4.3.4 Earthquake

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 earthquake hazard in Morris County.

2020 HMP Update Changes

- All subsections have been updated using best available data.
- Previous occurrences were updated with events that occurred between 2015 and 2019.
- The New Jersey Geologic and Water Survey (NJGWS) updated liquefaction data has been integrated into the vulnerability assessment.
- Updated HAZUS-MH version 4.2 probabilistic modeling was conducted using updated inventory data.

4.3.4.1 Profile

Hazard Description

An earthquake is the sudden movement of the Earth's surface caused by the release of stress accumulated within or along the edge of the Earth's tectonic plates, a volcanic eruption, or by a manmade explosion (Federal Emergency Management Agency [FEMA] 2001; Shedlock and Pakiser 1997). Most earthquakes occur at the boundaries where the Earth's tectonic plates meet (faults); less than 10% of earthquakes occur within plate interiors. New Jersey is in an area where the rarer plate interior-related earthquakes occur. As plates continue to move and plate boundaries change geologically over time, weakened boundary regions become part of the interiors of the plates. These zones of weakness within the continents can cause earthquakes in response to stresses that originate at the edges of the plate or in the deeper crust (Shedlock and Pakiser 1997).

The location of an earthquake is commonly described by its focal depth and the geographic position of its epicenter. The focal depth of an earthquake is the depth from the Earth's surface to the region where an earthquake's energy originates, also called the focus or hypocenter. The epicenter of an earthquake is the point on the Earth's surface directly above the hypocenter (Shedlock and Pakiser 1997). Earthquakes usually occur without warning and their effects can impact areas of great distance from the epicenter (FEMA 2001).

According to the U.S. Geological Survey (USGS) Earthquake Hazards Program, an earthquake hazard is any disruption associated with an earthquake that may affect residents' normal activities. This includes surface faulting, ground shaking, landslides, liquefaction, tectonic deformation, tsunamis, and seiches; each of these terms is defined below; however, not all occur within the Morris County planning area:

- *Surface faulting*: Displacement that reaches the earth's surface during a slip along a fault. Commonly occurs with shallow earthquakes—those with an epicenter less than 20 kilometers.
- *Ground motion (shaking):* The movement of the earth's surface from earthquakes or explosions. Ground motion or shaking is produced by waves that are generated by a sudden slip on a fault or sudden pressure at the explosive source and travel through the Earth and along its surface.
- *Landslide*: A movement of surface material down a slope.
- *Liquefaction*: A process by which water-saturated sediment temporarily loses strength and acts as a fluid, like the wet sand near the water at the beach. Earthquake shaking can cause this effect.
- *Tectonic Deformation*: A change in the original shape of a material caused by stress and strain.
- *Tsunami*: A sea wave of local or distant origin that results from large-scale seafloor displacements associated with large earthquakes, major sub-marine slides, or exploding volcanic islands.

- *Seiche*: The sloshing of a closed body of water, such as a lake or bay, from earthquake shaking (USGS 2012).

Earthquakes can cause large and sometimes disastrous landslides and mudslides. Any steep slope is vulnerable to slope failure, often as a result of loss of cohesion in clay-rich soils. Unless properly secured, hazardous materials can be released, causing significant damage to the environment and people. Earthen dams and levees are highly susceptible to seismic events and the impacts of their eventual failures can be considered secondary risks for earthquakes. Landslides are further discussed in Section 4.3.7 (Geologic Hazards) of this HMP update.

Earthquakes can also cause dam failures. The most common mode of earthquake-induced dam failure is slumping or settlement of earth-fill dams where the fill has not been property compacted. If the slumping occurs when the dam is full, then overtopping of the dam, with rapid erosion leading to dam failure is possible. Dam failure is also possible if strong ground motions heavily damage concrete dams. Earthquake-induced landslides into reservoirs have also caused dam failures. Dam failures are further discussed in Section 4.3.1 (Dam Failure) of this HMP update.

Another secondary effect of earthquakes that is often observed in low-lying areas near water bodies is ground liquefaction. Liquefaction is the conversion of water-saturated soil into a fluid-like mass. This can occur when loosely packed, waterlogged sediments lose their strength in response to strong shaking. Liquefaction effects may occur along the shorelines of the ocean, rivers, and lakes and they can also happen in low-lying areas away from water bodies in locations where the ground water is near the earth's surface.

Location

Earthquakes are most likely to occur in the northern parts of New Jersey, which includes Morris County, where significant faults are concentrated; however, low-magnitude events can and do occur in many other areas of the State. The National Earthquake Hazard Reduction Program (NEHRP) developed five soil classifications defined by their shear-wave velocity that impact the severity of an earthquake. The soil classification system ranges from A to E, as noted in Table 4.3.4-1, where A represents hard rock that reduces ground motions from an earthquake and E represents soft soils that amplify and magnify ground shaking and increase building damage and losses.

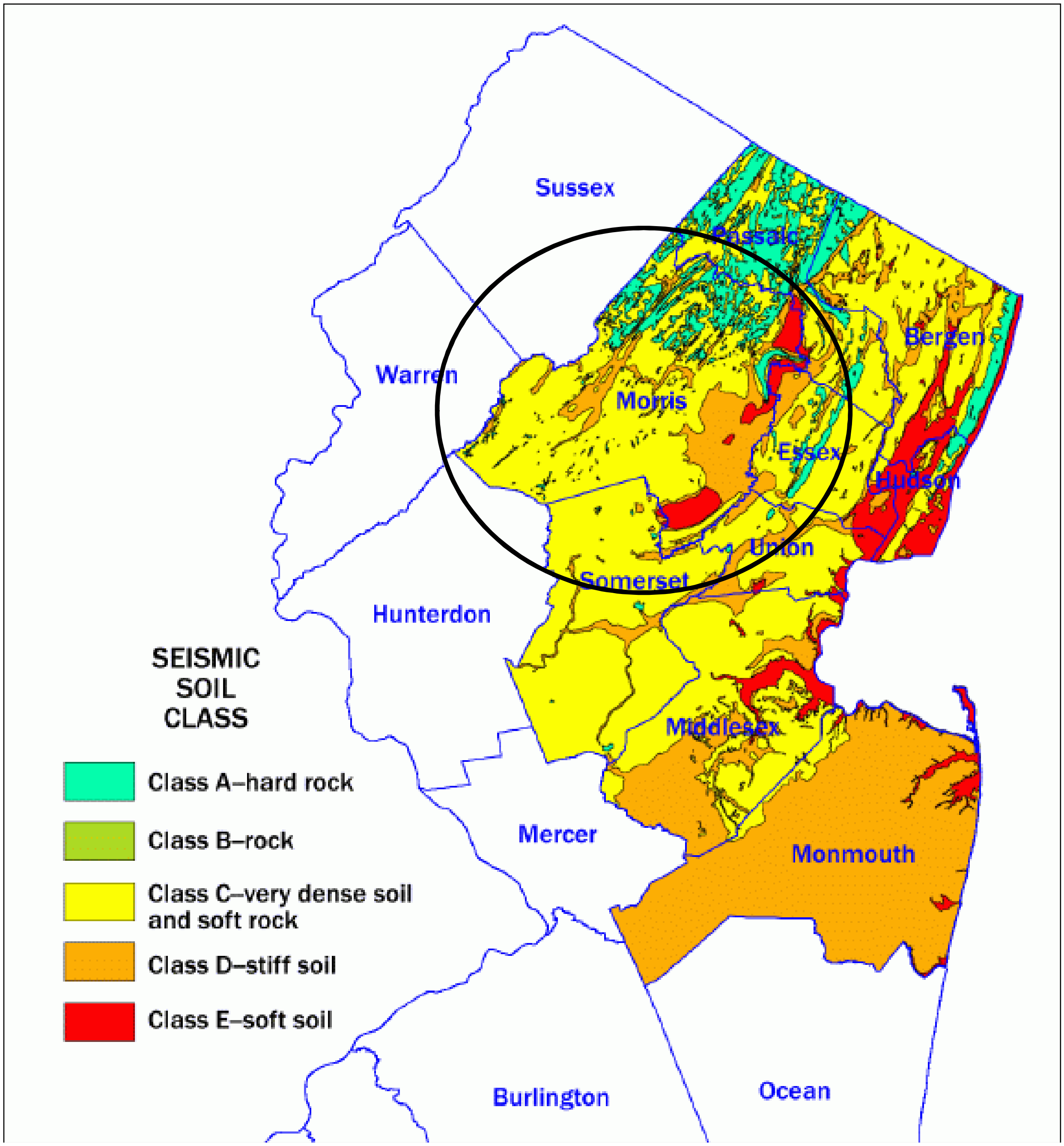
Table 4.3.4-1. NEHRP Soil Classifications

Soil Classification	Description
A	Hard Rock
B	Rock
C	Very dense soil and soft rock
D	Stiff soils
E	Soft soils

Source: FEMA 2014

Figure 4.3.4-1 illustrates the NEHRP soils located in the northeast quadrant of the State. The available NEHRP soils information is incorporated into the HAZUS-MH earthquake model for the risk assessment (discussed in further detail later in this section). According to this figure, Morris County is predominately underlain by class C soils, with bands of class A in the norther portion of the County, bands of class D in the central portion of the County, and large areas of class D and E in the eastern areas; refer to Figure 4.3.4-2.

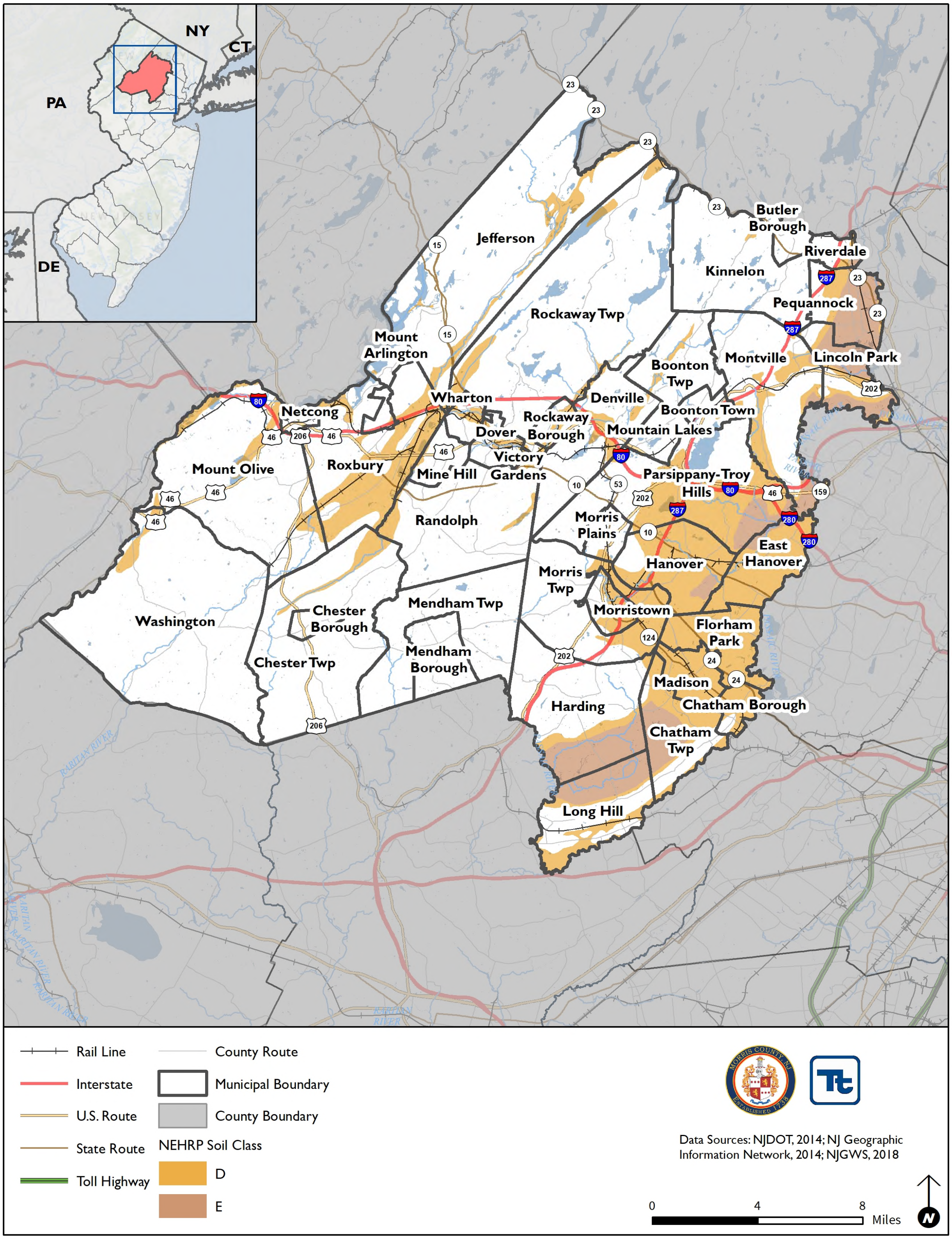
Figure 4.3.4-1. Seismic Soils in Northeastern New Jersey



Source: New Jersey Geological and Water Survey (NJGWS) and New Jersey Department of Environmental Protection (NJDEP) 2011

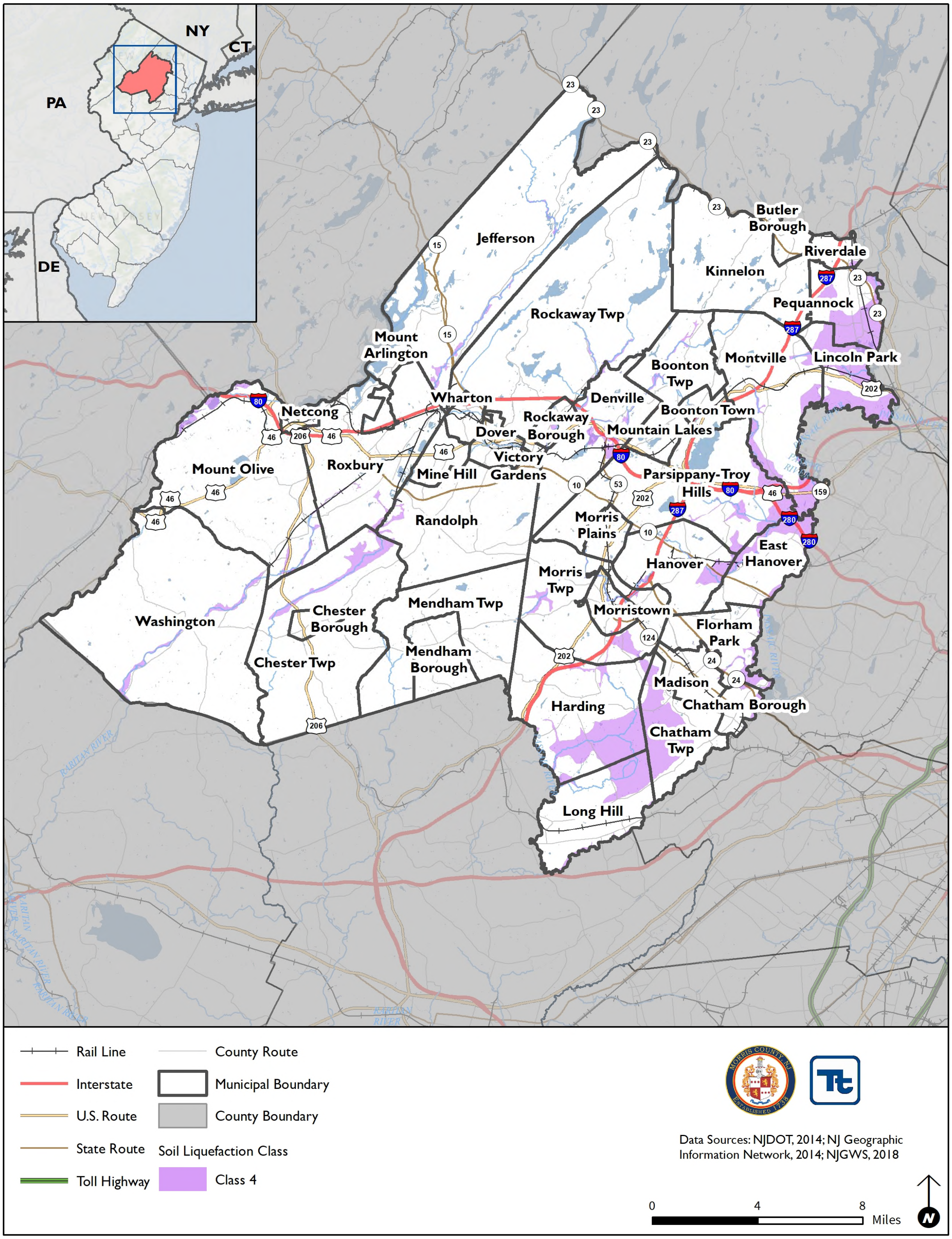
Note: The black circle indicates the location of Morris County. The County contains mainly class C soils, with areas of class A, B, D, and E.

Figure 4.3.4-2. NEHRP Soils in Morris County



Liquefaction has been responsible for tremendous amounts of damage in historical earthquakes around the world. Shaking behavior and liquefaction susceptibility of soils are determined by their grain size, thickness, compaction, and degree of saturation. These properties, in turn, are determined by the geologic origin of the soils and their topographic position. In terms of liquefaction susceptibility, the majority of the susceptibility is found in the eastern portion of Morris County with small areas throughout other areas of the County (see Figure 4.3.4-3).

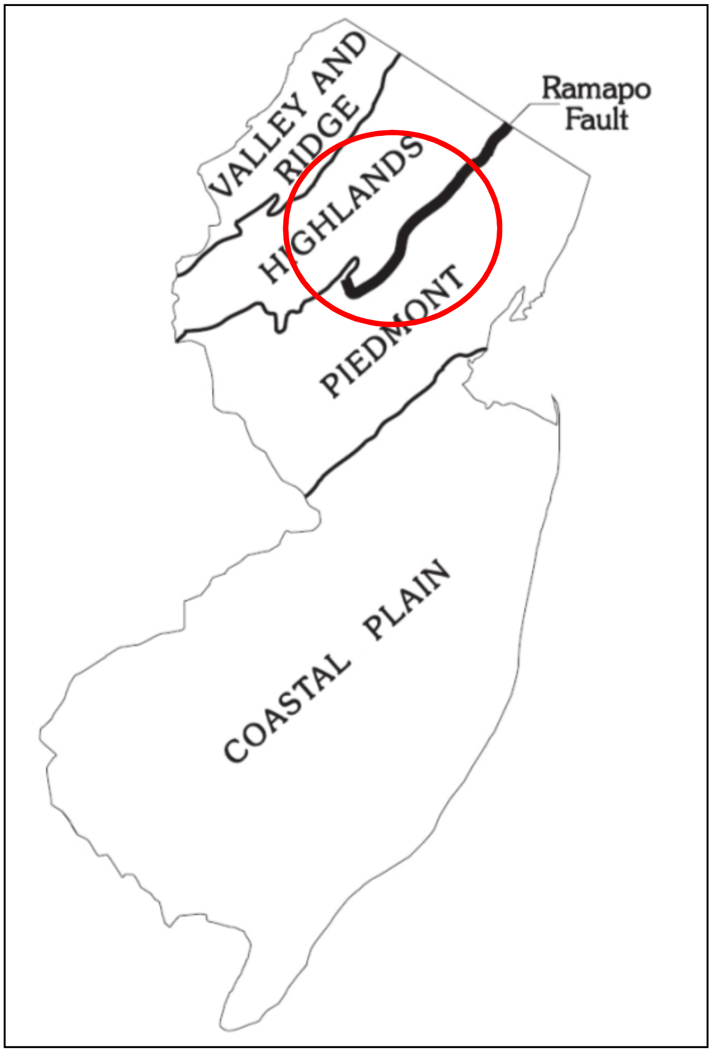
Figure 4.3.4-3. Liquefaction Susceptibility in Morris County



Faults are observed and mapped at the surface. There is no known surface ground displacement along faults in the eastern U.S. from historic earthquakes. Earthquake epicenters in eastern North America and the New Jersey area, in general, occur on known faults. The faults in these parts are from tectonic activity more than 200 million years ago (NJOEM 2019).

There are many faults in New Jersey; however, the Ramapo Fault, which separates the Piedmont and Highlands Physiographic Provinces, is best known and runs through Morris County. Numerous minor earthquakes have been recorded in the Ramapo Fault zone, a 10- to 20-mile-wide area lying adjacent to, and west, of the actual fault (Dombroski 1973 [revised 2005]). Figure 4.3.4-4 illustrates the relationship of the Ramapo fault line with the physiologic provinces of New Jersey.

Figure 4.3.4-4. Physiographic Provinces of New Jersey and the Ramapo Fault Line



Source: Dombroski 1973 (revised 2005)

Note: The red circle indicates the approximate location of Morris County. The County is part of Piedmont Province and the Highlands Province.

Extent

An earthquake's magnitude and intensity are used to describe the size and severity of the event. Magnitude describes the size at the focal point of an earthquake, and intensity describes the overall severity of shaking felt during the event. The earthquake's magnitude is a measure of the energy released at the source of the earthquake. Magnitude was formerly expressed by ratings on the Richter scale but is now most commonly expressed using the moment magnitude (Mw) scale. This scale is based on the total moment release of the earthquake (the product of the distance a fault moved and the force required to move it). The scale is as follows:

- Great Mw > 8
- Major Mw = 7.0 – 7.9
- Strong Mw = 6.0 – 6.9
- Moderate Mw = 5.0 – 5.9
- Light Mw = 4.0 – 4.9
- Minor Mw = 3.0 – 3.9
- Micro Mw = 3.0 – 3.9

The most commonly used intensity scale is the modified Mercalli intensity scale. Ratings of the scale, as well as the perceived shaking and damage potential for structures, are shown in Table 4.3.4-2. The modified Mercalli intensity scale is generally represented visually using shake maps, which show the expected ground shaking at any given location produced by an earthquake with a specified magnitude and epicenter An earthquake has only one magnitude and one epicenter, but it produces a range of ground shaking at sites throughout the region, depending on the distance from the earthquake, the rock and soil conditions at sites, and variations in the propagation of seismic waves from the earthquake due to complexities in the structure of the earth's crust. A USGS shake map shows the variation of ground shaking in a region immediately following significant earthquakes. Table 4.3.4-3 displays the MMI scale and its relationship to the areas peak ground acceleration (PGA).

Table 4.3.4-2. Modified Mercalli Intensity Scale

Mercalli Intensity	Description
a	Felt by very few people; barely noticeable.
II	Felt by few people, especially on upper floors.
III	Noticeable indoors, especially on upper floors, but may not be recognized as an earthquake.
IV	Felt by many indoors, few outdoors. May feel like passing truck.
V	Felt by almost everyone, some people awakened. Small objects move; trees and poles may shake.
VI	Felt by everyone; people have trouble standing. Heavy furniture can move; plaster can fall off walls. Chimneys may be slightly damaged.
VII	People have difficulty standing. Drivers feel their cars shaking. Some furniture breaks. Loose bricks fall from buildings. Damage is slight to moderate in well-built buildings; considerable in poorly built buildings.
VIII	Well-built buildings suffer slight damage. Poorly built structures suffer severe damage. Some walls collapse.
IX	Considerable damage to specially built structures; buildings shift off their foundations. The ground cracks. Landslides may occur.
X	Most buildings and their foundations are destroyed. Some bridges are destroyed. Dams are seriously damaged. Large landslides occur. Water is thrown on the banks of canals, rivers, and lakes. The ground cracks in large areas.
XI	Most buildings collapse. Some bridges are destroyed. Large cracks appear in the ground. Underground pipelines are destroyed.
XII	Almost everything is destroyed. Objects are thrown into the air. The ground moves in waves or ripples. Large amounts of rock may move.

Source: USGS 2016c

Table 4.3.4-3. Modified Mercalli Intensity and PGA Equivalents

Modified Mercalli Intensity	Acceleration (%g) (PGA)	Perceived Shaking	Potential Damage
I	< .17	Not Felt	None
II	.17 – 1.4	Weak	None
III	.17 – 1.4	Weak	None
IV	1.4 – 3.9	Light	None
V	3.9 – 9.2	Moderate	Very Light
VI	9.2 – 18	Strong	Light
VII	18 – 34	Very Strong	Moderate
VIII	34 – 65	Severe	Moderate to Heavy

Source: Freeman et al. 2004
Note: PGA Peak Ground Acceleration

The ground experiences acceleration as it shakes during an earthquake. The peak ground acceleration (PGA) is the largest acceleration recorded by a monitoring station during an earthquake. PGA is a measure of how hard the earth shakes in a given geographic area. It is expressed as a percentage of the acceleration due to gravity (%g). Horizontal and vertical PGA varies with soil or rock type. Earthquake hazard assessment involves estimating the annual probability that certain ground accelerations will be exceeded, and then summing the annual probabilities over a time period of interest. Damage levels experienced in an earthquake vary with the intensity of ground shaking and with the seismic capacity of structures, as noted in Table 4.3.4-4.

Table 4.3.4-4. Damage Levels Experienced in Earthquakes

Ground Motion Percentage	Explanation of Damages
1-2%g	Motions are widely felt by people; hanging plants and lamps swing strongly, but damage levels, if any, are usually very low.
Below 10%g	Usually causes only slight damage, except in unusually vulnerable facilities.
10 - 20%g	May cause minor-to-moderate damage in well-designed buildings, with higher levels of damage in poorly designed buildings. At this level of ground shaking, only unusually poor buildings would be subject to potential collapse.
20 - 50%g	May cause significant damage in some modern buildings and very high levels of damage (including collapse) in poorly designed buildings.
≥50%g	May causes higher levels of damage in many buildings, even those designed to resist seismic forces.

Source: NJOEM 2011
Note: %g Peak Ground Acceleration

National maps of earthquake shaking hazards provide information for creating and updating seismic design requirements for building codes, insurance rate structures, earthquake loss studies, retrofit priorities, and land use planning. After thorough review of the studies, professional organizations of engineers update the seismic-risk maps and seismic design requirements contained in building codes. The USGS updated the National Seismic Hazard Maps in 2014. New seismic, geologic, and geodetic information on earthquake rates and associated ground shaking were incorporated into these revised maps.

Figure 4.3.4-5 through Figure 4.3.4-7 illustrate geographic distributions of the modified Mercalli scale based on PGAs (%*g*) across Morris County for 100-, 500-, and 2,500-year MRP events by U.S. Census tract. A 100-year mean return period (MRP) event is an earthquake with 1-percent chance that mapped ground motion levels (PGA) will be exceeded in any given year. A 500-year MRP is an earthquake with 0.2 percent chance that mapped PGAs will be exceeded in any given year. A 2,500-year MRP is an earthquake with 0.04 percent chance that mapped PGAs will be exceeded in any given year.

Figure 4.3.4-5. Peak Ground Acceleration 100-Year Mean Return Period for Morris County

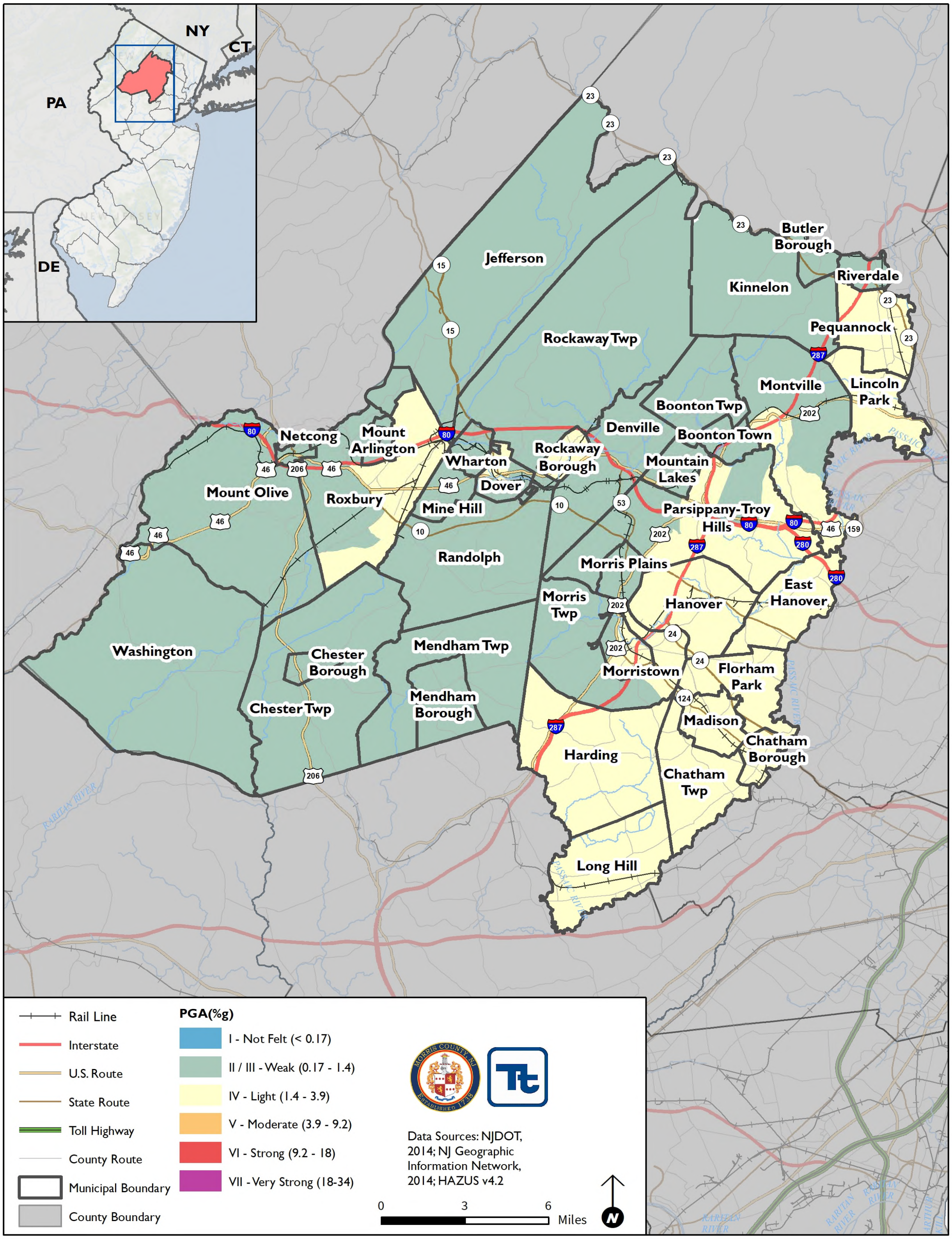


Figure 4.3.4-6. Peak Ground Acceleration 500-Year Mean Return Period for Morris County

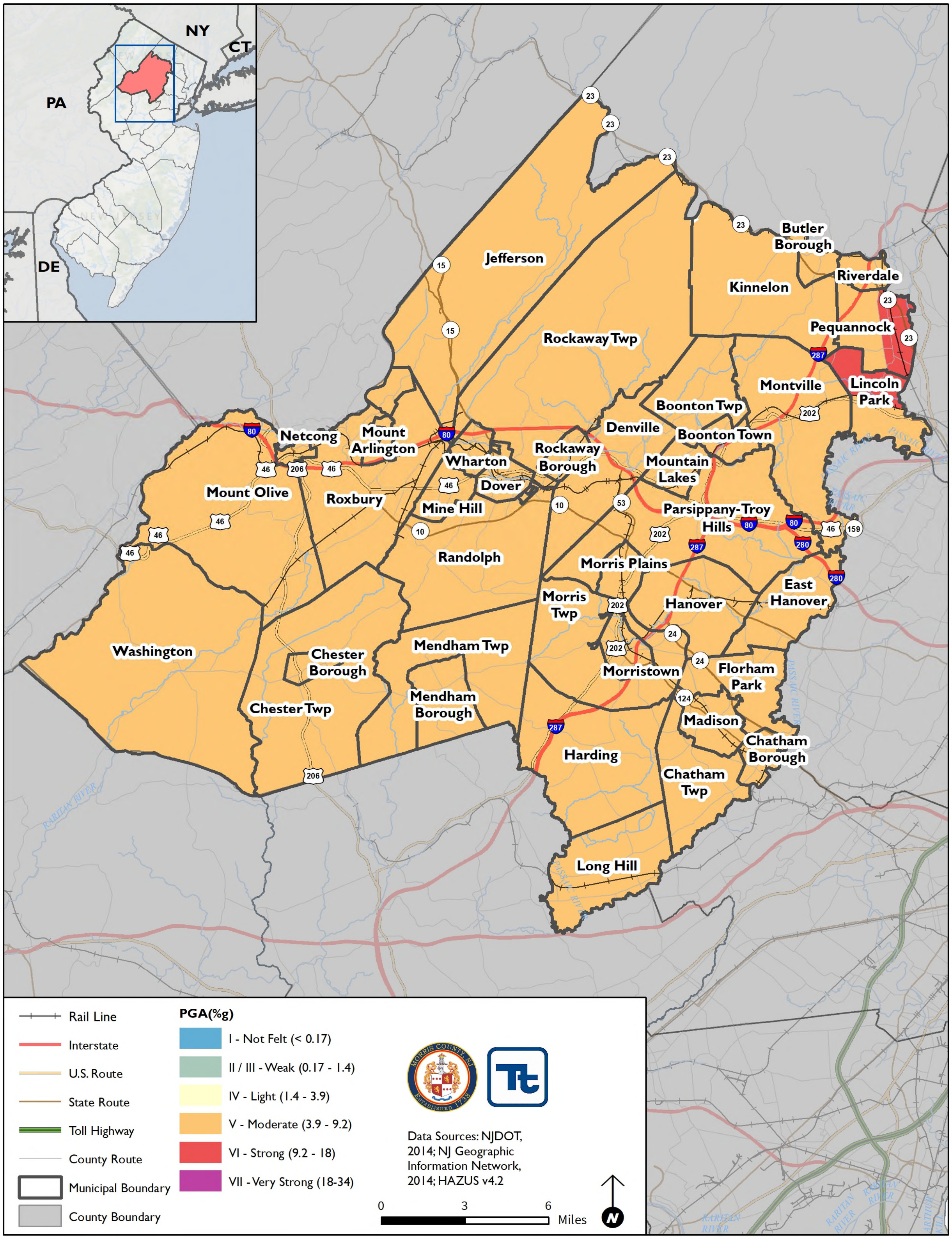
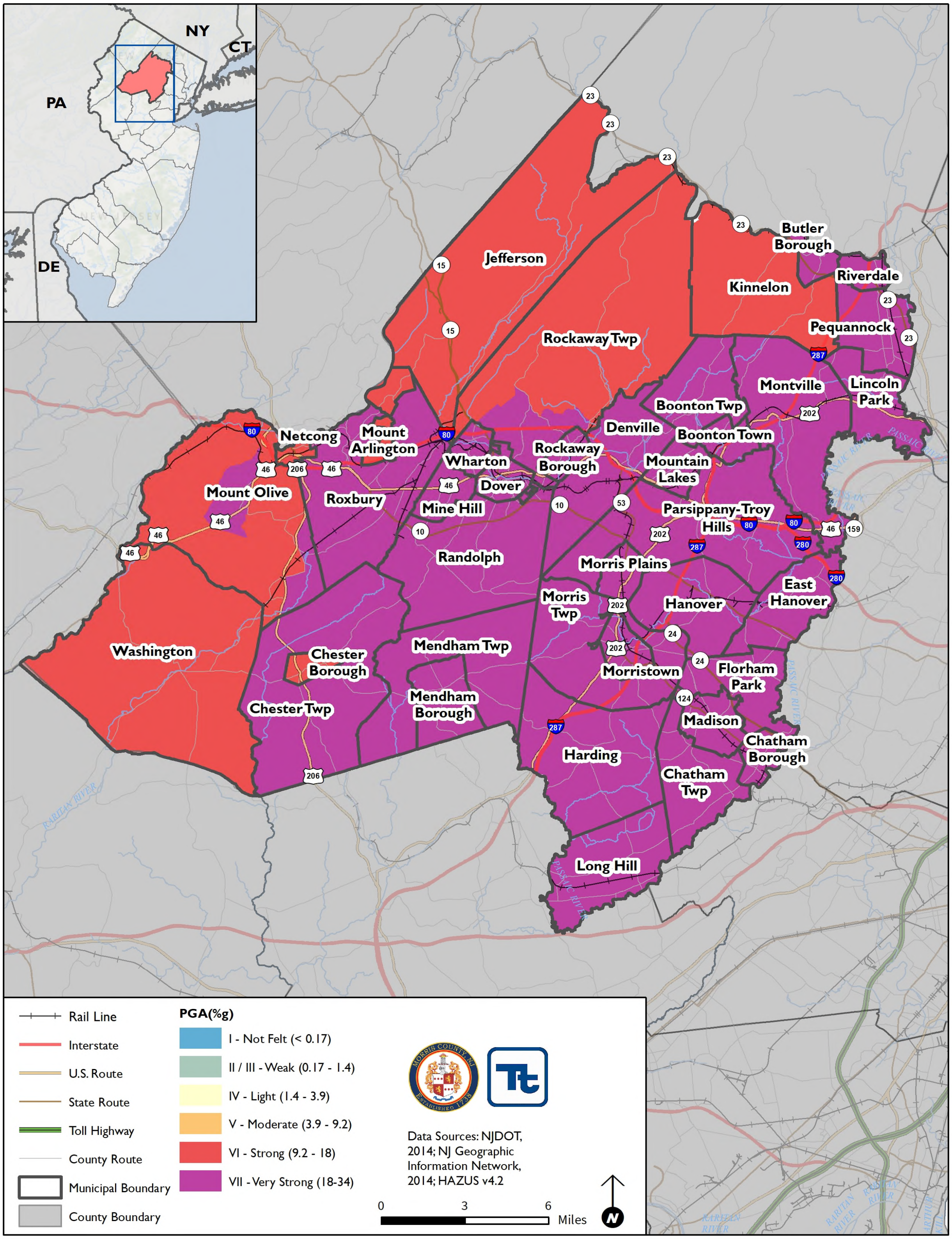


Figure 4.3.4-7. Peak Ground Acceleration 2,500-Year Mean Return Period for Morris County

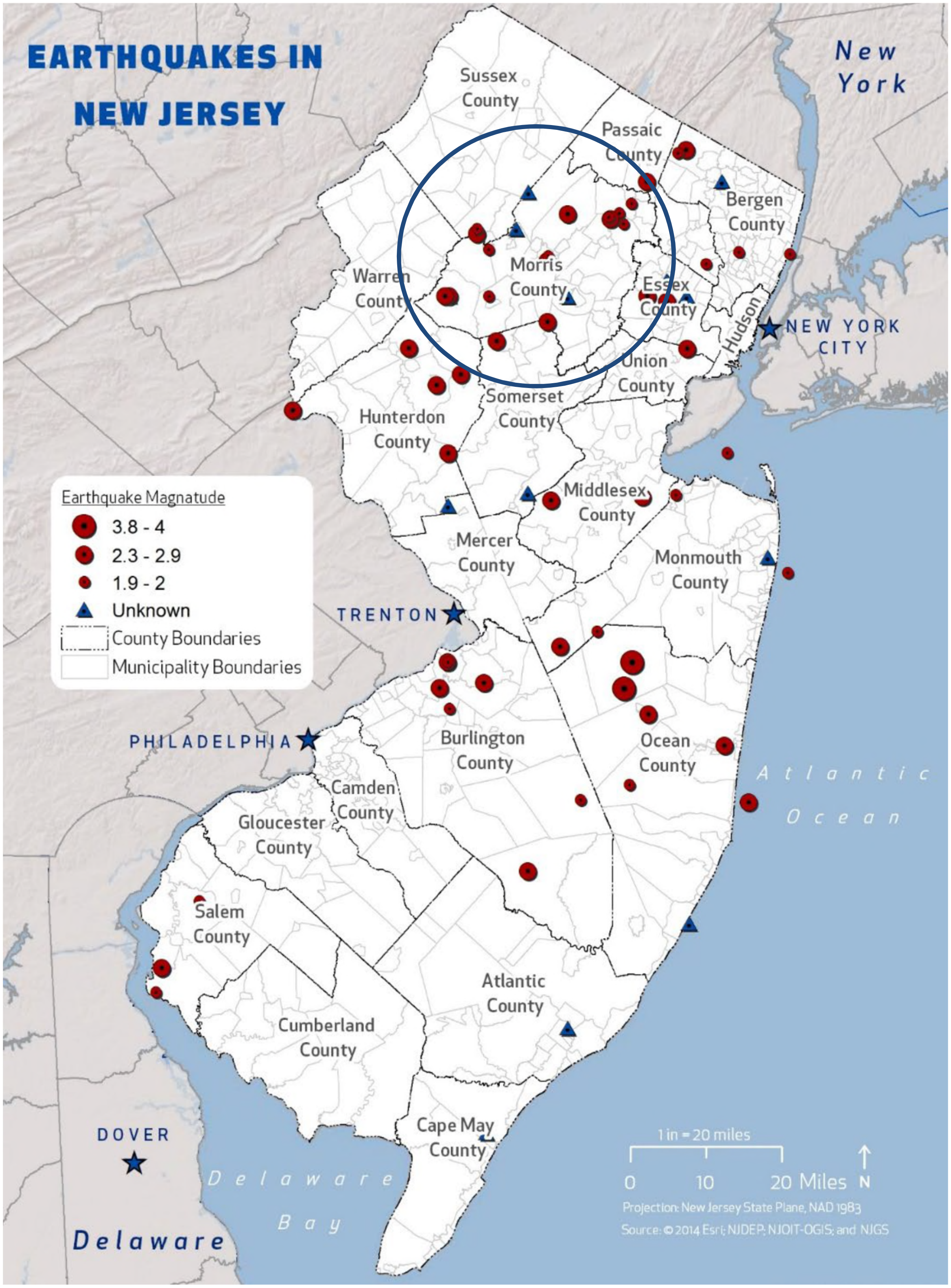


Previous Occurrences and Losses

New Jersey has a fairly extensive history of earthquakes. Small earthquakes occur several times a year and generally do not cause significant damage. The largest earthquake to impact New Jersey occurred in 1783. That earthquake, a magnitude 5.3 quake, occurred west of New York City and was felt from New Hampshire to Pennsylvania (Stover and Coffman 1993). Figure 4.3.4-8 illustrates earthquake events with epicenters located in New Jersey. Of the 178 events in the State, 17 earthquake epicenters were located in Morris County.

Earthquake events that have impacted Morris County between 2014 and 2019 are listed in Table 4.3.4-5. In the 2015 HMP, previous events were listed for the entirety of New Jersey. For the 2020 HMP, only events that impacted or could be felt in Morris County have been included. For events prior to 2014, refer to Appendix E (Risk Assessment Supplement). Please see Section 9 (Jurisdictional Annexes) for detailed information regarding impacts and losses to each municipality. The State of New Jersey has not been included in any FEMA disaster (DR) or emergency (EM) declarations for earthquake events.

Figure 4.3.4-8. Earthquakes with Epicenters in New Jersey, 1783 to 2017



Source: NJOEM 2019

Note: The blue circle indicates the location of Morris County. The figure shows that several earthquakes have been epicentered in Morris County.

Table 4.3.4-5. Earthquake Events Impacting Morris County, 2014 to 2019

Date of Event	Magnitude	FEMA Declaration Number	County Designated?	Location	Losses/Impacts
August 14, 2015	2.6 Earthquake	N/A	N/A	Bernardsville, New Jersey	A magnitude 2.6 earthquake took place in Bernardsville, NJ at the border of Morris and Somerset County. The quake was faintly felt in Morris County.
August 22, 2015	1.2 Earthquake	N/A	N/A	Fairfield	A magnitude 1.2 earthquake took place in Fairfield at the border of Essex and Morris County.
January 2, 2016	2.1 Earthquake	N/A	N/A	Ringwood, New Jersey	A magnitude 2.1 earthquake took place in Ringwood, NJ. The quake was faintly felt in Morris County.
February 19, 2016	1.1 Earthquake	N/A	N/A	Butler	A magnitude 1.1 Earthquake took place just north of Butler at the border of Morris and Passaic County.
February 21, 2016	0.5 Earthquake	N/A	N/A	Kinnelon	A magnitude 0.5 earthquake took place just north of Kinnelon at the border of Morris and Passaic County.
July 4, 2016	1.1 Earthquake	N/A	N/A	Kinnelon	A magnitude 1.1 earthquake took place in Kinnelon.
March 29, 2017	1.2 Quarry Blast	N/A	N/A	Riverdale	A quarry blast registered a 1.2 magnitude earthquake at Riverdale.
March 25, 2017	1.3 Earthquake	N/A	N/A	Morris Plains	A magnitude 1.3 earthquake took place in Morris Plains.
September 25, 2017	1.7 Earthquake	N/A	N/A	Morristown	A magnitude 1.7 earthquake took place in Morristown.
September 30, 2017	1.0 Earthquake	N/A	N/A	Morristown	A magnitude 1.0 earthquake took place in Morristown.
November 30, 2017	4.1 Earthquake	N/A	N/A	Dover, Delaware	Morris County residents felt ground shake from nearby 4.1 magnitude earthquake in Dover, Delaware. The quake was felt from central Virginia to Massachusetts.
April 12, 2019	1.8 Earthquake	N/A	N/A	Clifton, New Jersey	A magnitude 1.8 earthquake took place in Clifton, NJ. The quake was faintly felt in Morris County.
August 4, 2019	0.8 Earthquake	N/A	NA	Pompton Lakes	A magnitude 0.8 earthquake took place in Pompton Lakes.

Source: NJGWS 2019; USGS 2019
N/A Not Applicable/Not Available
NJ New Jersey

Probability of Future Occurrences

Earthquakes cannot be predicted and may occur any time of the day or year. The probability of damaging earthquakes affecting New Jersey and Morris County is low. However, there is a definite threat of major earthquakes that could cause widespread damage and casualties in New Jersey. Major earthquakes are infrequent in the State and may occur only once every few hundred years or longer, but the consequences of major earthquakes would be very high.

In Section 4.4 (Hazard Ranking), the identified hazards of concern for Morris 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 Steering Committee and Planning Committee, the probability of occurrence for earthquake events in the County is considered 'frequent' with minimal impacts.

Climate Change Impacts

The potential impacts of global climate change on earthquake probability are unknown. Some scientists feel that melting glaciers could induce tectonic activity. As ice melts and water runs off, tremendous amounts of weight are shifted on the Earth's crust. As newly freed crust returns to its original, pre-glacier shape, it could cause seismic plates to slip and stimulate volcanic activity according to research into prehistoric earthquakes and volcanic activity. National Aeronautics and Space Administration (NASA) and USGS scientists found that retreating glaciers in southern Alaska might be opening the way for future earthquakes (NJOEM 2019).

Secondary impacts of earthquakes could be magnified by future climate change. Soils saturated by repetitive storms could experience liquefaction during seismic activity because of the increased saturation. Dams storing increased volumes of water from changes in the hydrograph could fail during seismic events. There are currently no models available to estimate these impacts (NJOEM 2019).

4.3.4.2 Vulnerability Assessment

Earthquake vulnerability data was generated using the FEMA HAZUS-MH seismic model. A probabilistic assessment was conducted for the 100-, 500- and 2,500-year MRPs through a Level 2 analysis in HAZUS-MH to analyze the earthquake hazard and provide a range of loss estimates. Figure 4.3.4-2 shows the geographic distribution of the NEHRP soil types in the County. Figure 4.3.4-3 shows the geographic distribution of the liquefaction soil types in the County. Refer to Section 4.2 (Methodology and Tools) for additional details on the methodology used to assess earthquake risk.

Impact on Life, Health and Safety

The entire County may experience an earthquake. However, the degree of impact is dependent on many factors including the age and type of construction people live in, the soil types their homes are located on, the intensity of the earthquake. Whether directly or indirectly impacted, residents could be faced with business closures, road closures that could isolate populations, and loss of function of critical facilities and utilities.

According to the 2017 American Community Survey annual estimate, Morris County had a population of 498,847 people. Overall, risk to public safety and loss of life from an earthquake in the County is expected to be minimal for low magnitude events. However, there is a higher risk to public safety for those inside buildings due to structural damage or people walking below building ornamentations and chimneys that may be shaken loose and fall because of an earthquake.

As noted earlier, NEHRP soil classes D and E and liquefaction class 4 soils can amplify ground shaking to damaging levels even during a moderate earthquake, and thus increase risk to the population. Populations within municipalities located on NEHRP class D and E soils and high liquefaction susceptible soils were estimated and are listed in Table 4.3.4-6 below. Overall, approximately 170,939 people (34.3% of the County's population) reside on NEHRP class D and E soils. In addition, 22,461 people (4.5% of the County's population) reside in areas of high susceptibility to liquefaction. The Borough of Florham Park and the Borough of Madison have the greatest percent of their population living on NEHRP class D and E soils (100% and 99.9%, respectively). The Township of Pequannock has the greatest percent of its population living on liquefaction class 4 soils (53.6%).

Table 4.3.4-6. Approximate Population Living on NEHRP Class D and E and Liquefaction Susceptible Soils

Municipality	American Community Survey (2013-2017) Population	Estimated Population Exposed			
		NEHRP D&E Soils	% of Total	Liquefaction Class 4	% of Total
Town of Boonton	8,390	85	1.0%	0	0.0%
Township of Boonton	4,353	231	5.3%	13	0.3%
Borough of Butler	7,780	0	0.0%	0	0.0%
Chatham Borough	9,003	7,682	85.3%	49	0.5%
Chatham Township	10,507	5,628	53.6%	572	5.4%
Chester Borough	1,540	0	0.0%	0	0.0%
Chester Township	7,931	175	2.2%	3	0.0%
Denville Township	16,822	3,234	19.2%	1,357	8.1%
Town of Dover	18,307	5,195	28.4%	0	0.0%
Township of East Hanover	11,241	11,055	98.3%	822	7.3%
Borough of Florham Park	11,792	11,792	100.0%	76	0.6%
Township of Hanover	14,436	10,984	76.1%	43	0.3%
Township of Harding	3,887	295	7.6%	315	8.1%
Township of Jefferson	21,440	2,622	12.2%	11	0.1%
Borough of Kinnelon	10,242	189	1.8%	0	0.0%
Borough of Lincoln Park	10,464	6,010	57.4%	4,911	46.9%
Township of Long Hill	8,763	911	10.4%	184	2.1%
Borough of Madison	16,080	16,066	99.9%	0	0.0%
Borough of Mendham	4,992	0	0.0%	0	0.0%
Township of Mendham	5,877	0	0.0%	0	0.0%
Township of Mine Hill	3,609	492	13.6%	0	0.0%
Township of Montville	21,739	5,942	27.3%	1,896	8.7%
Township of Morris	22,498	9,838	43.7%	783	3.5%
Borough of Morris Plains	5,605	630	11.2%	0	0.0%
Town of Morristown	18,833	11,365	60.3%	160	0.9%
Borough of Mount Arlington	5,405	127	2.3%	0	0.0%
Township of Mount Olive	29,010	5,052	17.4%	171	0.6%
Borough of Mountain Lakes	4,309	0	0.0%	0	0.0%
Netcong Borough	3,245	0	0.0%	0	0.0%
Township of Parsippany-Troy Hills	53,444	20,629	38.6%	2,503	4.7%

Municipality	American Community Survey (2013-2017) Population	Estimated Population Exposed			
		NEHRP D&E Soils	% of Total	Liquefaction Class 4	% of Total
Township of Pequannock	15,499	14,633	94.4%	8,308	53.6%
Township of Randolph	25,918	728	2.8%	0	0.0%
Borough of Riverdale	4,238	2,110	49.8%	134	3.2%
Borough of Rockaway	6,473	1,685	26.0%	12	0.2%
Township of Rockaway	24,758	587	2.4%	15	0.1%
Township of Roxbury	23,458	12,948	55.2%	29	0.1%
Borough of Victory Gardens	1,655	160	9.7%	0	0.0%
Township of Washington	18,713	1,183	6.3%	93	0.5%
Borough of Wharton	6,591	675	10.2%	0	0.0%
Morris County (Total)	**498,847**	**170,939**	**34.3%**	**22,461**	**4.5%**

Sources: American Community Survey 5-year Estimate, 2017; NJGWS, 2016

Populations considered most vulnerable are those located in/near the built environment, particularly those near unreinforced masonry structures. Of these most vulnerable populations, socially vulnerable populations, including the elderly (persons over age 65) and individuals living below the poverty threshold, are most susceptible. Factors leading to this higher susceptibility include decreased mobility and financial ability to react or respond during a hazard, and the location and construction quality of their housing. Within the NEHRP class D and E soils, there are 29,464 people over the age of 65 and 8,484 people below the poverty level. Within liquefaction class 4 soils, there are 4,350 people over the age of 65 and 946 people below the poverty level.

Residents may be displaced or require temporary to long-term sheltering due to an earthquake event. The number of people requiring shelter is generally less than the number displaced because some displaced persons use hotels or stay with family or friends following a disaster event. Table 4.3.4-7 summarizes the households HAZUS-MH estimates will be displaced and population that may require short-term sheltering as a result of the 100-, 500- and 2,500-year MRP earthquake events.

Table 4.3.4-7. Summary of Estimated Sheltering Needs for Morris County

Scenario	Displaced Households	Persons Seeking Short-Term Shelter
100-Year Earthquake	0	0
500-Year Earthquake	69	37
2,500-Year Earthquake	905	483

Source: HAZUS-MH v4.2

According to the 1999-2003 NYCEM Summary Report (Earthquake Risks and Mitigation in the New York / New Jersey / Connecticut Region), a strong correlation exists between structural building damage and number of injuries and casualties from an earthquake event. Further, time of day also exposes different sectors of the community to the hazard. For example, HAZUS-MH considers residential occupancy at its maximum at 2:00 AM, whereas educational, commercial, and industrial sectors are at their maximum at 2:00 PM, and peak commute time is at 5:00 PM. Whether directly impacted or indirectly impacted, the entire population will be affected to some degree. Business interruption could prevent people from working, road closures could isolate populations, and loss of utilities could impact populations that suffered no direct damage from an event.

Table 4.3.4-8 summarizes the County-wide injuries and casualties estimated for the 100-, 500-, and 2,500-year MRP earthquake events.

Table 4.3.4-8. Estimated Number of Injuries and Casualties from the 100-, 500-, and 2,500-Year MRP Earthquake Events

Level of Severity	Time of Day		
	2:00 AM	2:00 PM	5:00 PM
100-year MRP			
Injuries	0	0	0
Hospitalization	0	0	0
Casualties	0	0	0
500-year MRP			
Injuries	20	31	23
Hospitalization	3	4	3
Casualties	0	1	0
2,500-year MRP			
Injuries	2004	312	227
Hospitalization	37	61	45
Casualties	7	12	9

Source: HAZUS-MH v4.2

Impact on General Building Stock

The entire County's general building stock is considered at risk and exposed to this hazard. As stated earlier, soft soils (NEHRP soil classes D and E) can amplify ground shaking to damaging levels even during a moderate earthquake (State of New Jersey 2019). Therefore, buildings located on NEHRP classes D and E soils and high liquefaction susceptible soils are at increased risk of damage from an earthquake. Table 4.3.4-9 summarizes the number and replacement cost value of buildings in Morris County located on NEHRP soils classes D and E and liquefaction class 4 soils.

Table 4.3.4-9. Number and Replacement Cost Value of Buildings Located on Seismic and Liquefaction Susceptible Soils

Municipality	Total Number of Buildings	Total RCV (Structure and Contents)	Buildings NEHRP Class "D" and "E" Soils			Buildings Liquefaction Class 4		
			Number	RCV	% of Total RCV	Number	RCV	% of Total RCV
Town of Boonton	3,262	$1,832,625,537	33	1.0%	$33,927,506	1.9%	0	0.0%
Township of Boonton	1,898	$1,388,780,135	111	5.8%	$166,548,877	12.0%	10	0.5%
Borough of Butler	2,701	$1,489,686,071	0	0.0%	$0	0.0%	0	0.0%
Chatham Borough	3,286	$1,673,960,469	2,820	85.8%	$1,458,301,271	87.1%	29	0.9%
Chatham Township	4,080	$2,300,237,613	2,448	60.0%	$1,368,843,490	59.5%	258	6.3%
Chester Borough	853	$694,668,411	0	0.0%	$0	0.0%	0	0.0%
Chester Township	3,680	$2,782,631,274	70	1.9%	$28,867,739	1.0%	4	0.1%
Denville Township	7,198	$4,397,845,504	1,382	19.2%	$894,700,008	20.3%	507	7.0%
Town of Dover	4,514	$2,640,787,978	1,384	30.7%	$951,675,214	36.0%	0	0.0%
Township of East Hanover	4,848	$4,740,072,304	4,779	98.6%	$4,703,188,849	99.2%	347	7.2%
Borough of Florham Park	3,805	$3,768,421,982	3,805	100.0%	$3,768,421,982	100.0%	26	0.7%
Township of Hanover	7,090	$5,609,469,027	5,662	79.9%	$5,073,465,211	90.4%	108	1.5%
Township of Harding	2,230	$1,808,255,972	207	9.3%	$130,159,850	7.2%	192	8.6%
Township of Jefferson	9,625	$4,421,074,958	1,101	11.4%	$484,647,435	11.0%	6	0.1%
Borough of Kinnelon	4,093	$2,858,766,250	76	1.9%	$47,482,164	1.7%	0	0.0%
Borough of Lincoln Park	4,166	$2,125,371,898	2,055	49.3%	$1,341,526,568	63.1%	1623	39.0%
Township of Long Hill	3,643	$2,253,461,094	480	13.2%	$342,138,859	15.2%	97	2.7%
Borough of Madison	6,301	$3,066,320,935	6,301	100.0%	$3,066,320,935	100.0%	0	0.0%
Borough of Mendham	2,139	$1,479,178,043	0	0.0%	$0	0.0%	0	0.0%
Township of Mendham	2,667	$2,099,041,883	0	0.0%	$0	0.0%	0	0.0%
Township of Mine Hill	1,590	$766,971,485	204	12.8%	$60,911,396	7.9%	0	0.0%
Township of Montville	8,179	$6,714,034,036	2,250	27.5%	$2,434,175,958	36.3%	749	9.2%
Township of Morris	9,713	$6,091,077,654	4,299	44.3%	$2,785,036,128	45.7%	317	3.3%
Borough of Morris Plains	2,378	$1,738,775,034	298	12.5%	$227,122,566	13.1%	0	0.0%
Town of Morristown	4,413	$2,945,511,672	2,314	52.4%	$1,714,784,391	58.2%	52	1.2%

Municipality	Total Number of Buildings	Total RCV (Structure and Contents)	Buildings NEHRP Class "D" and "E" Soils			Buildings Liquefaction Class 4		
			Number	RCV	% of Total RCV	Number	RCV	% of Total RCV
Borough of Mount Arlington	2,333	$1,065,424,961	63	2.7%	$35,122,417	3.3%	0	0.0%
Township of Mount Olive	9,115	$7,181,400,421	1,402	15.4%	$854,794,139	11.9%	54	0.6%
Borough of Mountain Lakes	1,642	$1,183,405,498	0	0.0%	$0	0.0%	0	0.0%
Netcong Borough	1,100	$695,081,980	2	0.2%	$4,579,971	0.7%	0	0.0%
Township of Parsippany-Troy Hills	17,064	$11,747,551,200	6,953	40.7%	$5,608,078,333	47.7%	833	4.9%
Township of Pequannock	5,642	$3,911,039,941	5,348	94.8%	$3,590,341,293	91.8%	3008	53.3%
Township of Randolph	8,600	$6,709,486,516	294	3.4%	$375,887,519	5.6%	1	0.0%
Borough of Riverdale	1,183	$1,165,082,666	563	47.6%	$469,298,571	40.3%	39	3.3%
Borough of Rockaway	2,617	$1,612,749,951	851	32.5%	$636,285,299	39.5%	18	0.7%
Township of Rockaway	11,485	$7,225,058,745	471	4.1%	$802,365,022	11.1%	23	0.2%
Township of Roxbury	9,544	$5,918,169,131	5,670	59.4%	$3,685,412,618	62.3%	23	0.2%
Borough of Victory Gardens	339	$163,035,099	41	12.1%	$47,807,502	29.3%	0	0.0%
Township of Washington	8,062	$5,265,032,309	491	6.1%	$397,709,902	7.6%	50	0.6%
Borough of Wharton	2,051	$1,539,335,501	250	12.2%	$729,851,119	47.4%	0	0.0%
Morris County (Total)	**189,129**	**$127,068,881,137**	**64,478**	**34.1%**	**48,319,780,104**	**38.0%**	**8,374**	**4.4%**

Sources: *Morris County 2019; Microsoft, 2018, Open Street Map, 2019; NJOIT, 2018; NJGWS, 2016*
RCV *Replacment Cost Value*

There is a strong correlation between PGA and damage a building might undergo (State of New Jersey 2019). The HAZUS-MH model is based on best available earthquake science and aligns with these statements. The HAZUS-MH probabilistic earthquake model was applied to analyze effects from the earthquake hazard on general building stock in Morris County. See Figure 4.3.4-5 through Figure 4.3.4-7 earlier in this profile which illustrates the geographic distribution of PGA (g) across the County for 100-, 500- and 2,500-year MRP events.

A building's construction determines how well it can withstand the force of an earthquake. FEMA has written guides to help homebuilders design homes based on their vulnerability to an earthquake event (FEMA 2006). Extra caution must be taken for structures with masonry chimneys, old chimneys, and open-front configurations such as one or two-family homes where the fronts are attached garages that have inadequate bracing length. The State of New Jersey HMP indicates that unreinforced masonry buildings are most at risk during an earthquake because the walls are prone to collapse outward, whereas steel and wood buildings absorb more of the earthquake's energy (State of New Jersey 2019). Additional attributes that affect a building's capability to withstand an earthquake's force include its age, number of stories, and quality of construction.

HAZUS-MH considers building construction and age of building as part of the analysis. Because a custom general building stock inventory was developed for Morris County, the building ages and types, where available, were incorporated into the HAZUS-MH model.

Potential building damage was evaluated using HAZUS-MH across the following damage categories: none, slight, moderate, extensive, and complete. Table 4.3.4-10 provides definitions of these five categories of damage to a light wood-framed building; definitions of categories of damage to other building types appear in HAZUS-MH technical manual documentation.

Table 4.3.4-10. Example of Structural Damage State Definitions for a Light Wood-Framed Building

Damage Category	Description
None	No damage recorded.
Slight	Small plaster or gypsum-board cracks at corners of door and window openings and wall-ceiling intersections; small cracks in masonry chimneys and masonry veneer.
Moderate	Large plaster or gypsum-board cracks at corners of door and window openings; small diagonal cracks across shear wall panels exhibited by small cracks in stucco and gypsum wall panels; large cracks in brick chimneys; toppling of tall masonry chimneys.
Extensive	Large diagonal cracks across shear wall panels or large cracks at plywood joints; permanent lateral movement of floors and roof; toppling of most brick chimneys; cracks in foundations; splitting of wood sill plates and/or slippage of structure over foundations; partial collapse of room-over-garage or other soft-story configurations.
Complete	Structure might have large permanent lateral displacement, can collapse, or be in imminent danger of collapse due to cripple wall failure or the failure of the lateral load resisting system; some structures can slip and fall off the foundations; large foundation cracks.

Source: HAZUS-MH Technical Manual

Building damage as a result of the 100-, 500- and 2,500-year MRP earthquake events was estimated using HAZUS-MH.

Table 4.3.4-11 lists the estimated numbers of buildings damaged (within general occupancy categories) from the 500- and 2,500-year MRP earthquake events. Damage loss estimates include structural and non-structural damage to the building and loss of contents. Table 4.3.4-12 lists estimated replacement cost values of buildings and contents damaged by the 100-, 500- and 2,500-year MRP earthquake events.

Table 4.3.4-11. Estimated Buildings Damaged by General Occupancy for 100-year and 1,000-year MRP Earthquake Events

Occupancy Class	Total Number of Buildings in Occupancy	Severity of Expected Damage	100-Year MRP		500-Year MRP		2,500-Year MRP	
			Building Count	Percent of Buildings	Building Count	Percent of Buildings	Building Count	Percent of Buildings
Residential Exposure (Single and Multi-Family Dwellings)	150,460	None	150,446	100.0%	147,169	97.8%	125,839	83.6%
		Minor	11	0.0%	2,616	1.7%	18,405	12.2%
		Moderate	3	0.0%	593	0.4%	5,223	3.5%
		Severe	0	0.0%	76	0.1%	860	0.6%
		Complete Destruction	0	0.0%	7	0.0%	133	0.1%
Commercial Buildings	11,838	None	11,834	100.0%	11,252	95.1%	8,742	73.8%
		Minor	3	0.0%	421	3.6%	1,735	14.7%
		Moderate	1	0.0%	144	1.2%	1,075	9.1%
		Severe	0	0.0%	19	0.2%	255	2.2%
		Complete Destruction	0	0.0%	1	0.0%	31	0.3%
Industrial Buildings	3,737	None	3,736	100.0%	3,566	95.4%	2,791	74.7%
		Minor	1	0.0%	123	3.3%	512	13.7%
		Moderate	0	0.0%	43	1.1%	345	9.2%
		Severe	0	0.0%	5	0.1%	80	2.1%
		Complete Destruction	0	0.0%	0	0.0%	9	0.2%
Government, Religion, Agricultural, and Education Buildings	2,358	None	2,357	100.0%	2,250	95.4%	1,777	75.4%
		Minor	0	0.0%	78	3.3%	339	14.4%
		Moderate	0	0.0%	26	1.1%	192	8.1%
		Severe	0	0.0%	3	0.1%	44	1.9%
		Complete Destruction	0	0.0%	0	0.0%	6	0.2%

Source: HAZUS-MH v4.2

Table 4.3.4-12. Estimated Building Damages (Structure and Contents) from the 100-, 500- and 2,500-Year MRP Earthquake Events

Municipality	Estimated Damages to Buildings			
	Total Replacement Cost Value	100-Year MRP	500-Year MRP	2,500-Year MRP
Town of Boonton	$1,832,625,537	$0	$1,761,003	$29,253,086
Township of Boonton	$1,388,780,135	$0	$1,026,565	$17,563,214
Borough of Butler	$1,489,686,071	$0	$1,359,460	$22,889,978
Chatham Borough	$1,673,960,469	$0	$3,090,109	$46,189,574
Chatham Township	$2,300,237,613	$0	$4,309,177	$60,352,650
Chester Borough	$694,668,411	$0	$414,086	$6,720,355
Chester Township	$2,782,631,274	$0	$1,274,254	$21,518,759

Municipality	Estimated Damages to Buildings			
	Total Replacement Cost Value	100-Year MRP	500-Year MRP	2,500-Year MRP
Denville Township	$4,397,845,504	$0	$4,164,208	$68,617,081
Town of Dover	$2,640,787,978	$0	$2,950,418	$46,582,037
Township of East Hanover	$4,740,072,304	$0	$7,083,416	$98,458,306
Borough of Florham Park	$3,768,421,982	$0	$7,077,018	$100,607,060
Township of Hanover	$5,609,469,027	$0	$6,775,702	$97,077,392
Township of Harding	$1,808,255,972	$0	$1,567,524	$23,298,776
Township of Jefferson	$4,421,074,958	$0	$2,043,557	$38,151,807
Borough of Kinnelon	$2,858,766,250	$0	$918,855	$18,399,729
Borough of Lincoln Park	$2,125,371,898	$74,658	$5,777,022	$73,538,879
Township of Long Hill	$2,253,461,094	$0	$3,818,732	$53,448,341
Borough of Madison	$3,066,320,935	$0	$5,957,889	$86,389,404
Borough of Mendham	$1,479,178,043	$0	$947,201	$15,901,835
Township of Mendham	$2,099,041,883	$0	$925,176	$16,131,699
Township of Mine Hill	$766,971,485	$0	$511,788	$8,624,841
Township of Montville	$6,714,034,036	$0	$6,013,318	$95,425,354
Township of Morris	$6,091,077,654	$0	$7,130,718	$110,648,291
Borough of Morris Plains	$1,738,775,034	$0	$1,294,737	$21,447,253
Town of Morristown	$2,945,511,672	$0	$6,015,445	$89,328,667
Borough of Mount Arlington	$1,065,424,961	$0	$750,693	$12,435,684
Township of Mount Olive	$7,181,400,421	$0	$3,859,643	$62,571,046
Borough of Mountain Lakes	$1,183,405,498	$0	$990,386	$16,628,601
Netcong Borough	$695,081,980	$0	$500,140	$7,984,313
Township of Parsippany-Troy Hills	$11,747,551,200	$0	$17,108,913	$253,958,676
Township of Pequannock	$3,911,039,941	$211,738	$11,842,209	$143,771,773
Township of Randolph	$6,709,486,516	$0	$4,629,395	$77,772,883
Borough of Riverdale	$1,165,082,666	$0	$853,086	$14,669,962
Borough of Rockaway	$1,612,749,951	$0	$1,954,125	$30,100,135
Township of Rockaway	$7,225,058,745	$0	$3,631,481	$64,064,710
Township of Roxbury	$5,918,169,131	$0	$4,972,625	$77,199,587
Borough of Victory Gardens	$163,035,099	$0	$161,556	$2,670,160
Township of Washington	$5,265,032,309	$0	$2,401,288	$40,694,306
Borough of Wharton	$1,539,335,501	$0	$2,339,405	$35,732,263
Morris County (Total)	**$127,068,881,137**	**$286,396**	**$140,202,322**	**$2,106,818,468**

*Source: HAZUS-MH v4.2 *Total Damages is sum of damages for all occupancy classes (residential, commercial, industrial, agricultural, educational, religious and government).*

The Borough of Lincoln Park and the Township of Pequannock are the only two municipalities that are estimated to experience building damages as a result of the 100-year MRP event ($64,469 and $169,503, respectively).

HAZUS-MH estimates nearly $116 million in damages to buildings in the County as a result of a 500-year earthquake event. This includes structural damage, non-structural damage and loss of contents, representing less than 1% of the total replacement value for general building stock in Morris County. For a 2,500-year MRP earthquake event, HAZUS-MH estimates nearly $1.76 billion in building damages, approximately 1.4% of the total general building stock replacement value. Residential buildings account for $109,853 (47.0%), $44,578,112 (38.4%), and $656,105,959 (37.1%) of the total losses for the 100-, 500- and 2,500-year MRP events, respectively and commercial losses account for $47,938 (20.5%), $16,974,421 (14.6%), and $211,824,105 (12.0%) of the total losses for the 100-, 500- and 2,500-year MRP events.

Historically, Building Officials Code Administration (BOCA) regulations in the northeast states were developed to address local concerns, including heavy snow loads and wind. Seismic requirements for design criteria are not as stringent as those of the west coast of the United States, which rely on the more seismically focused Uniform Building Code. As such, a smaller earthquake in the northeast can cause more structural damage than if it would occur in the west; especially for older and aging buildings.

Impact on Critical Facilities

All critical facilities in Morris County are considered exposed to the earthquake hazard. Refer to subsection "Critical Facilities" in Section 3 (County Profile) of this HMP for a complete inventory of critical facilities in Morris County.

Two sets of exposure analyses were conducted for critical facilities located in Morris County. The first analysis reviewed the number of County critical facilities and determined which facilities are constructed on NEHRP classes D or E soils and liquefaction class 4 soils. The analysis shows that 13 County critical facilities are located on NEHRP soils class D or E, and 5 are located on liquefaction class 4 soils.

Furthermore, 1,137 additional critical facilities are exposed countywide. The Borough of Madison has the greatest number of critical facilities located on NEHRP classes D or E soils (47 facilities), followed by the Township of Hanover with 45 facilities. Of the 47 facilities in the Borough of Madison, 27 were identified as community lifelines, and of the 45 facilities in the Township of Hanover 14 were identified as community lifeline. The Township of Pequannock has the greatest number of critical facilities located on liquefaction class 4 soils (11 facilities). Two of these facilities in the Town of Pequannock are considered community lifelines. Figure 4.3.4-9 and Figure 4.3.4-10 show the number of critical facilities by municipality that are exposed to NEHRP D and E soils and liquefaction class 4 soils, respectively.

Figure 4.3.4-9. Critical Facilities Exposed to NEHRP Soil Type D/E in Morris County Municipalities

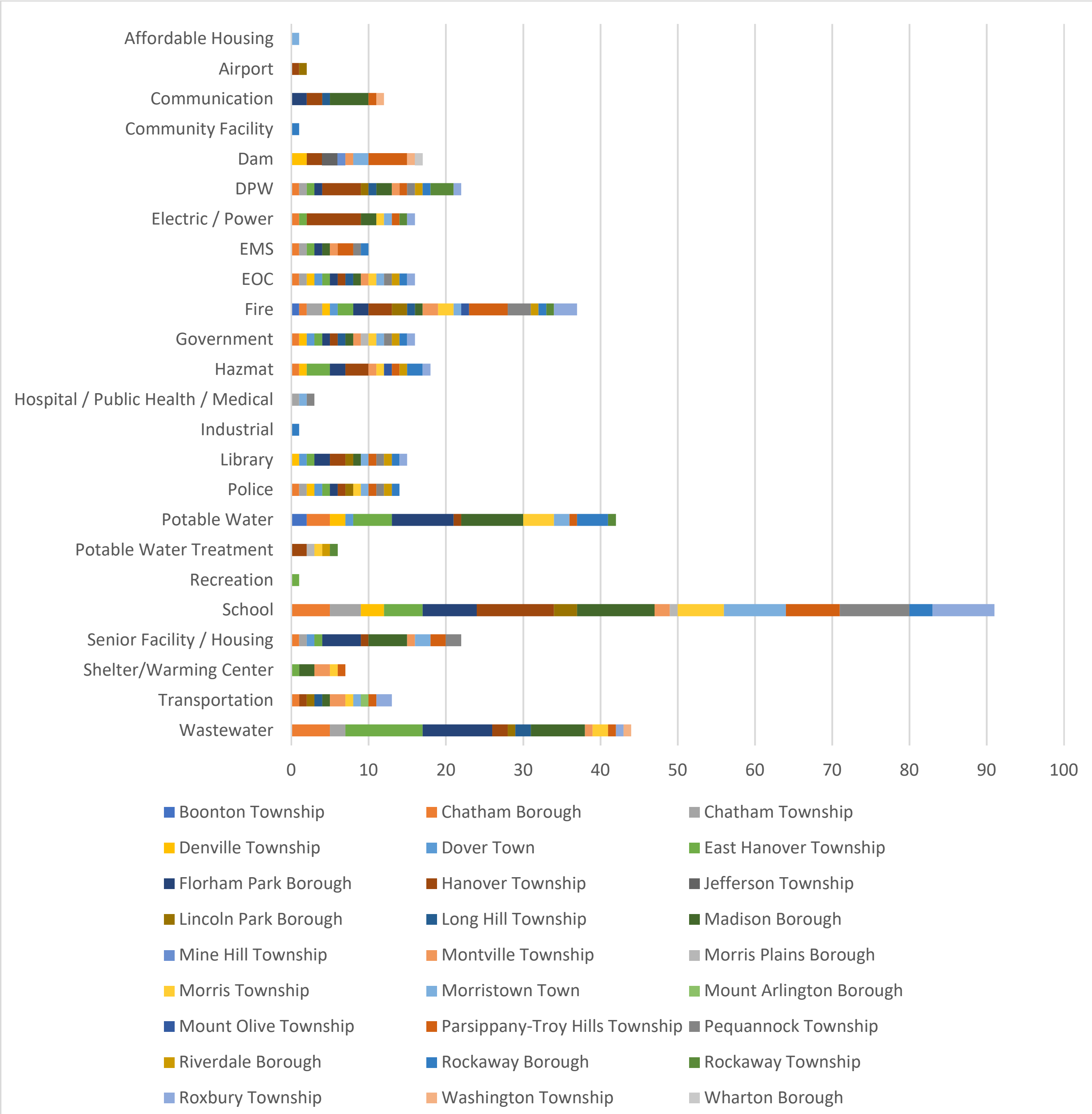
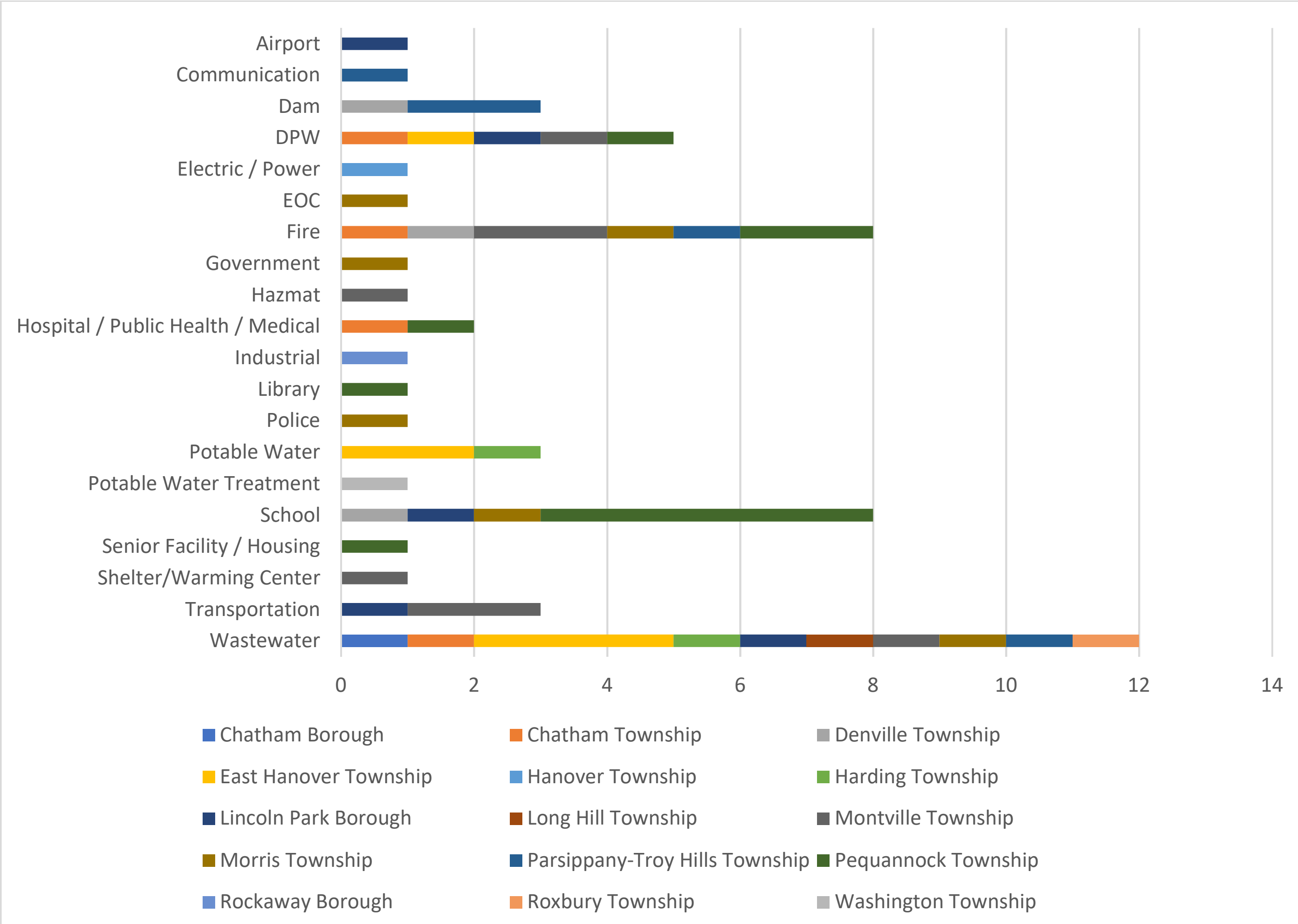


Figure 4.3.4-10. Critical Facilities Exposed to Liquefaction Class 4 Soils in Morris County Municipalities



The HAZUS-MH earthquake model was used to assign a probability of each damage state category defined in Table 4.3.4.-10, to every critical facility in the planning area, which was then averaged across the facility category. In addition, HAZUS-MH estimates the time to restore critical facilities to fully functional use. Results are presented as a probability of being functional at specified time increments (days after the event). For example, HAZUS-MH might estimate that a facility has 5 percent chance of being fully functional at day 3, and a 95-percent chance of being fully functional at day 90. Results of estimated impacts to critical facilities for the 100-, 500- and 2,500-year events in HAZUS-MH are shown in Table 4.3.4-13 through 4.3.4-15.

Table 4.3.4-13. Estimated Damage and Loss of Functionality for Critical Facilities for the 100-Year MRP Earthquake Event

Type	Percent Probability of Sustaining Damage Across All Categories					Percent Functionality			
	None	Slight	Moderate	Extensive	Complete	Day 1	Day 7	Day 30	Day 90
Essential Facilities									
Medical	99.3%	0.5%	0.1%	0.0%	0.0%	99.2%	99.7%	99.9%	99.9%
Police	96.5% - 99.2%	0% - 2.5%	0.2%	0.0%	0.0%	96.5% - 99.8%	99.7%	99.9%	99.9%
Fire	96.5% - 99.9%	0.6%	0.2%	0.0%	0.0%	96.5% - 99.9%	99.7%	99.9%	99.9%
EOC	99.9%	0.1%	0.0%	0.0%	0.0%	99.8%	99.9%	99.9%	99.9%
School	96.5% - 99.2%	0% - 2.5%	0.2%	0.0%	0.0%	96.5% - 99.9%	99.7%	99.9%	99.9%
Utilities									
Potable	100.0%	0.0%	0.0%	0.0%	0.0%	99.9%	99.9%	99.9%	99.9%
Wastewater	100.0%	0.0%	0.0%	0.0%	0.0%	99.9%	99.9%	99.9%	99.9%
Electric	100.0%	0.0%	0.0%	0.0%	0.0%	99.9%	99.9%	99.9%	99.9%
Communication	100.0%	0.0%	0.0%	0.0%	0.0%	99.9%	99.9%	99.9%	99.9%

Table 4.3.4-14. Estimated Damage and Loss of Functionality for Critical Facilities for the 500-Year MRP Earthquake Event

Type	Percent Probability of Sustaining Damage					Percent Functionality			
	None	Slight	Moderate	Extensive	Complete	Day 1	Day 7	Day 30	Day 90
Essential Facilities									
Medical	87% - 99.3%	0.5% - 8.7%	0% - 3.7%	0.4%	0.0%	87% - 99.2%	95.3% - 99.7%	99.5%	99.7%
Police	77.8% - 96.8%	2.4% - 13.1%	0% - 7.2%	0% - 1.6%	0.0%	77.7% - 96.8%	90.5% - 99.1%	99.5%	99.7%
Fire	77.8% - 98.8%	1% - 13.1%	0% - 7.2%	0.4%	0.0%	77% - 98.7%	90.5% - 99.6%	98.1% - 99.9%	99.7%
EOC	96.3%	2.8%	0.9%	0.1%	0.0%	96.2%	98.9%	99.8%	99.9%
School	77.7% - 98.7%	1% - 13.1%	0% - 7.2%	0% - 1.6%	0.0%	77.7% - 98.7%	90.5% - 99.6%	99.5%	99.7%
Utilities									
Potable	89% - 94.4%	5.2% - 10%	0.6%	0.0%	0.0%	95.5% - 97.8%	99.9%	99.9%	99.9%
Wastewater	68.6% - 96.5%	3.3% - 26.4%	0% - 4.8%	0.0%	0.0%	77.4% - 97.5%	99.8%	99.9%	99.9%
Electric	89.1%	10.1%	0.8%	0.0%	0.0%	94.1%	99.9%	99.9%	99.9%
Communication	88.6% - 99.3%	1% - 10.5%	0.5%	0.0%	0.0%	99.6%	99.9%	99.9%	99.9%

Table 4.3.4-15. Estimated Damage and Loss of Functionality for Critical Facilities for the 2,500-Year MRP Earthquake Event

Name	Percent Probability of Sustaining Damage					Percent Functionality			
	None	Slight	Moderate	Extensive	Complete	Day 1	Day 7	Day 30	Day 90
Essential Facilities									
Medical	45% - 90.9%	5.8% - 25.1%	3% - 21%	0% - 7.2%	0.7%	44.9% - 90.8%	69.5% - 96.4%	91.1% - 99.6%	94.7% - 99.8%
Police	33.5% - 79.2%	13% - 23.8%	6.4% - 25.4%	1.2% - 12.6%	0% - 4.7%	33.4% - 79.2%	56.6% - 91.9%	82.6% - 98.6%	88.9% - 99.2%
Fire	33.5% - 90.8%	6.4% - 23.8%	2.4% - 25.4%	0% - 12.6%	0% - 4.7%	33.4% - 90.7%	56.6% - 97%	82.6% - 99.6%	88.9% - 99.7%
EOC	76.3%	14.5%	7.5%	1.5%	0.2%	76.2%	90.4%	98.2%	99%
School	33.5% - 90.6%	6.5% - 25.1%	2.5% - 25.4%	0% - 12.6%	0% - 4.7%	33.4% - 90.6%	56.6% - 96.9%	82.6% - 99.6%	88.9% - 99.7%
Utilities									
Potable	20.7% - 30.7%	43.1%	22.2% - 30%	3.3% - 6.2%	0.5%	55.3% - 63.7%	94.5% - 97.1%	96.2% - 98%	99.5%
Wastewater	7.5% - 41.2%	31.2% - 43.6%	15.7% - 42%	1.7% - 16.6%	0% - 2.7%	23.6% - 56.2%	77.5% - 96.8%	83.3% - 98.4%	96.2% - 99.7%
Electric	20.8%	42.6%	29.9%	6.1%	0.6%	45.0%	96.2%	99.6%	99.9%
Communication	20% - 60.8%	31.5% - 43.5%	7.1% - 30.6%	0% - 6.4%	0.4%	78.7% - 95.8%	96.2% - 99.7%	99.7%	99.9%

Impact on Economy

Earthquakes also impact the economy, including loss of business function, damage to inventory (buildings, transportation, and utility systems), relocation costs, wage loss, and rental loss due to repair and replacement of buildings. HAZUS-MH estimates building-related economic losses, including income losses (wage, rental, relocation, and capital-related losses) and capital stock losses (structural, non-structural, content, and inventory losses). Economic losses estimated by HAZUS-MH are summarized in Table 4.3.4-.

Table 4.3.4-16. Building-Related Economic Losses from the 100-, 500- and 2,500-Year MRP Earthquake Events

Level of Severity	Mean Return Period		
	100-year	500-year	2,500-year
Income Losses			
Wage	$27,700	$7,093,200	$66,761,500
Capital Related	$19,100	$5,364,200	$51,071,100
Rental	$22,700	$6,701,400	$58,701,900

Level of Severity	Mean Return Period		
	100-year	500-year	2,500-year
Relocation	$43,800	$11,991,600	$114,616,100
Subtotal	**$113,300**	**$31,150,400**	**$291,150,600**
Capital Stock Losses			
Structural	$110,100	$30,118,500	$277,298,100
Non-Structural	$153,200	$80,456,000	$1,218,381,400
Content	$22,300	$29,627,200	$611,138,500
Inventory	$600	$729,200	$12,242,000
Subtotal	**$286,200**	**$140,930,900**	**$2,119,060,000**

Source: HAZUS-MH v4.2

Although the HAZUS-MH analysis did not compute estimates of damage to roadway segments and railroad tracks, assumedly these features would undergo damage due to ground failure - resulting in interruptions of regional transportation and of distribution of materials. Losses to the community that would result from damage to lifelines could exceed costs of repair (FEMA 2012).

Earthquake events can significantly affect road bridges, many of which provide the only access to certain neighborhoods. Because softer soils generally follow floodplain boundaries, bridges that cross watercourses should be considered vulnerable. Another key factor in degree of vulnerability is age of facilities and infrastructure, which correlates with standards in place at times of construction of these. HAZUS-MH estimated economic impacts to Morris County for 15-years after the earthquake event, including impacts to transportation infrastructure.

HAZUS-MH estimates volume of debris that may be generated as a result of an earthquake event to enable the study region to prepare for and rapidly and efficiently manage debris removal and disposal. Debris estimates were divided into two categories: (1) reinforced concrete and steel that require special equipment to break up before transport can occur, and (2) brick, wood, and other debris that can be loaded directly onto trucks by use of bulldozers (HAZUS-MH Earthquake User's Manual).

HAZUS-MH estimates the generation of 188 tons of total debris during the 100-year MRP event, 44,927 tons of debris during the 500-year MRP event and 365,837 tons of debris during the 2,500-year MRP event. Table 4.3.4- below lists estimated debris generated by the 100-, 500- and 2,500-year MRP events.

Table 4.3.4-17. Estimated Debris Generated by the 100-, 500- and 2,500-year MRP Earthquake Events

Municipality	100-Year		500-Year		2,500-Year	
	Brick/ Wood (tons)	Concrete/ Steel (tons)	Brick/Wood (tons)	Concrete/Steel (tons)	Brick/Wood (tons)	Concrete/Steel (tons)
Town of Boonton	0	0	554	192	3,545	1,968
Township of Boonton	0	0	269	90	1,780	942
Borough of Butler	0	0	411	130	2,620	1,328
Chatham Borough	0	0	660	228	4,354	2,916
Chatham Township	0	0	793	260	5,152	3,436
Chester Borough	0	0	132	48	859	493
Chester Township	0	0	298	78	1,946	801

Municipality	100-Year		500-Year		2,500-Year	
	Brick/ Wood (tons)	Concrete/ Steel (tons)	Brick/Wood (tons)	Concrete/Steel (tons)	Brick/Wood (tons)	Concrete/Steel (tons)
Denville Township	0	0	1,069	366	7,044	3,972
Town of Dover	0	0	914	328	5,967	3,703
Township of East Hanover	0	0	1,429	617	9,689	8,591
Borough of Florham Park	0	0	1,405	618	9,514	8,672
Township of Hanover	0	0	1,514	617	9,976	8,027
Township of Harding	0	0	301	92	1,919	1,057
Township of Jefferson	0	0	621	147	4,251	1,588
Borough of Kinnelon	0	0	280	70	1,839	702
Borough of Lincoln Park	38	9	1,114	450	7,438	6,539
Township of Long Hill	0	0	695	237	4,547	3,082
Borough of Madison	0	0	1,308	486	8,643	6,533
Borough of Mendham	0	0	252	77	1,638	780
Township of Mendham	0	0	210	50	1,378	508
Township of Mine Hill	0	0	134	35	874	357
Township of Montville	0	0	1,394	504	9,459	6,309
Township of Morris	0	0	1,571	546	10,393	6,769
Borough of Morris Plains	0	0	327	105	2,133	1,127
Town of Morristown	0	0	1,710	650	11,131	8,043
Borough of Mount Arlington	0	0	230	62	1,484	645
Township of Mount Olive	0	0	1,169	346	7,497	3,689
Borough of Mountain Lakes	0	0	239	75	1,525	763
Netcong Borough	0	0	175	56	1,125	580
Township of Parsippany-Troy Hills	0	0	4,187	1,540	27,496	19,264
Township of Pequannock	111	30	2,076	958	14,382	14,738
Township of Randolph	0	0	1,194	354	7,809	3,706
Borough of Riverdale	0	0	245	90	1,708	1,099
Borough of Rockaway	0	0	545	202	3,566	2,351
Township of Rockaway	0	0	985	279	6,566	2,935
Township of Roxbury	0	0	1,223	379	7,804	4,292
Borough of Victory Gardens	0	0	53	15	349	166
Township of Washington	0	0	656	175	4,246	1,807
Borough of Wharton	0	0	754	279	4,834	3,079
Morris County (Total)	**149**	**39**	**33,096**	**11,831**	**218,481**	**147,356**

Source: HAZUS-MH 4.2

Future Changes that May Impact Vulnerability

Understanding future changes that effect vulnerability in the County can assist in planning for future development and ensure establishment of appropriate mitigation, planning, and preparedness measures. The County considered the following factors to examine potential conditions that may 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

New development located in areas with softer NEHRP soil classes and high liquefaction susceptibility may be more vulnerable to the earthquake hazard. Information regarding new development, both recent and expected development, within Morris County was received during the planning process. Any development location that could be located using an address or Parcel ID were geocoded and overlaid with the NEHRP Class D and E soils spatial layer to determine vulnerability. In total, there are 24 new development sites located on NEHRP Class D and E soils. Current building codes require seismic provisions that should render new construction less vulnerable to seismic impacts than older, existing construction that may have been built to lower construction standards.

Specific areas of development are indicated in tabular form in the jurisdictional annexes in Volume II, Section 9 (Jurisdictional Annexes). Please refer to Figure 4.3.4-9 for the potential new development in the County and the NEHRP soil class and high liquefaction susceptibility areas.

Projected Changes in Population

The County has and is projected to continue experiencing population growth. As noted above, vulnerability greatly depends upon the location residents reside. The HAZUS-MH earthquake model indicates the Borough of Lincoln Park and the Township of Pequannock are most vulnerable to greater ground shaking and building impacts as a result of more frequent events such as the 100-year MRP event. Populations moving to Morris County and living in older buildings may be vulnerable to this hazard. As noted earlier, if moving into new construction, current building codes require seismic provisions that should render new construction less vulnerable to seismic impacts.

Climate Change

Because the impacts of climate change on the earthquakes are not well understood, a change in the County's vulnerability is difficult to determine. However, climate change has the potential to magnify secondary impacts of earthquakes. As a result of the climate change projections discussed above, the County's assets located on areas of saturated soils and on or at the base of steep slopes, are at a higher risk of landslides/mudslides because of seismic activity. Refer to Section 4.3.7 (Geologic Hazards) for additional discussion of the geological hazard. Failure of a dam storing increased volumes of water would result in flooding of the county's assets located in the inundation area.

Change of Vulnerability Since 2015 HMP

Overall, the entire County continues to be vulnerable to earthquakes. Several differences exist between the 2015 plan and this update. For the 2020 plan update, an updated general building stock based upon replacement cost value from MODIV tax assessment data and 2019 RS Means, and an updated critical facility inventory were used to assess the County's risk to the hazard areas. In addition, the 2017 ACS population estimates were used and estimated at a structural level in place of the 2010 U.S. Census blocks. Updated hazard areas were used as well; since the 2015 HMP, the NJGWS has released updated NEHRP and liquefaction susceptible soils data. The updated data was used for the exposure analysis and to update HAZUS-MH's default earthquake data. The largest increase in vulnerability reported is attributed to the availability of updated data which expands the delineated liquefaction Class 4 soils throughout the western and eastern borders of the County along the Passaic River. The updated vulnerability assessment provides a more current exposure analysis for the County.

Figure 4.3.4-11. Potential New Development in Morris County and NEHRP Soil Types