5.4.3 EARTHQUAKE

2016 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 earthquake hazard is discussed. The earthquake hazard is now located in Section 5 of the plan update.
- New and updated figures from federal and state agencies are incorporated. The 2010 U.S. Census data has been incorporated, where appropriate.
- Previous occurrences were updated with events that occurred between 2008 and 2015.
- A vulnerability assessment was conducted for the earthquake hazard using FEMA's HAZUS-MH earthquake model, and it now directly follows the hazard profile.

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 Sussex County.

5.4.3.1 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 percent 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).

According to the U.S. Geological Society (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:

- *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. Liquefaction susceptibility is determined by the geological history, depositional setting, and topographic position of the soil (Stanford 2003). 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.
- *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 2012a).

Location

Earthquakes are most likely to occur in the northern parts of New Jersey, which includes Sussex 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 5.4.3-1, 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 5.4.3-1. 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 2013

New Jersey Department of Transportation (NJDOT) compiled a report on seismic design consideration for bridges in New Jersey, dated March 2012. In the report, NJDOT classifies the seismic nature of soils according to the American Association of State Highway and Transportation Officials (AASHTO) Guide Specifications for Bridge Seismic Design (SGS). For the purpose of seismic analysis and design, sites can be classified into Soil Classes A, B, C, D, E and F, ranging from hard rock to soft soil and special soils (similar to NEHRP soil classifications); refer to Table 5.4.3-2.

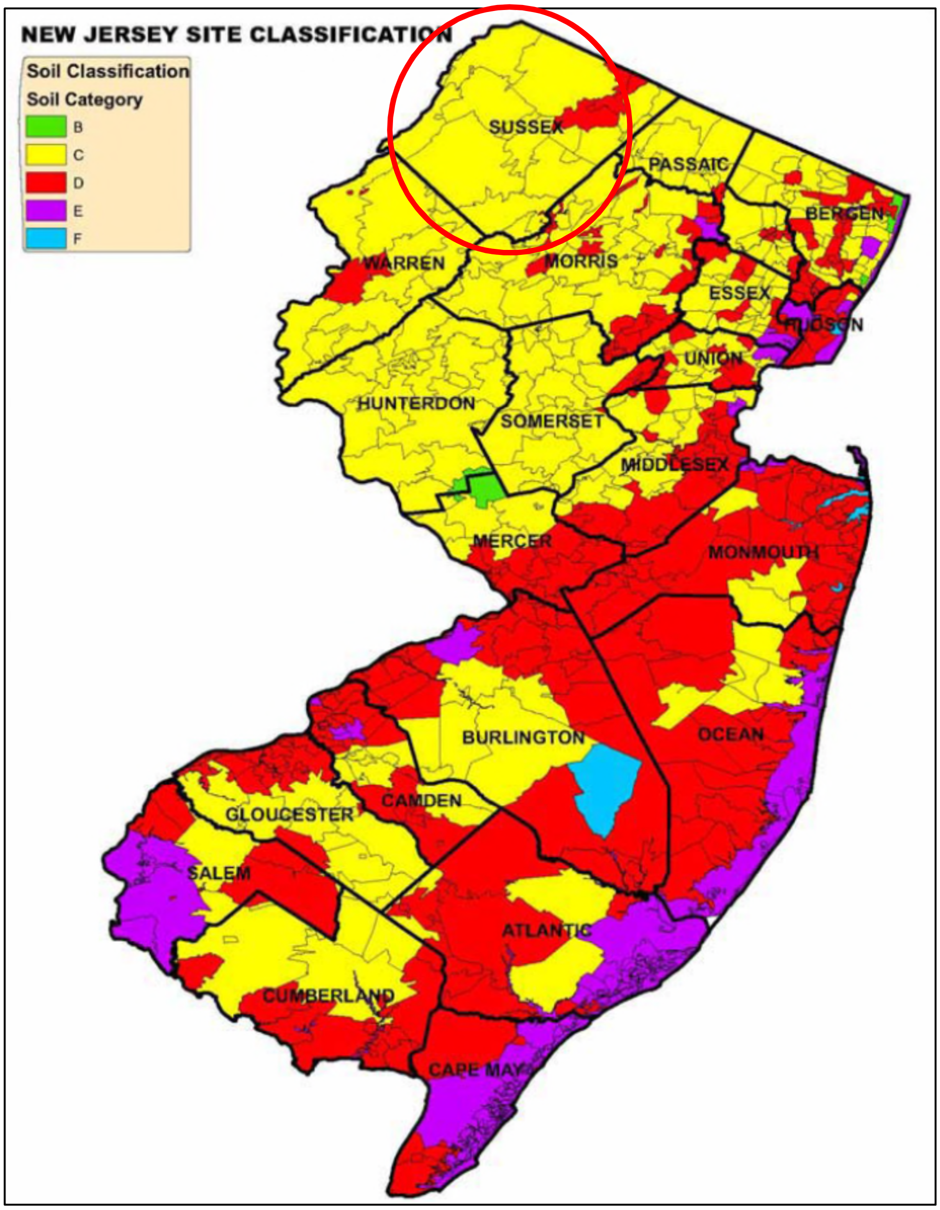
Table 5.4.3-2. NJDOT Soil Classifications

Soil Classification	Description
A-B	Rock sites
C	Very dense soil
D	Dense soil
E	Soft soil
F	Special soil requiring site-specific analysis

Source: NJDOT 2012

NJDOT also developed a Geotechnical Database Management System, which contains soil boring data across New Jersey. The soil boring logs were then used to classify soil sites. Through this analysis, NJDOT developed a map of soil site classes according to ZIP codes in New Jersey where each ZIP code was assigned a class based on its predominant soil condition. In Sussex County, most ZIP codes were rated as a Category C, and a few were rated as Category D. Figure 5.4.3-1 provides a visual confirmation of this information.

Figure 5.4.3-1. ZIP Code-Based Soil Site Class Map



Source: NJDOT 2012
Note: Sussex County is indicated by the red circle.
Soil Classes A and B are rock sites
Soil Class C is very dense soil
Soil Class D is dense soil
Soil Class E is soft soil
Soil Class F is special soil requiring site-specific analysis

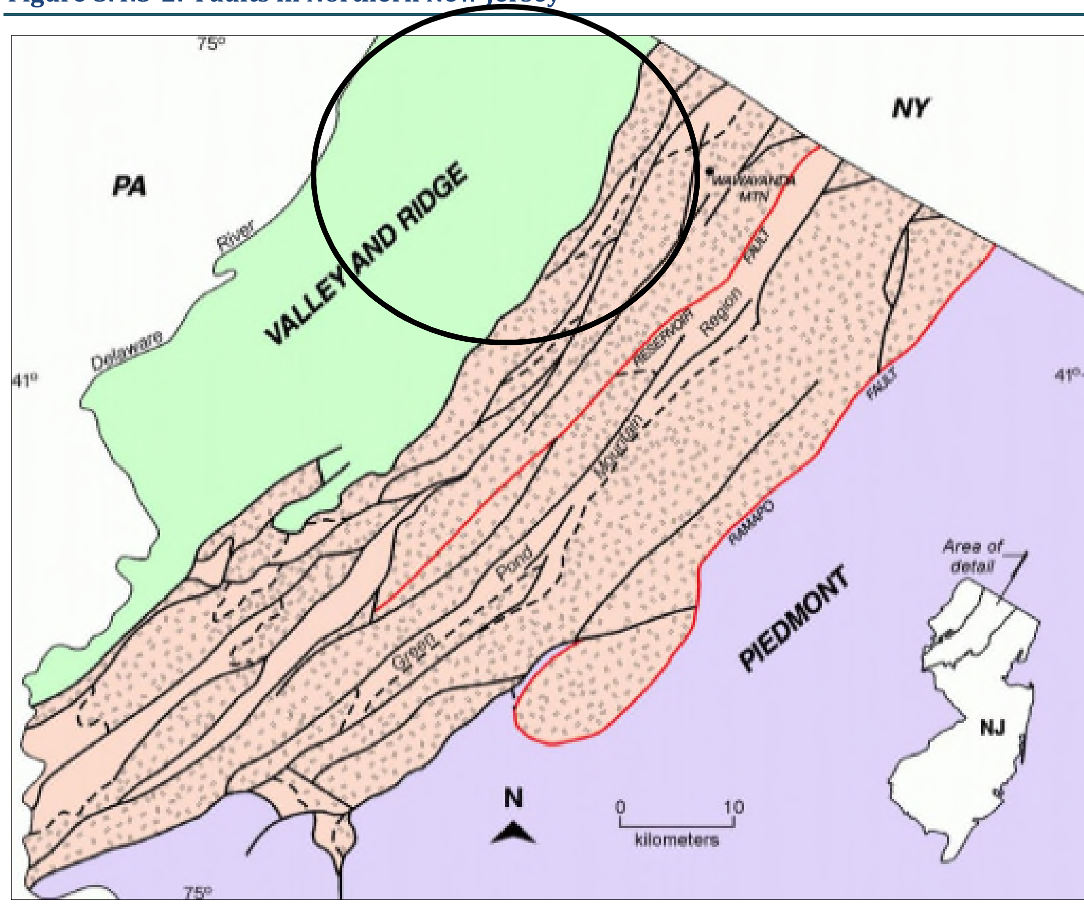
Liquefaction has been responsible for tremendous amounts of damage in historical earthquakes around the world. Shaking behavior and liquefaction susceptibility of soils are determined by their grain size, thickness, compaction, and degree of saturation. These properties, in turn, are determined by the geologic origin of the soils and their topographic position. Although this data has been calculated for parts of New Jersey, NJGWS has not yet completed this for Sussex County, New Jersey. Based on the Standard Penetration Test (SPT) data from the neighboring Morris County, which contains means, ranges, and standard deviations similar to Hudson, Essex, Union, and Bergen County data, it is likely that Sussex County soil properties are comparative. Although liquefaction susceptibility will vary throughout the county, the majority of the county most likely has a low to very low susceptibility, with a few small areas having moderate or high susceptibility. Once test boring samples are conducted and calculated for Sussex County, more accurate data regarding liquefaction vulnerability in specific areas will be able to be determined.

Liquefaction occurs in saturated soils and when it occurs, the strength of the soil decreases and the ability of a soil deposit to support foundations for buildings and bridges is reduced. Shaking from earthquakes often triggers an increase in water pressure which can trigger landslides and the collapse of dams. For information regarding dam failures, refer to Section 5.4.1 (Dam Failure) and for landslides refer to Section 5.4.6 (Geologic). On the other side, earthquakes contribute to landslide hazards. Earthquakes create stresses that make weak slopes fail. Earthquakes of magnitude 4.0 or greater have been known to trigger landslides.

Fractures or fracture zones along with rocks on adjacent sides have broken and moved upward, downward, or horizontally are known as faults (Volkert and Witte 2015). Movement can take place at faults and cause an earthquake. Earthquake epicenters in eastern North America and the New Jersey area, however, do not typically occur on known faults. The faults in these areas are the result of tectonic activity from over 200 million years ago. Many faults can be located in New Jersey and in parts of Sussex County. One of the most well-known faults in the state is the Ramapo Fault, which separates the Piedmont and Highlands Physiographic Provinces. As indicated in Figure 5.4.3-4, Sussex County might feel the effects of an earthquake along the Ramapo Fault; however, the fault itself is not located within county borders. The Reservoir Fault, which borders the Green Pond Mountain region, is another major faultline in New Jersey and is closer to county borders than the Ramapo Fault (Volkert and Witte 2015).

The New Jersey Highlands are a physiographic province in northern New Jersey and they span approximately 1,000 square miles of scenic and rugged terrain, which includes portions of Sussex County (specifically, 8 municipalities). Faults are a common feature in the Precambrian rocks of the Highlands. The faults range in width from a few tenths of an inch to hundreds of feet and in length from a few feet to as much as tens of miles. The Ramapo fault forms the boundary between the Highlands and Piedmont Provinces. It is a major structural feature, having a width of at least several hundred feet and stretching for a length of 50 miles from Somerset County northeast into New York State. It is the most seismically active fault in the region. Other faults in the region, including the Reservoir Fault, are also prime locations for earthquakes should they occur in the northern part of the state (Volkert and Witte 2015). Figure 5.4.3-2 illustrates the location of both faults in northern New Jersey and their relation to Sussex County.

Figure 5.4.3-2. Faults in Northern New Jersey



Source: Volkert and Witte 2015

Note (1): This is a simplified geologic map of northern New Jersey showing the location of the Highlands (tan). Solid black lines are faults and red lines mark the Reservoir and Ramapo fault lines. Short-dashed lines mark contacts between older Precambrian rocks and younger Paleozoic rocks.

Note (2): The black circle indicates the approximate location of Sussex County. The northern tip of the county is not visible in the map.

Extent

An earthquake's magnitude and intensity are used to describe the size and severity of the event. Magnitude describes the size at the focus of an earthquake and intensity describes the overall felt severity of shaking during the event. The earthquake's magnitude is a measure of the energy released at the source of the earthquake and is expressed by ratings on the Richter scale and/or the moment magnitude scale. The Richter Scale measures magnitude of earthquakes and has no upper limit; however, it is not used to express damage (USGS 2012c). Table 5.4.3-3 presents the Richter scale magnitudes and corresponding earthquake effects.

Table 5.4.3-3. Richter Magnitude Scale

Richter Magnitude	Earthquake Effects
2.5 or less	Usually not felt, but can be recorded by seismograph
2.5 to 5.4	Often felt, but causes only minor damage
5.5 to 6.0	Slight damage to buildings and other structures
6.1 to 6.9	May cause a lot of damage in very populated areas
7.0 to 7.9	Major earthquake; serious damage
8.0 or greater	Great earthquake; can totally destroy communities near the epicenter

Source: Michigan Tech University Date Unknown

The moment magnitude scale (MMS) is used to describe the size of an earthquake. It is based on the seismic moment and is applicable to all sizes of earthquakes (USGS 2012d). The Richter Scale is not commonly used anymore, as it has been replaced by the MMS which is a more accurate measure of the earthquake size (USGS 2012c). The MMS uses the following classifications of magnitude:

- Great—$M_W \geq 8$
- Major—$M_W = 7.0 - 7.9$
- Strong—$M_W = 6.0 - 6.9$
- Moderate—$M_W = 5.0 - 5.9$
- Light—$M_W = 4.0 - 4.9$
- Minor—$M_W = 3.0 - 3.9$
- Micro—$M_W < 3$

The intensity of an earthquake is based on the observed effects of ground shaking on people, buildings, and natural features, and varies with location. The Modified Mercalli (MMI) scale expresses intensity of an earthquake and describes how strong a shock was felt at a particular location in values. Table 5.4.3-4 summarizes earthquake intensity as expressed by the Modified Mercalli scale. Table 5.4.3-5 displays the MMI scale and its relationship to the areas peak ground acceleration.

Table 5.4.3-4. Modified Mercalli Intensity Scale

Mercalli Intensity	Shaking	Description
I	Not Felt	Not felt except by a very few under especially favorable conditions.
II	Weak	Felt only by a few persons at rest, especially on upper floors of buildings.
III	Weak	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
IV	Light	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Moderate	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Strong	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	Very Strong	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.

Table 5.4.3-4. Modified Mercalli Intensity Scale

Mercalli Intensity	Shaking	Description
VIII	Severe	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX	Violent	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X	Extreme	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.

Source: USGS 2014

Table 5.4.3-5. 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
IX	65-124	Violent	Heavy
X	>124	Extreme	Very Heavy

Source: Freeman et al. (Purdue University) 2004
Note: PGA Peak Ground Acceleration

Most damage and loss caused by an earthquake is directly or indirectly the result of ground shaking. Modern intensity scales use terms that can be physically measured with seismometers, such as the acceleration, velocity, or displacements (movement) of the ground. The most common physical measure is peak ground acceleration (PGA). PGA is one of the most important measures used to quantify ground motion. PGA is a good index of hazard to buildings because there is a strong correlation between it and the damage a building might experience (NYCEM 2003).

PGA expresses the severity of an earthquake and is a measure of how hard the earth shakes, or accelerates, in a given geographic area. PGA is expressed as a percent acceleration force of gravity (%g). For example, 1.0%g PGA in an earthquake (an extremely strong ground motion) means that objects accelerate sideways at the same rate as if they had been dropped from the ceiling. A 10%g PGA means that the ground acceleration is 10% that of gravity (NJOEM 2011). Damage levels experienced in an earthquake vary with the intensity of ground shaking and with the seismic capacity of structures, as noted in Table 5.4.3-6.

Table 5.4.3-6. 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.

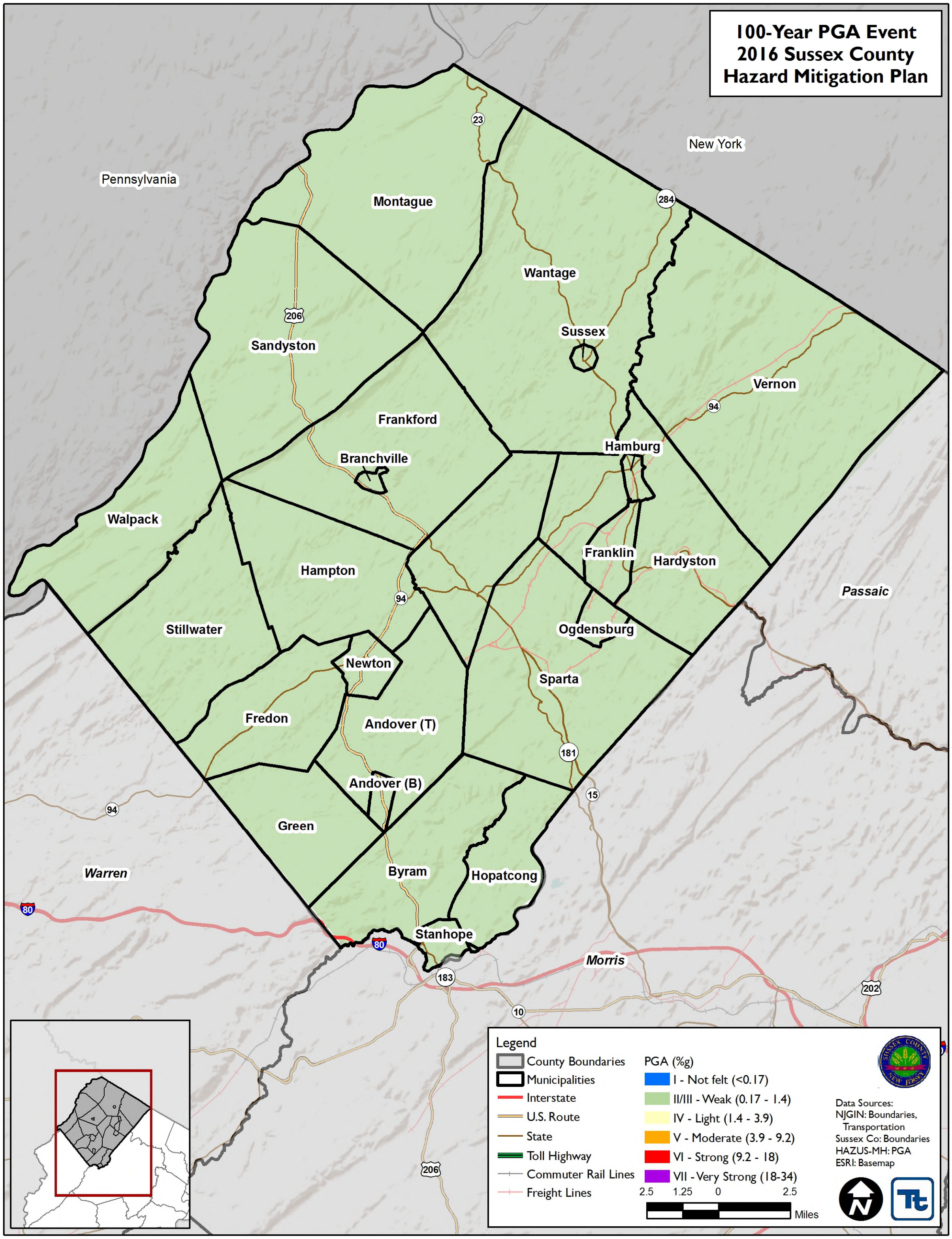
Source: NJOEM 2011
Note: %g Peak Ground Acceleration

National maps of earthquake shaking hazards have been produced since 1948. They provide information essential to creating and updating the seismic design requirements for building codes, insurance rate structures, earthquake loss studies, retrofit priorities and land use planning used in the U.S. Scientists frequently revise these maps to reflect new information and knowledge. Buildings, bridges, highways and utilities built to meet modern seismic design requirements are typically able to withstand earthquakes better, with less damages and disruption. After thorough review of the studies, professional organizations of engineers update the seismic-risk maps and seismic design requirements contained in building codes (Brown et al., 2001).

The USGS updated the National Seismic Hazard Maps in 2014, which superseded the 2008 maps. New seismic, geologic, and geodetic information on earthquake rates and associated ground shaking were incorporated into these revised maps. The 2014 map represents the best available data as determined by the USGS. According to the data, Sussex County has a PGA between 3%g and 5%g (USGS 2014). The 2014 PGA map can be found at http://earthquake.usgs.gov/hazards/products/conterminous/2014/2014pga10pct.pdf

A probabilistic assessment was conducted for the 100-, 500- and 2,500-year mean return periods (MRP) in HAZUS-MH 3.0 to analyze the earthquake hazard for Sussex County. The HAZUS analysis evaluates the statistical likelihood that a specific event will occur and what consequences will occur. Figure 5.4.3-3 through Figure 5.4.3-5 illustrates the geographic distribution of PGA (*g*) across the county or 100-, 500- and 2,500-year MRP events by Census-tract.

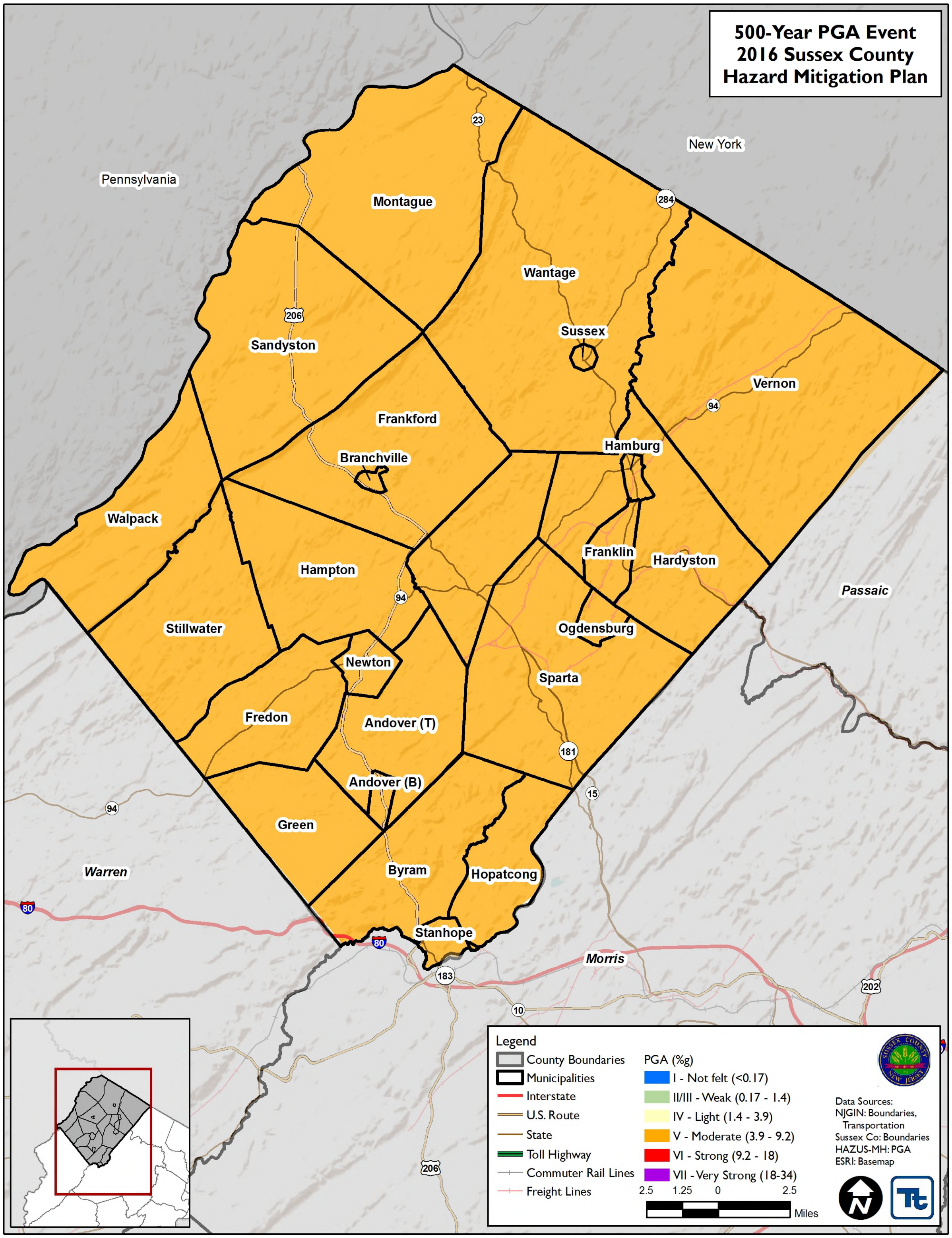
Figure 5.4.3-3. Peak Ground Acceleration 100-Year Mean Return Period for Sussex County



Source: HAZUS-MH 3.0

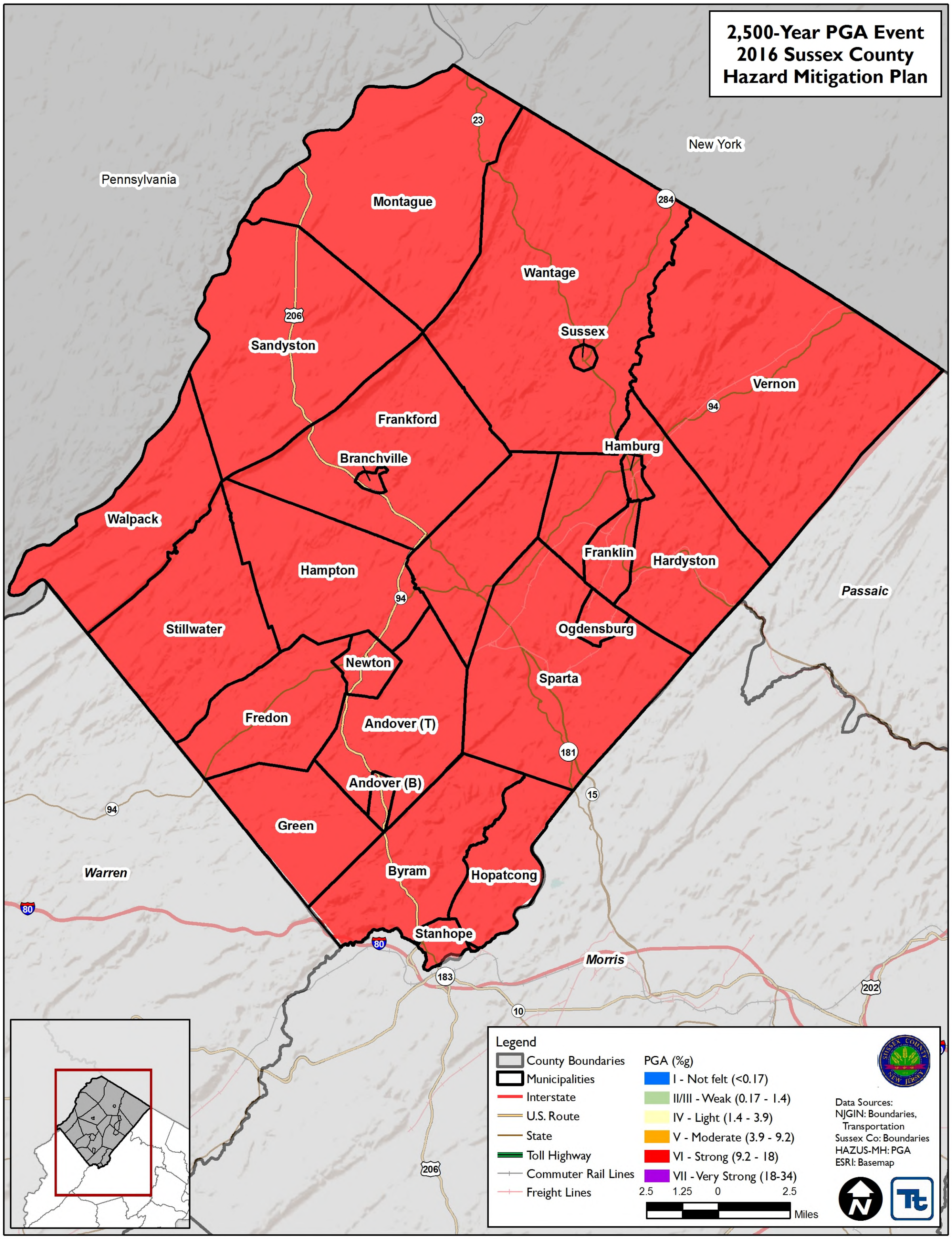
Note: The peak ground acceleration for the 100-year MRP is 1.27 to 1.35 %g.

Figure 5.4.3-4. Peak Ground Acceleration 500-Year Mean Return Period for Sussex County



Source: HAZUS-MH 3.0
Note: The peak ground acceleration for the 500-year MRP is 4.6 to 5.3 %g.

Figure 5.4.3-5. Peak Ground Acceleration 2,500-Year Mean Return Period for Sussex County



Source: HAZUS-MH 3.0
Note: The peak ground acceleration for the 2,500-year MRP is 14.4 to 18.0 %g.

Previous Occurrences and Losses

Historically, Sussex County has not experienced a major earthquake. However, there have been a number of earthquakes of relatively low intensity. The majority of earthquakes that have occurred in New Jersey have occurred along faults in the central and eastern Highlands, with the Ramapo fault being the most seismically active fault in the region (Volkert and Witte 2015); Sussex County can be impacted by earthquakes in the New Jersey Highlands. Small earthquakes may occur several times a year and generally do not cause significant damage. The largest earthquake to impact Sussex County was a magnitude 5.3 earthquake that was epicentered west of New York City. It was felt from New Hampshire to Pennsylvania (Stover and Coffman 1993; NJGWS 2014).

Between 1954 and 2015, FEMA has not issued any major disaster (DR) or emergency (EM) declarations for earthquakes in the State of New Jersey.

Table 5.4.3-7. FEMA DR and EM Declarations Since 2008 for Earthquake Events in Sussex County

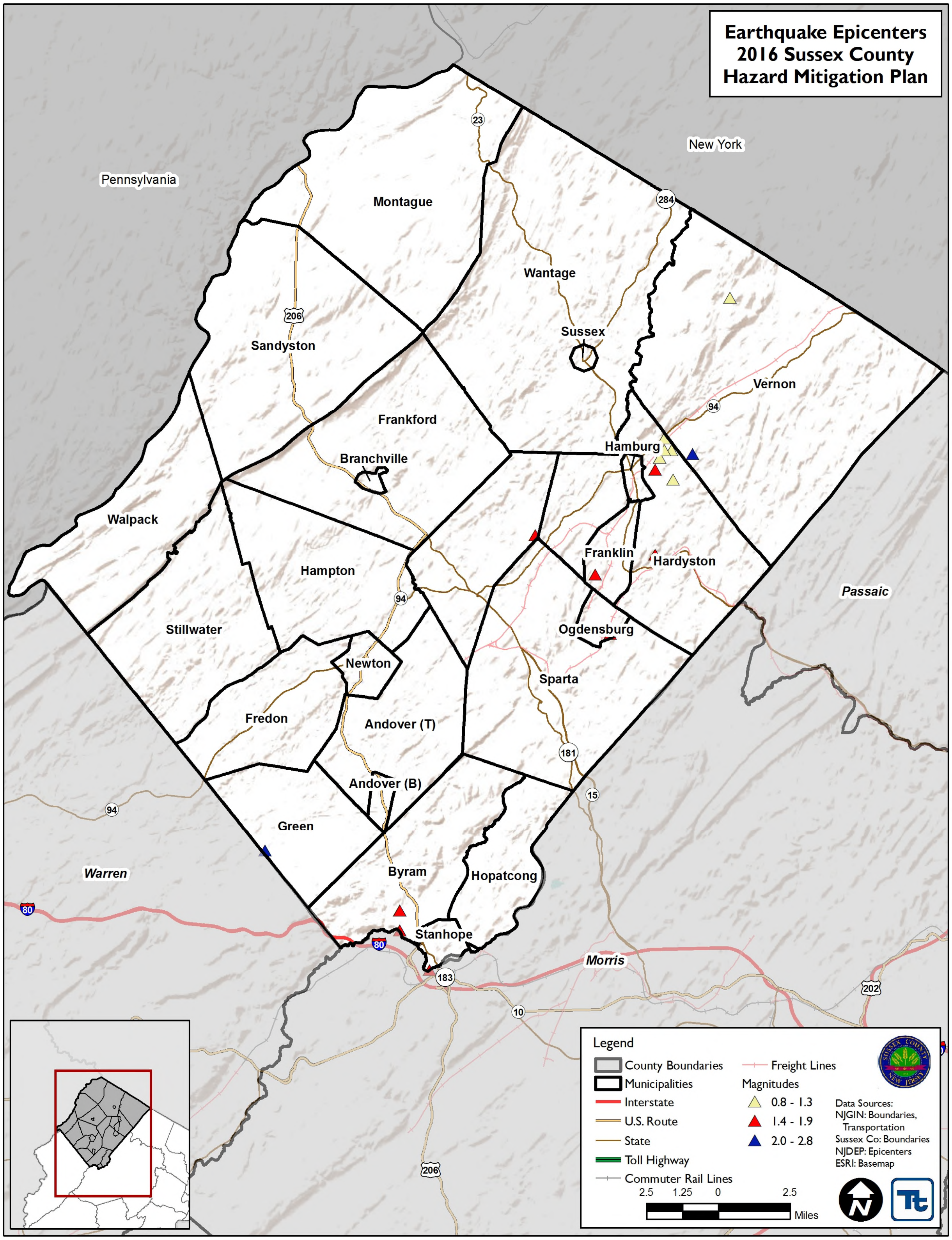
FEMA Declaration Number	Date(s) of Event	Event Type	Location
No DR or EM Declarations were recorded for Sussex County during this time period.			

Source: FEMA 2015

For this 2016 HMP update, known earthquake events that have impacted Sussex County or that have had its epicenter in the county, between 2008 and 2015 are identified in Appendix E. For events that occurred prior to 2008, see the 2011 Sussex County HMP. Please note that not all events that have occurred in Sussex County are included due to the extent of documentation and the fact that 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.

Figure 5.4.3-6 illustrates earthquake events where the epicenters were located in Sussex County. The figure shows that 20 earthquakes had epicenters in the county; all of these earthquakes occurred prior to 2008 and are not included in the table in Appendix E (NJGWS 2015).

Figure 5.4.3-6. Earthquakes with Epicenters in Sussex County, 1783 to 2015



Source: *NJDEP 2014*

Probability of Future Occurrences

Earthquakes cannot be predicted and may occur any time of the day or year. Major earthquakes are infrequent in the State and County and may occur only once every few hundred years or longer, but the consequences of major earthquakes may potentially be very high. Based on the historic record, the future probability of damaging earthquakes impacting Sussex County is low.

According to the New Jersey Geological and Water Survey (NJGWS), since 2008, Sussex County has had zero earthquakes with epicenters in the county. The county has about an 8.5 percent chance of having an earthquake of any magnitude with an epicenter somewhere in Sussex County in any given year; additionally, it has over a 40 percent chance of feeling an earthquake (regardless of the epicenter's location) in any given year. Refer to Table 5.4.3-8 which summarizes the probability of future earthquakes, of any given magnitude, impacting the county, as based on data from the previous occurrences table in Appendix E.

Table 5.4.3-8. Probability of Future Earthquake Events

Hazard Type	Number of Occurrences Between 1783 and 2015	Rate of Occurrence	Recurrence Interval (in years)	Probability of event Occurring in Any Given Year	Percent Chance of Occurring in Any Given Year
Earthquake with Epicenter inside Sussex County	20	0.09	11.65	0.09	8.58
Earthquakes Felt by the county (including those with epicenters outside Sussex County)	95	0.41	2.45	0.41	40.77

Source: NJGWS 2015

In Section 5.3, the identified hazards of concern for Sussex 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 earthquake events in the county is considered 'occasional' (hazard event is likely to occur within 100 years see 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. 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 (New Jersey State HMP 2014).

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 (New Jersey State HMP 2014).

5.4.3.2 VULNERABILITY ASSESSMENT

To understand risk, a community must evaluate what assets are exposed or vulnerable to the identified hazard. For the earthquake hazard, the entire county has been identified as exposed. Therefore, all assets in Sussex County (population, structures, critical facilities and lifelines), as described in the County Profile (Section 4), are exposed and potentially vulnerable. The following section includes an evaluation and estimation of the potential impact of the earthquake hazard on Sussex County including the following:

- Overview of vulnerability
- Data and methodology used for the evaluation
- Impact on: (1) life, health and safety of residents, (2) general building stock, (3) critical facilities, (4) economy, and (5) future growth and development
- Effect of climate change on vulnerability
- Change of vulnerability as compared to that presented in the 2011 Sussex County HMP
- Further data collections that will assist understanding this hazard over time

Overview of Vulnerability

Earthquakes usually occur without warning and can impact areas a great distance from their point of origin. The extent of damage depends on the density of population and building and infrastructure construction in the area shaken by the quake. Some areas may be more vulnerable than others based on soil type, the age of the buildings and building codes in place. Compounding the potential for damage – historically, Building Officials Code Administration (BOCA) used in the Northeast were developed to address local concerns including heavy snow loads and wind; seismic requirements for design criteria are not as stringent compared to the west coast's reliance on the more seismically-focused Uniform Building Code). As such, a smaller earthquake in the Northeast can cause more structural damage than if it occurred out west.

Ground shaking is the primary cause of earthquake damage to man-made structures. Damage can be increased when soft soils amplify ground shaking. Soils influence damage in different ways. One way is that soft soils amplify the motion of earthquake waves, producing greater ground shaking and increasing the stresses on structures. Another way is that loose, wet, sandy soils may lose strength and flow as a fluid when shaken, causing foundations and underground structures to shift and break (Stanford 2003).

Damage from earthquakes depends on the location, depth, and magnitude of the earthquake; the thickness and composition of soil and bedrock beneath the area in question; and the types of building structures. Soils influence damage in two ways. Soft soils amplify the motion of earthquake waves, producing greater ground shaking and increasing the stresses on structures. Loose, wet, sandy soils may lose strength and flow as a fluid when shaken (this is known as liquefaction). This causes foundations and underground structures to shift and break.

The entire population and general building stock inventory of the county is at risk of being damaged or experiencing losses due to impacts of an earthquake. Potential losses associated with the earth shaking were calculated for Sussex County for three probabilistic earthquake events, the 100-year, 500- and 2,500-year mean return periods (MRP). The impacts on population, existing structures, critical facilities and the economy within Sussex County are presented below, following a summary of the data and methodology used.

Data and Methodology

A probabilistic assessment was conducted for Sussex County for the 100-, 500- and 2,500-year MRPs through a Level 2 analysis in HAZUS-MH 3.0 to analyze the earthquake hazard and provide a range of loss estimates for Sussex County. The probabilistic method uses information from historic earthquakes and inferred faults, locations and magnitudes, and computes the probable ground shaking levels that may be experienced during a recurrence period by U.S. Census tract. Soil type data from the NJGWS is not available for Sussex County, so HAZUS-MH default data was used.

In addition to the probabilistic scenarios mentioned, an annualized loss run was conducted in HAZUS-MH 3.0 to estimate the annualized general building stock dollar losses for the county. The annualized loss methodology combines the estimated losses associated with ground shaking for eight return periods: 100, 250, 500, 750, 1000, 1500, 2000, 2500-year, which are based on values from the USGS seismic probabilistic curves. Annualized losses are useful for mitigation planning because they provide a baseline upon which to 1) compare the risk of one hazard across multiple jurisdictions and 2) compare the degree of risk of all hazards for each participating jurisdiction.

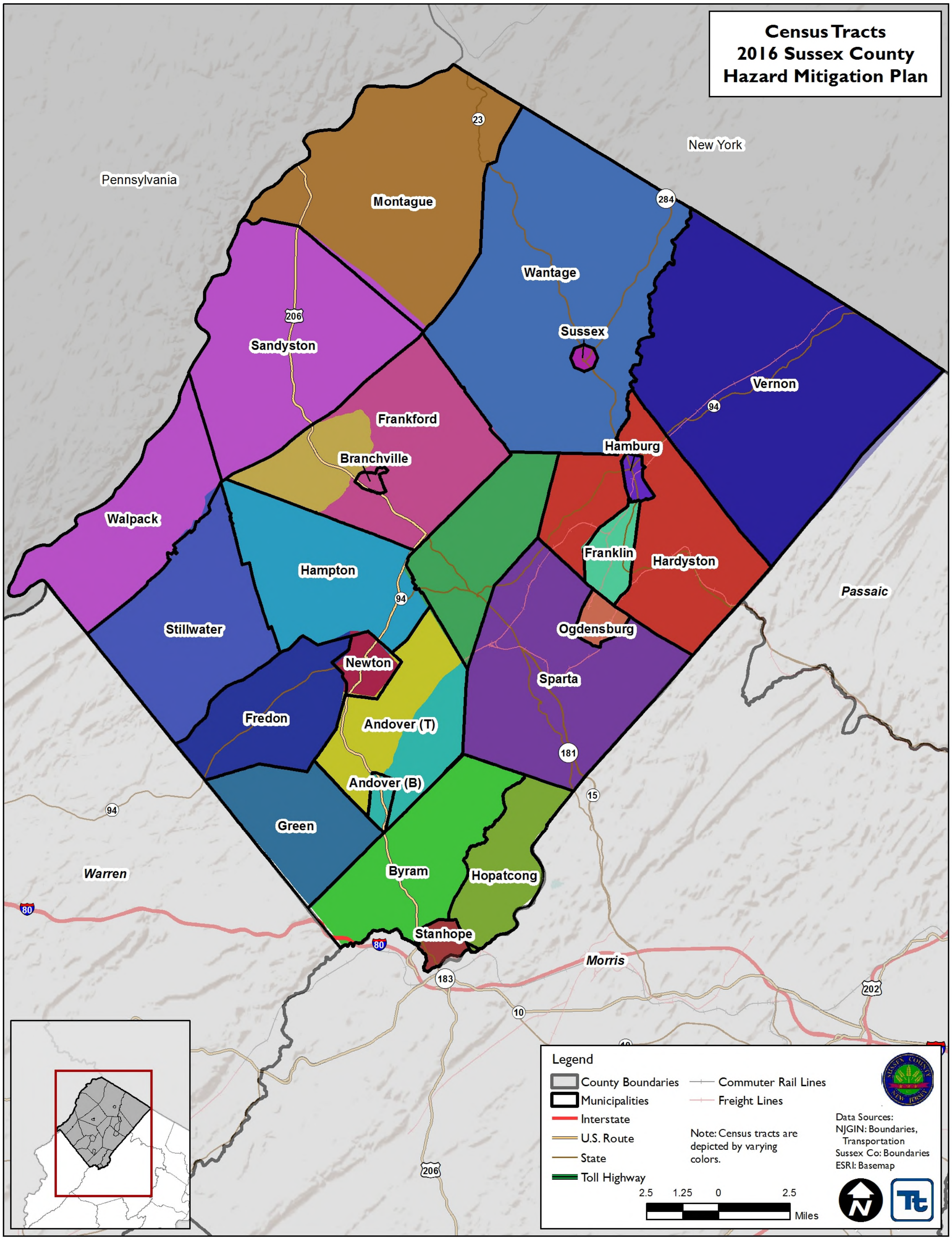
As noted in the HAZUS-MH Earthquake User Manual '*Uncertainties are inherent in any loss estimation methodology. They arise in part from incomplete scientific knowledge concerning earthquakes and their effects upon buildings and facilities. They also result from the approximations and simplifications that are necessary for comprehensive analyses. Incomplete or inaccurate inventories of the built environment, demographics and economic parameters add to the uncertainty. These factors can result in a range of uncertainly in loss estimates produced by the HAZUS Earthquake Model, possibly at best a factor of two or more*.' However, HAZUS' potential loss estimates are acceptable for the purposes of this HMP.

The building stock in HAZUS-MH was updated using the custom building inventory generated for the county. The occupancy classes available in HAZUS-MH 3.0 were condensed into the following categories (residential, commercial, industrial, agricultural, religious, government, and educational) to facilitate the analysis and the presentation of results. Residential loss estimates address both multi-family and single family dwellings. Impacts to critical facilities and utilities were also evaluated.

Data used to assess this hazard include data available in the HAZUS-MH 3.0 earthquake model and professional knowledge.

HAZUS-MH 3.0 generates results at the U.S. Census-tract level. The boundaries of the U.S. Census tracts are not always coincident with municipal boundaries in Sussex County. The results in the tables below are presented for the Census tracts with the associated municipalities listed for each tract. Figure 5.4.3-7 shows the spatial relationship between the Census tracts and the municipal boundaries.

Figure 5.4.3-7. Census Tracts in Sussex County



Source: *HAZUS-MH 3.0*

Impact on Life, Health and Safety

Overall, the entire population of Sussex County is exposed to an earthquake hazard event. The impact of earthquakes on life, health and safety is dependent upon the severity of the event. Risk to public safety and loss of life from an earthquake in Sussex County is minimal with higher risk occurring in buildings as a result of damage to the structure, or people walking below building ornamentation and chimneys that may be shaken loose and fall as a result of the quake.

Populations considered most vulnerable are those located in/near the built environment, particularly near unreinforced masonry construction. In addition, the vulnerable population includes the elderly (persons over the age of 65) and individuals living below the Census poverty threshold. These socially vulnerable populations are most susceptible, based on a number of factors including their physical and financial ability to react or respond during a hazard and the location and construction quality of their housing. Refer to Section 4 (County Profile) for the vulnerable population statistics in Sussex County.

Residents may be displaced or require temporary to long-term sheltering due to the event. The number of people requiring shelter is generally less than the number displaced as some displaced persons use hotels or stay with family or friends following a disaster event. In HAZUS-MH, estimated sheltering needs for the earthquake hazard are summarized at the Census tract level. HAZUS-MH estimates there will be no displaced households or people seeking short-term shelter as a result of the 100-year event. HAZUS-MH also estimates less than 10 displaced households and 10 people seeking short-term shelter county-wide as a result of the 500-year event. Table 5.4.3-9 summarizes the population HAZUS-MH estimates will be displaced or will require short-term sheltering for the 2,500-year MRP by municipality.

Table 5.4.3-9. Estimated Displaced Households and Population Seeking Short-Term Shelter from the 2,500-year MRP Events by Municipality

Municipality	2,500-Year MRP	
	Displaced Households	People Requiring Short-Term Shelter
Township of Andover	3	1
Township of Andover-Borough of Andover	2	1
Township of Byram	2	1
Township of Frankford	1	0
Township of Frankford-Borough of Branchville	2	1
Borough of Franklin	5	3
Township of Fredon	0	0
Township of Glen	0	0
Borough of Hamburg	6	3
Township of Hampton	1	1
Township of Hardyston	5	3
Borough of Hopatcong	4	2
Township of Lafayette	1	1
Township of Montague	4	2
Town of Newton	14	9
Borough of Ogdensburg	1	1
Township of Sandyston-Township of Walpack	0	0
Township of Sparta	8	4
Borough of Stanhope	3	2

Table 5.4.3-9. Estimated Displaced Households and Population Seeking Short-Term Shelter from the 2,500-year MRP Events by Municipality

Municipality	2,500-Year MRP	
	Displaced Households	People Requiring Short-Term Shelter
Township of Stillwater	1	0
Borough of Sussex	5	3
Township of Vernon	16	7
Township of Wantage	4	2
Sussex County Total	**87**	**47**

Source: HAZUS-MH 3.0
Note: The number of displaced households and persons seeking shelter was calculated using the 2010 U.S. Census data (HAZUS-MH 3.0 default demographic data).

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

There are no injuries or casualties estimated for the 100-year event. Table 5.4.3-10 and Table 5.4.3-11 summarize the county-wide injuries and casualties estimated for the 500- and 2,500-year MRP earthquake events, respectively.

Table 5.4.3-10. Estimated Number of Injuries and Casualties from the 500-Year MRP Earthquake Event

Level of Severity	Time of Day		
	2:00 AM	2:00 PM	5:00 PM
Injuries	4	0	0
Hospitalization	0	1	0
Casualties	4	0	0

Source: HAZUS-MH 3.0

Table 5.4.3-11. Estimated Number of Injuries and Casualties from the 2,500-Year MRP Earthquake Event

Level of Severity	Time of Day		
	2:00 AM	2:00 PM	5:00 PM
Injuries	34	45	35
Hospitalization	6	8	6
Casualties	1	1	1

Source: HAZUS-MH 3.0

Impact on General Building Stock

After considering the population vulnerable to the earthquake hazard, the value of general building stock exposed to and damaged by 100-, 500- and 2,500-year MRP earthquake events was evaluated. In addition, annualized losses were calculated using HAZUS-MH 3.0. The entire county's general building stock is considered at risk and exposed to this hazard.

The HAZUS-MH 3.0 model estimates the value of the exposed building stock and the loss (in terms of damage to the exposed stock). Refer to Table 4-7 in the County Profile (Section 4) for general building stock statistics (structure and contents).

For this plan update, a HAZUS-MH probabilistic model was run to estimate annualized dollar losses for Sussex County. Annualized losses are useful for mitigation planning because they provide a baseline upon which to 1) compare the risk of one hazard across multiple jurisdictions and 2) compare the degree of risk of all hazards for each participating jurisdiction. Please note that annualized loss does not predict what losses will occur in any particular year. The estimated annualized losses are approximately $2.3 million per year (building and contents) for the county.

According to NYCEM, where earthquake risks and mitigation were evaluated in the New York, New Jersey and Connecticut region, most damage and loss caused by an earthquake is directly or indirectly the result of ground shaking (NYCEM, 2003). NYCEM indicates there is a strong correlation between PGA and the damage a building might experience. The HAZUS-MH model is based on the best available earthquake science and aligns with these statements. HAZUS-MH 3.0 methodology and model were used to analyze the earthquake hazard for the general building stock for Sussex County. See Figure 5.4.3-3 through Figure 5.4.3-5 illustrates the geographic distribution of PGA (*g*) across the county or 100-, 500- and 2,500-year MRP events by Census-tract.

In addition, according to NYCEM, a building's construction determines how well it can withstand the force of an earthquake. The NYCEM report indicates that un-reinforced 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. Additional attributes that contribute to 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 the age of buildings as part of the analysis.

Potential building damage was evaluated by HAZUS-MH 3.0 across the following damage categories (none, slight, moderate, extensive and complete). Table 5.4.3-12 provides definitions of these five categories of damage for a light wood-framed building; definitions for other building types are included in HAZUS-MH technical manual documentation. General building stock damage for these damage categories by occupancy class and building type on a county-wide basis is summarized below for the 100-, 500- and 2,500-year events.

Table 5.4.3-12. Example of Structural Damage State Definitions for a Light Wood-Framed Building

Damage Category	Description
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.

Damage Category	Description
Complete	Structure may have large permanent lateral displacement, may collapse, or be in imminent danger of collapse due to cripple wall failure or the failure of the lateral load resisting system; some structures may slip and fall off the foundations; large foundation cracks.

Source: HAZUS-MH Technical Manual

Tables 5.4.3-13 and 5.4.3-14 summarize the damage estimated for the 500- and 2,500-year MRP earthquake events. HAZUS-MH estimates no damage to the building stock as a result of the 100-year event. Damage loss estimates include structural and non-structural damage to the building and loss of contents.

Table 5.4.3-13. Estimated Buildings Damaged by General Occupancy for 500-year and 2,500-year MRP Earthquake Events

Category	Average Damage State									
	500-Year MRP					2,500-Year MRP				
	None	Slight	Moderate	Extensive	Complete	None	Slight	Moderate	Extensive	Complete
Residential	54,653 (89.6%)	666 (1.1%)	148 (<1%)	18 (<1%)	2 (<1%)	49,069 (80.4%)	4,980 (8.2%)	1,222 (2%)	190 (<1%)	26 (<1%)
Commercial	2,075 (3.4%)	51 (<1%)	15 (<1%)	2 (<1%)	0 (0%)	1,787 (2.9%)	226 (<1%)	110 (<1%)	19 (<1%)	2 (<1%)
Industrial	171 (<1%)	5 (<1%)	2 (<1%)	0 (0%)	0 (0%)	145 (<1%)	19 (<1%)	11 (<1%)	2 (<1%)	0 (0%)
Education, Government, Religious and Agricultural	2,568 (4.2%)	63 (<1%)	17 (<1%)	1 (<1%)	0 (0%)	2,222 (3.6%)	284 (1%)	120 (<1%)	23 (<1%)	1 (<1%)

Source: HAZUS-MH 3.0

Table 5.4.3-14. Estimated Value (Building and Contents) Damaged by the 500- and 2,500-Year MRP Earthquake Events

Municipality	Total Replacement Cost Value (Building and Contents)	Estimated Total Damages*			Percent of Total Building and Contents *		
		Annualized Loss	500-Year	2,500-Year	Annualized Loss	500-Year	2,500-Year
Township of Andover	$649,634,032	$4,507	$294,135	$4,643,224	<1%	<1%	<1%
Township of Andover-Borough of Andover	$803,077,000	$5,948	$385,540	$6,195,143	<1%	<1%	<1%
Township of Byram	$1,533,053,238	$10,896	$697,588	$11,494,316	<1%	<1%	<1%
Township of Frankford	$641,999,080	$3,675	$249,415	$3,767,717	<1%	<1%	<1%
Township of Frankford-Borough of Branchville	$1,188,788,696	$7,937	$531,175	$8,027,019	<1%	<1%	<1%
Borough of Franklin	$875,822,684	$6,870	$453,402	$7,110,614	<1%	<1%	<1%
Township of Fredon	$843,240,122	$5,771	$377,871	$5,941,808	<1%	<1%	<1%
Township of Glen	$964,670,747	$6,212	$405,042	$6,470,904	<1%	<1%	<1%
Borough of Hamburg	$742,375,475	$6,069	$399,167	$6,271,068	<1%	<1%	<1%
Township of Hampton	$1,405,498,363	$9,527	$634,723	$9,774,688	<1%	<1%	<1%
Township of Hardyston	$1,675,301,658	$13,193	$859,826	$13,708,981	<1%	<1%	<1%
Borough of Hopatcong	$2,226,722,745	$16,310	$1,045,562	$17,280,283	<1%	<1%	<1%
Township of Lafayette	$808,223,135	$5,768	$378,971	$5,859,616	<1%	<1%	<1%
Township of Montague	$855,315,939	$4,816	$336,634	$4,837,353	<1%	<1%	<1%
Town of Newton	$1,475,297,242	$10,319	$675,651	$10,576,744	<1%	<1%	<1%
Borough of Ogdensburg	$391,320,172	$2,979	$195,496	$3,104,875	<1%	<1%	<1%
Township of Sandyston-Township of Walpack	$608,071,520	$3,445	$235,819	$3,436,620	<1%	<1%	<1%
Township of Sparta	$4,748,450,586	$35,370	$2,296,088	$37,195,525	<1%	<1%	<1%
Borough of Stanhope	$863,394,252	$7,086	$455,982	$7,417,681	<1%	<1%	<1%
Township of Stillwater	$923,565,485	$5,723	$381,305	$5,840,833	<1%	<1%	<1%
Borough of Sussex	$421,823,144	$3,106	$209,104	$3,151,032	<1%	<1%	<1%
Township of Vernon	$4,739,454,876	$36,590	$2,405,223	$37,991,811	<1%	<1%	<1%
Township of Wantage	$2,253,904,512	$15,183	$1,020,096	$15,385,987	<1%	<1%	<1%
Sussex County Total	**$31,639,004,702**	**$227,297**	**$14,923,812**	**$235,483,840**	**<1%**	**<1%**	**<1%**

Source: HAZUS-MH 3.0

**Total Damages is the sum of damages for all occupancy classes (residential, commercial, industrial, agricultural, educational, religious and government).*

Table 5.4.3-14. Estimated Value (Building and Contents) Damaged by the 500- and 2,500-Year MRP Earthquake Events (Continued)

Municipality	Total Replacement Value (Building and Contents)	Estimated Residential Damage		Estimated Commercial Damage	
		500-Year	2,500-Year	500-Year	2,500-Year
Township of Andover	$649,634,032	$201,716	$3,297,945	$48,513	$693,103
Township of Andover-Borough of Andover	$803,077,000	$292,241	$4,835,486	$56,932	$818,889
Township of Byram	$1,533,053,238	$611,810	$10,226,532	$44,694	$645,096
Township of Frankford	$641,999,080	$211,646	$3,232,248	$22,018	$308,102
Township of Frankford-Borough of Branchville	$1,188,788,696	$301,728	$4,781,721	$77,334	$1,096,987
Borough of Franklin	$875,822,684	$327,340	$5,271,900	$84,335	$1,207,437
Township of Fredon	$843,240,122	$252,682	$4,125,936	$21,382	$308,692
Township of Glen	$964,670,747	$330,326	$5,393,746	$12,149	$173,114
Borough of Hamburg	$742,375,475	$324,725	$5,208,645	$61,748	$869,266
Township of Hampton	$1,405,498,363	$520,329	$8,151,309	$40,804	$579,103
Township of Hardyston	$1,675,301,658	$686,162	$11,161,089	$86,521	$1,240,967
Borough of Hopatcong	$2,226,722,745	$962,150	$16,039,588	$48,994	$707,467
Township of Lafayette	$808,223,135	$207,958	$3,399,082	$32,791	$463,526
Township of Montague	$855,315,939	$271,266	$3,943,872	$23,126	$308,560
Town of Newton	$1,475,297,242	$427,609	$6,972,287	$183,129	$2,610,425
Borough of Ogdensburg	$391,320,172	$160,998	$2,595,561	$18,887	$267,060
Township of Sandyston-Township of Walpack	$608,071,520	$138,886	$2,080,409	$21,343	$290,921
Township of Sparta	$4,748,450,586	$2,031,975	$33,322,103	$139,106	$1,975,813
Borough of Stanhope	$863,394,252	$396,037	$6,528,411	$42,058	$605,769
Township of Stillwater	$923,565,485	$261,133	$4,120,945	$23,935	$338,329
Borough of Sussex	$421,823,144	$126,931	$1,977,331	$52,116	$724,490
Township of Vernon	$4,739,454,876	$1,994,033	$32,058,087	$270,780	$3,883,011
Township of Wantage	$2,253,904,512	$672,774	$10,577,499	$69,066	$950,379
Sussex County Total	**$31,639,004,702**	**$11,712,456**	**$189,301,730**	**$1,481,759**	**$21,066,504**

Source: HAZUS-MH 3.0

HAZUS-MH estimates no damages for the 100-year earthquake event. HAZUS-MH estimates $15 million (<1%) in damages to buildings in the county during a 500-year earthquake event. These damages include structural damage, non-structural damage and loss of contents, representing less than 1% of the total replacement value for general building stock in Sussex County. For a 2,500-year MRP earthquake event, HAZUS-MH estimates greater than $235 million in damages, or less than 1% of the total general building stock replacement cost value. Residential and commercial buildings account for most of the damage for earthquake events.

Earthquakes can cause secondary hazard events such as fires. HAZUS-MH estimates zero fires are anticipated as a result of the 100-, 500- and 2,500-year MRP events.

Impact on Critical Facilities

After considering the general building stock exposed to, and damaged by, 100-, 500- and 2,500-year MRP earthquake events, critical facilities were evaluated. All critical facilities (essential facilities, transportation systems, lifeline utility systems, high-potential loss facilities and user-defined facilities) in Sussex County are considered exposed and potentially vulnerable to the earthquake hazard. Refer to subsection "Critical Facilities" in Section 4 (County Profile) of this Plan for a description of the critical facilities in the county.

HAZUS-MH 3.0 estimates the probability that critical facilities may sustain damage as a result of 100-, 500- and 2,500-year MRP earthquake events. Additionally, HAZUS-MH estimates percent functionality for each facility days after the event. As a result of a 100-Year MRP event, HAZUS-MH 3.0 estimates that emergency facilities (police, fire, EMS and medical facilities), schools, utilities and specific facilities identified by Sussex County as critical will be nearly 100% functional. Therefore, the impact to critical facilities is not significant for the 100-year event.

Table 5.4.3-15 and Table 5.4.3-16 list the percent probability of critical facilities sustaining the damage category as defined by the column heading and percent functionality after the event for the 500-year and 2,500-year MRP earthquake events.

Table 5.4.3-15. Estimated Damage and Loss of Functionality for Critical Facilities and Utilities in Sussex County for the 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
Critical Facilities									
Medical	95	3	2	<1	0	95	99	100	100
Police	88-95	4-8	1-4	<1	<1	88-95	96-98	99-100	100
Fire	88-96	3-8	1-4	<1	<1	88-96	96-99	99-100	100
EOC	89-95	4-8	1-3	<1	<1	89-95	96-99	99-100	100
School	95-96	3-4	1	<1	0	95-96	98-99	100	100
Utilities									
Potable Water	98	1-2	<1	0	0	99	100	100	100
Wastewater	98	1.5	<1	0	0	99	100	100	100
Electric	98-99	1-2	<1	0	0	99	100	100	100
Communication	100	0	0	0	0	100	100	100	100

Source: HAZUS-MH 3.0

Table 5.4.3-16. Estimated Damage and Loss of Functionality for Critical Facilities and Utilities in Sussex County for the 2,500-Year MRP Earthquake Event

	Percent Probability of Sustaining Damage					Percent Functionality			
Name	None	Slight	Moderate	Extensive	Complete	Day 1	Day 7	Day 30	Day 90
Critical Facilities									
Medical	74	15	8-9	2	<1	74	89	98	99
Police	61-74	15-20	8-14	2-4	<1	61-74	80-89	95-98	97-99
Fire	61-77	14-20	7-14	1-5	<1	61-77	89-91	95-98	97-99
EOC	62-75	15-19	8-14	2-4	<1	62-75	91-90	95-98	97-99
School	72-77	14-17	7-9	1-2	<1	72-77	88-91	98	99
Utilities									
Potable Water	77-79	12-13	8-9	<1	<1	98-91	99	100	100
Wastewater	78	13	9	<1	<1	83	99	100	100
Electric	78-80	12-13	8-9	<1	<1	85-87	100	100	100
Communication	100	0	0	0	0	100	100	100	100

Source: HAZUS-MH 3.0

Impact on Economy

The risk of a damaging earthquake, in combination with the density of value of buildings in New Jersey, place the State 10th among all states for potential economic loss from earthquakes (Stanford 2003).

Impacts on the economy as a result of an earthquake may include the following: loss of business function, damage to inventory, relocation costs, wage loss and rental loss due to the repair/replacement of buildings. A Level 2 HAZUS-MH analysis estimates the total economic loss associated with each earthquake scenario, which includes building- and lifeline-related losses (transportation and utility losses) based on the available inventory (facility [or GIS point] data only). Direct building losses are the estimated costs to repair or replace the damage caused to the building. This is reported in the "Impact on General Building Stock" subsection. Lifeline-related losses include the direct repair cost to transportation and utility systems and are reported in terms of the probability of reaching or exceeding a specified level of damage when subjected to a given level of ground motion. Additionally, economic loss includes business interruption losses associated with the inability to operate a business due to the damage sustained during the earthquake as well as temporary living expenses for those displaced. These losses are discussed below.

HAZUS-MH estimates there will be no losses to income or capital as a result of the 100-year event. It is significant to note that for the 500-year event, HAZUS-MH 3.0 estimates the county will incur approximately $1.8 million in income losses (wage, rental, relocation and capital-related losses) in addition to the 500-year event estimated structural, non-structural, content and inventory losses ($14.95 million).

For the 2,500-year event, HAZUS-MH 3.0 estimates the county will incur approximately $15.5 million in income losses, mainly to the commercial and residential occupancy classes associated with wage, rental, relocation and capital-related losses. In addition, HAZUS-MH estimates greater than an estimated $236.2 million in structural, non-structural, content and inventory losses related to the 2,500-year MRP event.

Roadway segments and railroad tracks may experience damage due to ground failure and regional transportation and distribution of these materials will be interrupted as a result of an earthquake event. Losses to the community that result from damages to lifelines can be much greater than the cost of repair (HAZUS-MH 3.0 Earthquake User Manual, 2012).

Earthquake events can significantly impact road bridges. These are important because they often provide the only access to certain neighborhoods. Since softer soils can generally follow floodplain boundaries, bridges that cross watercourses should be considered vulnerable. A key factor in the degree of vulnerability will be the age of the facility or infrastructure, which will help indicate to which standards the facility was built. HAZUS-MH estimates the long-term economic impacts to the county for 15-years after the 2,500-year earthquake event. In terms of the transportation infrastructure, HAZUS-MH estimates $1.18 million in direct repair costs to bridges, highway, railways, bus, and airport facilities in the county. There are no losses computed by HAZUS-MH for business interruption due to transportation or utility lifeline losses.

HAZUS-MH 3.0 also estimates the volume of debris that may be generated as a result of an earthquake event to enable the study region to prepare and rapidly and efficiently manage debris removal and disposal. Debris estimates are divided into two categories: (1) reinforced concrete and steel that require special equipment to break it up before it can be transported, and (2) brick, wood and other debris that can be loaded directly onto trucks with bulldozers (HAZUS-MH Earthquake User's Manual).

For the 100-year MRP event, HAZUS-MH 3.0 estimates 0 tons of debris will be generated. For the 500-year MRP event, HAZUS-MH 3.0 estimates greater than 5,000 tons of debris may be generated. For the 2,500-year MRP event, HAZUS-MH 3.0 estimates greater than 40,000 tons of debris may be generated. Table 5.4.3-21 summarizes the estimated debris generated as a result of these events by municipality (Census-tract).

Table 5.4.3-17. Estimated Debris Generated by the 500- and 2,500-year MRP Earthquake Events

Municipality	500-Year		2,500-Year	
	Brick/ Wood (tons)	Concrete/ Steel (tons)	Brick/ Wood (tons)	Concrete/ Steel (tons)
Township of Andover	101	26	632	252
Township of Andover-Borough of Andover	122	29	776	292
Township of Byram	253	51	1,608	518
Township of Frankford	88	19	524	172
Township of Frankford-Borough of Branchville	154	45	937	426
Borough of Franklin	129	34	802	329
Township of Fredon	122	32	760	305
Township of Glen	123	28	762	263
Borough of Hamburg	108	26	675	255
Township of Hampton	168	41	1,029	398
Township of Hardyston	304	70	1,908	691
Borough of Hopatcong	383	73	2,446	742
Township of Lafayette	108	34	666	328
Township of Montague	121	27	698	244
Town of Newton	183	47	1,140	472
Borough of Ogdensburg	68	16	427	155
Township of Sandyston-Township of Walpack	76	22	447	201
Township of Sparta	750	158	4,732	1,583
Borough of Stanhope	118	29	758	299
Township of Stillwater	124	32	759	300
Borough of Sussex	54	15	328	145

Table 5.4.3-17. Estimated Debris Generated by the 500- and 2,500-year MRP Earthquake Events

Municipality	500-Year		2,500-Year	
	Brick/ Wood (tons)	Concrete/ Steel (tons)	Brick/ Wood (tons)	Concrete/ Steel (tons)
Township of Vernon	815	177	5,057	1,730
Township of Wantage	323	86	1,951	800
Sussex County Total	**4,796**	**1,115**	**29,822**	**10,900**

Source: HAZUS-MH 3.0

Future Growth and Development

As discussed in Section 4, areas targeted for future growth and development have been identified across the county. It is anticipated that the human exposure and vulnerability to earthquake impacts in newly developed areas will be similar to those that currently exist within the county. 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.

Change of Vulnerability

Sussex County continues to be vulnerable to the earthquake hazard. However, there are differences between the potential loss estimates between this plan update to the results in the 2011 HMP. For the 2016 update, probabilistic scenarios were evaluated using a Level 2 HAZUS-MH analysis. The 2010 U.S. Census data, 2015 MODIV tax data, and an updated critical facility inventory were used for this update.

Effect of Climate Change on Vulnerability

Providing projections of future climate change for a specific region is challenging. 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.

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.

Additional Data and Next Steps

A Level 2 HAZUS-MH earthquake analysis was conducted for Sussex County using the default model data, with the exception of the updated building and critical facility. Additional data needed to further refine and enhance the county's vulnerability assessment include NEHRP soils to be integrated into the HAZUS-MH model. Identifying un-reinforced masonry critical facilities and privately-owned buildings (i.e., residences) using local knowledge and/or pictometry/orthophotos would be valuable as these buildings may not withstand earthquakes of certain magnitudes. This information will facilitate developing plans to provide emergency response/recovery efforts for these properties. Further mitigation actions include training of county and municipal personnel to provide post-hazard event rapid visual damage assessments, increase of county and local debris management and logistic capabilities, and revised regulations to prevent additional construction of non-reinforced masonry buildings.