slump to the east of the main area of slumping occurred and a smaller reactivation of the previous larger slump also occurred.

Source: NJGWS 2018; NJ.Com 2015; Burlington County Times 2015

FEMA Federal Emergency Management Agency

N/A Not Applicable

NJGWS New Jersey Geological and Water Survey



Probability of Future Occurrences

Based upon risk factors for the county and past occurrences, it is likely that geological hazards will occur in Burlington County in the future. Landslide probabilities are largely a function of surface geology, but are also influenced by both weather and human activities. The vast majority of the County (96 percent) lies outside of mapped hazard areas. Therefore, the probability would be low; however, that probability would increase slightly within the narrow band of land roughly bounding the Delaware River in the northwestern portion of Burlington County in the municipalities of: Cities of Beverly and Burlington, Townships of Burlington, Cinnaminson, Delanco, Delran, Edgewater Park, Riverside and Florence, and the Boroughs of Palmyra and Riverton, and a small portion (approximately 2 percent) of the Township of Moorestown. Areas of past landslides are also more susceptible. There are presumably other smaller landslides and sinkholes that have occurred in the county that have not been reported to the NJGWS and are not included in these calculations.

The probability of future landslides and sinkholes having a significant impact on life and property in Burlington County is relatively low. The county will continue to experience the direct and indirect impacts of geological hazards and its impacts on occasion, with the secondary effects causing potential disruption or damage to communities. The table below shows the probability of future geologic events impacting the county.

According to NJGWS, 2013 Burlington County HMP, and NOAA-NCEI Storm Events Database, Burlington County experienced eight landslide events between 1950 and 2018. The table below shows these statistics, as well as the annual average number of events and the percent chance of these individual landslide hazards occurring in Burlington County in future years.

Table 5.4.5-3. Probability of Future Occurrence of Landslide and Sinkhole Events

Hazard Type	Number of Occurrences Between 1950 and 2018	Rate of Occurrence or Annual Number of Events (average)	Recurrence Interval (in years) (# Years/Number of Events)	Probability of Event in any given year	Percent chance of occurrence in any given year
Landslide – Debris Flow	4	0.06	17.25	6	5.8
Landslide – Rockfall	0	0	0	0	0
Landslide – Rockslide	0	0	0	0	0
Landslide – Slump	4	0.12	8.63	0.12	11.59

Sources: NJGWS 2018; NOAA-NCEI 2018; NJ.com 2015; NJ State HMP 2014

In Section 5.3, the identified hazards of concern for Burlington County were ranked. The probability of occurrence, or likelihood of the event, is one parameter used for hazard rankings. Based on historical records and input from the Planning Committee, the probability of occurrence for geological hazards in the county is considered ‘frequent’ (likely to occur within 25 years, as presented in Table 5.3-3).

Climate Change Impacts

Providing projections of future climate change for a specific region is challenging. Shorter term projections are more closely tied to existing trends making longer term projections even more challenging. The further out a prediction reaches the more subject to changing dynamics it becomes.

Temperatures in the Northeast United States have increased 1.5 degrees Fahrenheit (°F) on average since 1900. Most of this warming has occurred since 1970. The State of New Jersey, for example, has observed an increase



in average annual temperatures of 1.2°F between the period of 1971-2000 and the most recent decade of 2001-2010 (ONJSC, 2011). Winter temperatures across the Northeast have seen an increase in average temperature of 4°F since 1970 (Northeast Climate Impacts Assessment [NECIA] 2007). By the 2020s, the average annual temperature in New Jersey is projected to increase by 1.5°F to 3°F above the statewide baseline (1971 to 2000), which was 52.7°F. By 2050, the temperature is projected to increase 3°F to 5°F (Sustainable Jersey Climate Change Adaptation Task Force 2013). Both northern and southern New Jersey have become wetter over the past century. Northern New Jersey's 1971-2000 precipitation average was over 5" (12-percent) greater than the average from 1895-1970. Southern New Jersey became 2" (5-percent) wetter late in the 20th century (Office of New Jersey State Climatologist).

Landslides

Climate change may impact storm patterns, increasing the probability of more frequent, intense storms with varying duration. Increase in global temperature could affect the snowpack and its ability to hold and store water. Warming temperatures also could increase the occurrence and duration of droughts, which would increase the probability of wildfire, reducing the vegetation that helps to support steep slopes. All of these factors would increase the probability for landslide occurrences.

Subsidence/Sinkholes

Similar to landslides, climate change will affect subsidence and sinkholes in New Jersey. As discussed throughout this profile, one of the triggers for subsidence and sinkholes is an abundance of moisture which has the potential to permeate the bedrock causing an event. Climatologists expect an increase in annual precipitation amounts. This increase will coincide with an increased risk in subsidence and sinkholes in vulnerable areas.

More recently, sinkholes have been correlated to land use practices, especially from groundwater pumping and from construction and development practices. Sinkholes may also form when the land surface is changed, such as when industrial and runoff-storage ponds are created. The substantial weight of the new material can trigger an underground collapse of supporting material, thus causing a sinkhole. Additionally, the overburden sediments that cover buried cavities in the aquifer systems are delicately balanced by groundwater fluid pressure. Groundwater is helping keep the surface soil in place. Pumping groundwater for urban water supply and for irrigation can produce new sinkholes in sinkhole-prone areas. If pumping results in a lowering of groundwater levels, then underground structural failure, sinkholes may occur as well (USGS 2014).

5.4.5.2 VULNERABILITY ASSESSMENT

To understand risk, a community must evaluate what assets are exposed and/or vulnerable to the identified hazard. For landslide and other geologic hazards, areas of slopes greater than 15 percent and carbonate formations have been identified as the hazard area. The following text summarizes the potential impact of geologic hazards on the county. Refer to Section 5.1 for additional details on the methodology used to assess geologic hazard risk.

Impact on Life, Health and Safety

Overall, a landslide or subsidence event would be an isolated incidence and impact the populations within the immediate area of the incident. Specifically, the population located downslope of the landslide hazard areas are particularly vulnerable to this hazard. In addition to causing damages to residential buildings and displacing residents, landslides and subsidence events can block off or damage major roadways and inhibit travel for emergency responders or populations trying to evacuate the area. Due to the nature of Census block data, it is difficult to determine demographics of populations vulnerable to mass movements of geological material.



Table 5.4.5-4 summarizes the population located on steep slopes and the areas underlain by carbonate bedrock by municipality (U.S. Census 2010). Bordentown Township has the greatest total number of people located on areas of steep slopes (703), while the Pemberton Borough has the greatest percentage of its population located on areas of steep slopes (37.7 percent). Evesham Township has the greatest total number of people located above carbonate formations and susceptible to subsidence events with 4,067 people. North Hanover Township has 19.7% of its population located above carbonate formations and has the greatest percentage exposed to the hazard area.

Table 5.4.5-4. Estimated Population Located in the Hazard Areas

Municipality	Total Population (2010 U.S. Census)	Steep Slopes (Greater than 15%)		Carbonate Formations	
		Population Exposed	Population Exposed	Percent Total	Percent Total
Bass River Township	1,443	65	4.5%	0	0.0%
Beverly City	2,577	0	0.0%	0	0.0%
Bordentown City	3,924	77	2.0%	0	0.0%
Bordentown Township	11,367	703	6.2%	0	0.0%
Burlington City	9,920	94	0.9%	0	0.0%
Burlington Township	22,594	50	0.2%	0	0.0%
Chesterfield Township	7,699	3	0.0%	0	0.0%
Cinnaminson Township	15,569	312	2.0%	0	0.0%
Delanco Township	4,283	55	1.3%	0	0.0%
Delran Township	16,896	112	0.7%	0	0.0%
Eastampton Township	6,069	50	0.8%	0	0.0%
Edgewater Park Township	8,881	0	0.0%	0	0.0%
Evesham Township	45,538	525	1.2%	4,067	8.9%
Fieldsboro Borough	540	22	4.1%	0	0.0%
Florence Township	12,109	150	1.2%	0	0.0%
Hainesport Township	6,110	223	3.6%	0	0.0%
Lumberton Township	12,559	289	2.3%	0	0.0%
Mansfield Township	8,544	202	2.4%	0	0.0%
Maple Shade Township	19,131	0	0.0%	0	0.0%
Medford Lakes Borough	4,146	145	3.5%	0	0.0%
Medford Township	23,033	202	0.9%	2,990	13.0%
Moorestown Township	20,726	257	1.2%	0	0.0%
Mount Holly Township	9,536	96	1.0%	0	0.0%
Mount Laurel Township	41,864	339	0.8%	0	0.0%
New Hanover Township	7,385	0	0.0%	256	3.5%
North Hanover Township	7,678	0	0.0%	1,512	19.7%
Palmyra Borough	7,398	0	0.0%	0	0.0%
Pemberton Borough	1,409	531	37.7%	0	0.0%
Pemberton Township	27,912	0	0.0%	391	1.4%



Municipality	Total Population (2010 U.S. Census)	Steep Slopes (Greater than 15%)		Carbonate Formations	
		Population Exposed	Population Exposed	Percent Total	Percent Total
Riverside Township	8,079	109	1.3%	0	0.0%
Riverton Borough	2,779	103	3.7%	0	0.0%
Shamong Township	6,490	0	0.0%	0	0.0%
Southampton Township	10,464	260	2.5%	886	8.5%
Springfield Township	3,414	90	2.6%	235	6.9%
Tabernacle Township	6,949	0	0.0%	0	0.0%
Washington Township	687	2	0.3%	0	0.0%
Westampton Township	8,813	40	0.5%	0	0.0%
Willingboro Township	31,629	535	1.7%	0	0.0%
Woodland Township	1,788	0	0.0%	0	0.0%
Wrightstown Borough	802	0	0.0%	0	0.0%
Burlington County	448,734	5,641	1.3%	10,337	2.3%

Source: United States Census 2010; USGS 2016; NJGS 2008

Note: The hazard area boundaries were overlaid on the U.S. Census block; the blocks with their centroids within hazard areas were totaled for each municipality.

Socially vulnerable populations (e.g. the elderly and low-income populations) are particularly vulnerable to a hazard event. Within the steep slope hazard area, there are approximately 1,120 people over the age of 65 and 469 people considered low income populations. As for populations within areas underlain by carbonate formations, there are approximately 1,730 people over the age 65 and 1,095 people considered low income populations.

Impact on General Building Stock

Landslides have the potential of destabilizing the foundation of structures, which may result in monetary losses to businesses and residents. Table 5.4.5-5 summarize the exposed building stock located on steep slopes by municipality and Table 5.4.5-6 summarizes the exposed building stock underlain by carbonate bedrock by municipality. There are 952 buildings located on areas of steep slopes countywide. Medford Township has the greatest number of buildings and greatest percentage of buildings located on areas of steep slopes (105 – 21.6 percent). Medford Township also has the greatest total number of buildings located above carbonate formations and susceptible to subsidence events with 1,294 structures worth \$1.7 billion. North Hanover Township has 24.9% of its building stock located above carbonate formations and has the greatest percentage exposed to the hazard area.

Table 5.4.5-5. Estimated General Building Stock Located on Areas of Steep Slopes (Greater than 15%)

Municipality	Total Number of Buildings	Total Replacement Cost (Estimated Structure and Contents)	Steep Slopes (Greater than 15%)			
			# Buildings	Percent Total	Estimated Replacement Cost Value	Percent Total
Bass River Township	1,863	\$1,027,917,130	3	0.2%	\$2,057,647	0.2%
Beverly City	964	\$471,487,138	1	0.1%	\$120,186	0.0%
Bordentown City	1,219	\$1,244,995,904	14	1.1%	\$19,220,137	1.5%
Bordentown Township	3,113	\$2,820,041,247	50	1.6%	\$39,476,063	1.4%



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Municipality	Total Number of Buildings	Total Replacement Cost (Estimated Structure and Contents)	Steep Slopes (Greater than 15%)			
			# Buildings	Percent Total	Estimated Replacement Cost Value	Percent Total
Burlington City	3,644	\$3,215,233,092	14	0.4%	\$6,495,782	0.2%
Burlington Township	7,757	\$8,013,259,672	50	0.6%	\$50,120,811	0.6%
Chesterfield Township	2,093	\$2,443,294,418	40	1.9%	\$27,111,803	1.1%
Cinnaminson Township	6,358	\$5,703,895,752	42	0.7%	\$13,193,532	0.2%
Delanco Township	1,562	\$1,422,201,479	19	1.2%	\$4,304,164	0.3%
Delran Township	5,191	\$5,145,622,596	42	0.8%	\$11,727,208	0.2%
Eastampton Township	2,499	\$1,687,017,512	26	1.0%	\$7,519,101	0.4%
Edgewater Park Township	2,567	\$2,307,285,215	21	0.8%	\$4,189,004	0.2%
Evesham Township	14,319	\$14,666,082,424	24	0.2%	\$10,508,242	0.1%
Fieldsboro Borough	242	\$139,371,126	6	2.5%	\$2,224,837	1.6%
Florence Township	2,522	\$2,787,263,607	33	1.3%	\$55,721,336	2.0%
Hainesport Township	2,747	\$3,447,208,735	30	1.1%	\$125,342,076	3.6%
Lumberton Township	4,009	\$5,459,557,257	34	0.8%	\$24,958,176	0.5%
Mansfield Township	2,798	\$4,056,501,589	48	1.7%	\$88,678,811	2.2%
Maple Shade Township	6,006	\$4,385,500,913	15	0.2%	\$3,425,847	0.1%
Medford Lakes Borough	1,909	\$1,280,050,871	27	1.4%	\$12,246,894	1.0%
Medford Township	10,627	\$12,845,907,494	105	1.0%	\$63,000,770	0.5%
Moorestown Township	8,736	\$10,108,801,626	22	0.3%	\$48,638,926	0.5%
Mount Holly Township	4,573	\$3,498,352,996	50	1.1%	\$20,245,355	0.6%
Mount Laurel Township	12,900	\$14,653,800,804	33	0.3%	\$25,363,584	0.2%
New Hanover Township	1,964	\$3,022,835,486	10	0.5%	\$11,311,016	0.4%
North Hanover Township	2,901	\$3,079,878,987	21	0.7%	\$18,034,941	0.6%
Palmyra Borough	2,713	\$1,788,398,557	1	0.0%	\$641,764	0.0%
Pemberton Borough	514	\$345,869,906	1	0.2%	\$452,244	0.1%
Pemberton Township	13,511	\$9,374,914,679	40	0.3%	\$12,516,733	0.1%
Riverside Township	2,868	\$2,039,139,951	7	0.2%	\$3,280,023	0.2%
Riverton Borough	1,274	\$916,434,789	8	0.6%	\$7,079,243	0.8%
Shamong Township	3,623	\$2,738,384,433	22	0.6%	\$20,956,497	0.8%
Southampton Township	7,982	\$6,722,347,774	22	0.3%	\$4,954,969	0.1%
Springfield Township	2,876	\$3,853,514,909	16	0.6%	\$20,022,395	0.5%
Tabernacle Township	4,452	\$3,619,040,765	18	0.4%	\$12,145,684	0.3%
Washington Township	939	\$597,426,933	4	0.4%	\$1,736,567	0.3%
Westampton Township	3,006	\$4,269,433,407	11	0.4%	\$6,027,729	0.1%
Willingboro Township	12,395	\$8,259,747,413	17	0.1%	\$2,447,308	0.0%
Woodland Township	1,323	\$1,656,748,246	2	0.2%	\$2,411,475	0.1%
Wrightstown Borough	485	\$411,963,035	3	0.6%	\$6,251,788	1.5%
Burlington County	173,044	\$165,526,729,867	952	0.6%	\$796,160,667	0.5%

Source: Burlington County; NJ Department of Treasury, 2017; USGS 2016

Note: Areas of steep slopes were overlaid on the custom general building stock inventory; the structures with their centroids within hazard areas were totaled for each municipality.



Table 5.4.5-6. Estimated Building Located in the Carbonate Formation Hazard Area

Municipality	Total Number of Buildings	Total Replacement Cost (Estimated Structure and Contents)	Carbonate Formation			
			# Buildings	Percent Total	Estimated Replacement Cost Value	Percent Total
Bass River Township	1,863	\$1,027,917,130	0	0.0%	\$0	0.0%
Beverly City	964	\$471,487,138	0	0.0%	\$0	0.0%
Bordentown City	1,219	\$1,244,995,904	0	0.0%	\$0	0.0%
Bordentown Township	3,113	\$2,820,041,247	0	0.0%	\$0	0.0%
Burlington City	3,644	\$3,215,233,092	0	0.0%	\$0	0.0%
Burlington Township	7,757	\$8,013,259,672	0	0.0%	\$0	0.0%
Chesterfield Township	2,093	\$2,443,294,418	0	0.0%	\$0	0.0%
Cinnaminson Township	6,358	\$5,703,895,752	0	0.0%	\$0	0.0%
Delanco Township	1,562	\$1,422,201,479	0	0.0%	\$0	0.0%
Delran Township	5,191	\$5,145,622,596	0	0.0%	\$0	0.0%
Eastampton Township	2,499	\$1,687,017,512	0	0.0%	\$0	0.0%
Edgewater Park Township	2,567	\$2,307,285,215	0	0.0%	\$0	0.0%
Evesham Township	14,319	\$14,666,082,424	839	5.9%	\$823,363,133	5.6%
Fieldsboro Borough	242	\$139,371,126	0	0.0%	\$0	0.0%
Florence Township	2,522	\$2,787,263,607	0	0.0%	\$0	0.0%
Hainesport Township	2,747	\$3,447,208,735	0	0.0%	\$0	0.0%
Lumberton Township	4,009	\$5,459,557,257	10	<1%	\$6,301,132	<1%
Mansfield Township	2,798	\$4,056,501,589	0	0.0%	\$0	0.0%
Maple Shade Township	6,006	\$4,385,500,913	0	0.0%	\$0	0.0%
Medford Lakes Borough	1,909	\$1,280,050,871	0	0.0%	\$0	0.0%
Medford Township	10,627	\$12,845,907,494	1,294	12.2%	\$1,740,439,973	13.5%
Moorestown Township	8,736	\$10,108,801,626	0	0.0%	\$0	0.0%
Mount Holly Township	4,573	\$3,498,352,996	0	0.0%	\$0	0.0%
Mount Laurel Township	12,900	\$14,653,800,804	0	0.0%	\$0	0.0%
New Hanover Township	1,964	\$3,022,835,486	121	6.2%	\$72,805,949	2.4%
North Hanover Township	2,901	\$3,079,878,987	723	24.9%	\$322,034,143	10.5%
Palmyra Borough	2,713	\$1,788,398,557	0	0.0%	0	0.0%
Pemberton Borough	514	\$345,869,906	1	0.2%	\$1,180,580	0.3%
Pemberton Township	13,511	\$9,374,914,679	494	3.7%	\$818,250,019	8.7%
Riverside Township	2,868	\$2,039,139,951	0	0.0%	\$0	0.0%
Riverton Borough	1,274	\$916,434,789	0	0.0%	\$0	0.0%
Shamong Township	3,623	\$2,738,384,433	0	0.0%	\$0	0.0%
Southampton Township	7,982	\$6,722,347,774	921	11.5%	\$627,336,936	9.3%
Springfield Township	2,876	\$3,853,514,909	180	6.3%	\$331,822,080	8.6%
Tabernacle Township	4,452	\$3,619,040,765	0	0.0%	\$0	0.0%
Washington Township	939	\$597,426,933	0	0.0%	\$0	0.0%
Westampton Township	3,006	\$4,269,433,407	0	0.0%	\$0	0.0%
Willingboro Township	12,395	\$8,259,747,413	0	0.0%	\$0	0.0%
Woodland Township	1,323	\$1,656,748,246	0	0.0%	\$0	0.0%
Wrightstown Borough	485	\$411,963,035	1	<1%	\$210,870	<1%
Burlington County	173,044	\$165,526,729,867	4,584	2.6%	\$4,743,744,814	2.9%

Source: Burlington County; NJ Department of Treasury, 2017; NJGS, 2008



Note: The NJGS Carbonate Formation boundaries were overlaid on the custom general building stock inventory; the structures with their centroids within hazard areas were totaled for each municipality.

Impact on Critical Facilities

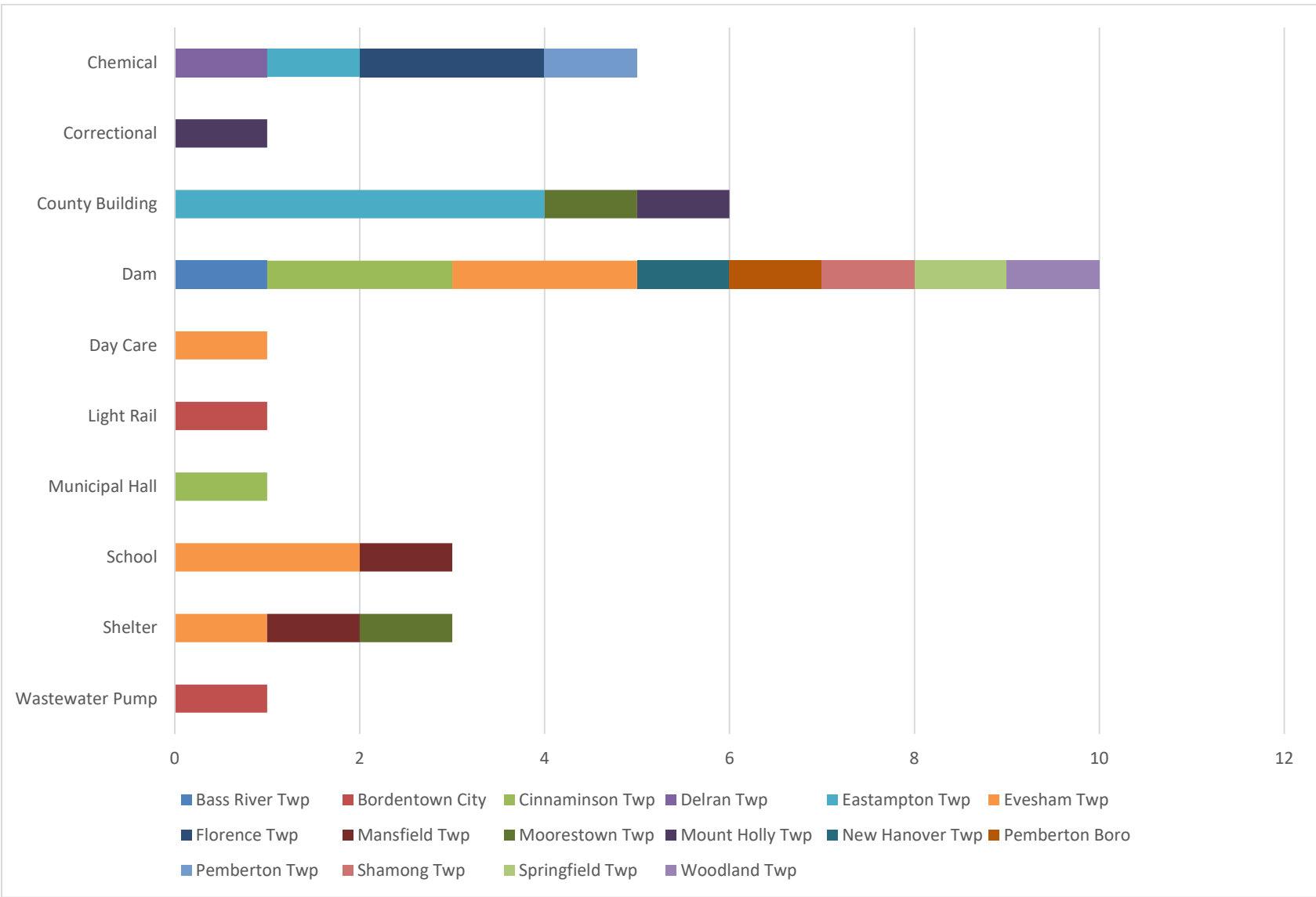
In addition to critical facilities, a significant amount of infrastructure can be exposed to mass movements of geological material:

- **Roads**—Access to major roads is crucial to life-safety after a disaster event and to response and recovery operations. Landslides can block egress and ingress on roads, causing isolation for neighborhoods, traffic problems, and delays for public and private transportation. This can result in economic losses for businesses.
- **Bridges**—Landslides can significantly impact road bridges. Mass movements can knock out bridge abutments or significantly weaken the soil supporting them, making them hazardous for use.
- **Power Lines**—Power lines are generally elevated above steep slopes; but the towers supporting them can be subject to landslides. A landslide could trigger failure of the soil underneath a tower, causing it to collapse and ripping down the lines. Power and communication failures due to landslides can create problems for vulnerable populations and businesses.
- **Rail Lines** – Similar to roads, rail lines are important for response and recovery operations after a disaster. Landslides can block travel along the rail lines, which would become especially troublesome, because it would not be as easy to detour a rail line as it is on a local road or highway. Many residents rely on public transport to get to work around the county and into Philadelphia and New York City, and a landslide event could prevent travel to and from work.

Several other types of infrastructure may also be exposed to landslides, including water and sewer infrastructure. At this time all critical facilities, infrastructure, and transportation corridors located within the hazard areas are considered vulnerable until more information becomes available. Figure 5.4.5-3 and Figure 5.4.5-4 display the critical facilities located on areas of steep slopes and above carbonate formations, respectively. Overall there are 32 critical facilities located on steep slopes, with dams being the most exposed with 10. There are 68 critical facilities located above carbonate formations. Senior facilities and dams have the greatest exposure to carbonate formations with 8 facilities each.



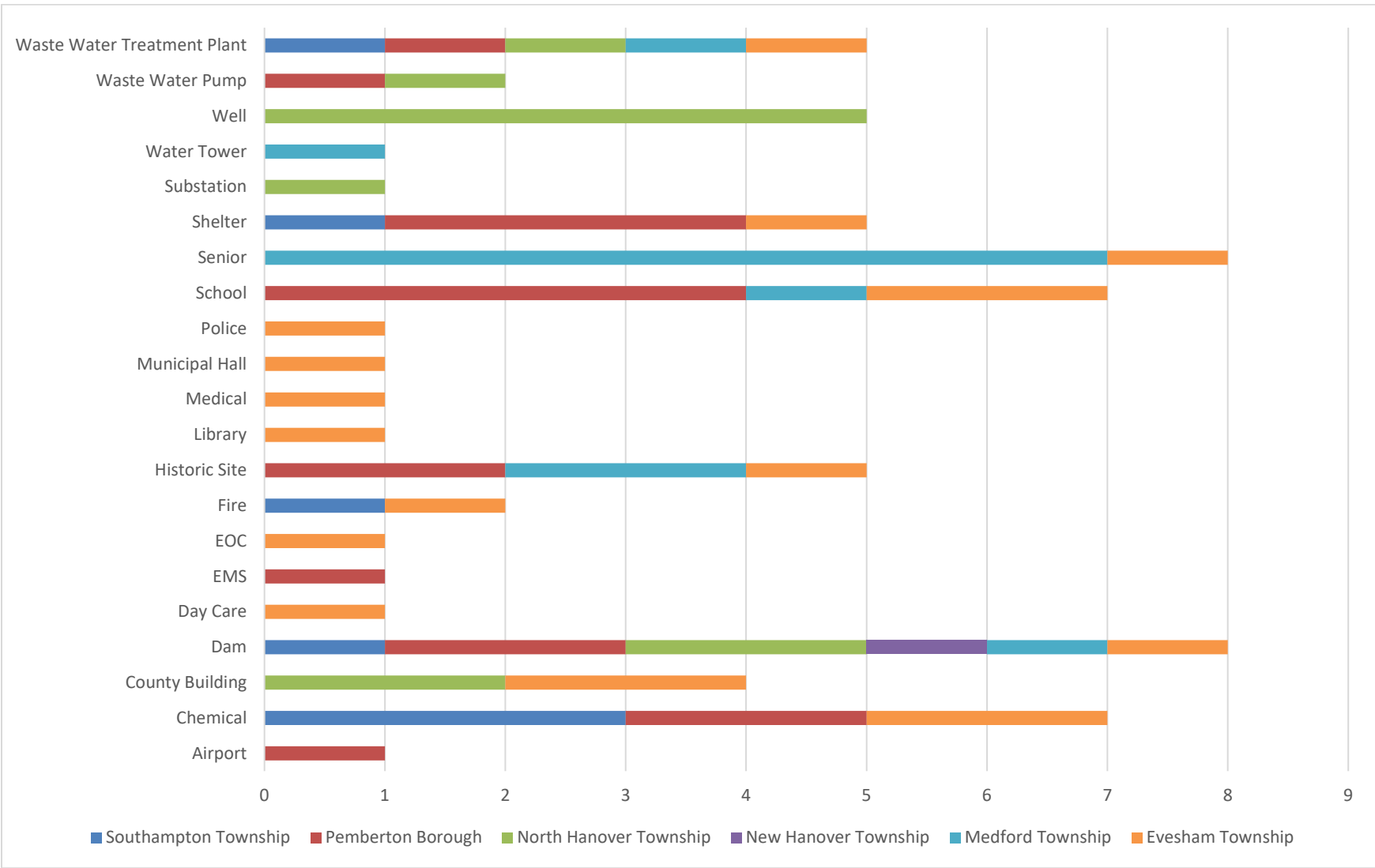
Figure 5.4.5-3. Critical Facilities Located on Areas of Steep Slopes (Greater than 15%)



Source: Burlington County; USGS 2016



Figure 5.4.5-4. Critical Facilities Located in the Carbonate Formation Hazard Area



Source: Burlington County; NJGS, 2008
Note: EMS – Emergency Medical Services
EOC – Emergency Operation Center



Impact on the Economy

Geologic hazards can impose direct and indirect impacts on society. Direct costs include the actual damage sustained by buildings, property and infrastructure. Indirect costs, such as clean-up costs, business interruption, loss of tax revenues, reduced property values, and loss of productivity are difficult to measure. Additionally, ground failure threatens transportation corridors, fuel and energy conduits, and communication lines (USGS 2005). Estimated potential damages to general building stock can be quantified as discussed above. For the purposes of this analysis, general building stock damages are discussed further.

A landslide or sinkhole/subsidence event will alter the landscape. In addition to changes in topography, vegetation and wildlife habitats may be damaged or destroyed, and soil and sediment runoff will accumulate downslope potentially blocking waterways and roadways and impacting quality of streams and other water bodies. Additional environmental impacts include loss of forest productivity. There are 952 buildings located on steep slopes and account for \$796 million, or less than 1-percent of the County's total building cost; for areas above carbonate formations, there are 4,584 buildings worth \$4.7 billion (2.9% of the County's total) exposed. These dollar value losses to Burlington County's total building inventory replacement cost value would impact Burlington County's tax base and the local economy.

The New Jersey Turnpike, I-295, and Route 130 are the major roadways that traverse the western portion of the county from northeast to southwest. These roads serve as the major thoroughfares of the county and run through the most densely populated areas of the county; all three of these roadways traverse areas of steep slopes. Other major roadways that traverse areas of steep slopes include the Garden State Parkway, NJ-38, NJ-413, NJ-70, NJ-73, NJ-90, US-206, and US-9. Lengths of US-206 and State Route 70 intersect areas underlain by carbonate formations.

Since the county is substantially developed in the areas adjacent to the Delaware River many of the major utilities including power generation plants and regional sewerage treatment plants are located with the landslide moderate susceptibility/low incidence area.

Future Growth and Development

As discussed in Section 4 and Volume II, Section 9, areas targeted for future growth and development have been identified across Burlington County. It is anticipated that new development within the identified landslide and subsidence hazard areas will be exposed to such risks. Any developments at or near the base of steep slopes may be at risk to losses from a landslide. Although areas of steep slopes are most at risk for landslides, landslides are still possible on lesser slopes, and future developments are not completely free of risk.

There are no recent or proposed developments around the County located on areas of steep slopes. There are 5 new developments located above carbonate formations; three of these developments are located in Medford Township. Refer to Figure 5.4.5-5 for a map of proposed new development and the landslide susceptibility areas of Burlington County.

Effect of Climate Change on Vulnerability

A direct impact of climate change on landslides is difficult to determine. Multiple secondary effects of climate change have the potential to increase the likelihood of landslides. Warming temperatures resulting in wildfires would reduce vegetative cover along steep slopes and destabilize the soils due to destruction of the root system; increased intensity of rainfall events would increase saturation of soils on steep slopes. Under these future conditions, the County's assets located on or at the base of these steep slopes will have an increased risk to landslides. Roadways and other transportation infrastructure located in these areas will also be at an increased



risk of closure, which would impact the County's risk as described above under Impact on Life, Health, and Safety, General Building Stock, and Critical Facilities and Impact on Economy.

Higher temperatures and the possibility of more intense, less frequent summer rainfall, may lead to changes in water resource availability. The projection in the increase of average temperatures may lead to an increase in the frequency of droughts. Sinkhole activity intensifies in some karst areas increases during periods of drought. With an increase in drought periods, the number of sinkholes can increase (Linares et al. 2016). Additionally, changes to the water balance of an area including over-withdrawal of groundwater, diverting surface water from a large area and concentrating it in a single point, artificially creating ponds of surface water, and drilling new water wells will cause sinkholes. These actions can also serve to accelerate the natural processes of bedrock degradation, which can have a direct impact on sinkhole creation.

Change of Vulnerability Since the 2014 HMP

Burlington County and all plan participants continue to be vulnerable to the landslide hazards. Several differences exist between the 2013 Plan and this update. For this plan update, an updated general building stock based upon replacement cost value from MODIV tax assessment data and 2018 RS Means, and an updated critical facility inventory were used to assess the county's risk to the hazard areas. Additionally, steep slopes were used to delineate the landslide hazard area for this plan to provide a more detailed assessment of the County's risk. The County also requested that the risk to subsidence and sinkholes be assessed for the this HMP update. Due to differences in data used for the vulnerability assessment, a direct comparison could not be conducted to determine whether there has been a change in vulnerability since the last HMP.



Figure 5.4.5-5. Potential New Development and Landslide Hazard Boundaries

