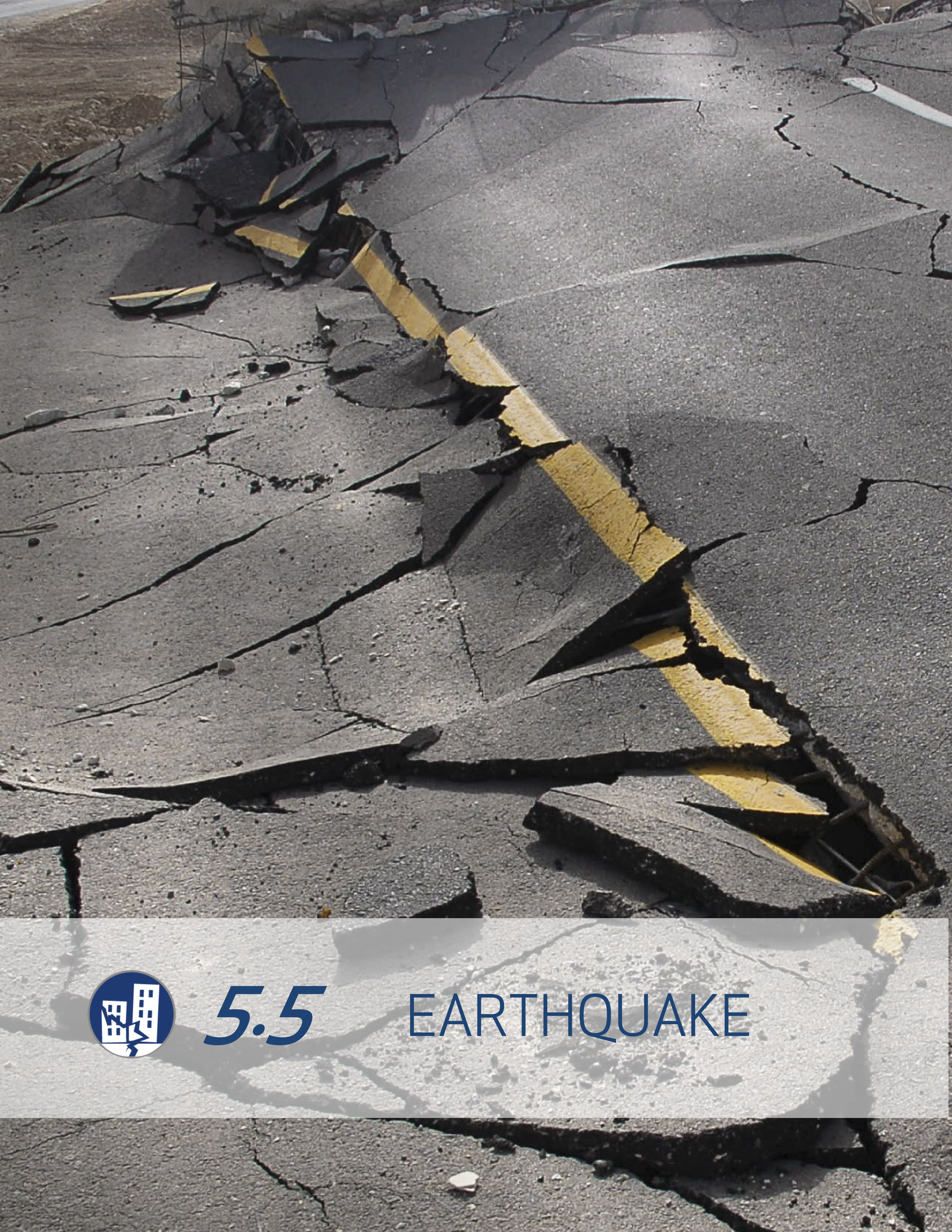


5.5 EARTHQUAKE

SECTION 5.5 EARTHQUAKE

5.5.1 HAZARD DESCRIPTION

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

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

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 5.5-1, 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 5.5-1 NEHRP Soil Classifications

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

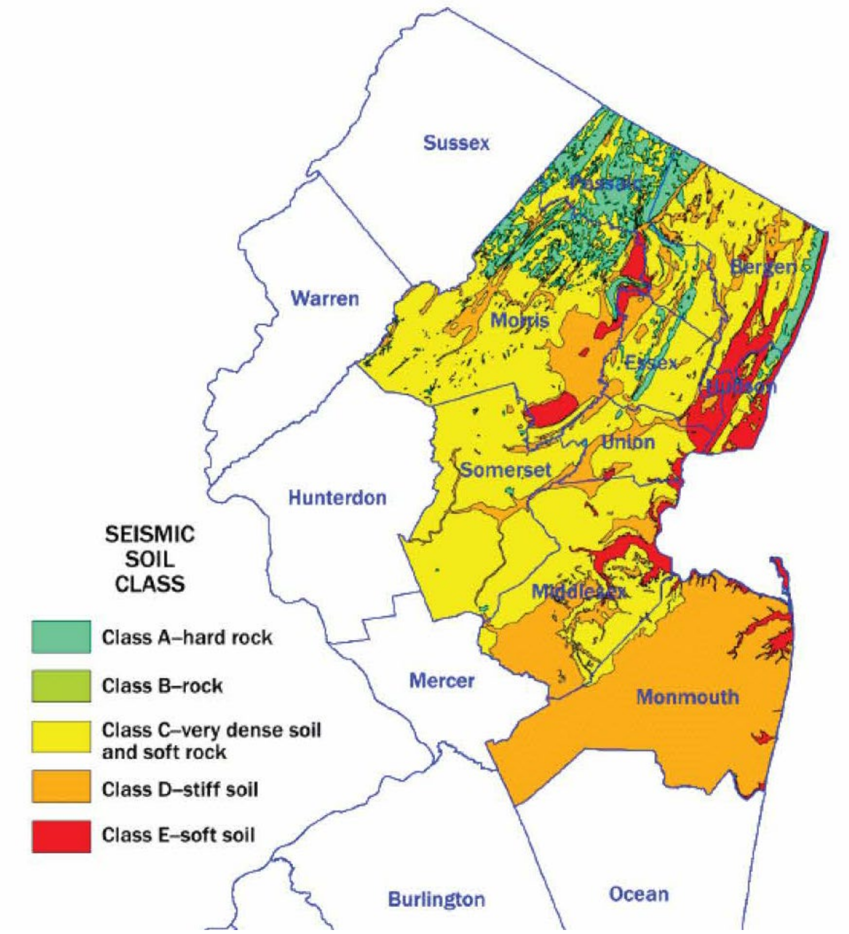
Source: FEMA 2013

5.5.2 LOCATION

Earthquakes are most likely to occur in the northern parts of New Jersey, where significant faults are concentrated; however, low-magnitude events can and do occur in many other areas of the State. Figure 5.5-1 illustrates the NEHRP soils located in the northeast quadrant the State. The data was 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 (discussed in further detail later in this section).

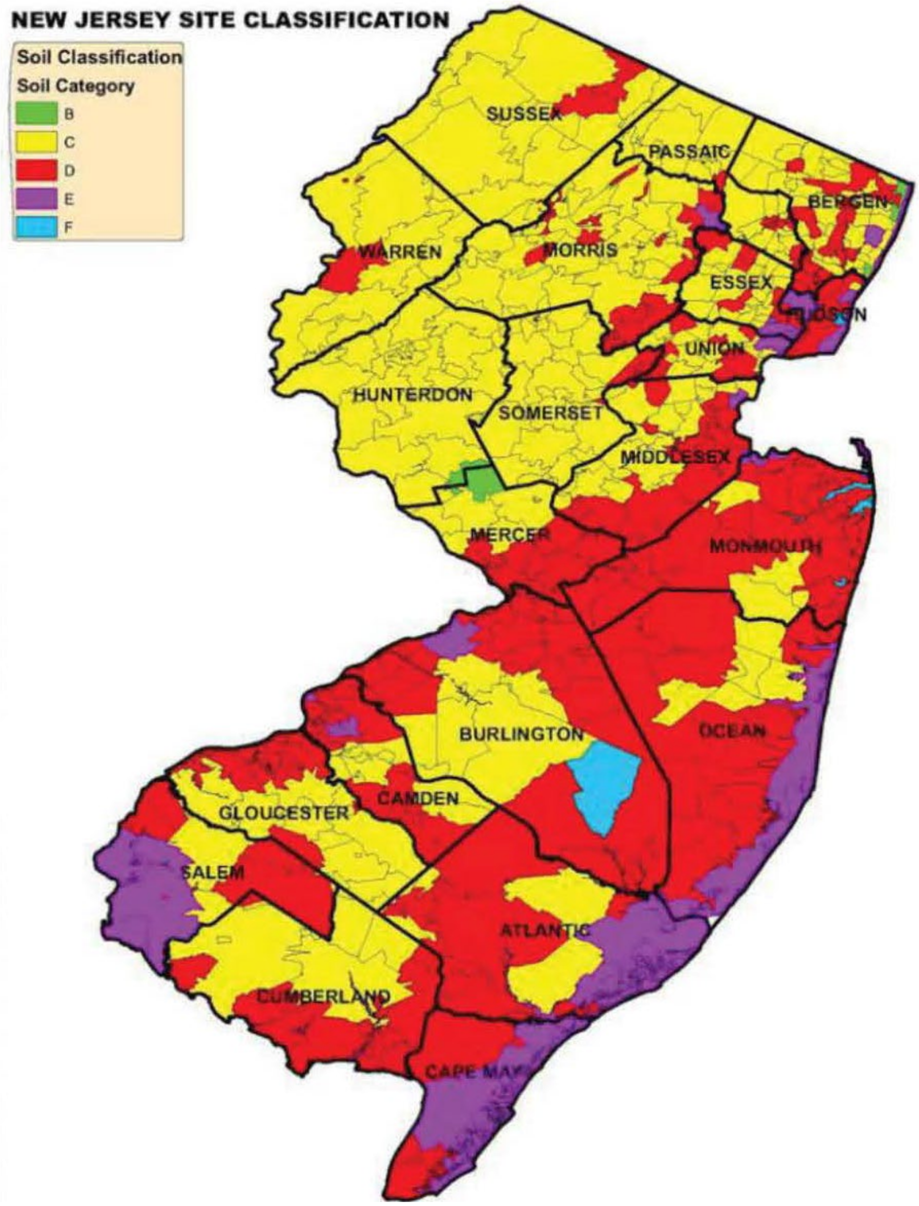
New Jersey Department of Transportation (NJDOT) compiled a report on seismic design consideration for bridges in New Jersey, dated March 2012. In the report, NJDOT classifies the seismic nature of soils according to the American Association of State Highway and Transportation Officials (AASHTO) Guide 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 a large number of 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; the ZIP code-based soil site class map for New Jersey is included as Figure 5.5-2.

Figure 5.5-1 Seismic Soils in Northeastern New Jersey



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

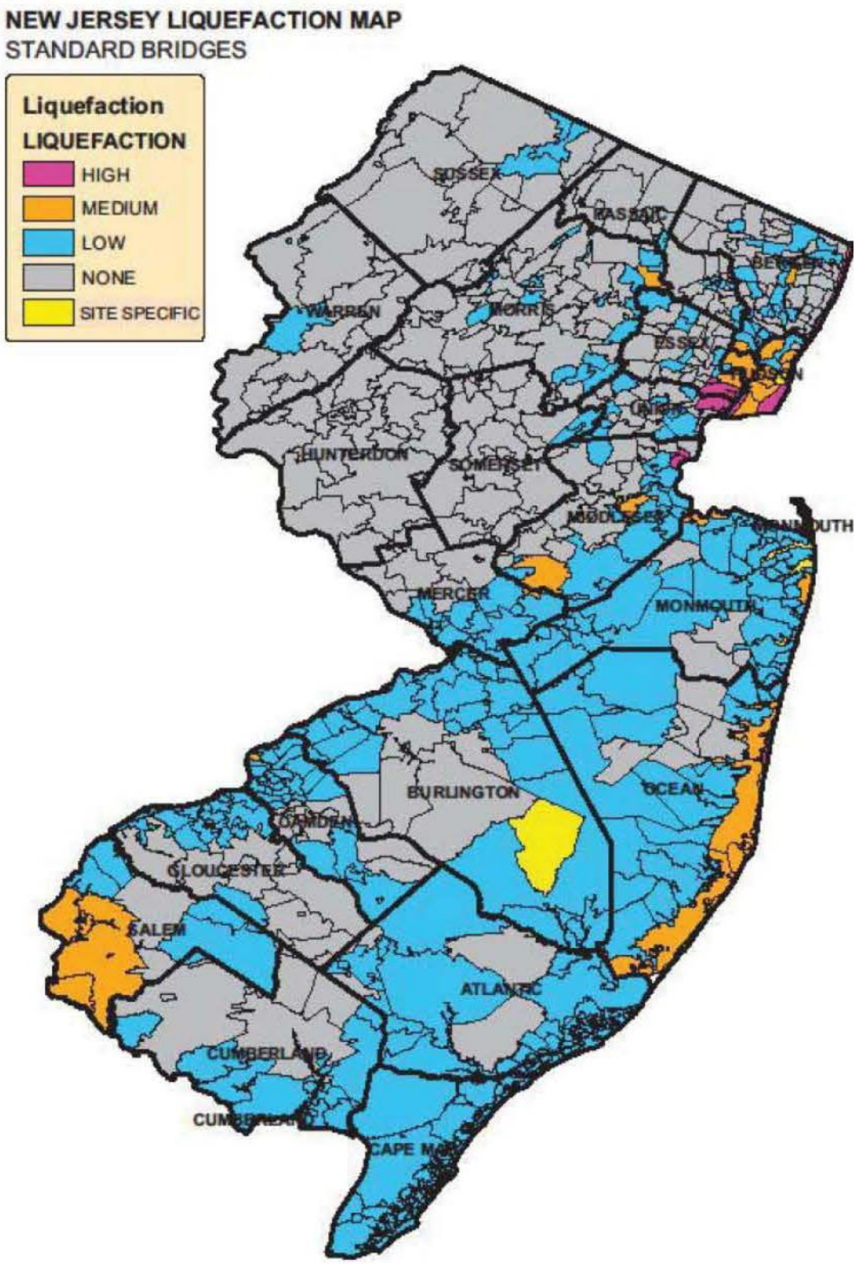
Figure 5.5-2 ZIP Code-Based Soil Site Class Map



Source: NJDOT, 2012
Note: 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

Also, in this report, if a ZIP code belonged to site class D or E has few or no soil boring logs, its liquefaction hazard was determined using an approach similar to that used for determining its site class. 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. Figure 5.5-3 illustrates the liquefaction map for New Jersey.

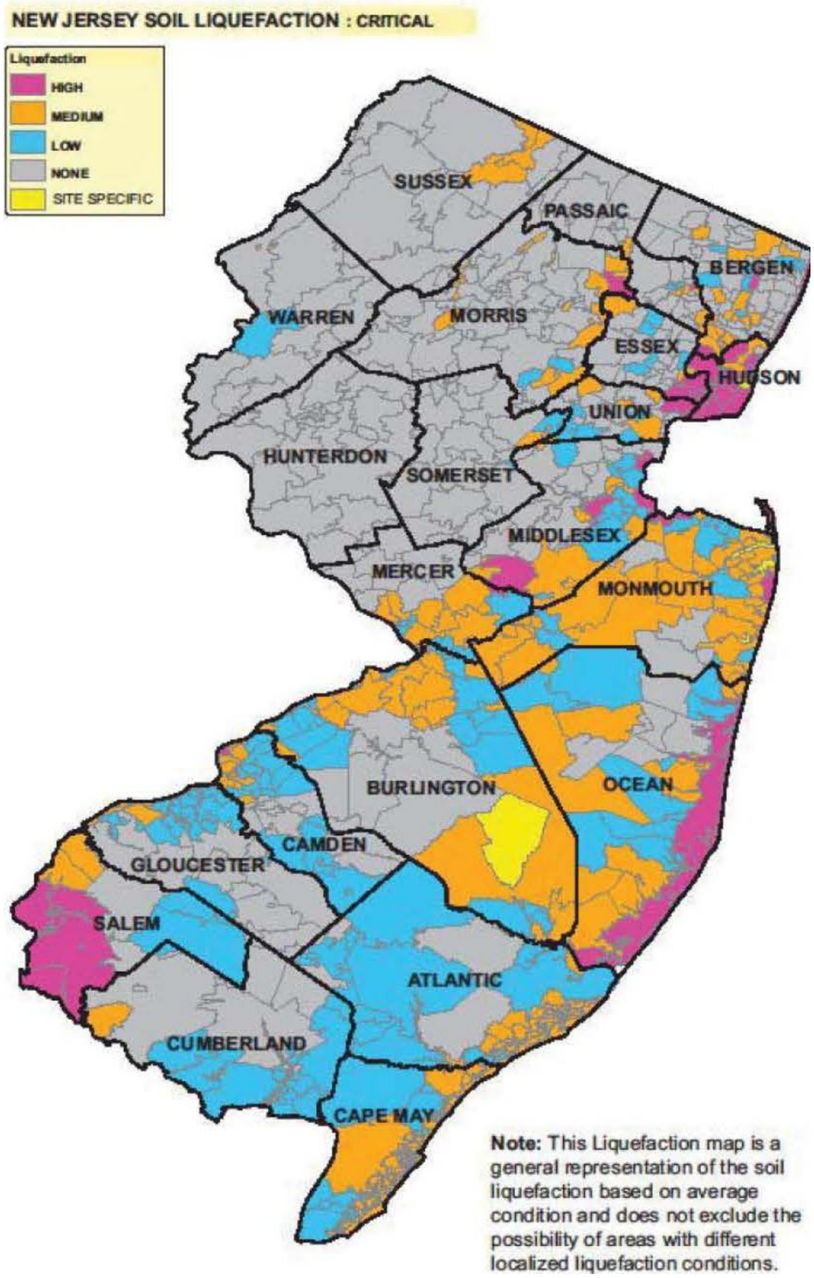
Figure 5.5-3 Liquefaction Map of New Jersey for Standard Bridges



Source: NJDOT, 2012

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. Compared to the hazard for 1,000-year earthquake, the areas with "medium" liquefaction hazard are classified as "high," and some areas with "low" hazard have "medium" liquefaction hazard. Figure 5.5-4 presents the liquefaction hazard map for critical bridges in New Jersey.

Figure 5.5-4 Liquefaction Hazard Map of New Jersey for Critical Bridges

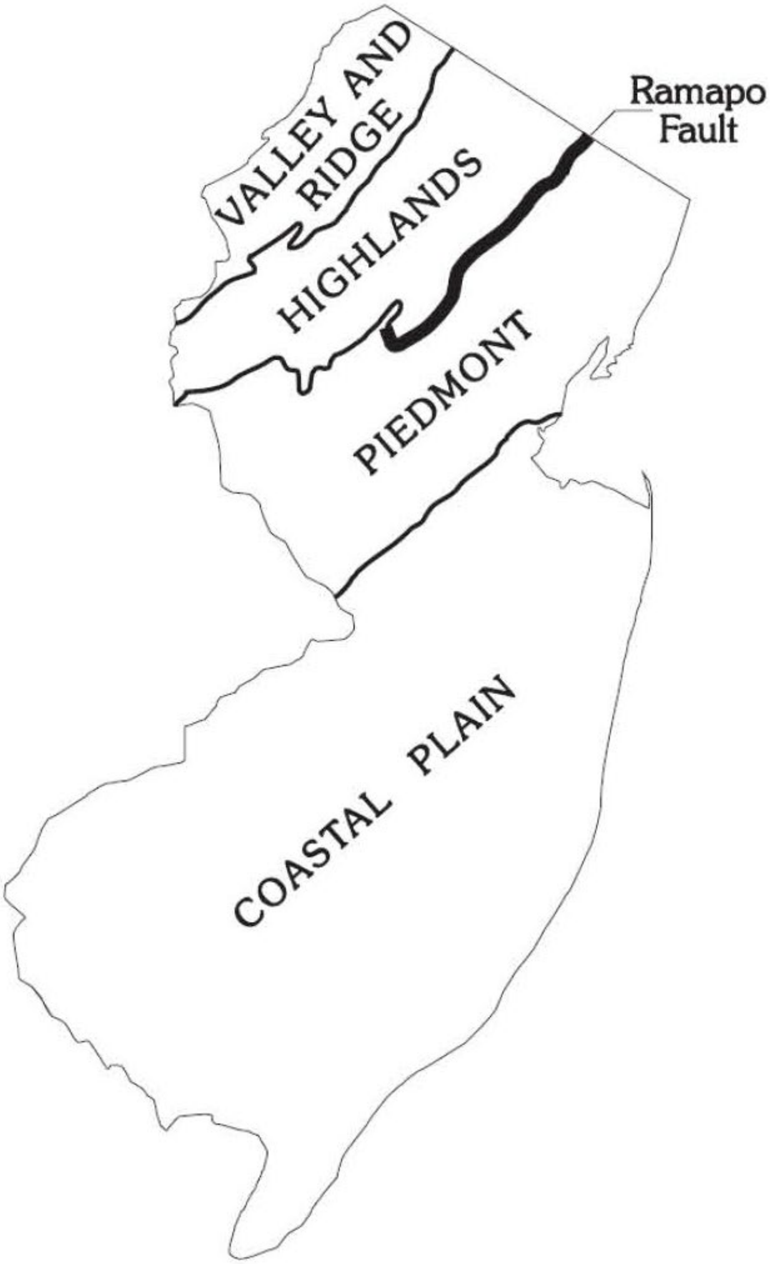


Source: NJDOT, 2012

Faults are observed and mapped at the surface. There is no known surface ground displacement along faults in the eastern United States from historic earthquakes. Earthquake epicenters in eastern North America and the New Jersey area, in general, do not now occur on known faults. The faults in these parts 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 5.5-5 illustrates the relationship of the Ramapo fault line with the physiologic provinces of New Jersey.

Figure 5.5-5 Physiographic Provinces of New Jersey and the Ramapo Fault Line



Source: Dombroski 1973 (revised 2005)

Figure 5.5-6 Seismic Hazard in NJ

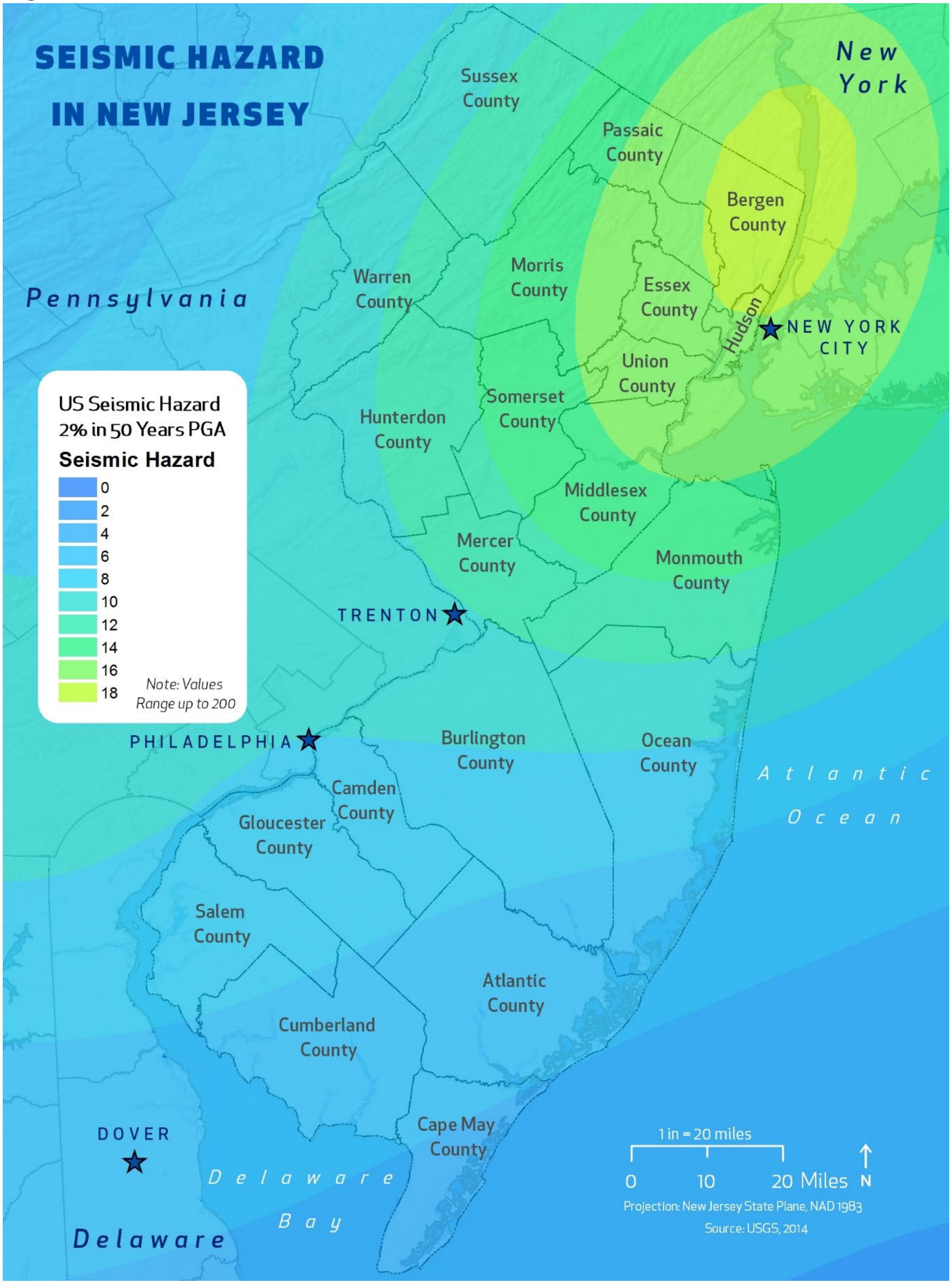
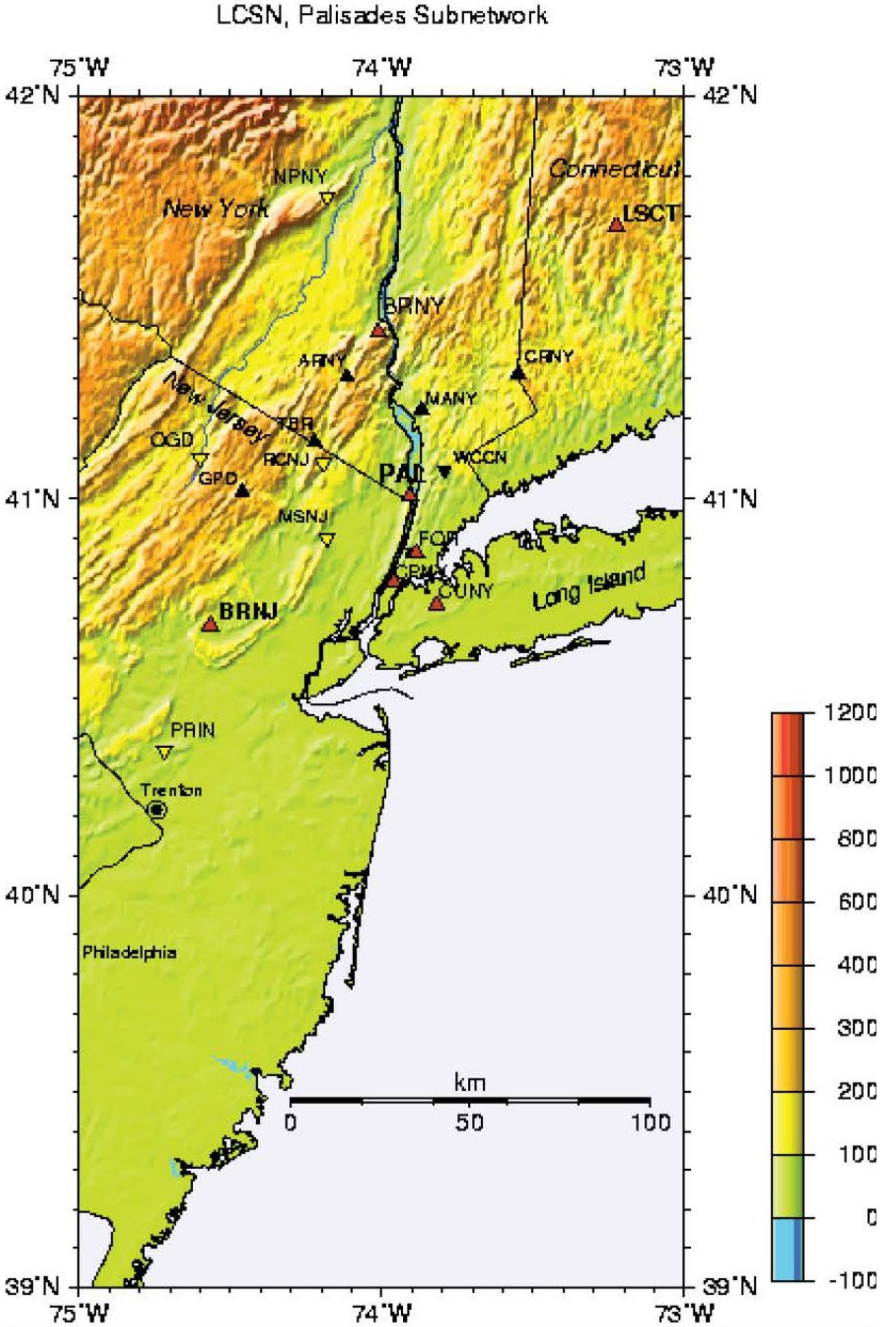


Figure 5.5-7 New Jersey Lamont-Doherty Seismic Stations Locations

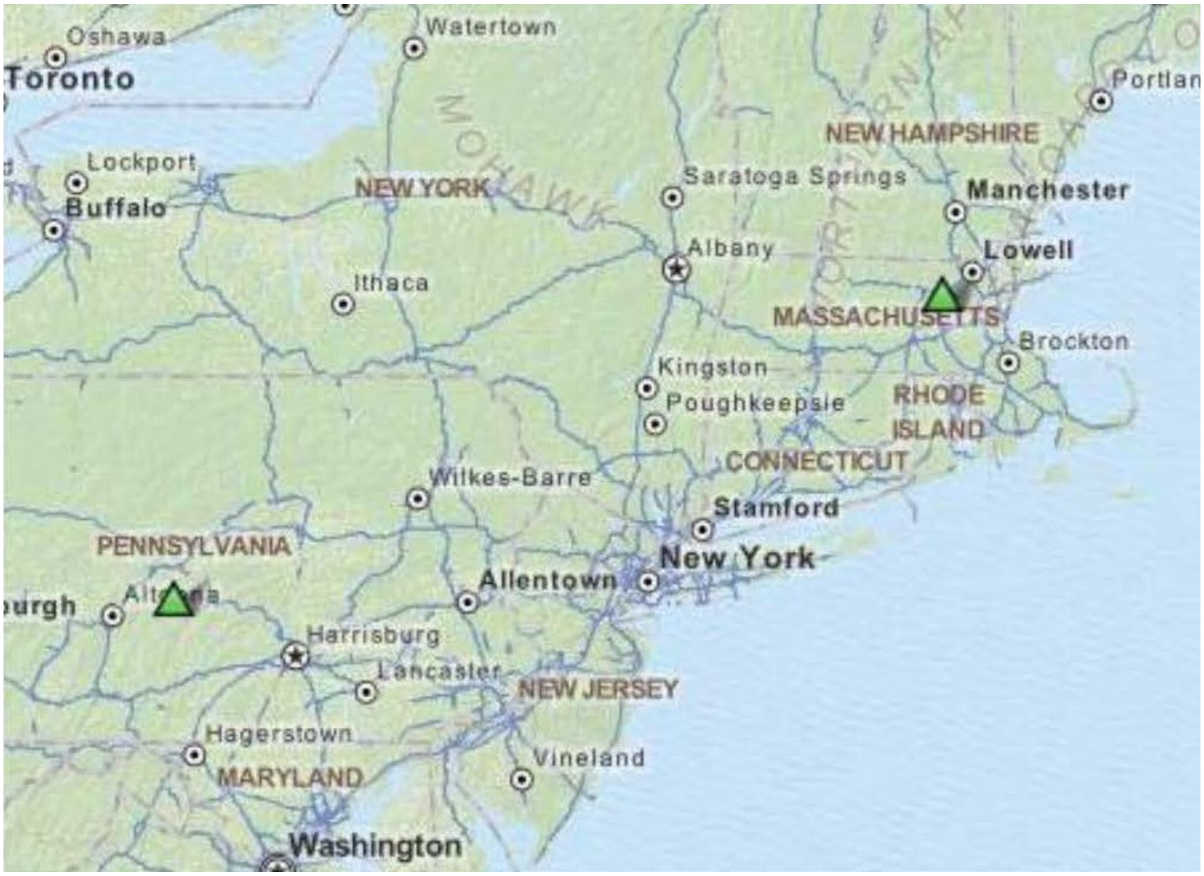


Source: LCSN, 2006

The Lamont-Doherty Cooperative Seismographic Network (LCSN) monitors earthquakes that occur primarily in the northeastern United States. The goal of the project is to compile a complete earthquake catalog for this region, to assess the earthquake hazards, and to study the causes of the earthquakes in the region. The LCSN operates 40 seismographic stations in the following seven states: Connecticut, Delaware, Maryland, New Jersey, New York, Pennsylvania, and Vermont. In New Jersey, there are several Lamont-Doherty Seismic Stations as part of the Palisades Sub-Network, as shown in Figure 5.5-7. The network is composed of broadband and short-period seismographic stations (LCSN, 2012a).

In addition to the Lamont-Doherty Seismic Stations, the USGS operates a global network of seismic stations to monitor seismic activity. While no seismic stations are located in New Jersey, nearby stations are positioned in State College, Pennsylvania and New Haven, Connecticut. Figure 5.5-8 shows locations of USGS seismic stations near New Jersey.

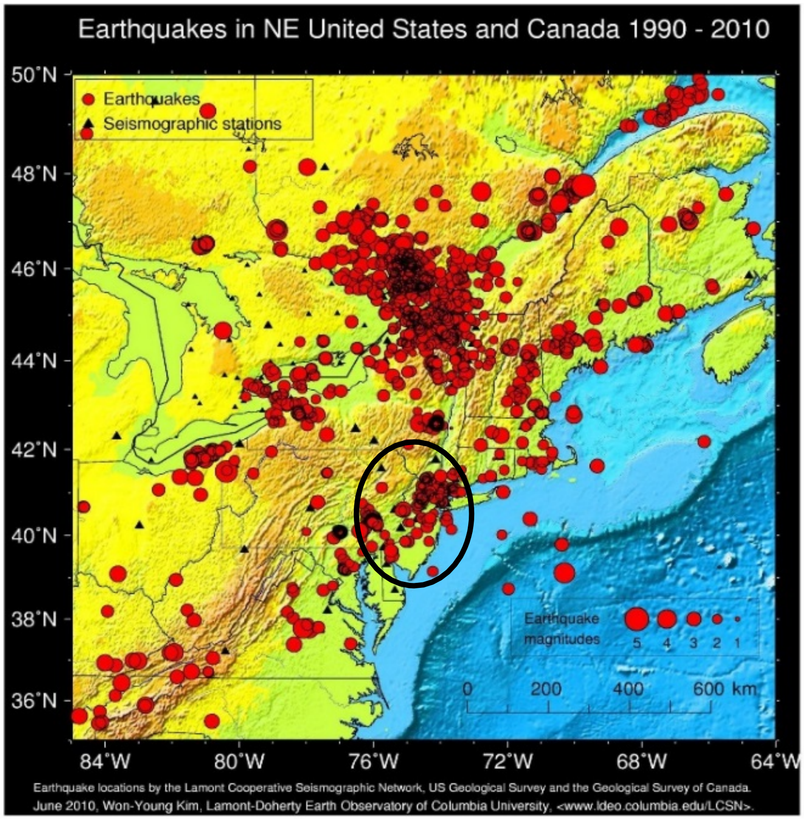
Figure 5.5-8 USGS Seismic Stations near New Jersey



Source: USGS, 2012

Earthquakes above a 5.0 magnitude have the potential for causing damage near their epicenters, and larger-magnitude earthquakes have the potential for causing damage over larger, wider areas. In New Jersey history, the earthquake with the highest magnitude occurred in 1783 with an epicenter west of New York City. This earthquake had a magnitude of 5.3. Earthquakes seem to occur with regularity across New Jersey. As mentioned earlier, earthquakes are concentrated along the Ramapo Fault System; however, earthquakes have occurred as far south as Salem County. A full discussion of past occurrences of earthquakes in New Jersey is presented in the following section. Figure 5.5-9 illustrates earthquake activity in the northeastern United States from 1990 – 2010, with New Jersey circled in black.

Figure 5.5-9 Earthquake Epicenters in the Northeast 1990 – 2010



Source: LCSN, 2010

5.5.3 EXTENT

Seismic waves are the vibrations from earthquakes that travel through the Earth and are recorded on instruments called seismographs. The magnitude or extent of an earthquake is a measured value of the earthquake size, or amplitude of the seismic waves, using a seismograph. 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 express damage. An earthquake in a densely populated area, which results in many deaths and considerable damage, may have the same magnitude and shock in a remote area that did not experience any damage. Table 5.5-2 presents the Richter scale magnitudes and corresponding earthquake effects.

Table 5.5-2 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 5.5-3 summarizes earthquake intensity as expressed by the Modified Mercalli scale. Table 5.5-4 displays the Modified Mercalli scale and peak ground acceleration equivalent.

Table 5.5-3 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 polesmay 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 5.5-4 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 5.5-5.

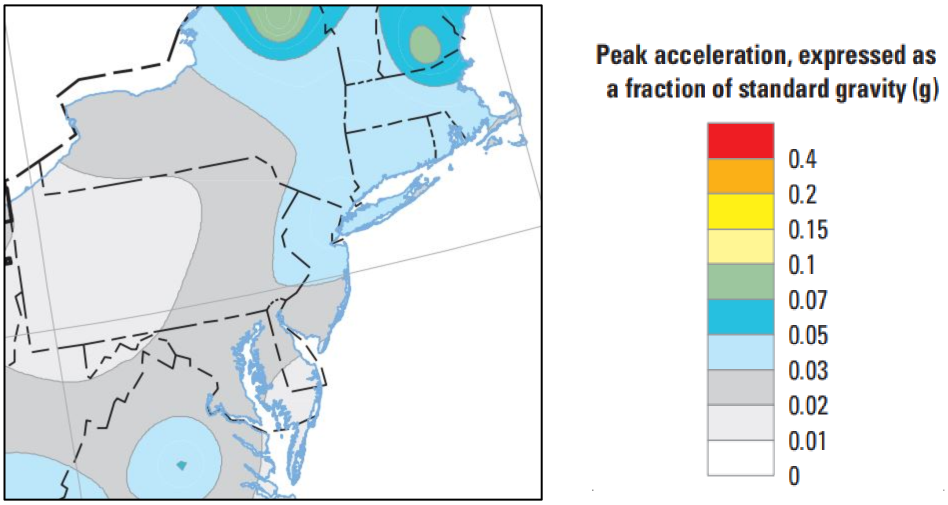
Table 5.5-5 Damage Levels Experienced in Earthquakes

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

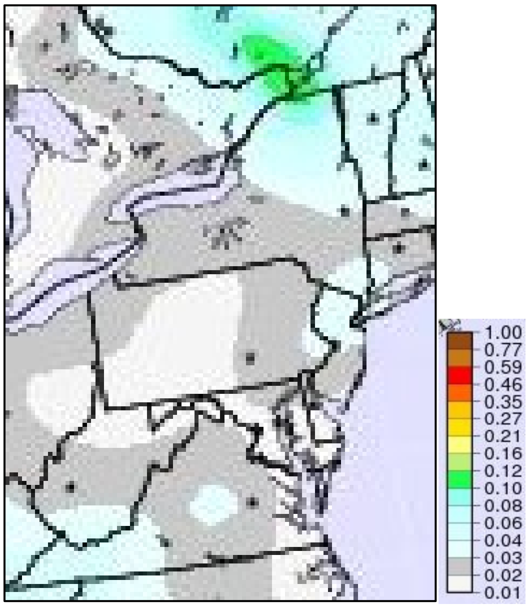
According to USGS Earthquake Hazards Program, PGA maps (also known as earthquake hazard maps) are used as planning tools when designing buildings, bridges, highways, and utilities so that they can withstand shaking associated with earthquake events. These maps are also used as planning tools for the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

Figure 5.5-10 2014 Seismic Hazard Map, PGA with 10% Probability of Exceedance in 50 Years



Source: USGS, 2014

Figure 5.5-11 2008 Seismic Hazard Map, PGA with 10% Probability of Exceedance in 50 Years



Source: USGS, 2008

The USGS updated the National Seismic Hazard Maps in 2014, which supersede 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, presented as Figure 5.5-10, represents the best-available data as determined by the USGS (USGS, 2014). The 2008 Seismic Hazard Map shows that New Jersey has a PGA between 1%g and 4%g (Figure 5.5-10). The 2014 Seismic Hazard Map shows that New Jersey has a PGA between 1%g and 5%g (Figure 5.5-11). These maps are based on peak ground acceleration (%g) with 10% probability of exceedance in 50 years.

5.5.4 PREVIOUS OCCURRENCES AND LOSSES

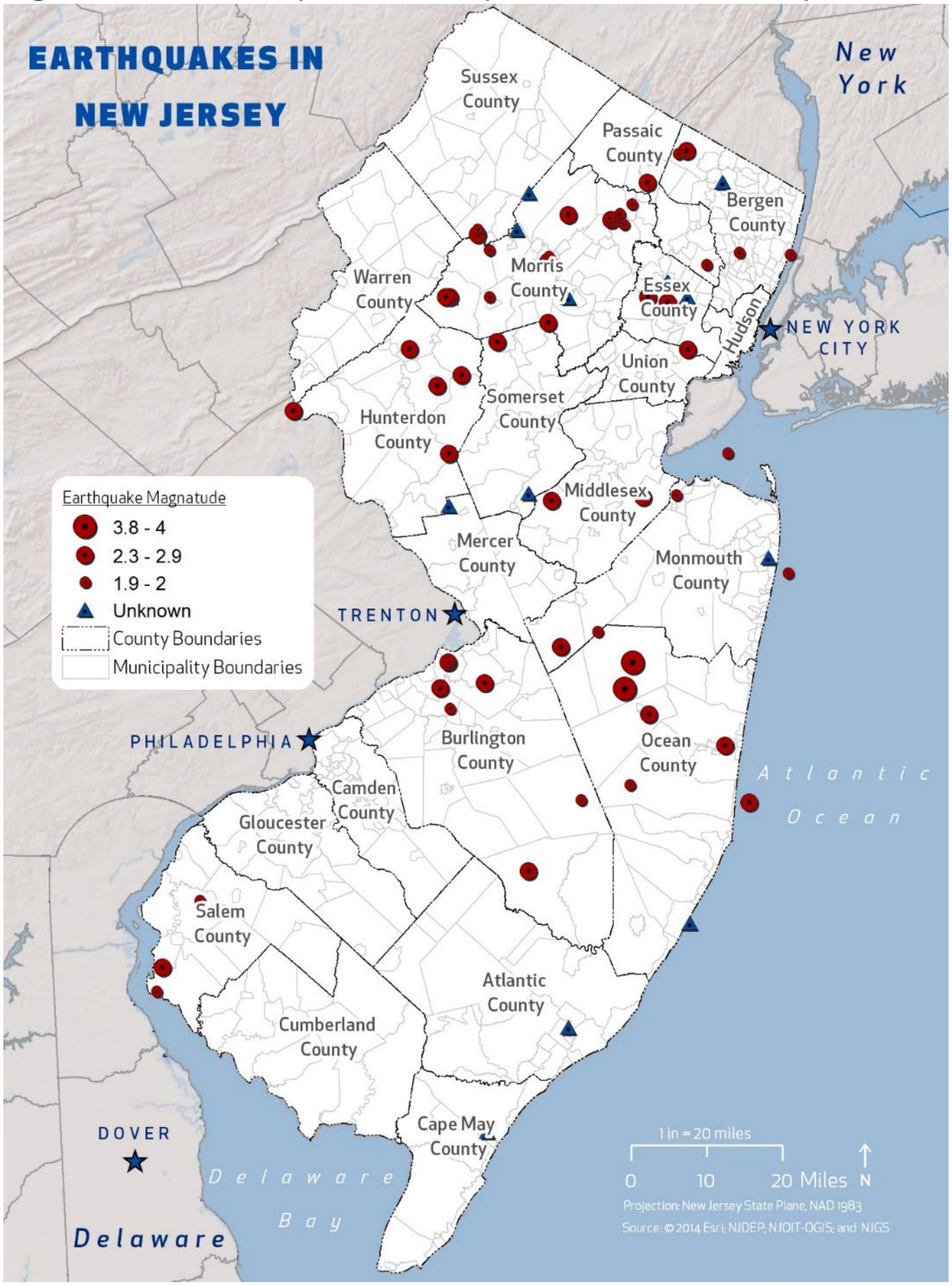
New Jersey has a fairly extensive history of earthquakes, mostly because of the factors discussed previously in the location section. Small earthquakes occur several times a year and generally do not cause significant damage. The largest earthquake to impact New Jersey occurred in 1783. That earthquake, a magnitude 5.3 quake, occurred west of New York City and was felt from New Hampshire to Pennsylvania (Stover and Coffman, 1993).

Many sources provided historical information regarding previous occurrences and losses associated with earthquake events throughout the State of New Jersey. With so many sources reviewed for the purpose of this HMP, loss and impact information for many events could vary depending on the source. Therefore, the accuracy of monetary figures discussed is based only on available information identified during research for this HMP update. Table 5.8-6 outlines the history of earthquake events in New Jersey.

There have been four historic earthquakes that caused damage in the State: 1737 (New York City), 1783 (west of New York City), 1884 (New York City), and 1927 (New Jersey coast near Asbury). Damages in New Jersey were relatively minor from these events, including building damage such as chimney collapse and objects falling from shelves. The 2014 Plan also stated that New Jersey has felt several large earthquakes that caused major damage near their epicenters: 1755 (Cape Ann, Massachusetts), 1886 (Charleston, South Carolina), and three large earthquakes near New Madrid, Missouri (December 16, 1811; January 23, 1812; and February 7, 1812).

For this Plan update, earthquake events will be further discussed that occurred in the State between January 1, 2010 and December 31, 2017. Table 5.5-6 lists earthquakes that had epicenters in New Jersey from 1783 through 2017. Figure 5.5-12 maps these epicenters. Incidents occurring prior to 2010 are based on the previous HMP and other research, including events recorded by the New Jersey Geological and Water Survey (NJGWS) and United States Geological Survey (USGS).

Figure 5.5-12 Earthquakes with Epicenters in New Jersey, 1783 to 2017



Source: NJDEP, 2017

Table 5.5-6 Earthquake Incidents that Impacted New Jersey, 1737 to 2017

Date(s)	Magnitude	Location	Losses/Impacts
12/19/1737	5.2	Greater NYC Area*	Threw down chimneys
11/30/1783	5.3	North-Central New Jersey*	Two foreshocks (11/24 and 11/30) and one aftershock (11/30); threw down chimneys
1/25/1841	0.0	West Orange, NJ	No reference and/or no damage reported.
10/26/1845	3.8	Greater NYC Area*	No reference and/or no damage reported.
9/9/1848	4.4	Greater NYC area*	No reference and/or no damage reported.
3/5/1861	0.0	Newark, NJ	No reference and/or no damage reported.
12/11/1874	3.4	Near Nyack and Tarrytown, NY	No reference and/or no damage reported.
9/10/1877	0.0	Burlington, NJ	No reference and/or no damage reported.
8/10/1880	0.0	Near Morristown, NJ	1 aftershock 9/1/1880.
8/10/1884	5.2	Greater NYC Area	Threw down chimneys; felt from Virginia to Maine
1/4/1885	3.4	Hudson Valley	No reference and/or no damage reported.
9/1/1895	4.1	Near High Bridge, NJ	Felt over a considerable area to the northeast and southwest. The total felt area covered points from Maine to Virginia in a long, narrow elliptical zone of about 92,000 square kilometers. Articles fell from shelves and buildings rocked (intensity VI) in several Hunterdon County towns. The shock was fairly sharp at Camden and Burlington. At Philadelphia, Pennsylvania, broken windows and overturned crockery were reported.
5/27/1902	0.0	Bayonne-Wayne, NJ	No reference and/or no damage reported.
8/11/1902	0.0	Bayonne-Wayne, NJ	No reference and/or no damage reported.
1/20/1905	4.5	Greater NYC Area*	Probably located offshore
4/23/1910	0.0	Near Atlantic City, NJ	No reference and/or no damage reported.
11/6/1912	0.0	Near Long Beach, NJ	No reference and/or no damage reported.
8/5/1919	0.0	Cinnaminson, NJ	No reference and/or no damage reported.
6/1/1927	3.9	Near Asbury Park, NJ	Occurred in the Asbury Park area. Three shocks were felt along the coast from Sandy Hook to Toms River. Maximum intensities of VII were observed at Asbury Park and Long Branch. Several chimneys fell, plaster cracked, and articles were thrown from shelves. The felt area extended over approximately 7,800 square kilometers.
1/25/1933	0.0	Near Trenton, NJ	A sharp jolt was felt over central New Jersey from Lakehurst to Trenton. Although there is some doubt whether the shock was of seismic origin, the event was felt most strongly at Lakehurst, where people reported they were rolled out of bed (intensity V). Other people reported pictures shaken from walls. The shock was also felt at Bordentown, Burlington, Columbus, Englishtown, Freehold, Hightstown, New Egypt, Robbinsville, and White Horse.
7/19/1937	3.5	Western Long Island, NY	One or few earthquakes beneath Long Island
9/30/1937	0.0	Verona, NJ	No reference and/or no damage reported.
5/16/1938	0.0	Verona, NJ	No reference and/or no damage reported.

Date(s)	Magnitude	Location	Losses/Impacts
8/23/1938	3.8	Northeast of New Egypt, NJ	Caused minor damage at Gloucester City and Hightstown (intensity V). The total felt area was about 13,000 square kilometers, including bordering portions of Delaware and Pennsylvania. Glassware was broken at Gloucester City and Hightstown and some furniture was displaced at Pitman. A few windows and some glassware were reported broken at Ardmore, Pennsylvania. Four smaller shocks occurred on 8/23 and one on 8/26.
8/23/1938	4.0	Freehold, NJ	4 aftershocks felt.
12/6/1938	0.0	Verona, NJ	No reference and/or no damage reported.
9/13/1939	0.0	Union City, NJ	No reference and/or no damage reported.
11/15/1939	3.4	Salem County, NJ	The disturbance was reportedly felt from Trenton to Baltimore, Maryland, and from Cape May to Philadelphia and its adjoining counties. About 16,000 square kilometers were affected. Small objects were reported to have overturned at Deepwater, but little or no damage was noted.
4/1/1947	2.7	Pompton Lakes NJ	No reference and/or no damage reported.
10/16/1949	0.0	Hopewell, NJ	No reference and/or no damage reported.
9/3/1951	3.6	Rockland County, NY	Northeastern New Jersey experienced minor effects.
8/17/1953	3.2	Bergen County, NJ	No reference and/or no damage reported.
3/31/1954	0.0	Long Branch, NJ	No reference and/or no damage reported.
3/23/1957	2.9	Schooley's Mountain, NJ	A shock affected west-central New Jersey, near the site of the 1895 earthquake. Chimneys cracked (intensity VI), windows and dishes broke, and pictures fell at Lebanon. A cracked chimney was also reported from Hamden. At Long Valley, some walls were cracked and plaster fell. The felt area was small in comparison with the other shocks previously described.
12/27/1961	2.7	5 km W of Flemington, NJ	No reference and/or no damage reported.
10/13/1962	0.0	Pompton Lakes, NJ	No reference and/or no damage reported.
12/10/1968	2.7	Southeast of Camden, NJ	No reference and/or no damage reported.
4/25/1969	0.0	Near Sussex, NJ	No reference and/or no damage reported.
10/6/1969	0.0	Ogdensburg, NJ	No reference and/or no damage reported.
2/28/1973	3.5	East of Wilmington, DE	No reference and/or no damage reported.
7/10/1973	2.6	East of Wilmington, DE	No reference and/or no damage reported.
3/11/1976	2.8	Pompton Lakes, NJ	1 aftershock, some damage
4/13/1976	3.1	Near Ridgefield, NJ	The shock was felt widely.
12/5/1976	0.0	N/A	No reference and/or no damage reported.
12/5/1976	1.8	Schooley's Mountain, NJ	1 aftershock felt on 12/07
1/21/1977	2.7	Lakehurst, NJ	No reference and/or no damage reported.
6/10/1977	1.1	High Bridge, NJ	No reference and/or no damage reported.
7/2/1977	2.3	Hampton, NJ	No reference and/or no damage reported.
10/27/1977	1.5	Sparta, NJ	No reference and/or no damage reported.
11/27/1977	1.8	Oakland, NJ	No reference and/or no damage reported.

Date(s)	Magnitud e	Location	Losses/Impacts
12/23/1977	2.3	Schooley's Mountain, NJ	Five foreshocks felt between 12/4 to12/8, and five aftershocks felt on 12/23
2/15/1978	1.6	Boonton, NJ	No reference and/or no damage reported.
4/3/1978	2.0	Off Sandy Hook	No reference and/or no damage reported.
5/18/1978	1.5	Bloomingdale, NJ	No reference and/or no damage reported.
6/16/1978	0.0	Sparta, NJ	No reference and/or no damage reported.
6/30/1978	2.9	Mahwah-Oakland, NJ	1 aftershock on same day.
1/30/1979	3.5	Cheesequake, NJ	No reference and/or no damage reported.
2/2/1979	1.9	Chester, NJ	No reference and/or no damage reported.
2/23/1979	2.9	Chester, NJ	No reference and/or no damage reported.
3/10/1979 "Cheesequake Earthquake"	3.1	Bernardsville, NJ (epicenter in Morris County)	Felt by some people in Manhattan
3/25/1980	2.8	Hainesburg, NJ	No reference and/or no damage reported.
4/5/1980	2.9	South of Seaside, NJ	No reference and/or no damage reported.
8/2/1980	2.8	Keyport, NJ	No reference and/or no damage reported.
8/30/1980	3.0	Medford Lakes, NJ	No reference and/or no damage reported.
3/19/1981	2.0	Boonton, NJ	No reference and/or no damage reported.
5/18/1981	2.1	Ramsey, NJ	No reference and/or no damage reported.
6/21/1981	1.8	Denville, NJ	No reference and/or no damage reported.
4/12/1982	2.4	Mount Holly, NJ	No reference and/or no damage reported.
7/29/1982	2.4	Seaside Heights, NJ	No reference and/or no damage reported.
9/16/1982	1.6	Franklin, NJ	No reference and/or no damage reported.
2/19/1983	2.7	Oldwick, NJ	No reference and/or no damage reported.
6/1/1983	1.5	Dover, NJ	No reference and/or no damage reported.
9/6/1983	1.5	Fort Lee, NJ	No reference and/or no damage reported.
9/15/1983	1.5	Ringwood, NJ	No reference and/or no damage reported.
3/12/1984	2.0	Asbury Park, NJ	No reference and/or no damage reported.
5/13/1984	2.1	Mount Hope, NJ	No reference and/or no damage reported.
6/3/1984	1.3	Kinnelon, NJ	No reference and/or no damage reported.
6/6/1984	1.7	Near Morristown, NJ	No reference and/or no damage reported.
8/2/1984	1.7	Mount Olive, NJ	No reference and/or no damage reported.
8/12/1984	2.4	Byram, NJ	No reference and/or no damage reported.
8/12/1984	2.1	Byram, NJ	No reference and/or no damage reported.
10/25/1984	2.0	Near Mount Olive, NJ	No reference and/or no damage reported.
12/3/1984	1.5	Byram, NJ	No reference and/or no damage reported.
12/13/1984	1.7	Byram, NJ	No reference and/or no damage reported.
12/14/1984	1.7	North of Milford, NJ	No reference and/or no damage reported.
12/15/1984	1.8	Byram, NJ	No reference and/or no damage reported.
12/17/1984	1.6	Byram, NJ	No reference and/or no damage reported.
10/19/1985	4.0	Ardsley, NY	Many people in the NYC area felt this earthquake.
2/8/1986	1.7	Flanders, NJ	No reference and/or no damage reported.
2/23/1986	1.8	Port Murray, NJ	No reference and/or no damage reported.

Date(s)	Magnitude	Location	Losses/Impacts
6/29/1986	1.5	Kinnelon, NJ	No reference and/or no damage reported.
7/15/1986	1.5	Franklin, NJ	No reference and/or no damage reported.
9/15/1986	2.3	Near New Egypt, NJ	No reference and/or no damage reported.
9/15/1986	1.9	Near Roebling, NJ	No reference and/or no damage reported.
11/23/1986	2.8	Tranquility, NJ	Felt in Sussex and Warren.
4/24/1987	1.9	South of Lake Mohawk, NJ	No reference and/or no damage reported.
5/16/1987	1.4	Near Paterson, NJ	No reference and/or no damage reported.
8/5/1987	1.7	Southwest of Newton, NJ	No reference and/or no damage reported.
8/6/1987	1.1	Southwest of Newton, NJ	No reference and/or no damage reported.
8/6/1987	1.1	Southwest of Newton, NJ	No reference and/or no damage reported.
12/6/1987	2.1	Burlington, NJ	No reference and/or no damage reported.
4/13/1988	1.4	Dover, NJ	No reference and/or no damage reported.
8/20/1988	1.0	10 km Northwest of Morristown, NJ	No reference and/or no damage reported.
12/22/1988	1.0	Wanaque, NJ	No reference and/or no damage reported.
12/23/1988	1.1	Wanaque, NJ	No reference and/or no damage reported.
1/22/1989	2.0	Englewood, NJ	No reference and/or no damage reported.
1/27/1989	1.1	New York-New Jersey Border	No reference and/or no damage reported.
9/3/1989	2.0	South of Staten Island	No reference and/or no damage reported.
9/3/1989	2.5	South of Staten Island	No reference and/or no damage reported.
1/26/1990	1.0	Franklin, NJ	No reference and/or no damage reported.
5/10/1990	1.8	Mount Freedom, NJ	No reference and/or no damage reported.
8/21/1990	0.7	Wanaque, NJ	No reference and/or no damage reported.
10/23/1990	2.9	Hancock's Bridge, NJ	Felt in New Jersey, Delaware, and Pennsylvania
5/12/1991	1.3	Wanaque, NJ	No reference and/or no damage reported.
7/5/1991	1.3	Pompton Plains, NJ	No reference and/or no damage reported.
9/29/1991	2.2	Somerdale Borough, NJ	No reference and/or no damage reported.
1/9/1992	3.1	New Brunswick, NJ	No reference and/or no damage reported.
3/4/1992	1.4	Kinnelon, NJ	No reference and/or no damage reported.
6/7/1992	0.4	Jefferson Township, NJ	No reference and/or no damage reported.
10/13/1992	1.0	West Milford, NJ	No reference and/or no damage reported.
2/26/1993	2.5	Cherry Hill, NJ	No reference and/or no damage reported.
5/15/1993	2.6	Perrineville, NJ	No reference and/or no damage reported.
5/23/1994	1.6	Butler, NJ	No reference and/or no damage reported.
1/27/1995	2.3	Rockaway, NJ	No reference and/or no damage reported.
4/1/1995	1.5	Rockaway, NJ	No reference and/or no damage reported.
5/26/1995	1.5	Kinnelon, NJ	No reference and/or no damage reported.
10/27/1995	1.3	Northeast of Newton, NJ	No reference and/or no damage reported.
10/27/1995	1.4	Northeast of Newton, NJ	No reference and/or no damage reported.
2/18/1996	1.5	Ringwood, NJ	No reference and/or no damage reported.
2/19/1996	1.7	Ringwood, NJ	1 aftershock felt 22 minutes later
2/19/1996	0.8	5 km West Ringwood, NJ	No reference and/or no damage reported.
2/23/1996	0.8	6.4 km West of Ringwood, NJ	No reference and/or no damage reported.

Date(s)	Magnitude	Location	Losses/Impacts
2/26/1996	0.0	Near Mount Arlington, NJ	No reference and/or no damage reported.
10/24/1996	2.0	9 km South Crestwood Village, NJ	No reference and/or no damage reported.
11/12/1996	1.3	21 km Northeast of Newton, NJ	No reference and/or no damage reported.
11/12/1996	0.8	21 km Northeast of Newton, NJ	No reference and/or no damage reported.
3/11/1997	0.0	3 km West of Rendall Park, NJ	No reference and/or no damage reported.
5/25/1997	0.5	1 km Northeast of Fort Lee, NJ	No reference and/or no damage reported.
6/27/1997	1.6	4.6 km North of Rockaway, NJ	No reference and/or no damage reported.
7/15/1997	2.3	12 km Northeast of Princeton, NJ	No reference and/or no damage reported.
10/21/1997	0.5	3 km Southwest Woodcliff Lake, NJ	No reference and/or no damage reported.
10/24/1997	0.5	3 km Southwest Secaucus, NJ	No reference and/or no damage reported.
3/25/1998	1.9	13 km South of Salem, NJ	No reference and/or no damage reported.
6/20/1998	1.2	2 km Southeast Kinnelon, NJ	No reference and/or no damage reported.
6/30/1998	1.9	3 km South of Butler, NJ	No reference and/or no damage reported.
1/12/1999	1.4	1 km Northwest of Clifton, NJ	No reference and/or no damage reported.
1/31/1999	1.5	2 km West of Emerson, NJ	No reference and/or no damage reported.
5/31/1999	2.3	8 km West of Fort Dix, NJ	No reference and/or no damage reported.
1/17/2001	2.4	Manhattan	Felt in the Upper East Side of Manhattan, Long Island City, and Queens, NY
7/14/2001	1.9	7.1 km Northeast of Boonton, NJ	No reference and/or no damage reported.
10/17/2001	2.6	Manhattan	Felt in the Upper East Side of Manhattan, Long Island City, Astoria, and Queens, NY
8/9/2002	1.5	5.4 km North of Somerville, NJ (epicenter in Bridgewater)	No reference and/or no damage reported.
8/24/2003	1.5	6 km Southwest of Morris Plains, NJ	No reference and/or no damage reported.
8/26/2003	3.5	3 km North of Milford, NJ	No reference and/or no damage reported.
3/22/2004	2.1	2 km Northeast of from Runnemede, NJ	No reference and/or no damage reported.
12/17/2004	2.0	6 km Southeast from Pennsville, NJ	No reference and/or no damage reported.
4/23/2005	1.9	1.3 km East of Lodi, NJ	No reference and/or no damage reported.
12/9/2005	2.1	16 km West of Franklin Lakes, NJ	Aftershock felt 55 minutes later
2/16/2006	2.6	22 km Northeast of Newton, NJ	No reference and/or no damage reported.
2/17/2006	0.9	20 km Northeast of Newton, NJ	No reference and/or no damage reported.
2/21/2006	1.3	20.4 km Northeast of Newton, NJ	No reference and/or no damage reported.
5/15/2006	2.0	9 km South of Fair Lawn, NJ	No reference and/or no damage reported.
6/28/2007	2.1	7 km East of Fairfield, NJ	No reference and/or no damage reported.
2/3/2009	3.0	3.5km South-Southwest of Rockaway, NJ	There were reports of people having felt this earthquake throughout New Jersey.
2/14/2009	2.4	5 km North-Northeast of Boonton, NJ	There were reports of people having felt this earthquake throughout New Jersey.
2/18/2009	1.1	3 km South-Southwest of Kinnelon, NJ	No reference and/or no damage reported.

Date(s)	Magnitude	Location	Losses/Impacts
2/16/2009	1.4	1 km East-Southeast of Oradell, NJ	No reference and/or no damage reported.
2/16/2009	2.3	2 km South-Southeast of Dover, NJ	No reference and/or no damage reported.
7/1/2009	2.8	2.25km East-Southeast of Pennsville, NJ	There were reports of people having felt this earthquake throughout New Jersey.
12/21/2009	2.3	13 km South of Phillipsburg, NJ	No reference and/or no damage reported.
12/26/2009	2.0	8 km Northwest of Morris Pains, NJ	No reference and/or no damage reported.
2/5/2010	1.5	3 km Northwest of Far Hills, NJ	No reference and/or no damage reported.
2/7/2010	1.2	3 km Northwest of far Hills, NJ	No reference and/or no damage reported.
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.
5/8/2011	1.2	1 km Southwest of Clifton, NJ	No reference and/or no damage reported.
5/10/2011	1.9	2 km North of Mount Holly, NJ	No reference and/or no damage reported.
5/29/2011	1.3	3 km South of Fort Lee, NJ	No reference and/or no damage reported.
5/29/2011	1.9	24 km South-Southwest of Lakehurst, NJ	No reference and/or no damage reported.
6/9/2011	1.6	2 km Southeast of S. Plainfield, 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, from Georgia to southern Canada and from Indiana to coastal Maine. It was followed by four aftershocks. 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 after the tremor. 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.
7/17/2012	1.1	16 km Northwest of Morristown, NJ	No reference and/or no damage reported.
7/18/2012	1.1	18 km Northwest of Morristown, NJ	No reference and/or no damage reported.
8/23/2012	1.2	1.4 km East of Ringwood, NJ	No reference and/or no damage reported.
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.
6/23/2013	1.0	2.7 km SW of Morris Plains, NJ	No reference and/or no damage reported.
5/31/2014	1.7	3.7 km SW of Morris Plains, NJ	No reference and/or no damage reported.
6/19/2014	1.3	1.4 km S of Morris Plains, NJ	No reference and/or no damage reported.
7/8/2014	1.5	2.6 km W of Bellmawr, NJ	No reference and/or no damage reported.
7/18/2014	2.0	16.3 km E of Highlands, NJ	No reference and/or no damage reported.
9/3/2014	0.6	5 km NE of Wanaque, NJ	No reference and/or no damage reported.
12/13/2014	1.0	2 km N of Wanaque, NJ	No reference and/or no damage reported.
12/28/2014	0.5	1 km N of Butler, NJ	No reference and/or no damage reported.
3/27/2015	0.8	2.2 km SW of Clifton, NJ	No reference and/or no damage reported.
7/12/2015	1.1	1 km NW of Butler, NJ	No reference and/or no damage reported.
8/14/2015	0.8	4.4 km N of Butler, NJ	No reference and/or no damage reported.
8/22/2015	1.1	1.1 km NW of Butler, 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.
2/19/2016	1.4	5 km WNW of Fairfield, NJ	No reference and/or no damage reported.

Date(s)	Magnitude	Location	Losses/Impacts
5/27/2016	2.7	3.5 km N of Bernardsville, NJ	No reference and/or no damage reported.
7/4/2016	1.2	2 km N of Wanaque, NJ	No reference and/or no damage reported.
7/31/2016	1.2	2 km SW of Clifton, NJ	No reference and/or no damage reported.
8/9/2016	1.5	2 km SW of Clifton, NJ	No reference and/or no damage reported.
8/9/2016	1.9	13 km SE of Twin Rivers, NJ	No reference and/or no damage reported.
9/20/2016	1.3	2 km S of Park Ridge, NJ	No reference and/or no damage reported.
11/6/2016	1.2	4 km SW of Ringwood, NJ	No reference and/or no damage reported.
11/6/2016	1.6	3 km W of Jersey City, NJ	No reference and/or no damage reported.
3/25/2017	1.0	13 km SW of Ramblewood, NJ	No reference and/or no damage reported.
9/25/2017	1.9	6 km N of Boonton, 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.
11/8/2017	1.4	3.5 km NW of Keansburg, NJ	Sandy Hook Bay

Source: NJGWS 2013; USGS 2012d; Won-Young Kim, Lamont-Doherty Earth Observatory of Columbia University 1999, NJGS, 2017

5.5.4.2 FEMA DISASTER DECLARATIONS

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

5.5.5 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 is defined by the number of events over a specified period of time. There have been zero earthquake-related disasters declared for the State of New Jersey, therefore the entire historical record was consulted. The historical record indicates 204 earthquakes recorded for New Jersey from 1783 to 2017. Based on this statistic, the State may experience one earthquake of any magnitude each year.

5.5.5.1 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.

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.

5.5.6 IMPACT ANALYSIS

5.5.6.1 SEVERITY AND WARNING TIME

The level of seismic hazard—the frequency and severity of earthquakes—is substantially lower in New Jersey than in more seismically active states such as California or Alaska. 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 has been built with minimal or no consideration of earthquakes, making them more vulnerable to earthquake damage.

The NJGWS indicates that although the United States east of the Rocky Mountains has fewer and generally smaller earthquakes than the west, at least two factors increase risk in the eastern United States and New Jersey. Because of the geologic differences, eastern earthquakes affect areas 10 times larger than western ones of the same magnitude. Also, the eastern United States is more densely populated, with New Jersey being the most densely populated state in the country.

According to USGS data, damage caused by an earthquake will begin at a level of ground shaking of approximately 0.1g. The Modified Mercalli Intensity scale associates damage with levels of earthquakes. According to this scale, the damage that can be expected from this range of ground shaking will vary from plaster cracking and disruption of building contents, to moderate damage to poorly constructed buildings. It should be noted, however, that the expected probability of such a level of ground shaking is extremely low, and according to the USGS data can be expected to occur once every 2,476 years.

Because of this low frequency of occurrence and the relatively low levels of ground shaking that would be experienced, the entire State of New Jersey can be expected to have a low-to-moderate risk to earthquake damage as compared to other areas of the country. The relatively small difference in the level of impact from one area of the State to another does not justify differentiating risk levels from one portion of the State to another.

There is currently no reliable way to predict the day or month that an earthquake will occur at any given location. An Earthquake Early Warning System is being developed by the USGS for the west coast of the United States. This system uses existing seismic networks to detect moderate to large earthquakes very rapidly so that a warning can be sent before destructive seismic waves arrive to locations outside the area where the earthquake begins. These warnings will allow people to take protective action and can also trigger automatic responses to safeguard critical infrastructure. Under the Disaster Relief Act of 1974, the USGS has the federal responsibility to issue alerts for earthquakes, enhance public safety, and reduce losses through effective forecasts and warnings. USGS currently issues rapid, automatic earthquake information via the Internet, e-mail messages, text messages, and social media (USGS, 2012).

5.5.6.2 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 5.7 (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 5.3 (Dam/Levee Failure) of this Plan update.

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

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.

5.5.6.3 ENVIRONMENTAL IMPACTS

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 5.3 Dam and Levee Failure and 5.7 Geologic Hazards for additional information.

5.5.2 VULNERABILITY ASSESSMENT

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 2019 plan update, a probabilistic statewide assessment was conducted for the average annual loss through a Level 2 analysis in HAZUS-MH 4.2 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. The NEHRP soils and the landslide susceptibility classifications provided by the State Geologist were included in HAZUS for the earthquake analysis (Figures 5.5-1 and 5.5-2 presented earlier in this section illustrate NEHRP soil classifications of areas throughout New Jersey). Additional information on the landslide hazard is included in Section 5.7 Geologic Hazards of this HMP update.

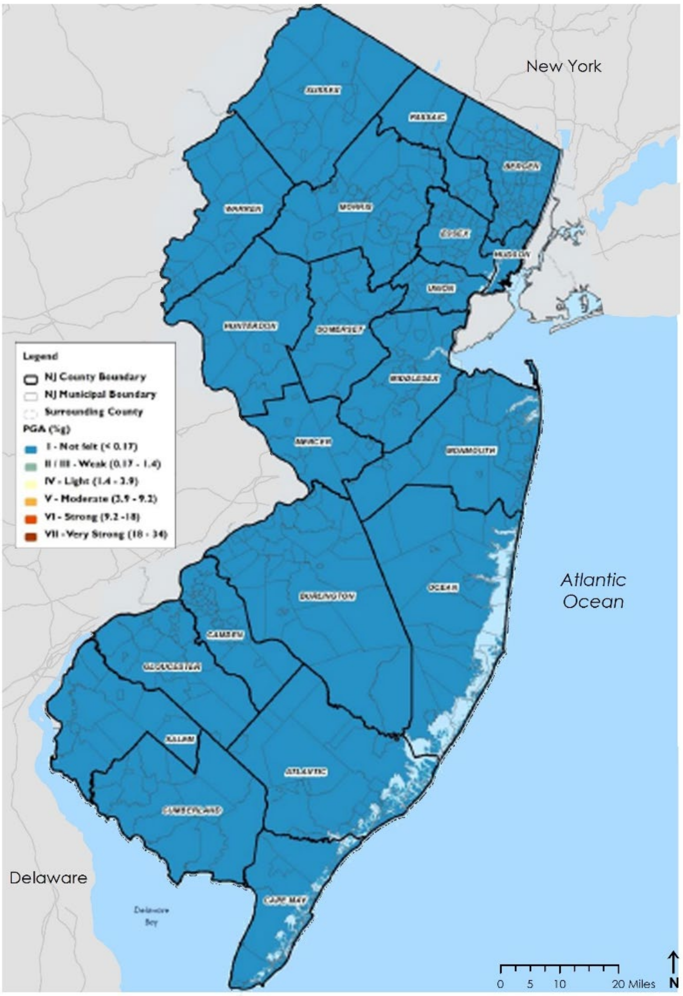
5.5.6.4 ASSESSING VULNERABILITY BY JURISDICTION

All 21 New Jersey counties included earthquakes as a hazard of concern in their local HMPs (listed in Table 5.1-2 in Section 5.1, State Risk Assessment Overview). A review of the historic record indicates earthquake epicenters have occurred in 20 of the 21 New Jersey Counties. As listed in Table 5.5-6 and illustrated in Figure 5.5-10 and Figure 5.5-12 earlier in this section, these greatest number of earthquake events with epicenters in New Jersey have been in the northern part of the State.

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 5.5-1 presented earlier in this profile illustrates soil classification area in New Jersey.)

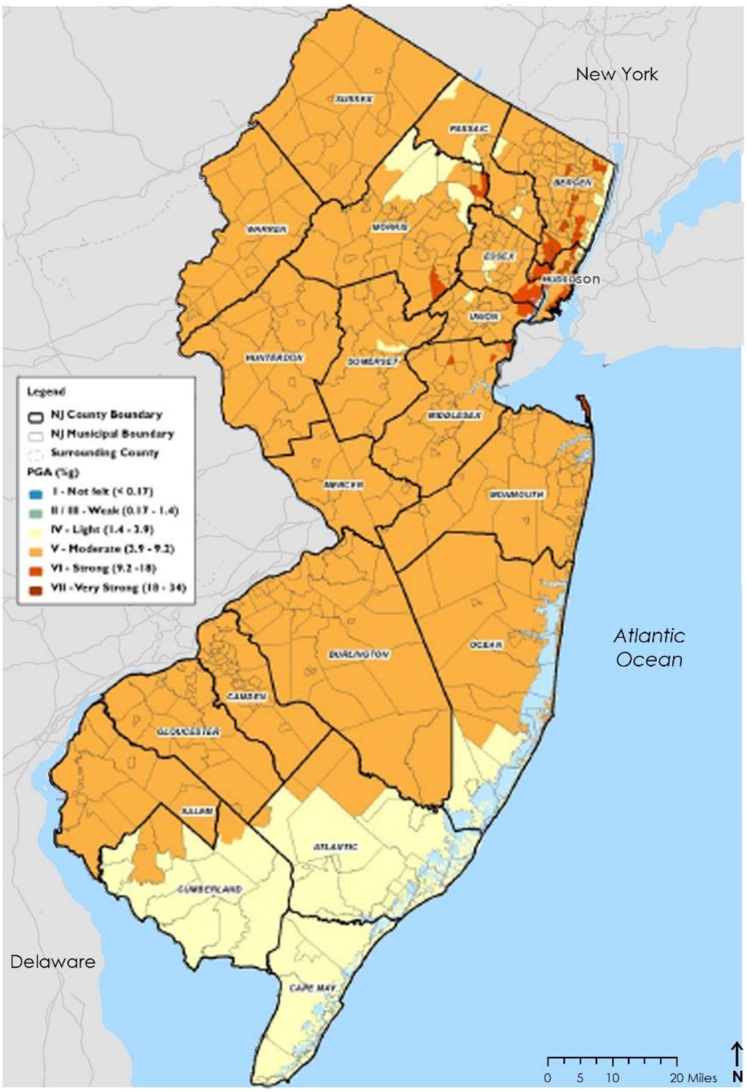
According to NYCEM, where earthquake risks and mitigation were evaluated in the New York, New Jersey, and Connecticut region, most damage and loss caused by an earthquake is directly or indirectly the result of ground shaking (NYCEM, 2003). NYCEM indicates a strong correlation between PGA and the damage a building might experience. The HAZUS-MH model is based on the best-available earthquake science and aligns with these statements. The HAZUS-MH 4.2 methodology and model were used to analyze the earthquake hazard across the State. Figure 5.5-13 through Figure 5.5-16 illustrate the geographic distribution of PGA (%g) across New Jersey for 100-, 500-, 1,000- and 2,500-year: MRP events at the United States 2000 Census-tract level.

Figure 5.5-13 Peak Ground Acceleration Modified Mercalli Scale for a 100-Year MRP Earthquake Event



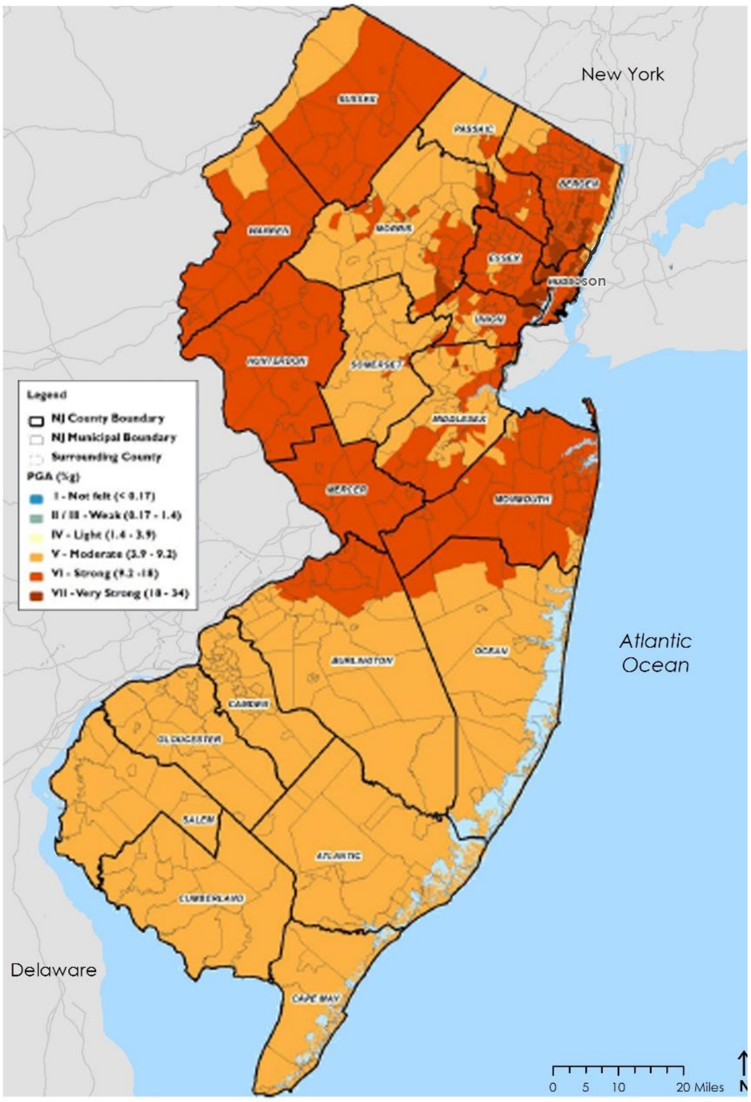
Source: HAZUS-MH 4.2.

Figure 5.5-14 Peak Ground Acceleration Modified Mercalli Scale for a 500-Year MRP Earthquake Event



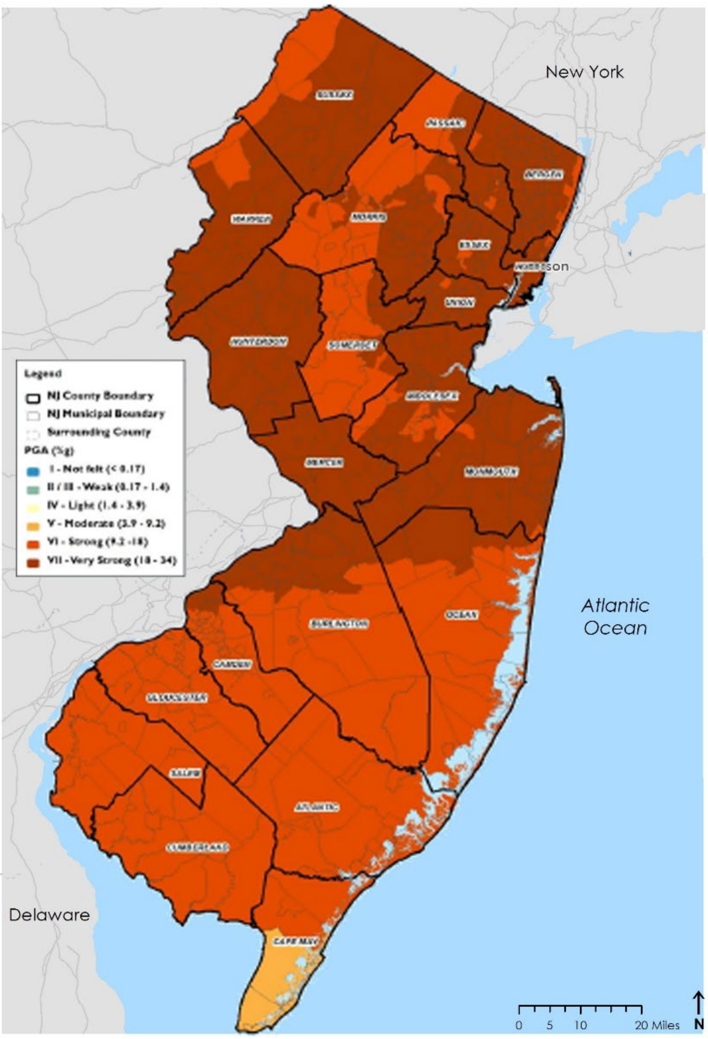
Source: HAZUS-MH 4.2.

Figure 5.5-15 Peak Ground Acceleration Modified Mercalli Scale for a 1,000-Year MRP Earthquake Event



Source: HAZUS-MH 4.2.

Figure 5.5-16 Peak Ground Acceleration Modified Mercalli Scale for a 2,500- Year MRP Earthquake Event



Source: HAZUS-MH 4.2.

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.

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.

5.5.6.5 ESTIMATING POTENTIAL LOSSES BY JURISDICTION

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 4, 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. Financial annual loss in the planning area were estimated earthquakes through the Level 4.2 HAZUS-MH analysis; results of these analyses are summarized in Table 5.5-7.

Table 5.5-7 Estimated Shelter Requirements HAZUS-MH Probabilistic Scenario

	Average Annual Loss	
County	Displaced Households	Short-Term Sheltering Needs
Atlantic	$ 102,827,048	$ 66,679,641
Bergen	$ 335,704,542	$ 192,412,684
Burlington	$ 166,316,970	$ 93,648,020
Camden	$ 190,980,001	$ 123,230,296
Cape May	$ 40,812,000	$ 21,653,928
Cumberland	$ 51,930,000	$ 40,077,785
Essex	$ 283,712,000	$ 210,380,857
Gloucester	$ 104,271,000	$ 61,002,831
Hudson	$ 246,437,001	$ 168,022,351
Hunterdon	$ 47,169,000	$ 24,329,882
Mercer	$ 133,155,000	$ 84,603,715
Middlesex	$ 281,142,939	$ 176,377,078
Monmouth	$ 233,969,916	$ 131,858,006
Morris	$ 180,512,076	$ 96,526,771
Ocean	$ 220,912,599	$ 125,631,745
Passaic	$ 166,783,001	$ 130,852,020
Salem	$ 25,290,000	$ 15,316,131
Somerset	$ 117,759,000	$ 64,663,516
Sussex	$ 54,752,000	$ 29,149,458
Union	$ 188,118,001	$ 130,403,711
Warren	$ 41,480,000	$ 22,496,265
Total	3,214,034,094	2,009,316,691

Source: HAZUS-MH v4.2

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. Table 5.5-8 summarizes the estimated potential annual losses to all of the buildings in the State.

Table 5.5-8 Earthquake Estimated Potential Losses to Buildings (Structure and Contents) HAZUS-MH Scenarios

County	Average Annual Loss		
	Structure Loss	Content Loss	Total Building Loss
Atlantic	$ 90,153,048	$ 102,471,437	$ 192,624,484
Bergen	$ 313,615,333	$ 379,288,329	$ 692,903,662
Burlington	$ 156,182,767	$ 167,975,976	$ 324,158,742
Camden	$ 159,480,556	$ 184,242,874	$ 343,723,429
Cape May	$ 61,693,547	$ 64,426,574	$ 126,120,121
Cumberland	$ 39,930,015	$ 48,623,856	$ 88,553,871
Essex	$ 219,094,126	$ 286,397,288	$ 505,491,413
Gloucester	$ 93,386,536	$ 98,255,387	$ 191,641,923
Hudson	$ 133,463,991	$ 194,735,909	$ 328,199,900
Hunterdon	$ 55,287,358	$ 59,631,821	$ 114,919,178
Mercer	$ 125,767,849	$ 149,299,967	$ 275,067,816
Middlesex	$ 272,595,529	$ 323,177,569	$ 595,773,098
Monmouth	$ 230,166,676	$ 247,914,745	$ 478,081,421
Morris	$ 203,188,907	$ 230,117,237	$ 433,306,144
Ocean	$ 202,097,268	$ 201,427,436	$ 403,524,704
Passaic	$ 131,752,193	$ 169,132,647	$ 300,884,840
Salem	$ 20,141,014	$ 21,943,653	$ 42,084,667
Somerset	$ 126,265,806	$ 140,101,072	$ 266,366,879
Sussex	$ 58,765,003	$ 60,502,720	$ 119,267,724
Union	$ 163,176,482	$ 197,985,771	$ 361,162,253
Warren	$ 38,076,644	$ 41,629,364	$ 79,706,009
Total	$ 2,894,280,647	$3,369,281,633	6,263,562,280

Source: HAZUS-MH v4.2

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. Access to major roads is crucial to life and safety after a disaster event, as well as to response and recovery operations. Further, water and sewer infrastructure would likely suffer considerable damage in the event of an earthquake. It should be assumed that these systems could be exposed to potential breakage and failure.

Lifeline-related losses include the direct repair cost to transportation and utility systems; losses 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 because of damage sustained during an earthquake, as well as temporary living expenses for those displaced. These losses are presented in Table 5.5-9.

Table 5.5-9 Estimated Potential Economic Losses for New Jersey

	Average Annual Loss	
Income Losses		
Wage	$	320,076,162
Rental Loss	$	483,854,716
Relocation	$	926,537,419
Subtotal	*$*	*1,730,468,296*
Capital Stock Losses		
Structural	$	2,894,280,647
Non-Structural	$	10,936,202,525
Content	$	3,369,281,633
Inventory	$	61,083,144
Subtotal	*$*	*17,260,847,949*
Total	$	18,991,316,245

Source: HAZUS-MH v. 4.2

5.5.6.6 ASSESSING VULNERABILITY TO STATE FACILITIES

All State-owned and leased buildings are exposed to the earthquake hazard. As mentioned earlier, the 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. Soft soils (NEHRP soil classed D and E) can amplify ground shaking to damaging levels even in a moderate earthquake (NYCEM, 2003).

Tables 5.5-10 and 5.5-11 summarize the number of State-owned and leased buildings located on soil classes A through E (where data are available) by county and State agency, respectively.

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.

Table 5.5-10 Number of State-Owned and Leased Buildings per NEHRP Soil Class by County

COUNTY	CLASS A	CLASS B	CLASS C	CLASS D	CLASS E	NO DATA AVAILABLE	TOTAL
Atlantic	0	0	0	0	0	X	0
Bergen	6	0	59	5	9	-	79
Burlington	0	0	0	0	0	X	0
Camden	0	0	0	0	0	X	0
Cape May	0	0	0	0	0	X	0
Cumberland	0	0	0	0	0	X	0
Essex	0	0	41	12	49	-	102
Gloucester	0	0	0	0	0	X	0
Hudson	2	0	16	3	32	-	53
Hunterdon	0	0	0	0	0	X	0
Mercer	0	0	0	0	0	X	0
Middlesex	0	0	309	25	0	-	334
Monmouth	0	0	8	427	15	-	450
Morris	5	0	187	34	1	-	227
Ocean	0	0	0	0	0	X	0
Passaic	14	0	230	6	0	-	250
Salem	0	0	0	0	0	X	0
Somerset	0	0	127	11	0	-	138
Sussex	0	0	0	0	0	X	0
Union	0	0	44	9	0	-	53
Warren	0	0	0	0	0	X	0
Statewide Total	27	0	1021	532	106	-	1686

Source: NJOMB 2018; NJGWS NEHRP 2016

Table 5.5-11 Number of State-Owned and Leased Buildings per NEHRP Soil Class by Agency

AGENCY	CLASS A	CLASS B	CLASS C	CLASS D	CLASS E	TOTAL
Agriculture	0	0	0	9	0	9
Banking and Insurance	0	0	0	0	0	0
Chief Executive	0	0	1	0	0	1
Children and Families	1	0	35	30	3	69
Community Affairs	0	0	3	1	0	4
Corrections	0	0	107	2	36	145
Education	0	0	9	0	0	9
Environmental Protection	14	0	279	165	39	497
Health	0	0	0	0	0	0
Human Services	2	0	166	4	1	173
Judiciary	0	0	34	9	3	46
Juvenile Justice Commission	1	0	95	6	0	102
Labor and Work Force Dev.	0	0	19	9	0	28

AGENCY	CLASS A	CLASS B	CLASS C	CLASS D	CLASS E	TOTAL
Law and Public Safety	0	0	2	3	1	6
Legislature	0	0	0	0	0	0
Military and Veterans Affairs	0	0	53	78	0	131
Miscellaneous Commissions	0	0	0	0	0	0
Motor Vehicles Commission	1	0	44	26	1	72
Personnel	0	0	0	0	0	0
State	0	0	0	1	0	1
State Police	1	0	20	12	4	37
Transportation	5	0	142	59	13	219
Treasury	1	0	12	118	5	136
Total	26	0	1021	532	106	1685

Source: NJOMB 2018; NJGWS NEHRP 2016

5.5.6.7 ESTIMATING POTENTIAL LOSSES TO STATE FACILITIES

HAZUS-MH does not estimate potential dollar losses to individual facilities at this time. When this capability is available, the State can enhance this section of the State HMP. For the purposes of the 2014 Plan update, to estimate potential losses to the State-owned and leased buildings, the exposure analysis methodology was used. As mentioned earlier, 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.

Table 5.5-12 summarizes the replacement cost value of the State-owned and leased buildings located on each NEHRP soil class by county. Table 5.5-13 summarizes the replacement cost value of buildings located on each NEHRP soil class by State agency.

Table 5.5-12 State-Owned and Leased Building Replacement Cost Value and Associated NEHRP Soil Class by County

COUNTY	CLASS A	CLASS B	CLASS C	CLASS D	CLASS E	NO DATA AVAILABLE	TOTAL
Atlantic	$0	$0	$0	$0	$0	X	$0
Bergen	$1,196,474	$0	$70,152,503	$51,715,535	$44,353,551	-	$167,418,063
Burlington	$0	$0	$0	$0	$0	X	$0
Camden	$0	$0	$0	$0	$0	X	$0
Cape May	$0	$0	$0	$0	$0	X	$0
Cumberland	$0	$0	$0	$0	$0	X	$0
Essex	$0	$0	$201,058,813	$299,497,755	$322,117,991	-	$822,674,560
Gloucester	$0	$0	$0	$0	$0	X	$0
Hudson	$1,584,047	$0	$86,618,885	$624,344	$191,977,975	-	$280,805,250
Hunterdon	$0	$0	$0	$0	$0	X	$0
Mercer	$0	$0	$0	$0	$0	X	$0
Middlesex	$0	$0	$586,561,461	$46,421,729	$0	-	$632,983,190
Monmouth	$0	$0	$828,791	$434,137,767	$28,419,479	-	$463,386,037
Morris	$1,973,762	$0	$339,417,153	$39,657,623	$4,699,383	-	$385,747,921
Ocean	$0	$0	$0	$0	$0	X	$0
Passaic	$12,172,239	$0	$274,908,969	$12,348,704	$0	-	$299,429,912

COUNTY	CLASS A	CLASS B	CLASS C	CLASS D	CLASS E	NO DATA AVAILABLE	TOTAL
Salem	$0	$0	$0	$0	$0	X	$0
Somerset	$0	$0	$195,120,517	$31,564,934	$0	-	$226,685,451
Sussex	$0	$0	$0	$0	$0	X	$0
Union	$0	$0	$144,177,495	$20,389,043	$0	-	$164,566,538
Warren	$0	$0	$0	$0	$0	X	$0
State Total	$16,926,522	$0	$1,898,844,586	$936,357,435	$591,568,380	-	$3,443,696,922

Source: NJOMB, 2018; NJGWS NEHRP, 2016

Table 5.5-13 State-Owned and Leased Building Replacement Cost Value and Associated NEHRP Soil Classes, by State Agency

AGENCY	CLASS A	CLASS B	CLASS C	CLASS D	CLASS E	TOTAL
Agriculture	$ -	$ -	$ -	$ 3,021,682	$ -	$ 3,021,682
Banking and Insurance	$ -	$ -	$ -	$ -	$ -	$ -
Chief Executive	$ -	$ -	$ 6,803,870	$ -	$ -	$ 6,803,870
Children and Families	$ 4,310,252	$ -	$ 301,900,344	$ 97,397,247	$ 37,393,157	$ 441,000,999
Community Affairs	$ -	$ -	$ 74,653,474	$ 1,186,510	$ -	$ 75,839,984
Corrections	$ -	$ -	$ 169,271,504	$ 7,984,035	$ 122,433,556	$ 299,689,094
Education	$ -	$ -	$ 28,679,390	$ -	$ -	$ 28,679,390
Environmental Protection	$ 3,253,663	$ -	$ 83,438,657	$ 82,276,940	$ 121,124,882	$ 290,094,142
Health	$ -	$ -	$ -	$ -	$ -	$ -
Human Services	$ 951,718	$ -	$ 276,412,190	$ 31,572,331	$ 2,079,212	$ 311,015,452
Judiciary	$ -	$ -	$ 383,509,635	$ 177,480,228	$ 14,654,413	$ 575,644,277
Juvenile Justice Commission	$ 265,639	$ -	$ 81,831,411	$ 64,987	$ -	$ 82,162,036
Labor and Workforce Dev.	$ -	$ -	$ 105,736,139	$ 46,063,597	$ -	$ 151,799,736
Law and Public Safety	$ -	$ -	$ 10,973,373	$ 100,165,221	$ 184,475	$ 111,323,069
Legislature	$ -	$ -	$ -	$ -	$ -	$ -
Military and Veterans Affairs	$ -	$ -	$ 160,506,508	$159,296,058	$ -	$ 319,802,566
Miscellaneous Commissions	$ -	$ -	$ -	$ -	$ -	$ -
Motor Vehicles Commission	$ 1,475,571	$ -	$ 95,291,228	$ 19,589,183	$ 2,668,347	$ 119,024,329
Personnel	$ -	$ -	$ -	$ -	$ -	$ -
State	$ -	$ -	$ -	$ 2,625,851	$ -	$ 2,625,851
State Police	$ 5,473,205	$ -	$ 37,349,425	$ 29,092,103	$ 11,023,969	$ 82,938,703
Transportation	$ 1,165,015	$ -	$ 34,467,812	$ 37,351,993	$ 8,760,677	$ 81,745,497
Treasury	$ 31,459	$ -	$ 48,019,627	$ 141,189,467	$ 271,245,692	$ 460,486,244
State Total	$16,926,522	$ -	$1,898,844,586	$936,357,435	$591,568,380	$3,443,696,922

Source: NJOMB, 2018; NJGWS NEHRP, 2016

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 5.5-14 summarizes the estimated total loss to highway bridges across the State for each probabilistic scenario.

Table 5.5-14 Estimated Cost to Repair Highway Bridges for Probabilistic Earthquake Events

Level of Severity	Average Annual Loss
Economic Loss	$ 50,708,906

Source: HAZUS-MH v. 4.2

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. Table 5.5-15 summarizes the critical facilities located on NEHRP soil classes D and E (where data are available).

Table 5.5-15 Number of Critical Facilities Exposed to NEHRP Soil Classes D and E

County	Total Number	Airport	Special Needs	Communication	Correctional Institutions	Dams	Electric Power	EMS	EOC	Ferry	Fire	Highway Bridges	Highway Tunnels	Light Rail Facilities	Medical	Military	Natural Gas	Oil	Police	Ports	Potable Water	Rail Facilities	Rail Tunnels	School	Shelters	Storage of Critical Records	Wastewater
Atlantic	388	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bergen	1,148	1	14	0	1	23	2	25	0	1	32	0	0	0	1	0	0	0	17	0	2	12	0	86	52	0	3
Burlington	747	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Camden	701	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cape May	229	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cumberland	251	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Essex	784	2	5	0	2	10	1	6	0	0	10	2	0	7	3	0	0	0	11	3	2	4	0	44	11	0	4
Gloucester	346	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hudson	493	0	2	1	1	0	2	7	0	8	12	3	1	11	3	0	1	0	7	4	2	6	1	30	12	0	4
Hunterdon	328	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mercer	538	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Middlesex	816	0	15	0	0	16	3	32	1	0	26	5	0	0	2	0	0	1	11	0	2	2	0	92	40	0	0
Monmouth	905	1	52	1	1	126	1	122	1	2	115	0	0	0	7	2	0	0	52	1	3	13	0	307	47	0	9
Morris	913	1	24	0	1	33	3	33	0	0	30	0	0	0	3	1	0	0	16	0	1	8	0	95	28	0	11
Ocean	621	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Passaic	648	0	4	1	0	6	0	10	0	0	9	0	0	0	0	0	0	0	4	0	1	5	0	30	13	0	3
Salem	201	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Somerset	539	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sussex	542	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Union	607	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Warren	351	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	12,096	5	116	3	6	230	12	235	2	11	234	10	1	18	19	3	1	1	118	8	13	50	1	684	203	0	34