4.5 EARTHQUAKE

SECTION 4.5 EARTHQUAKE

4.5-1 HAZARD OVERVIEW

Hazard Definition

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 (FEMA, 2001; Shedlock and Pakiser, 1997). Most earthquakes occur where the Earth's tectonic plates meet (faults) although some also occur within plate interiors. 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). Less than 10% of earthquakes occur within plate interiors. New Jersey experiences both types of earthquakes.

Earthquakes usually occur without warning and their effects can impact areas of great distance from the epicenter (FEMA, 2001). 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). Hazards resulting from earthquakes include 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 on a 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).

Ground shaking is the primary cause of earthquake damage to man-made structures. 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).

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, 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. The following section discusses where these soil classifications can be found in New Jersey.

Secondary Hazards

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 4.8: Geologic Hazards of this Plan 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: Dam and Levee Failure of this Plan update.

As per the United States Search and Rescue Task force, tsunamis are formed as a result of earthquakes, volcanic eruptions, or landslides that occur under the ocean. When these events occur, huge amounts of energy are released as a result of quick, upward bottom movement. A wave is formed when huge volumes of ocean water are pushed upward. A large earthquake can lift large portions of the seafloor, which will cause the formation of huge waves.

As with other natural hazards, earthquakes can trigger serious disruptions in critical lifelines. These include, but are not limited to, power outages, fuel shortage, infrastructure failure for water supply and energy distribution.

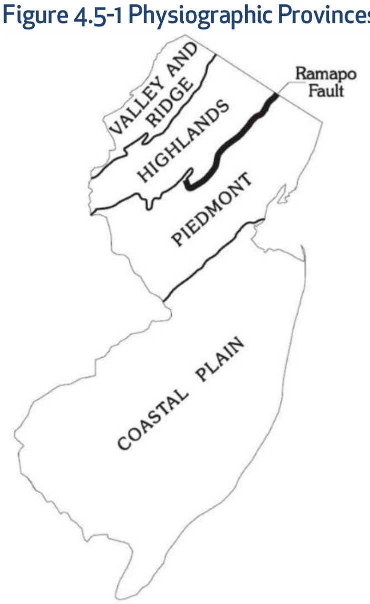
4.5-2 LOCATION, EXTENT, AND MAGNITUDE

Location

The level of seismic risk—the threat to buildings, infrastructure, and people—is significant in New Jersey, especially in the northern portion of the State. The level of seismic risk in New Jersey is higher than might be expected because the majority of buildings and infrastructure have been built with minimal or no consideration of earthquakes, making them more vulnerable to earthquake damage. The seismic hazard, as shown in Figure 4.5-2 below, is highest in Bergen, Hudson, and Passaic Counties and steadily decreases as you move both west and south from those locations. The seismic hazard is measured as the peak ground acceleration (PGA) that has a 2% chance of being exceeded in 50 years (annual probability of 0.000404) (USGS, 2019). PGA is discussed in more detail later in this section.

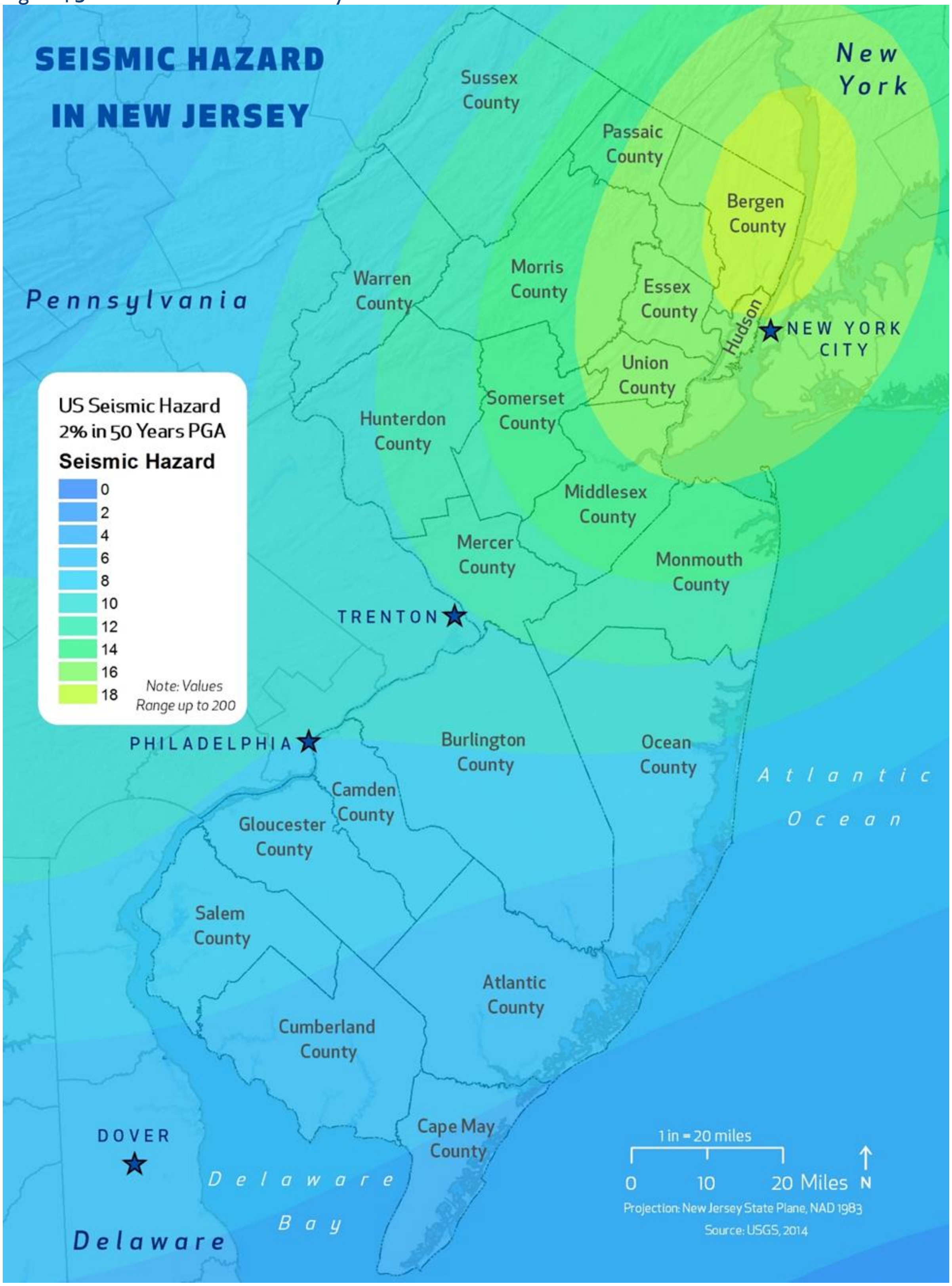
Generally, earthquake epicenters in eastern North America and the New Jersey area occur on known faults. The faults in the region are from tectonic activity more than 200 million years ago (Muessig, 2013). There are many faults in New Jersey; however, the Ramapo Fault, which separates the Piedmont and Highlands Physiographic Provinces, is best known. 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 4.5-1 illustrates the relationship of the Ramapo fault line with the physiologic provinces of New Jersey.

Figure 4.5-1 Physiographic Provinces of New Jersey and the Ramapo Fault Line



Source: Dombroski, 1973 (revised 2005)

Figure 4.5-2 Seismic Hazard in New Jersey

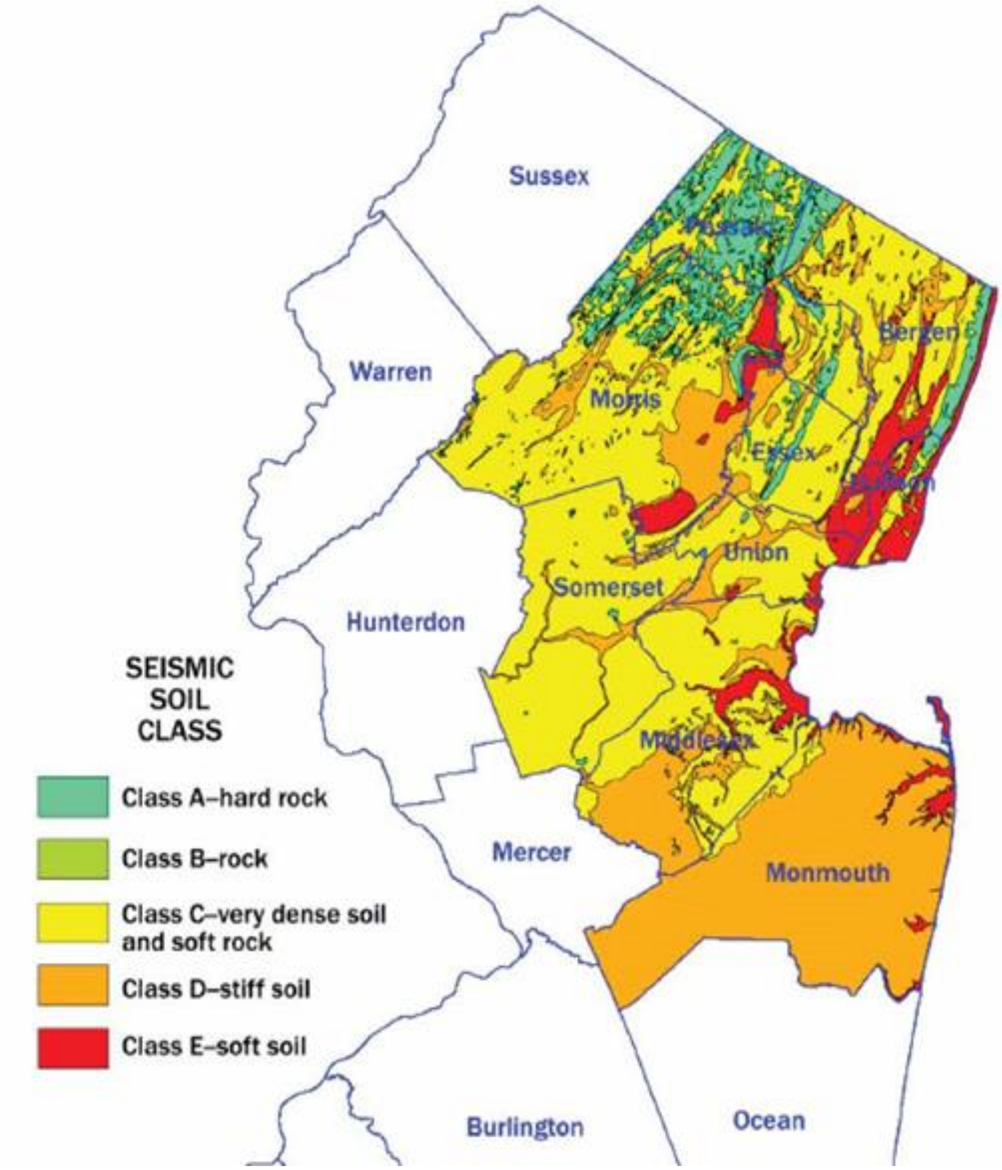


Source: USGS, 2019

Figure 4.5-3 illustrates the NEHRP soils located in the northeast quadrant the State. The data were available from the New Jersey Geologic and Water Survey. The available NEHRP soils information is incorporated into the HAZUS-MH earthquake model for the risk assessment. 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.

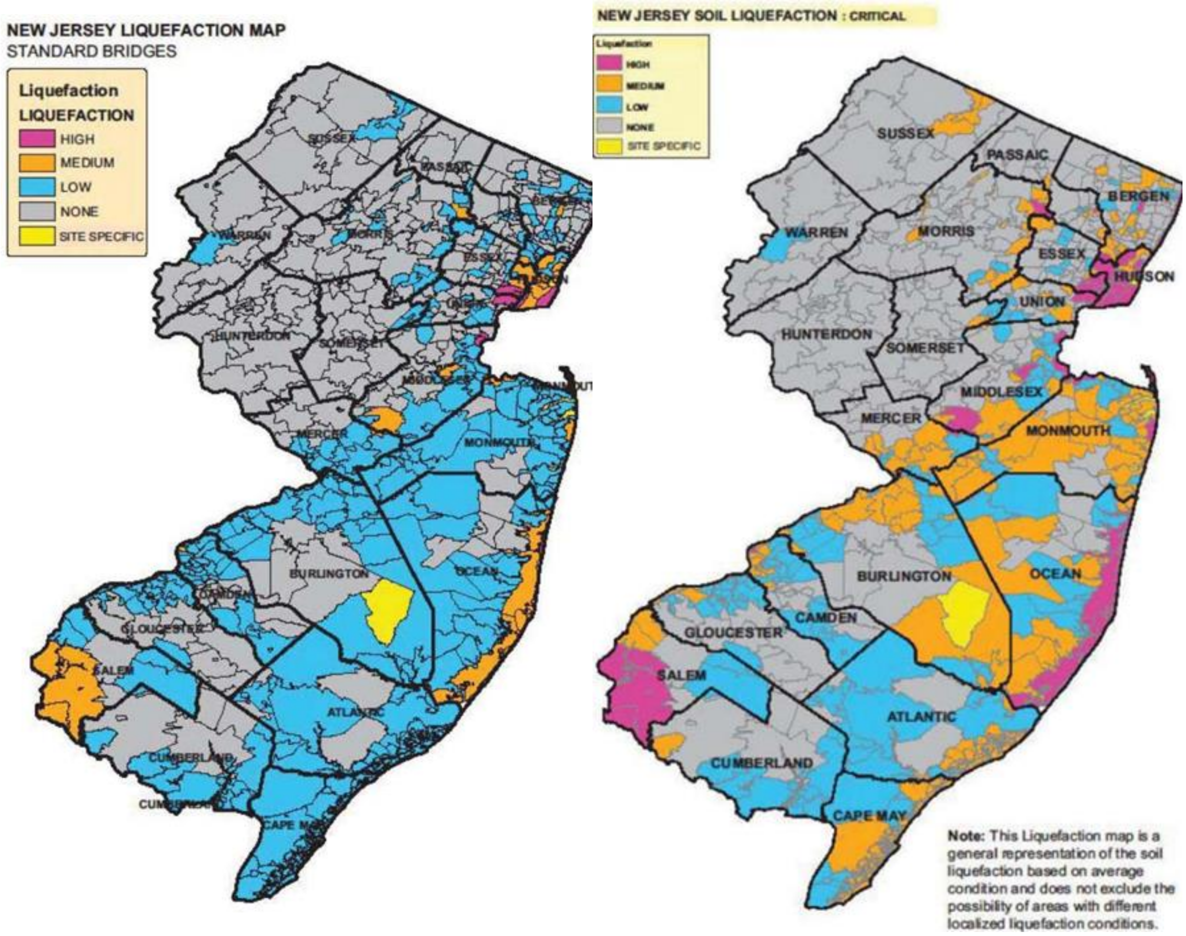
NJDOT developed a Geotechnical Database Management System (GDMS) which contains many soil boring data across New Jersey. The boring logs provide information on Standard Penetration Test (SPT) blow count and soil description, and these boring logs were used to classify soil sites. Using this site classification analysis, NJDOT generated a map of soil site classes according to ZIP codes in New Jersey. Each ZIP code was assigned a site class based on its predominant soil condition. Soil site class maps were generated for all 21 counties in New Jersey.

Figure 4.5-3 Seismic Soil Classes for Counties in Northeastern New Jersey



Using the 1,000-year earthquake spectra in AASHTO-SGS, liquefaction hazard maps for all New Jersey counties were generated. Liquefaction hazard maps are for preliminary design and reference only for bridge construction. Using a factor of 1.5 to the Peak Ground Acceleration (PGA) of 1,000-year earthquake, the liquefaction hazard maps for New Jersey's counties were generated. Figure 4.5-4 illustrates the liquefaction map for New Jersey.

Figure 4.5-4 Liquefaction Hazard Map of New Jersey for Standard and Critical Bridges



Source: NJDOT, 2012

Extent and Magnitude

Seismic waves are the vibrations from earthquakes that travel through the Earth. The magnitude or extent of an earthquake is a measured value of the earthquake size, or amplitude of the seismic waves. The Richter magnitude scale (Richter scale) was developed in 1932 as a mathematical device to compare the sizes of earthquakes. The Richter scale is the most widely known scale that measures the magnitude of earthquakes. It has no upper limit and is not used to measure damage. An earthquake in a densely populated area, which results in many deaths and considerable damage, may have the same magnitude and shock as found in a remote area that did not experience any damage. Table 4.5-1 presents the Richter Magnitude Scale and corresponding earthquake effects.

Table 4.5-1 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, 2007

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 scale expresses intensity of an earthquake; the scale is a subjective measure that describes how strong a shock was felt at a particular location. The Modified Mercalli scale expresses the intensity of an earthquake's effects in a given locality in values ranging from I to XII. Table 4.5-2 summarizes earthquake intensity as expressed by the Modified Mercalli scale. Table 4.5-3 displays the Modified Mercalli scale and peak ground acceleration (PGA) equivalent.

Table 4.5-2 Modified Mercalli Intensity Scale

Mercalli Intensity	Description
I	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: Michigan Tech University 2007

Table 4.5-3 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

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 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. 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 4.5-4.

Table 4.5-4 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

According to the USGS Earthquake Hazards Program, PGA maps (also known as earthquake hazard maps) are used as planning tools when designing buildings, bridges, highways, and utilities so that they can withstand shaking associated with earthquake events. These maps are also used as planning tools for the development of building codes that establish construction requirements appropriate to preserve public safety.

4.5-3 PREVIOUS OCCURRENCES AND LOSSES

FEMA Disaster Declarations

Based on all sources researched, New Jersey was not included in any FEMA disaster declarations for earthquake-related events.

Historical Events Summary

New Jersey has a fairly extensive history of earthquakes, mostly because of the factors discussed previously in the location section. Small earthquakes occur several times a year and generally do not cause significant damage. Table 4.5-5 summarizes all earthquake incidents since 2010 of magnitude 2.0 or above. Aside from a magnitude 5.8- earthquake in 2011, there have not been any losses or impacts reported in New Jersey since 2010. Following the table below, Figure 4.5-5 maps all earthquakes with epicenters in New Jersey from 1783 to 2023.

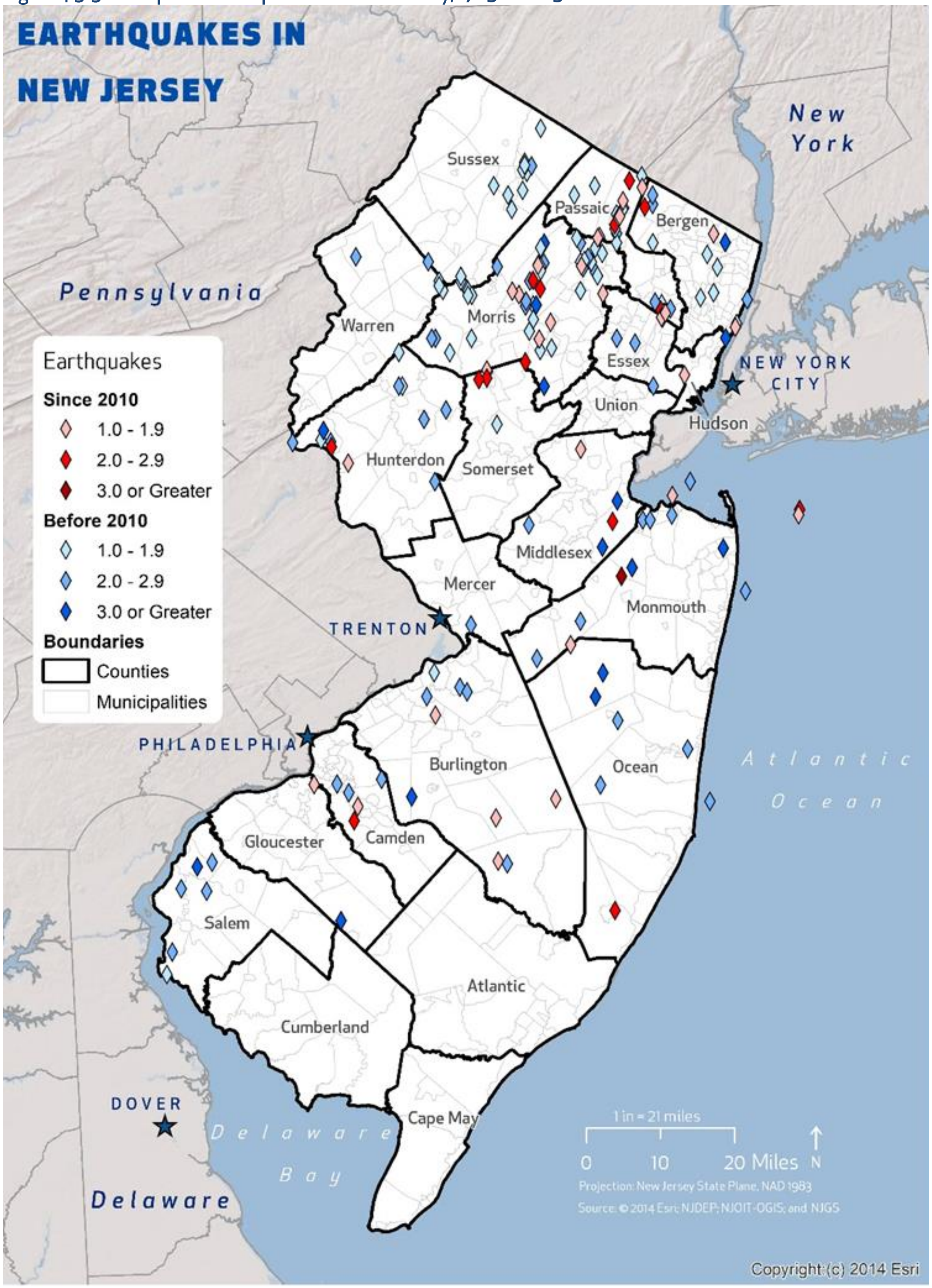
Table 4.5-5 Earthquake Incidents that Impacted New Jersey, 2010 to 2023

Date(s)	Magnitude	Location	Losses/Impacts
2/10/2010	2.2	1 km West of Wanaque	No reference and/or no damage reported.
2/21/2010	2.6	Gladstone, NJ	This earthquake hit just before 9 a.m. and prompted numerous phone calls to police. No damages were reported. Many people in New Jersey reported having felt this earthquake.
2/21/2010	2.3	Gladstone, NJ	This event was most likely an aftershock from the morning's earthquake. Numerous people in New Jersey reported having felt this earthquake.
6/6/2010	2.3	6 km Southeast of Sayreville, NJ	People reported having felt this earthquake throughout New Jersey.
12/25/2010	2.1	1 km West of Clifton, NJ	No reference and/or no damage reported.

Date(s)	Magnitude	Location	Losses/Impacts
8/23/2011	5.8	Central Virginia	A moderate earthquake occurred in central Virginia and was felt throughout most of the east coast. In New Jersey, the intensity ranged from one to four (weak to light). Areas underlain by thick silt and clay felt a stronger ground motion than did those where rock was very close to the surface. The quake was felt in South Brunswick and residents were calling 911 wanting to know what happened; some thought it was an explosion. It was also felt in the offices of Alcatel-Lucent in Murray Hill (Union County). Ceiling tiles fell out at a Sears store in Middletown. In Plainfield (Union County), employees in the Park Madison building were evacuated. Union County's administration building in Elizabeth reported continuous shaking. In New Brunswick (Middlesex County), employees were evacuated from the County administration building. Atlantic City (Atlantic County) went into emergency mode with evacuations of high rises, hospitals, schools, casinos, and hotels. The County OEM received reports of a crack in a wall in a house and broken water pipe in a building. There were minor scattered power outages reported throughout the state.
11/5/2012	2.0	3 km Southwest of Mahwah, NJ	People reported having felt this earthquake in various parts of New Jersey.
11/23/2012	2.2	Greater Philadelphia Area/New Jersey	Numerous reports of people having felt the earthquake in southwestern New Jersey.
7/18/2014	2.0	16.3 km E of Highlands, NJ	No reference and/or no damage reported.
1/2/2016	2.1	2.4 km NW of Ringwood, NJ	No reference and/or no damage reported.
5/27/2016	2.7	3.5 km N of Bernardsville, NJ	No reference and/or no damage reported.
9/30/2017	2.1	1 km E of Rockaway, NJ	No reference and/or no damage reported.
2/7/2018	2.17	5 km NNW of Lake Mohegan, New York	No reference and/or no damage reported.
7/19/2019	2.18	4 km NW of Spring Ridge, Pennsylvania	No reference and/or no damage reported.
9/9/2020	3.1	3 km WSW of Marlboro, New Jersey	No reference and/or no damage reported.
10/22/2020	2.2	9 km SE of Merritt Park, New York	No reference and/or no damage reported.
12/3/2020	2.1	0 km ENE of Milford, New Jersey	No reference and/or no damage reported.
6/9/2021	2.4	0 km SE of Tuckerton, New Jersey	No reference and/or no damage reported.
11/13/2021	2.1	2 km WSW of Sinking Spring, Pennsylvania	No reference and/or no damage reported.
8/30/2022	2.3	New Jersey (specific location unlisted)	No reference and/or no damage reported.

Source: USGS 2023; NJGWS 2013; NJGWS, 2017

Figure 4.5-5 Earthquakes with Epicenters in New Jersey, 1783 to 2023



Source: NJDEP 2023

4.5-4 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 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.

For the purposes of this Plan update, the probability of future occurrences for earthquakes is defined by the number of events over a specified period of time. There have been zero earthquake-related disasters declared for New Jersey, therefore the entire historical record was consulted. The historical record indicates 228 earthquakes recorded for New Jersey from 1783 to 2022.

Potential Effects of Climate Change

Predicting the potential impacts of global climate change on earthquake probability is challenging. It is not well understood how change in the climate is or is not related to seismic activity. Some scientists believe melting glaciers could induce tectonic activity. As ice melts and water runs off, massive amounts of weight are shifted on the Earth's crust. As newly freed crust may alter shape, it could cause seismic plates to slip and stimulate volcanic activity (NASA, 2019).

Scientists know earthquakes can be triggered or inhibited by changes in the amount of stress on a fault. Climate variables that could alter fault stress loads include rain and snowfall, drought, and groundwater depletion, although the potential magnitude of these variables is unclear (NASA, 2019). Additionally, secondary impacts of earthquakes could be magnified by future climate change. Soils saturated by repetitive storms or sea level rise could experience liquefaction during seismic activity because of the increased saturation (Poitras et. al, n.d.). 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.

4.5-5 VULNERABILITY ASSESSMENT

Vulnerable Jurisdictions

All 21 New Jersey counties included earthquakes as a hazard of concern in their local HMPs. A review of the historic record indicates earthquake epicenters have occurred in 20 of the 21 New Jersey Counties. The greatest number of earthquake events with epicenters in New Jersey have been in the northern part of the State, however, all counties except for Cape May County list earthquakes as a hazard of concern in their hazard mitigation plans, as summarized in the table below. In addition to the rankings created by the counties, the table below includes the Hazard Risk Rating data from FEMA's National Risk Index for Natural Hazards, which rank earthquakes as "Relatively Low" or "Very Low" for every county. The ratings are relative to other jurisdictions and based on an equation that accounts for expected annual loss, social vulnerability, and community resilience.

Table 4.5-6 Earthquake Risk Rankings

County	NRI Earthquake Hazard Risk Rating	Ranking of Earthquake Hazard by County HMP
Atlantic	Relatively Low	Low
Bergen	Relatively Low	Profiled, Not Ranked
Burlington	Relatively Low	Medium
Camden	Relatively Low	High
Cape May	Very Low	Not Profiled
Cumberland	Relatively Low	Low
Essex	Relatively Low	Low
Gloucester	Relatively Low	Low
Hudson	Relatively Low	High
Hunterdon	Very Low	High
Mercer	Relatively Low	High
Middlesex	Relatively Low	Low

County	NRI Earthquake Hazard Risk Rating	Ranking of Earthquake Hazard by County HMP
Monmouth	Relatively Low	Low
Morris	Relatively Low	High
Ocean	Relatively Low	Low
Passaic	Relatively Low	High
Salem	Very Low	Low
Somerset	Relatively Low	Low
Sussex	Very Low	High
Union	Relatively Low	Low
Warren	Very Low	Medium

Source: FEMA NRI (accessed June 2023), County HMPs (accessed June 2023)

Built Environment

Table 4.5-7 shows estimated potential annual losses (EAL) for earthquake by county in the state of New Jersey. Total building EAL was derived from FEMA's National Risk Index (NRI) while EAL for state owned assets was calculated using Replacement Cost Value for state owned facilities per county derived from LBAM data and Expected Annual Loss Rate for Buildings by county provided by the NRI.

Table 4.5-7 Estimated Potential Annual Losses for Earthquake

County	Total Buildings	State-Owned Assets
Atlantic	$488,818.20	$3,337.92
Bergen	$3,067,556.50	$2,753.84
Burlington	$1,254,718.50	$8,063.33
Camden	$1,189,900.80	$5,863.96
Cape May	$169,000.10	$508.67
Cumberland	$338,590.80	$7,270.90
Essex	$1,799,877.70	$11,483.58
Gloucester	$845,649.90	$1,491.93
Hudson	$1,402,845.20	$4,705.56
Hunterdon	$328,524.70	$2,144.56
Mercer	$1,282,181.60	$42,510.62
Middlesex	$3,114,858.10	$10,245.72
Monmouth	$2,076,820.40	$5,939.05
Morris	$1,159,407.90	$3,618.23
Ocean	$1,130,400.30	$3,241.85
Passaic	$1,098,024.90	$3,256.79
Salem	$229,662.00	$1,135.02
Somerset	$1,171,393.60	$3,012.40
Sussex	$218,984.10	$596.66
Union	$1,750,489.00	$3,104.13
Warren	$159,347.80	$442.76

Source: FEMA NRI, NJOMB, 2023

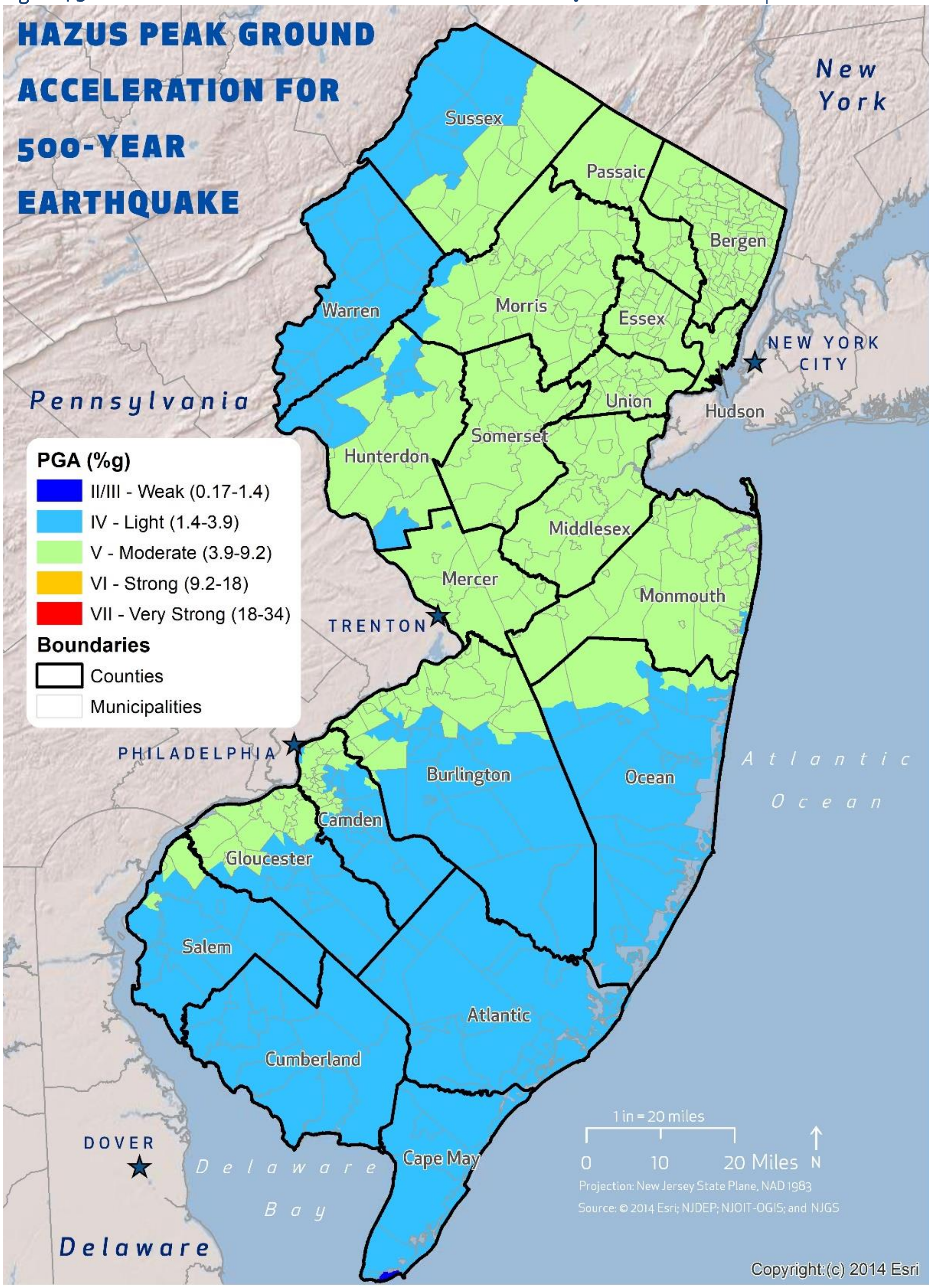
To understand risk, the assets exposed to earthquake hazard areas are identified in this section. For the earthquake hazard, the entire State of New Jersey is exposed. However, certain areas, buildings, and infrastructure are at greater risk than others because of the soils on which they are located and their manner of construction.

In the previous plan, HAZUS was used to quantify loss estimates for several scenario earthquakes. For the 2024 plan update, a probabilistic statewide assessment was conducted in HAZUS-MH 6.0 to analyze the earthquake hazard for New Jersey. The HAZUS analysis evaluates the statistical likelihood that a specific event will occur and the related consequences. Additional information on the landslide hazard is included in Section 4.8 Geologic Hazards of this HMP update.

All buildings are exposed to an earthquake; however, those located on NEHRP soil classes D and E may have increased potential for building damage and losses. Spatial data were only available for nine counties as provided by the New Jersey Geologic and Water Survey. All nine counties with NEHRP soils delineated contain Class E soils, which amplify and magnify ground shaking and increase building damage and losses. (Figure 4.5-3 presented earlier in this profile illustrates soil classification area in New Jersey.)

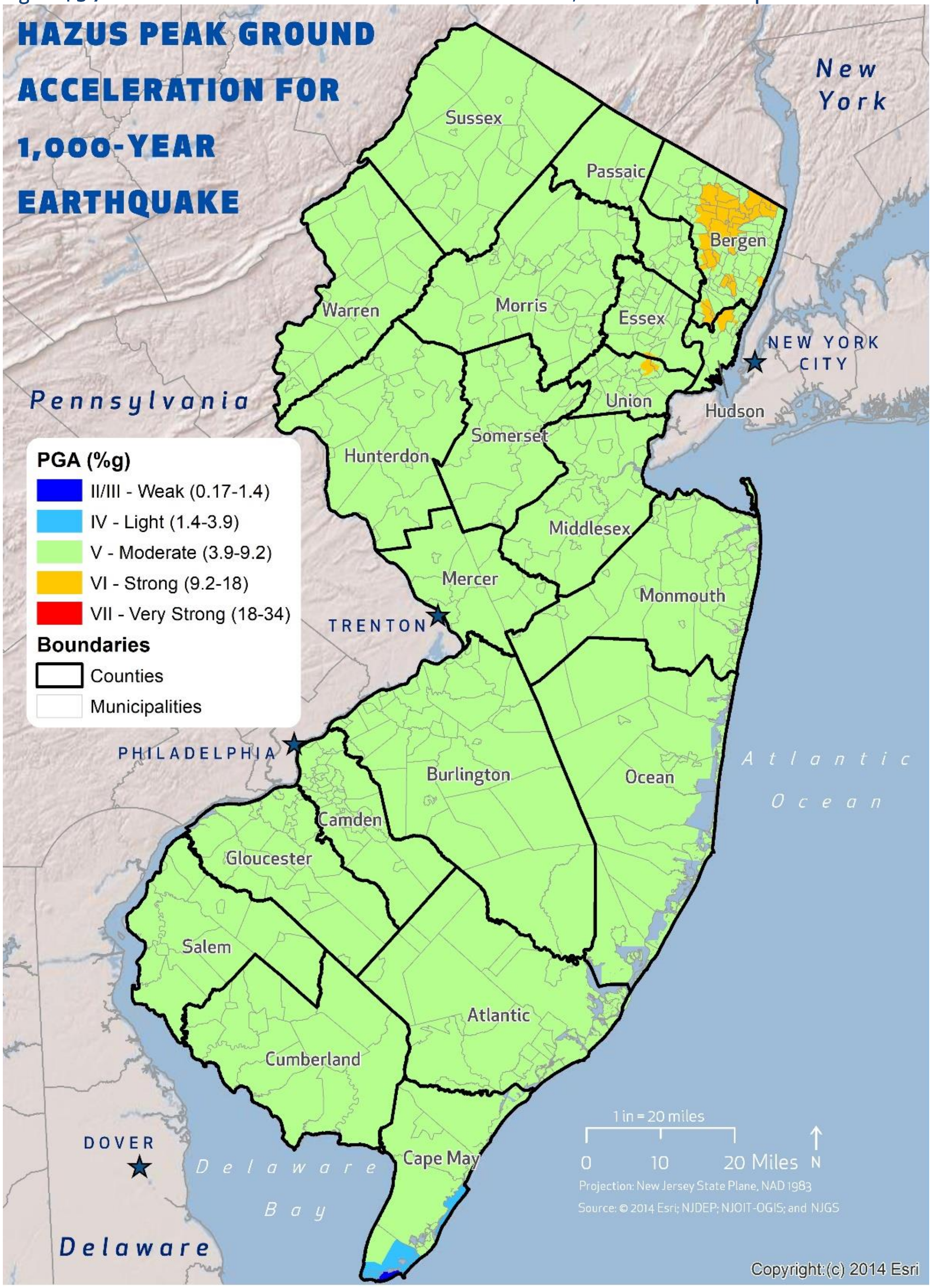
According to New York City Area Consortium for Earthquake Loss Mitigation (NYCEM), where earthquake risks and mitigation were evaluated in the New York, New Jersey, and Connecticut region, most damage and loss caused by an earthquake is directly or indirectly the result of ground shaking (NYCEM, 2003). NYCEM indicates 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. The HAZUS-MH 6.0 methodology and model were used to analyze the earthquake hazard across the State. Figure 4.5-6 through Figure 4.5-8 illustrate the geographic distribution of PGA (%g) across New Jersey for 500-, 1,000- and 2,500-year: MRP events at the United States 2020 Census-tract level.

Figure 4.5-6 Peak Ground Acceleration Modified Mercalli Scale for a 500-Year MRP Earthquake Event



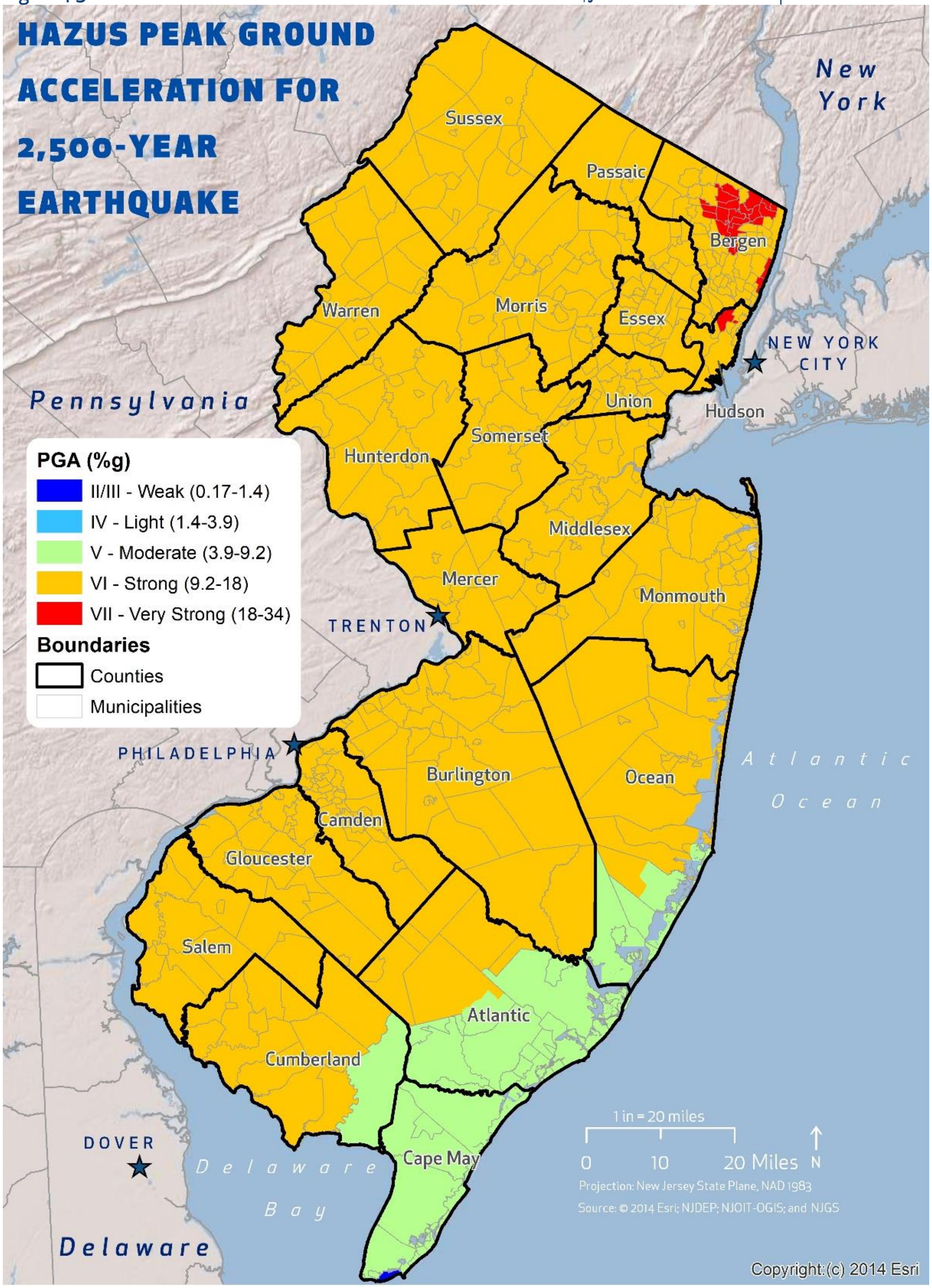
Source: HAZUS v6.0

Figure 4.5-7 Peak Ground Acceleration Modified Mercalli Scale for a 1,000-Year MRP Earthquake Event



Source: HAZUS v6.0

Figure 4.5-8 Peak Ground Acceleration ModifiedMercalliScale for a 2,500-Year MRP Earthquake Event



Source: HAZUS v6.0

In general, the northern half of New Jersey is more vulnerable to potential damage from an earthquake. Bergen, Essex, Hudson, Hunterdon, Middlesex, Monmouth, Mercer, Passaic, Somerset, Sussex, and Union counties have the highest potential of sustaining damage during an event. The urban centers in Essex, Hudson, and Bergen Counties have the highest vulnerability to potential damage due to having more structures and a larger population than other areas in the State.

Northern New Jersey, especially areas in proximity to the Ramapo Fault, have historically been the most active for instances of earthquakes. However, the average strength of earthquakes with epicenters in New Jersey is only 1.8 on the Richter scale. Earthquakes of this magnitude are usually not felt. Based on historical records, New Jersey is not particularly vulnerable to many instances of higher-magnitude earthquakes and the hazards associated with smaller-intensity earthquake events are minimal. Older buildings and infrastructure will likely be the most vulnerable to the hazards associated with earthquakes, as new buildings must meet the more stringent requirements of the Uniform Construction Code and International Building Code. New land development that takes place in northern New Jersey in proximity to the Ramapo Fault will likely have the most susceptibility to experiencing the effects of an earthquake and associated hazards.

As mentioned earlier in this section, NJDOT in cooperation with the United States Department of Transportation (USDOT) has created liquefaction vulnerability maps for standard and critical bridges within each New Jersey County (USDOT, 2012). These liquefaction maps indicate there is a high potential for liquefaction to impact bridges within portions of Bergen, Essex, Hudson, Middlesex, Ocean, and Union Counties.

HAZUS-MH estimates the extent of damage and cost to repair highway bridges as a result of each probabilistic scenario. Although no bridges are estimated to be completely destroyed, HAZUS-MH estimates slight, moderate, and extensive damages as a result of the 500-, 1,000- and 2,500-year probabilistic events. Table 4.5-8 summarizes the estimated total loss to highway bridges across the State for each probabilistic scenario.

Table 4.5-8 Estimated Cost to Repair Highway Bridges for Probabilistic Earthquake Events

Level of Severity	500 Year Event	1,000 Year Event	2,500 Year Event
Economic Loss	$63,000	$1,294,000	$19,384,000

Source: HAZUS-MH v.6.0

All critical facilities in the planning area are exposed to the earthquake hazard. In addition, increased risk is associated with hazardous materials releases, which have the potential to occur during an earthquake from fixed facilities, transportation-related incidents (vehicle transportation), and pipeline distribution. Transportation corridors and pipelines can be disrupted during an earthquake, leading to the release of materials to the surrounding environment, and disrupting services well beyond the primary area of impact. Facilities holding hazardous materials are of particular concern because of possible isolation of surrounding neighborhoods. During an earthquake, structures storing these materials could rupture and leak into the surrounding area or an adjacent waterway, having a disastrous effect on the environment. As mentioned earlier, softer soils can amplify and magnify ground shaking and increase building damage and losses.

HAZUS-MH estimates the direct building losses to repair or replace the damage caused to the building. According to NYCEM, a building's construction determines how well it can withstand the force of an earthquake. The NYCEM report 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. 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. Because the default general building stock was used for this HAZUS-MH analysis, the default building ages and building types already incorporated into the inventory were used. Tables 4.5-9 through 4.5-11 summarize the estimated potential annual losses to all buildings in the State for each probabilistic scenario (500-, 1,000-, and 2,500-Year Event), and Table 4.5-12 summarizes annualized losses. Total building loss consists of structure loss and content loss together.

Table 4.5-9 Earthquake Estimated Potential Losses to Buildings (Structure and Contents) HAZUS-MH 500 Year Scenario

County	500 Year Event		
	Structure Loss	Content Loss	Total Building Loss
Atlantic	$8,853,000	$2,629,000	$11,482,000
Bergen	$40,897,000	$29,138,000	$70,035,000
Burlington	$19,476,000	$9,107,000	$28,583,000
Camden	$17,925,000	$8,213,000	$26,138,000
Cape May	$3,374,000	$689,000	$4,063,000
Cumberland	$6,074,000	$2,082,000	$8,156,000
Essex	$21,596,000	$15,511,000	$37,107,000
Gloucester	$12,521,000	$5,744,000	$18,265,000
Hudson	$17,468,000	$12,551,000	$30,019,000
Hunterdon	$5,047,000	$2,249 ,000	$7,296,000
Mercer	$18,758,000	$10,289 ,000	$29,047,000
Middlesex	$42,325,000	$27,396 ,000	$69,721,000
Monmouth	$28,461,000	$15,446 ,000	$43,907,000
Morris	$14,912,000	$8,958 ,000	$23,870,000
Ocean	$17,277,000	$7,527 ,000	$24,804,000
Passaic	$13,861,000	$9,518 ,000	$23,379,000
Salem	$3,729,000	$1,486 ,000	$5,215,000
Somerset	$16,395,000	$9,507 ,000	$25,902,000
Sussex	$3,281 ,000	$1,419 ,000	$4,700,000
Union	$23,778 ,000	$16,549,000	$40,327,000
Warren	$2,675 ,000	$904 ,000	$3,579,00
Total	$338,683 ,000	$196,912,000	$535,595,000

Source: HAZUS-MH v6.0

Table 4.5-10 Earthquake Estimated Potential Losses to Buildings (Structure and Contents) HAZUS-MH 1000 Year Event

County	1,000 Year Event		
	Structure Loss	Content Loss	Total Building Loss
Atlantic	$23,138 ,000	$15,070,000	$38,208,000
Bergen	$111,633,000	$161,320,000	$272,953,000
Burlington	$51,658,000	$49,461,000	$101,119,000
Camden	$48,332,000	$46,874,000	$95,206,000
Cape May	$9,065,000	$4,488,000	$13,553,000
Cumberland	$16,299,000	$12,584,000	$28,883,000
Essex	$60,851,000	$95,057,000	$155,908,000
Gloucester	$34,258,000	$34,025,000	$68,283,000
Hudson	$48,212,000	$73,813,000	$122,025,000
Hunterdon	$14,359,000	$14,364,000	$28,723,000
Mercer	$49,938,000	$55,164,000	$105,102,000
Middlesex	$115,768,000	$154,116,000	$269,884,000
Monmouth	$79,141,000	$89,588,000	$168,729,000

County	1,000 Year Event		
	Structure Loss	Content Loss	Total Building Loss
Morris	$42,837,000	$57,055,000	$99,892,000
Ocean	$46,443,000	$42,200,000	$88,643,000
Passaic	$38,788,000	$57,742,000	$96,530,000
Salem	$10,304,000	$9,421,000	$19,725,000
Somerset	$45,226,000	$54,280,000	$99,506,000
Sussex	$9,394,000	$9,497,000	$18,891,000
Union	$64,114,000	$89,455,000	$153,569,000
Warren	$7,791,000	$6,621,000	$14,412 ,000
Total	**$927,549,000**	**$1,132,195,000**	**$2,059,744 ,000**

Source: HAZUS-MH v6.0

Table 4.5-11 Earthquake Estimated Potential Losses to Buildings (Structure and Contents) HAZUS-MH 2,500 Year Scenario

County	2,500 Year Event		
	Structure Loss	Content Loss	Total Building Loss
Atlantic	$68,835,000	$79,200,000	$148,035,000
Bergen	$345,136,000	$799,036,000	$1,144,172,000
Burlington	$159,875,000	$242,799,000	$402,674,000
Camden	$68,835,000	$241,638,000	$310,473,000
Cape May	$27,255,000	$26,703,000	$53,958,000
Cumberland	$51,445,000	$67,812,000	$119,257,000
Essex	$193,075,000	$509,080,000	$702,155,000
Gloucester	$110,517,000	$180,267,000	$290,784,000
Hudson	$151,058,000	$376,465,000	$527,523,000
Hunterdon	$46,181,000	$84,779,000	$130,960,000
Mercer	$152,776,000	$266,497,000	$419,273,000
Middlesex	$362,943,000	$751,909,000	$1,114,852,000
Monmouth	$250,955,000	$466,978,000	$717,933,000
Morris	$138,141,000	$333,487,000	$471,628,000
Ocean	$144,094,000	$217,462,000	$361,556,000
Passaic	$121,844,000	$304,667,000	$426,511,000
Salem	$33,863,000	$52,296,000	$86,159,000
Somerset	$141,980,000	$278,067,000	$420,047,000
Sussex	$30,460,000	$59,922,000	$90,382,000
Union	$197,854,000	$422,226,000	$620,080,000
Warren	$25,333,000	$44,496,000	$69,829,000
Total	**$2,822,455,000**	**$5,805,786,000**	**$8,628,241,000**

Source: HAZUS-MH v6.0

Table 4.5-12 Earthquake Estimated Potential Losses to Buildings (Structure and Contents) HAZUS-MH Annualized

County	Average Annual Loss		
	Structure Loss	Content Loss	Total Building Loss
Atlantic	$80,000	$67,000	$147,000
Bergen	$435,000	$682,000	$1,117,000
Burlington	$207,000	$211,000	$418,000
Camden	$192,000	$205,000	$397,000
Cape May	$30,000	$21,000	$51,000
Cumberland	$59,000	$57,000	$116,000
Essex	$235,000	$419,000	$654,000
Gloucester	$138,000	$152,000	$290,000
Hudson	$189,000	$317,000	$506,000
Hunterdon	$55,000	$67,000	$122,000
Mercer	$200,000	$233,000	$433,000
Middlesex	$462,000	$650,000	$1,112,000
Monmouth	$311,000	$392,000	$703,000
Morris	$163,000	$265,000	$428,000
Ocean	$178,000	$184,000	$362,000
Passaic	$149,000	$252,000	$401,000
Salem	$40,000	$43,000	$83,000
Somerset	$177,000	$235,000	$412,000
Sussex	$35,000	$46,000	$81,000
Union	$255,000	$370,000	$625,000
Warren	$29,000	$34,000	$63,000
Total	**$3,619,000**	**$4,902,000**	**$8,521,000**

Source: HAZUS-MH v6.0

Lifeline Impacts

FEMA created the eight Community Lifelines to contextualize information from incidents, communicate impacts in plain language, and promote a more unified effort across a community that focuses on stabilizes these lifelines during response. More information on these lifelines can be found in Section 4.1: Risk Assessment Overview. Table 4.5-13 showcases the most likely lifelines to be impacted by earthquake, including a short description of anticipated impacts.

Table 4.5-13 Lifelines Most Likely Impacted by Earthquake

Lifeline Categories	Notable Impacts
Safety and Security	Community safety may be threatened due to potential direct harm from earthquakes and compounding effects on administration of services. Transportation infrastructure issues may directly impact the abilities of law enforcement, fire service, search and rescue, and other government services to respond to an earthquake hazard.
Food, Hydration, Shelter	Earthquakes can cause damage to structures which provide shelter, while the food supply chain may be disrupted due to impacts on transportation infrastructure. Drinking water delivery may be impacted and access to alternative sources difficult due to competition.
Health and Medical	Potential Impacts to the Health and Medical lifeline can a result of physical damage to medical structures and impacts on transportation or energy infrastructure. Medical facilities can be impacted due to power disruptions or damage to structures from earthquakes, while patient movement and medical supply chains can be impacted by damage to transportation infrastructure.
Energy	Earthquakes have the potential to cause direct damage to infrastructure and its ability to provide power to the grid. Additionally, this could result in potential increases in fuel usage for those who lost access to electrical heating.

Lifeline Categories	Notable Impacts
Communications	Earthquakes can pose a threat to communications systems. Many types of communications equipment are impacted by power failures or destruction of communication lines. Wi-Fi and cellular data infrastructure can be crippled in such cases leaving many without access to communication lifelines.
Transportation	Anticipated impacts for the Transportation lifeline consist largely of direct damage to infrastructure. Ground shaking can directly cause physical damage to various components of the transportation systems, including structural damage to facility buildings, bridges, signal systems, overpasses, tunnels, and derailment of trains. Damage to this lifeline causes a cascading effect among most others.
Hazardous Materials	Hazardous Materials facilities could be impacted by power disruptions due to effects to energy infrastructure. Transport of hazardous materials can be impacted by transportation infrastructure issues and dangerous road conditions including the potential for spills or releases.
Water Systems	Earthquakes could pose a threat to the Water System lifeline. Water infrastructure in the ground such as pipes and above ground infrastructure including aqueducts, pumping stations, and water treatment plants can be directly damaged.

Population and the Economy

Economic Impacts

Earthquakes have the potential to impact economies at both the local and regional scale. Losses can include structural and non-structural damage to buildings, loss of business function, damage to inventory, relocation costs, wage loss, and rental loss caused by the repair and replacement of buildings. Roads that cross earthquake-prone soils have the potential to be significantly damaged during an earthquake event, potentially impacting commodity flows. Additionally, economic loss includes business interruption losses associated with the inability to operate a business because of damage sustained during an earthquake, as well as temporary living expenses for those displaced. These losses are presented in Table 4.5-14.

Table 4.5-14 Estimated Potential Economic Losses for New Jersey

Loss Category	500 Year Event	1,000 Year Event	2,500 Year Event	Annualized
Income Losses				
Wage	$99,665,000	$270,148,000	$847,933,000	$1,097,000
Rental Loss	$84,739,000	$226,803,000	$692,621,000	$885,000
Relocation	$170,711,000	$477,737,000	$1,538,270,000	$1,894,000
Subtotal	$355,115,000	$974,688,000	$3,078,824,000	$3,876,000
Capital Stock Losses				
Structural	$338,684,000	$927,550,000	$2,905,511,000	$3,618,000
Non-Structural	$645,356,000	$2,643,825,000	$11,345,600,000	$10,803,000
Content	$196,912,000	$1,132,195,000	$5,805,786,000	$4,901,000
Inventory	$12,998,000	$74,801,000	$360,092,000	$316,000
Subtotal	$1,193,950,000	$4,778,371,000	$20,416,989,000	$19,638,000
Total	**$1,549,065,000**	**$5,753,059,000**	**$24,091,154,000**	**$23,514,000**

Source: HAZUS-MH v.6.0

Population and Changes in Development

The entire population of New Jersey is potentially exposed to direct and indirect impacts from earthquakes. The degree of exposure is dependent on many factors, including the age and construction type of the structures people live in, the soil types their homes are constructed on, and their proximity to fault locations.

The entire population of New Jersey is exposed to the risk posed by an earthquake event; however, populations considered most vulnerable include the elderly (persons over the age of 65) and individuals living below the United States 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, the location and construction quality of their housing, and the ability to be self-sustaining for prolonged periods of time after an incident because of limited ability to stockpile supplies. Section 3.0 State Profile, of this HMP summarizes the State's demographics.

Residents may be displaced or may require temporary to long-term sheltering because of an earthquake 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. This number was estimated for 500-, 1000-, and 2500-year earthquakes through the HAZUS-MH v.6.0 analysis; results of these analyses are summarized in Table 4.5-15.

Table 4.5-15 Estimated Shelter Requirements HAZUS-MH Probabilistic Scenario

County	Number of People Needing Short-Term Shelter		
	500 Year Event	1,000 Year Event	2,500 Year Event
Atlantic	10	33	113
Bergen	54	177	647
Burlington	20	63	227
Camden	31	98	363
Cape May	2	6	22
Cumberland	7	23	85
Essex	69	237	897
Gloucester	11	36	137
Hudson	65	220	833
Hunterdon	3	9	35
Mercer	28	87	310
Middlesex	53	178	665
Monmouth	27	90	337
Morris	12	44	171
Ocean	24	78	283
Passaic	41	141	529
Salem	3	10	40
Somerset	15	51	187
Sussex	2	6	26
Union	48	154	560
Warren	2	7	28
Total	**527**	**1,749**	**6,495**

Source: HAZUS-MH v6.0

Ecosystems and Natural Lands

Earthquakes can cause disastrous environmental impacts. In summary, earthquake events may trigger landslides, mudslides, slope failure, dam failures, and tsunamis. Each of these secondary events can also be devastating to the environment. Refer to the Secondary Hazards subsection presented earlier for a more detailed discussion of these secondary events and their impacts on the environment. Further, refer to Sections 4.3 Dam and Levee Failure and 4.8 Geologic Hazards for additional information.