10. GEOLOGICAL HAZARDS

10.1 HAZARD PROFILE

10.1.1 Hazard Description

For this HMP update, geological hazards include earthquakes, landslides, and subsidence/sinkholes.

Earthquakes

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 (FEMA 2013). Most earthquakes occur at the boundaries where the tectonic plates meet (faults); fewer than 10 percent of earthquakes occur within plate interiors. As plates continue to move and plate boundaries change over geologic 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.

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 (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 at great distance from the epicenter.

An earthquake impact is anything associated with an earthquake that may affect normal human activities (FEMA 2001). USGS identifies the following types of impacts, although not all these events affect Passaic County (USGS n.d., NOAA 2023):

- Surface faulting—Displacement that reaches the earth's surface during slip along a fault. Commonly occurs with shallow earthquakes, those with an epicenter less than 12 miles.
- 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 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 when you wiggle your toes in the wet sand near the water at the beach. This effect can be caused by earthquake shaking.
- Tectonic Deformation—A change in the original shape of a material due to stress and strain.
- Tsunami—A sea wave of local or distant origin that results from large-scale seafloor displacements associated with large earthquakes.
- Seiche—The sloshing of a closed body of water from earthquake shaking.

Landslides

The term “landslide” includes a wide range of ground movement, such as rock falls, deep failure of slopes, and shallow debris flows. Gravity acting on an over-steepened slope is the primary reason for a landslide. Contributing factors include the following (USGS n.d.):

- Erosion by rivers, glaciers, or ocean waves, which creates over-steepened slopes
- Rock and soil slopes weakened by saturation due to snowmelt or heavy rains
- Earthquakes, which generate energy that makes weak slopes fail
- Excess weight from rain/snow accumulation, rock/ore stockpiling, waste piles, or man-made structures.

In New Jersey, there are four main types of landslides:

- Slumps are coherent masses that move downslope by rotational slip on surfaces that underlie and penetrate the landslide deposit (NJDEP 2009).
- A debris flow, also known as a mudslide, is a form of rapid mass movement in which loose soil, rock, organic matter, air, and water mobilize as slurry that flows downslope. Debris flows are often caused by intense surface water from heavy precipitation or rapid snow melt. This precipitation loosens surface matter, thus triggering the slide.
- Rockfalls are common on roadway cuts and steep cliffs. These landslides are abrupt movements of geological material such as rocks and boulders. Rockfalls happen when these materials become detached.
- Rockslides are detached segments of bedrock sliding on bedrock, joint, or fault surfaces (NPS 2023).

Subsidence/Sinkholes

Land subsidence is the sudden sinking or gradual downward settling of the earth’s surface with little or no horizontal motion, owing to the subsurface movement of earth materials (USGS 2018). Subsidence often occurs through the loss of subsurface support in karst terrain, which may result from a number of natural or human-caused occurrences. Karst is a landscape characterized by dissolution of underlying carbonate rocks (limestone and dolomite) by surface water or groundwater over time. The dissolution process causes surface depressions and the development of sinkholes, sinking streams, enlarged bedrock fractures, caves, and underground streams (NJOEM 2019).

Sinkholes, the type of subsidence most frequently seen in New Jersey, are a common geologic feature in areas with underlying limestone, carbonate rock, salt beds, or other rocks that are soluble in water. They can result from natural or human causes:

- Natural sinkholes result when, over thousands of years, carbonate bedrock is dissolved by acidic rainwater moving in fractures or cracks in the bedrock. This creates larger openings in the rock through which water and overlying soil materials travel. Over time the voids enlarge until the roof over the void is unable to support the land above, at which time it collapses, forming a sinkhole.
- Human-caused sinkholes involve changes to the water balance of an area such as over-withdrawing groundwater, diverting surface water from a large area and concentrating it in a single point; artificially creating ponds of surface water; and drilling new water wells. These actions can accelerate the natural processes of creation of soil voids, which can have a direct impact on sinkhole creation (NJOEM 2019).

Both natural and human-made sinkholes can occur without warning. Slumping or falling fence posts, trees, or foundations, sudden formation of small ponds, wilting vegetation, discolored well water, and/or structural cracks in

walls and floors are signs that a sinkhole may be forming. Sinkholes can range from steep-walled holes to bowl or cone-shaped depressions. When sinkholes occur in developed areas, they can cause severe property damage, disruption of utilities, damage to roadways, injury, and loss of life (NJOEM 2019).

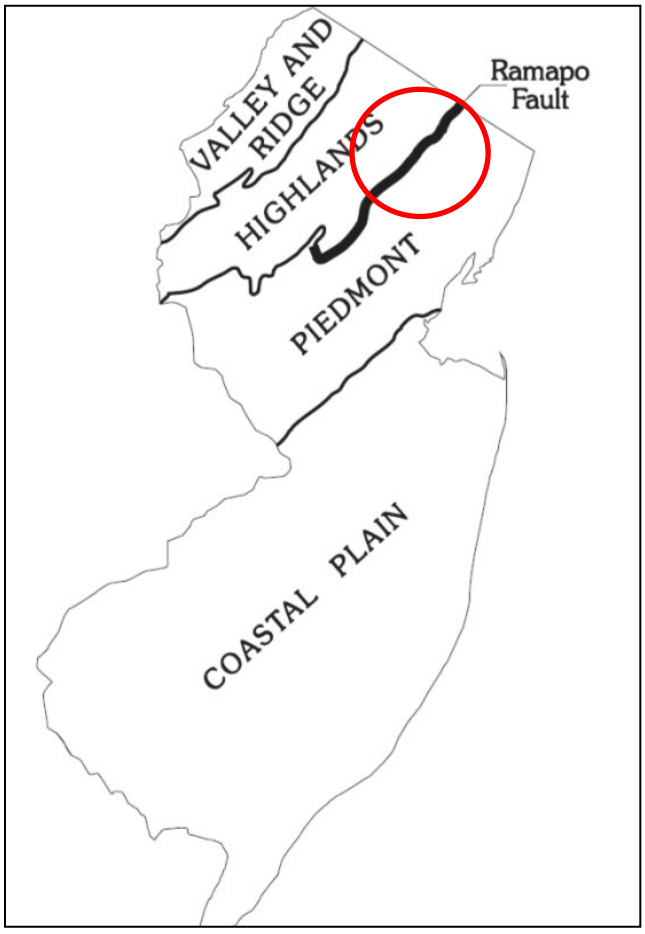
10.1.2 Location

Earthquakes

Faults

Earthquakes in New Jersey are most likely in the northern parts of the state, where significant faults are concentrated; this includes Passaic County (NJDEP 2024). There are many faults in the state. 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 (NJDEP 2024). Figure 10-1 illustrates the relationship of the Ramapo fault line with the physiologic provinces of the state. Passaic County is located in the Highlands and Piedmont Province and near the Ramapo Fault line.

Figure 10-1. Physiographic Provinces of the State of New Jersey and Ramapo Fault Line



Note: The red circle indicates the approximate location of Passaic County.
Source: Dombroski 1998 (Revised in 2005)

Soils Susceptible to Shaking

The National Earthquake Hazard Reduction Program (NEHRP) developed five soil classifications that affect the severity of an earthquake's impacts, based on the velocity at which earthquake-generated waves of energy travel through the soil. The soil classification system ranges from A to E, as shown in Table 10-1. Class A soils are hard rock, which reduces ground motions from an earthquake. Class E soils are soft soils that amplify ground shaking and increase damage and injuries. NEHRP soil information is incorporated into the Hazus earthquake model for the risk assessment of the earthquake hazard.

Table 10-1. 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 n.d.

Passaic County is predominantly underlain by Class A soils, with bands of Class C soils throughout and areas of Class E soil in the southeastern portion of the county. Figure 10-2 shows the NEHRP soil distribution in the northeast quadrant of New Jersey. Figure 10-3 shows the locations of NEHRP Class D and E soils in Passaic County.

A New Jersey Department of Transportation (NJDOT) report on seismic design for bridges in the state (Anil Agrawal 2012) classifies soils according to the American Association of State Highway and Transportation Officials Guide Specifications for Bridge Seismic Design. Sites are classified into Soil Classes A, B, C, D, E and F, ranging from hard rock to soft soil and special soils (similar to the NEHRP soil classifications); refer to Table 10-2.

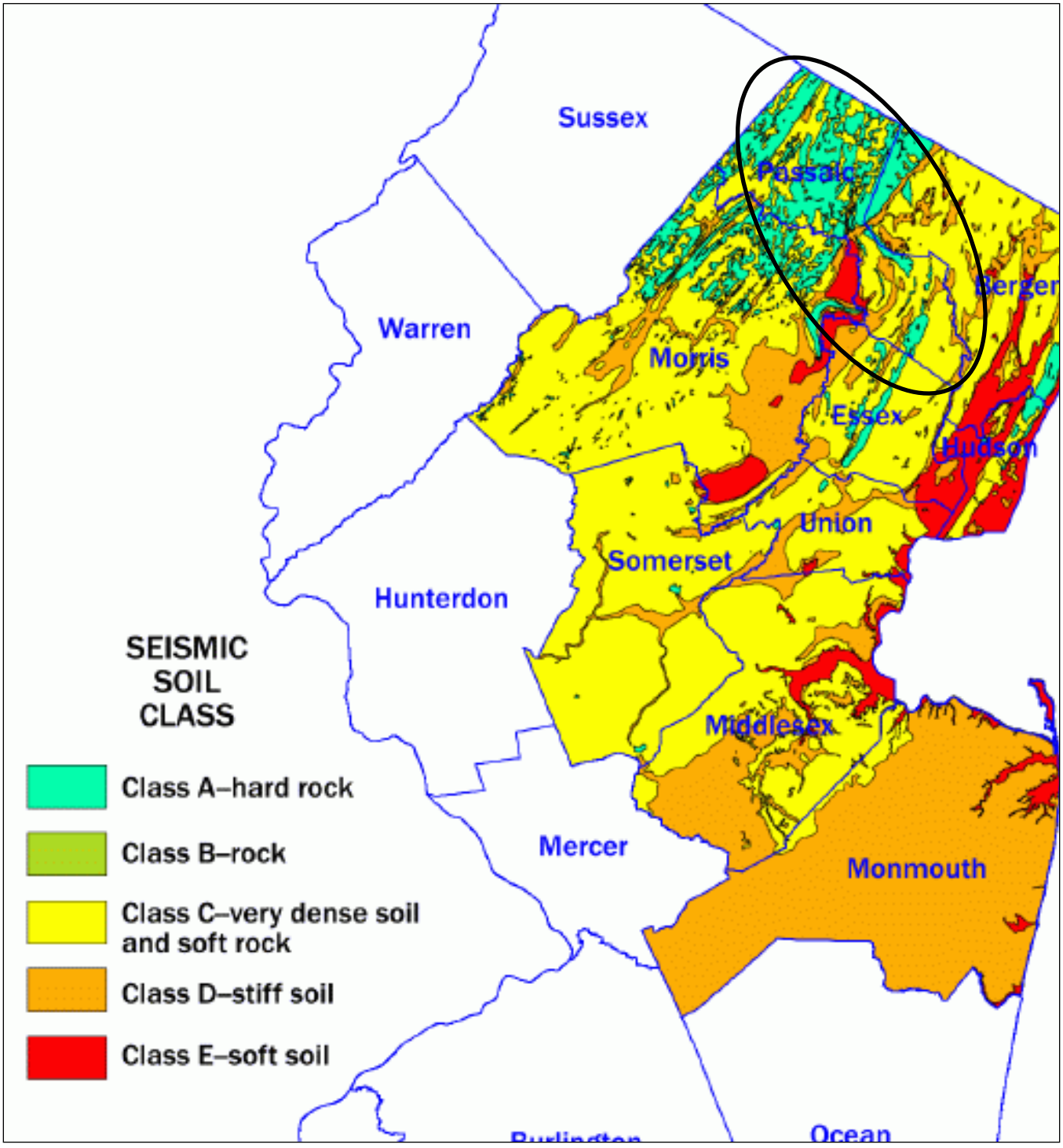
Table 10-2. NJDOT Soil Classifications

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

Source: NJDOT 2012

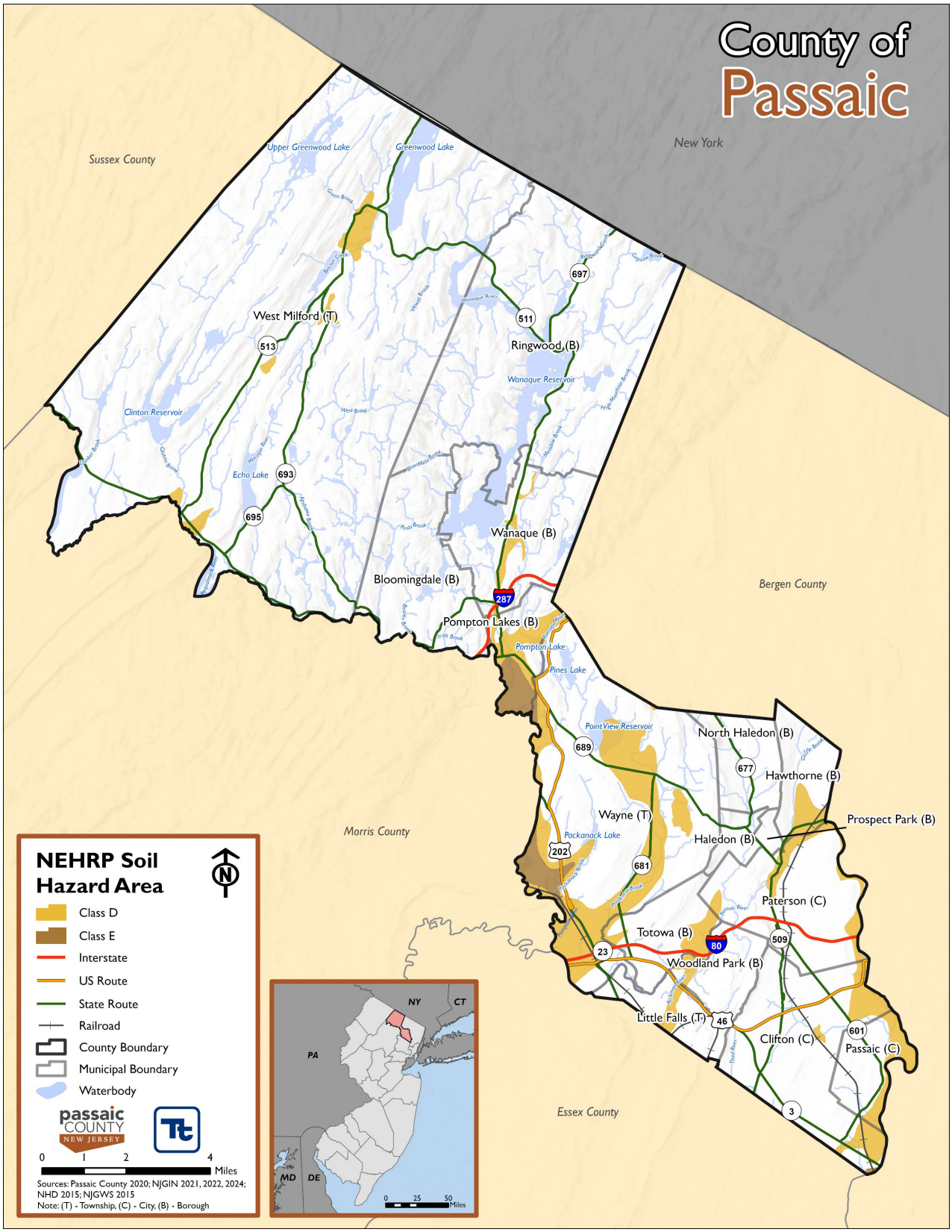
NJDOT also developed a Geotechnical Database Management System that contains soil boring data across the state. The soil boring logs were used to classify soil sites. Through this analysis, NJDOT developed a statewide map of soil site classes in which each ZIP code is assigned a class based on its predominant soil condition. In Passaic County, most ZIP codes are rated as Category C (Anil Agrawal 2012).

Figure 10-2. Seismic Soils in Northeastern New Jersey



Note: The black circle indicates the location of Passaic County.
Source: New Jersey Geological and Water Survey (NJGWS) and New Jersey Department of Environmental Protection (NJDEP) 2011

Figure 10-3. NEHRP Soils in Passaic County



Landslides

Landslides are common in New Jersey, primarily in the northern region of the state. In Passaic County, the areas most susceptible to landslides are near the center and southeastern portions of the County. Landslide risk is commonly assessed based on the susceptibility of an area to landslides (based on soils and slopes) and the past incidence of landslide events in the area. With the exception of the far southeastern area, most of Passaic County has high landslide susceptibility with moderate incidence. The central portion of the County has moderate landslide susceptibility with low incidence. The remainder of the County has a low susceptibility.

The New Jersey Geologic Survey (currently known as the NJGWS) determined landslide susceptibility for nine counties in New Jersey (Bergen, Essex, Hudson, Middlesex, Monmouth, Morris, Passaic, Somerset, and Union) (NJOEM 2024). Areas within these counties are classified into Class A, B, and C landslide susceptible classes, and several subclasses within these main classifications (FEMA 2020):

- Class A, which is strongly cemented rock at varying slope angles, includes AII, AIV and AVI.
- Class B, which is weakly cemented rock and soil at varying slope angles, includes subclasses BIII, BIV, BV, and BVI.
- Class C, which is shale and clayey soil at varying slope angles, includes subclasses CV, CVI, CVII, CIX, and CX.

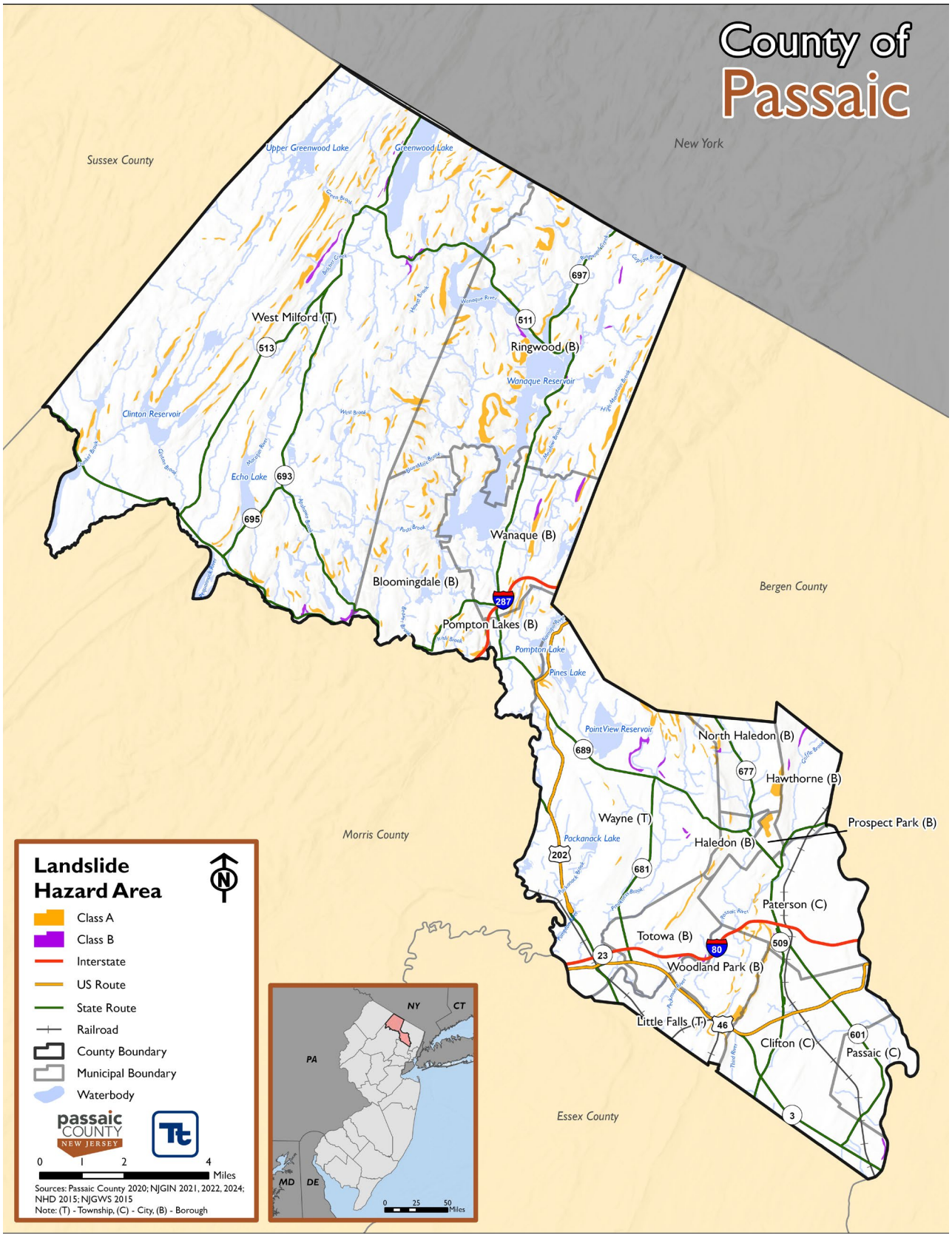
Figure 10-4 shows the landslide susceptibility in Passaic County. There are small areas throughout the County with Class A and Class B landslide susceptibility. Table 10-3 summarizes the area within each class. In total, 3,980 square miles (3.4 percent) of the County is identified as having Class A landslide susceptibility, and 364 square miles (0.3 percent) is identified as having Class B landslide susceptibility.

Table 10-3. Total Land Area Located in the Landslide Class A and B Hazard Areas

Jurisdiction	Total Land Area Excluding Water Bodies (acres)	Land Area (Excluding Water Bodies) in the Landslide Hazard Area			
		Class A Hazard Area (acres)	% of Jurisdiction Total	Class B Hazard Area (acres)	% of Jurisdiction Total
Bloomingdale (B)	5,615.2	209.4	3.7%	5.7	0.1%
Clifton (C)	7,314.8	51.1	0.7%	13.3	0.2%
Haledon (B)	778.6	40.3	5.2%	0.0	0.0%
Hawthorne (B)	2,153.0	14.6	0.7%	26.6	1.2%
Little Falls (T)	1,840.8	17.0	0.9%	0.0	0.0%
North Haledon (B)	2,257.5	110.2	4.9%	5.2	0.2%
Passaic (C)	2,073.4	0.0	0.0%	0.0	0.0%
Paterson (C)	5,564.1	68.3	1.2%	8.0	0.1%
Pompton Lakes (B)	1,831.8	50.3	2.7%	0.0	0.0%
Prospect Park (B)	300.8	58.0	19.3%	0.0	0.0%
Ringwood (B)	15,986.4	1,140.0	7.1%	42.3	0.3%
Totowa (B)	2,611.0	43.1	1.6%	24.9	1.0%
Wanaque (B)	5,060.5	238.6	4.7%	48.0	0.9%
Wayne (T)	15,232.7	188.2	1.2%	70.6	0.5%
West Milford (T)	48,071.3	1,654.7	3.4%	119.6	0.2%
Woodland Park (B)	1,965.8	96.4	4.9%	0.0	0.0%
Passaic County (Total)	118,657.8	3,980.1	3.4%	364.3	0.3%

Source: (NJGIN 2024); (NJGWS 2015)

Figure 10-4. Landslide Susceptibility in Passaic County



Areas of potential landsliding in Passaic County include steep slopes on basalt bedrock and till in the Watchung Mountains, steep slopes on gneiss and till in the Highlands, and a few steep slopes cut into glacial deposits by postglacial river erosion in the Pequannock, Wanaque, Passaic, and Preakness Valleys (NJGS 2004).

Subsidence/Sinkholes

New Jersey is susceptible subsidence and sinkholes, primarily in the northern region of the state. Sinkholes are generally concentrated in the northwestern part of the state. Areas underlain by carbonate rock may contain surface depressions and open drainage passages making the areas unstable and susceptible to subsidence and surface collapse. As a result, the alteration of drainage patterns, placement of impervious coverage, grade changes or increased loads can result in land subsidence and sinkhole formation (AGI 2001). In northern New Jersey, there are more than 225 square miles that are underlain by limestone, dolomite, and marble. In some areas, no sinkholes have appeared, while in others, sinkholes are common.

Figure 10-5 illustrates the locations of carbonate-bearing geologic formations in Passaic County. These formations are areas of potential natural subsidence. These geologic units contain a high enough percentage of carbonate minerals such as calcite and/or dolomite for karst features such as sinkholes to form. Some of these units are more prone to sinkhole development than others due to a greater carbonate content in the rock. Although not every unit listed has documented sinkholes, all are susceptible to dissolution by groundwater with resulting potential for sinkholes. According to this figure, carbonate rock formations can be found in the Township of West Milford, and the Boroughs of Wanaque, Ringwood, and Bloomingdale.

The region's susceptibility to subsidence is also due in part to the number of abandoned mines throughout New Jersey. There are approximately 450 underground mines in the state, all of which are now abandoned. Although these mines have closed, continued development in the northern part of the state has been problematic because of the extensive mining there, which has caused widespread subsidence. Many of the surface openings were improperly filled in, and roads and structures have been built adjacent to or on top of these former mine sites. The mapped locations of some of the abandoned mines are inaccurate.

Figure 10-6 shows the location of the mapped abandoned mines in Passaic County. The data from NJDEP and the figure indicate that Passaic County has at least 45 abandoned mines—mainly iron mines, with one graphite mine—all located in northern and central Passaic County (NJOEM 2019).

10.1.3 Extent

Earthquakes

Event Magnitude

An earthquake's magnitude describes the size at the focal point of an earthquake. Magnitude is most commonly expressed using the moment magnitude (Mw) scale. This scale is based on the total moment release of the earthquake (the product of the distance a fault moved, and the force required to move it) (USGS 2012).

Intensity, Shaking, and Peak Ground Acceleration

An earthquake has only one magnitude and one epicenter, but it produces a range of ground shaking at sites throughout the region, depending on the distance from the earthquake, the rock and soil conditions at sites, and variations in the propagation of seismic waves from the earthquake due to complexities in the structure of the earth's crust.

Figure 10-5. Carbonate Rock Regions of Passaic County

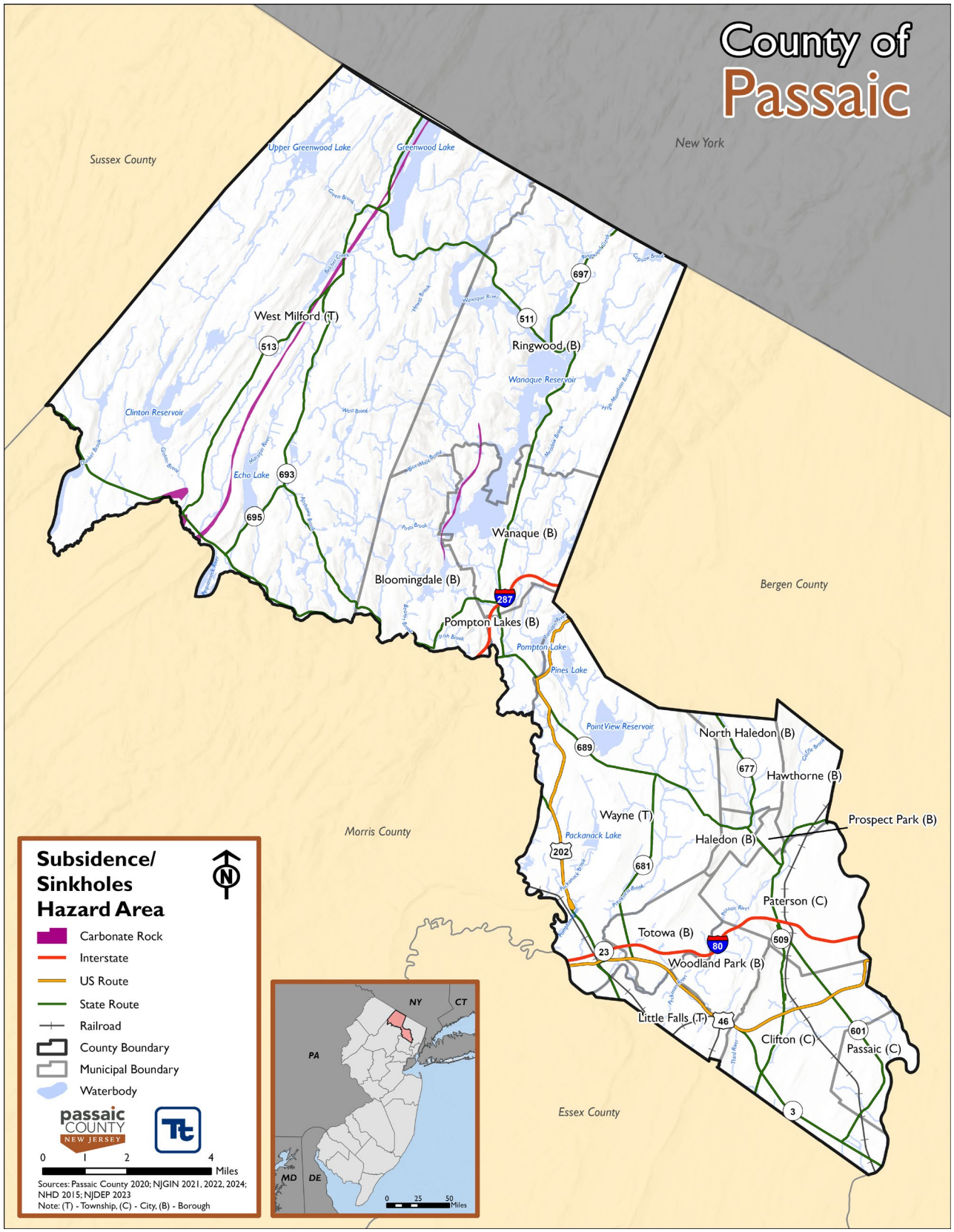
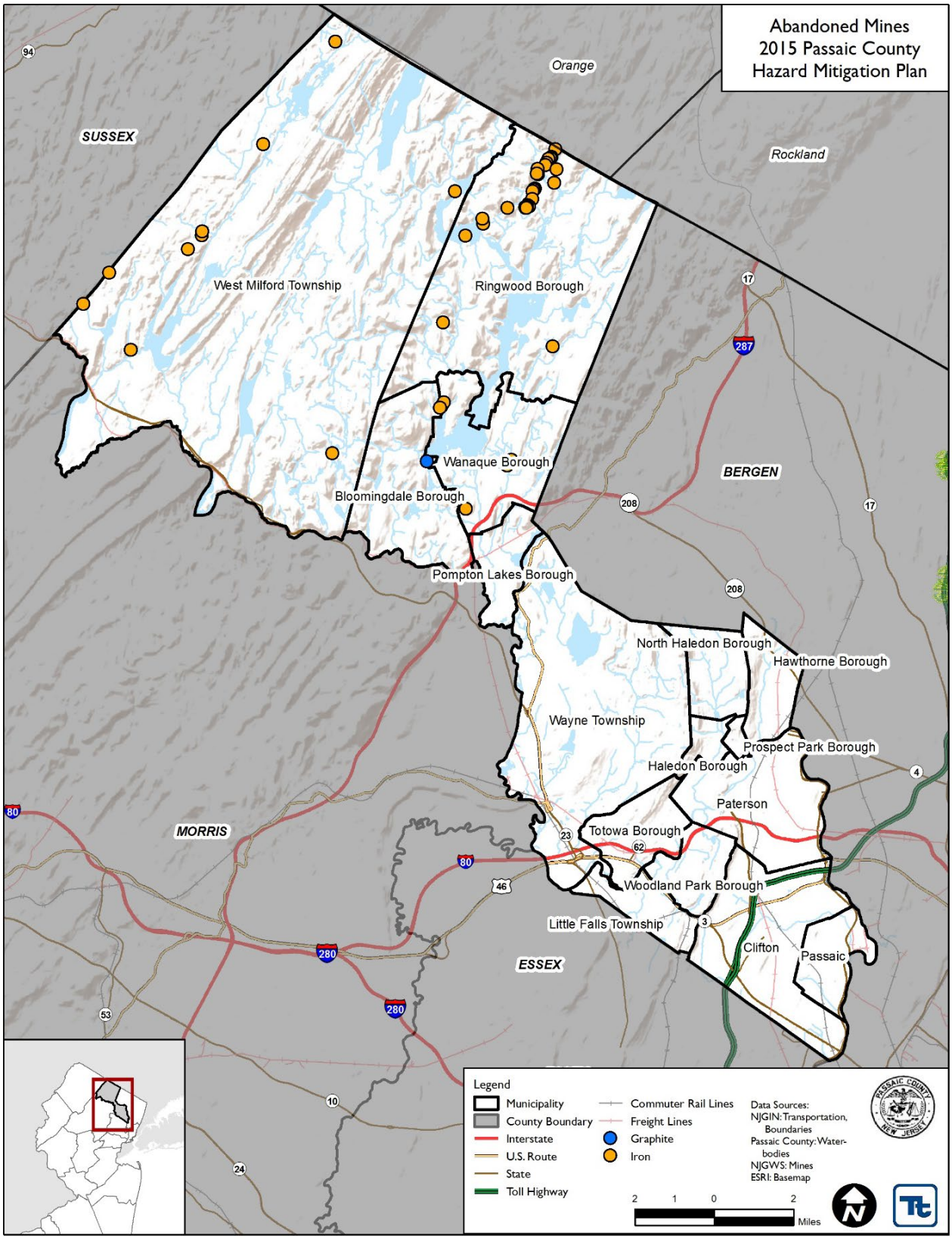


Figure 10-6. Abandoned Mines in Passaic County



The most used intensity scale is the modified Mercalli intensity scale (MMI). Ratings of the scale, as well as the perceived shaking and damage potential for structures, are shown in Table 10-4. The modified Mercalli intensity scale is generally represented visually using maps that show the expected ground shaking at any given location produced by an earthquake with a specified magnitude and epicenter.

Table 10-4. 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: USGS 2021

The ground experiences acceleration as it shakes during an earthquake. The peak ground acceleration (PGA) is the largest acceleration that occurs during an earthquake. PGA is a measure of how hard the earth shakes in a given geographic area. It is expressed as a percentage of the acceleration due to gravity (%g). Horizontal and vertical PGA varies with soil or rock type (UNDRR n.d.). Table 10-5 displays the MMI scale and its relationship to the area's PGA. Damage levels experienced in an earthquake vary with the intensity of ground shaking and with the seismic capacity of structures, as noted in Table 10-6.

Table 10-5. Modified Mercalli Intensity and PGA Equivalents

Modified Mercalli Intensity	Peak Ground Acceleration (%g)	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: USGS 2021

Table 10-6. Damage Levels Experienced in Earthquakes

Ground Motion	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 and more damage in poorly designed buildings. Only unusually poor buildings would be subject to potential collapse.
20 - 50%g	May cause significant damage in some modern buildings and very high levels of damage (including collapse) in poorly designed buildings.
≥50%g	May causes higher levels of damage in many buildings, even those designed to resist seismic forces.

Source: NJOEM 2011
Note: %g = peak ground acceleration as a percent of the acceleration due to gravity

Earthquake hazard assessment involves estimating the annual probability that certain ground accelerations will be exceeded and then summing the annual probabilities over a time period of interest. National maps of earthquake shaking hazards provide information for creating and updating seismic design requirements for building codes, insurance rate structures, earthquake loss studies, retrofit priorities, and land use planning. After thorough review of the studies, professional organizations of engineers update the seismic-risk maps and seismic design requirements contained in building codes. The USGS updated the National Seismic Hazard Maps in 2023 to produce a standard of practice for public policy and other engineering applications (USGS 2023).

A probabilistic assessment was conducted for the 500- and 2,500-year mean return period (MRP) earthquake events in Hazus to analyze the earthquake hazard for Passaic County. The Hazus analysis evaluates the statistical likelihood that a specific event will occur and what consequences will occur. A 500-year MRP is an earthquake with 0.2 percent chance that mapped PGAs will be exceeded in any given year. A 2,500-year MRP is an earthquake with 0.04 percent chance that mapped PGAs will be exceeded in any given year. Figure 10-7 and Figure 10-8 illustrate the geographic distribution of PGA for the 500- and 2,500-year MRP events.

Liquefaction

Liquefaction occurs in saturated soils. When it occurs, the strength of the soil decreases and the ability of a soil deposit to support foundations for buildings and bridges is reduced. Liquefaction has been responsible for tremendous amounts of damage in historical earthquakes around the world. Shaking behavior and liquefaction susceptibility of soils are determined by their grain size, thickness, compaction, and degree of saturation. These properties, in turn, are determined by the geologic origin of the soils and their topographic position. Figure 10-9 shows the liquefaction susceptibility class for natural soils in Passaic County. The categories are as follows:

- Category 1 – Very Low
- Category 2 – Low
- Category 3 – Moderate
- Category 4 – High

The majority of Passaic County has low to no liquefaction susceptibility (NJDEP 2021). In some areas, these natural soils are overlaid with fill, particularly those in Category 4. Typically, fill has a low liquefaction susceptibility. Uncompacted sand and silt fills may liquefy. The behavior or fill during seismic shaking should be addressed on a site-specific basis.

Figure 10-7. Peak Ground Acceleration 500-Year MRP for Passaic County

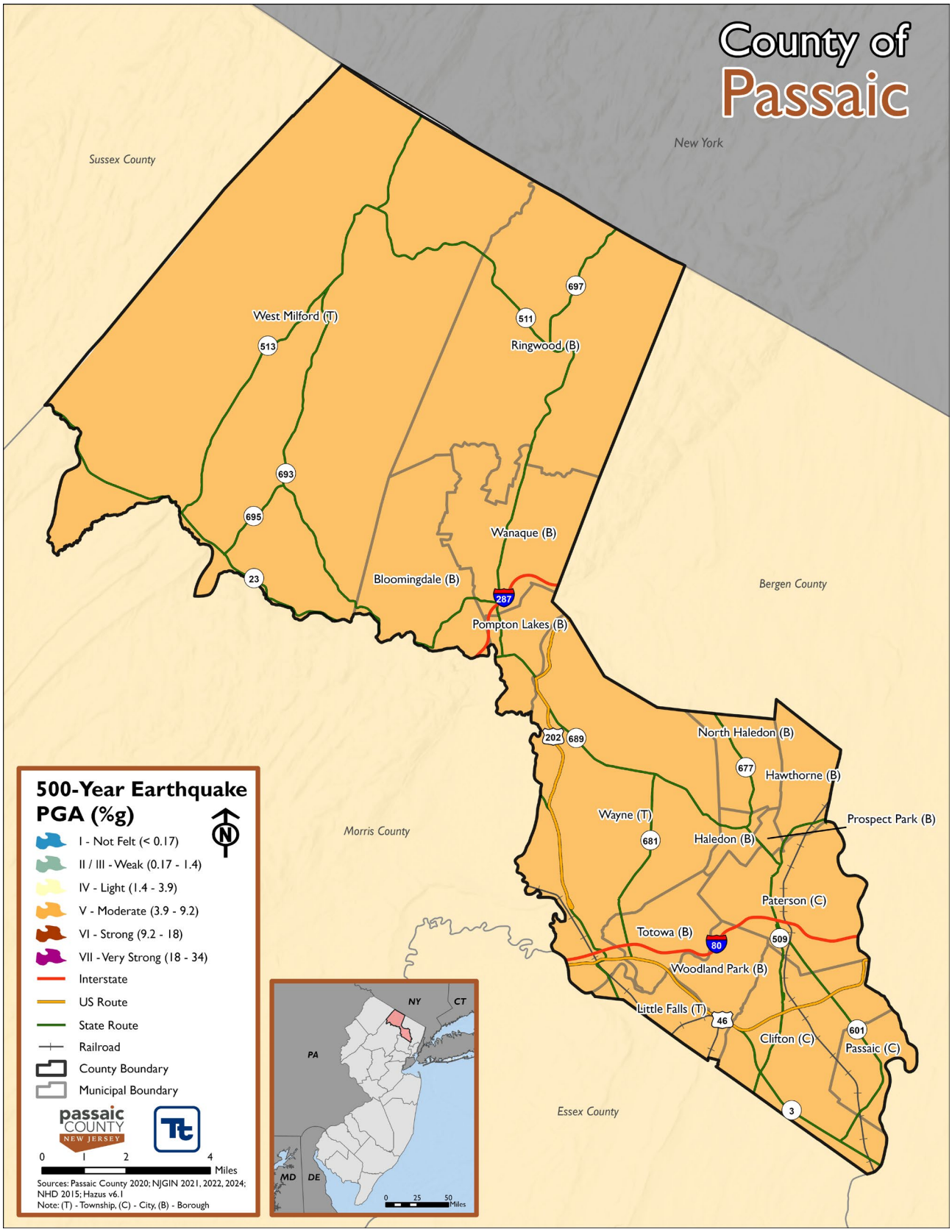


Figure 10-8. Peak Ground Acceleration 2,500-Year MRP for Passaic County

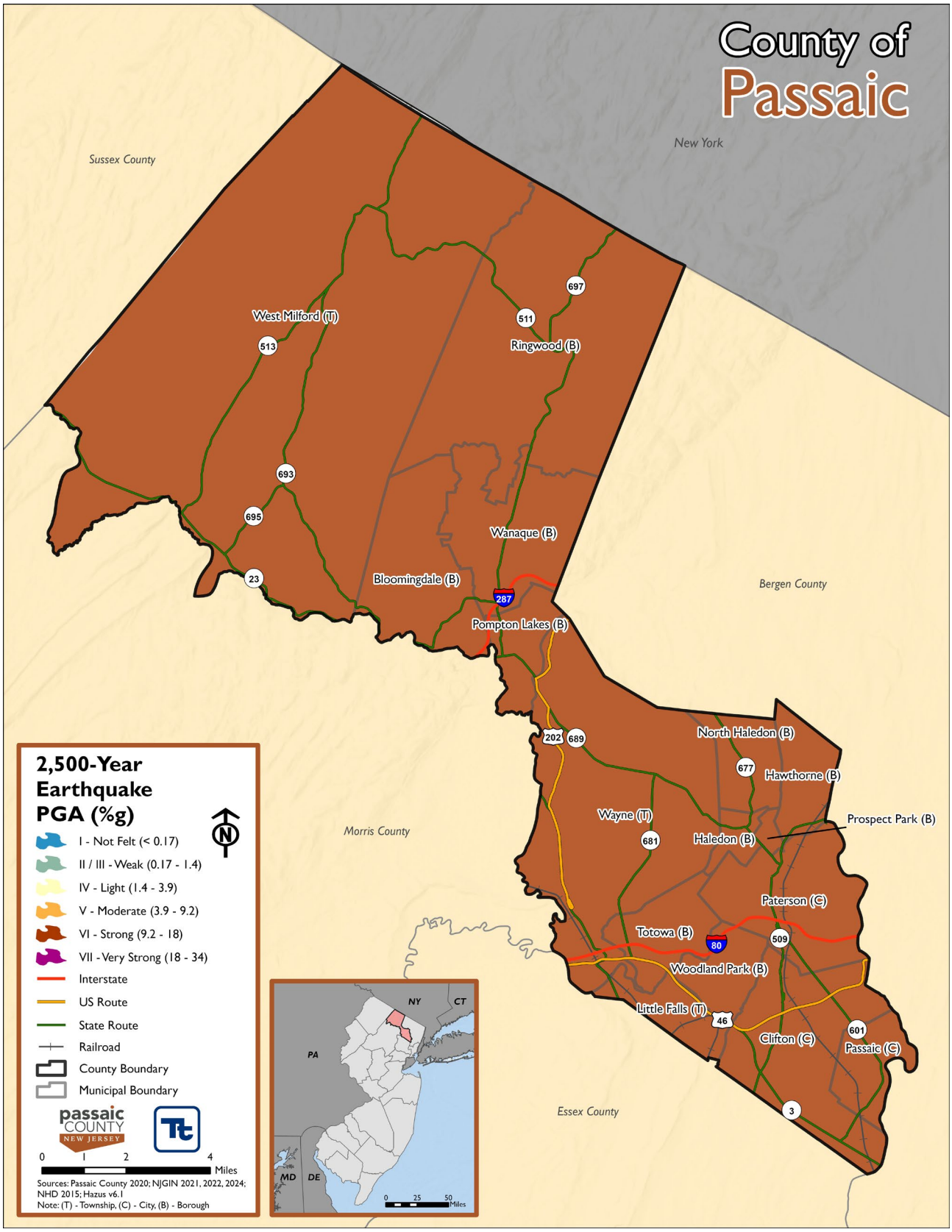
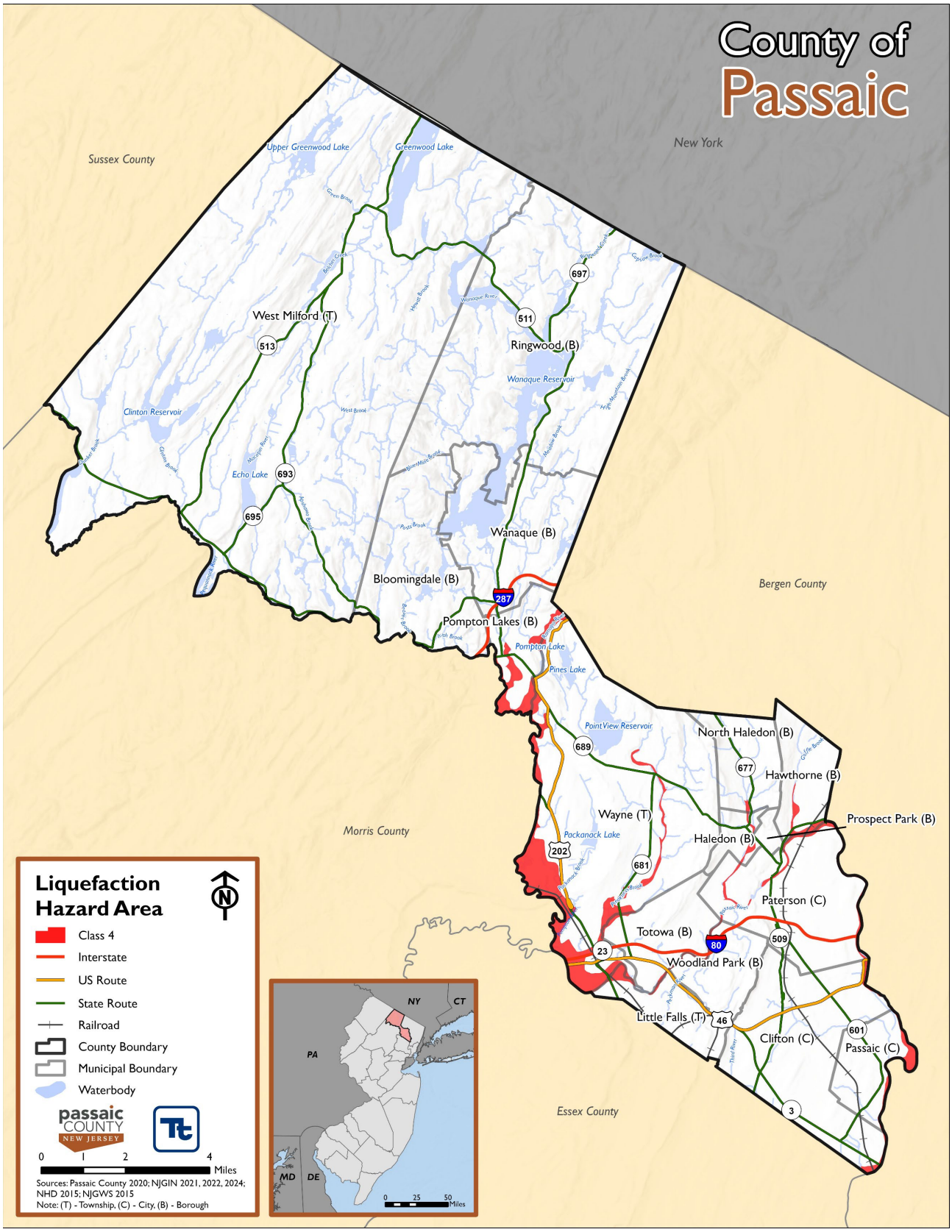


Figure 10-9. Liquefaction Susceptibility Class in Passaic County



Landslide

To determine the extent of a landslide hazard, the affected areas need to be identified and the probability of the landslide occurring within some time period needs to be assessed. Natural variables that contribute to the overall extent of potential landslide activity in an area include soil properties, topographic position and slope, and historical incidence. The landslide hazard is often represented by landslide incidence and/or susceptibility, as defined below (NJGWS 2013):

- Landslide incidence is the number of landslides that have occurred in a given geographic area. High incidence means greater than 15 percent of a given area has been involved in landsliding; medium incidence means that 1.5 to 15 percent of an area has been involved; and low incidence means that less than 1.5 percent of an area has been involved.
- Landslide susceptibility is the probable degree of response of geologic formations to natural or artificial cutting, to loading of slopes, or to unusually high precipitation. It can be assumed that unusually high precipitation or changes in existing conditions can initiate landslide movement. Landslide susceptibility depends on slope angle and the geologic material underlying the slope. High, medium, and low susceptibility are delimited by the same percentages used for classifying the incidence of landsliding.

Subsidence/Sinkhole

Subsidence in the U.S. has directly affected more than 17,000 square miles in 45 states, and associated annual costs are estimated to be $125 million. Global positioning systems (GPS) are used to monitor subsidence on a regional scale. Benchmarks are commonly spaced approximately 4 miles apart (USGS 2013).

Another method to monitor subsidence is Interferometric Synthetic Aperture Radar (InSAR). InSAR is a remote sensing technique that uses radar signals to interpolate land surface elevation changes. It is a cost-effective solution for measuring land surface deformation for a region while offering a high degree of spatial detail and resolution (USGS 2013).

10.1.4 Previous Occurrences

FEMA Major Disaster and Emergency Declarations

Passaic County has not been included in any major disaster (DR) or emergency (EM) declarations for geological hazard-related events (FEMA 2023).

USDA Declarations

The U.S. Secretary of Agriculture is authorized to designate counties as disaster areas to make emergency loans from the U.S. Department of Agriculture (USDA) to producers suffering losses in those counties and in contiguous counties. Between 2019 and 2023, Passaic County was not included in any USDA geological hazard-related agricultural disaster declarations (USDA 2024).

Previous Events

For this plan update, three geological hazard events were identified that impacted Passaic County between August 2019 and December 2023, as listed in Table 10-7. For events prior to 2019, refer to the 2020 Passaic County HMP.

Table 10-7. Geological Hazard Events in Passaic County (2019 to 2023)

Event Date	Event Type	FEMA Declaration Number	Passaic County Included in Declaration?	Location Impacted	Description
September 9, 2020	Earthquake	N/A	N/A	1.8 miles southwest of Marlboro, NJ	3.1 magnitude earthquake resulted in shaking felt across the County
August 30, 2022	Earthquake	N/A	N/A	Outside Rockaway, NJ	1.7 magnitude earthquake resulted in shaking felt across the County
August 30, 2022	Earthquake	N/A	N/A	Outside Rockaway, NJ	2.3 magnitude earthquake resulted in shaking felt across the County

Source: USGS 2023; FEMA 2023

Note: The searched events included earthquakes, landslides, debris flow, sinkholes. Only those with known events were reflected in the table.

10.1.5 Probability of Future Occurrences

Probability Based on Previous Occurrences

New Jersey and Passaic County have not experienced a major geological hazard event. However, there have been a number of earthquakes of relatively low intensity. The majority of earthquakes in New Jersey have occurred along faults in the central and eastern Highlands, with the Ramapo fault being the most seismically active fault in the region (Volkert 2015). Small earthquakes may occur several times a year and generally do not cause significant damage.

The probability of future occurrences was calculated for geological hazards, as shown in Table 10-8. Based on historical records and input from the Planning Partnership, the probability of occurrence for earthquake in the County is considered “occasional.”

Table 10-8. Probability of Future Geological Hazards

Hazard Type	Number of Occurrences Between 1954 and 2024	Percent Chance of Occurring in Any Given Year
Earthquakes	3	4.2 %
Landslides	3	4.2.%
Rockslides	2	2.8 %
Debris Flow	3	4.2 %
Subsidence/Sinkholes	1	1.4 %
Total	**12**	**17 %**

Source: (NOAA-NCEI 2024) (NJDEP 2024) (USGS 2024)

Note: Not all events that have occurred in Passaic County are included due to limited documentation and the fact that not all sources have been identified or researched.

Effect of Climate Change on Future Probability

Earthquakes

The potential impacts of global climate change on earthquake probability are unknown. Some science suggests 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 (NJOEM 2019). The lack of glaciers in New Jersey and the surrounding area makes it unlikely that glacier retreat will increase the occurrence of earthquake in Passaic County.

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 (NJOEM 2019).

Landslides

Increase in global temperature could affect the snowpack and its ability to hold and store water, resulting in an increase in the occurrence and duration of droughts. This in turn could increase the probability of wildfire, leading to the reduction in vegetation growth that helps to support steep slopes. Climate change may impact storm patterns, increasing the probability of more frequent, intense storms that could loosen unprotected soils. All these factors would increase the probability for landslide occurrences.

Subsidence/Sinkholes

One of the triggers for subsidence and sinkholes is an abundance of moisture that can permeate the bedrock. Climatologists expect an increase in annual precipitation amounts. This increase will coincide with an increased risk in subsidence and sinkholes in vulnerable areas.

10.1.6 Cascading Impacts on Other Hazards

Geological hazards such as earthquakes or landslides can elevate the risk of a dam failure. Seismic activity can cause slumping or settling of earth-filled dams, especially if the fill is not properly compacted. If the slumping occurs when the dam is full, then overtopping of the dam is possible, with rapid erosion leading to dam failure. Dam failure is also possible if strong ground motions heavily damage concrete dams. Earthquake-induced landslides into reservoirs have also caused dam failures.

10.2 VULNERABILITY AND IMPACT ASSESSMENT

To estimate the County's risk to the geologic hazard, the following hazard datasets were analyzed:

- NEHRP D&E Soils – sourced from NJGWS (2015)
- Liquefaction Class 4 - sourced from NJGWS (2015)
- Landslide Classes A and B – sourced from NJGWS (2015)
- Carbonate Rock – sourced from NJDEP (2023)

These datasets were overlaid on the updated asset inventory maps (population, building stock, critical facilities, and new development). Assets with their centroid located in the hazard area were totaled to estimate the totals and values at risk from the impacts of a geologic event.

The risk assessment for earthquake also included a Level 2 probabilistic assessment in Hazus for the 500- and 2,500-year MRP events to estimate injuries and structure damage. The probabilistic method uses information from historic earthquakes and inferred faults, locations and magnitudes, and computes the probable ground shaking levels that may be experienced during a recurrence period.

10.2.1 Life, Health, and Safety

Overall Population

Earthquakes

The entire County may experience the impacts of an earthquake. However, the degree of impact on people is dependent on many factors including the age and type of construction people live in, the soil type that homes are located on, and the intensity of the earthquake. Overall, risk to public safety and loss of life from an earthquake in the County is minimal for low magnitude events. However, there is a higher risk to public safety for those inside buildings due to structural damage or people walking below building ornamentations and chimneys that may be shaken loose and fall because of an earthquake.

NEHRP Soil Classes D and E amplify ground shaking to damaging levels and thus increase risk to the population. As shown in Table 10-9, 64,743 persons live within the NEHRP Soil Class D and E hazard areas. The Township of Wayne has the greatest population in the hazard area with 11,914 people.

Table 10-9. Estimated Population Living in the NEHRP Soils Class D and E Hazard Areas

Jurisdiction	Total Population (2022 ACS 5-Year Estimate)	Population in the NEHRP Soils (D&E) Hazard Area	
		Number of Persons	% of Jurisdiction Total
Bloomingdale (B)	7,726	0	0.0%
Clifton (C)	89,451	9,915	11.1%
Haledon (B)	8,945	0	0.0%
Hawthorne (B)	19,456	3,461	17.8%
Little Falls (T)	14,229	1,267	8.9%
North Haledon (B)	8,801	0	0.0%
Passaic (C)	70,048	10,946	15.6%
Paterson (C)	157,864	10,612	6.7%
Pompton Lakes (B)	11,052	9,594	86.8%
Prospect Park (B)	6,299	42	0.7%
Ringwood (B)	11,692	0	0.0%
Totowa (B)	10,975	2,584	23.5%
Wanaque (B)	11,217	1,916	17.1%
Wayne (T)	54,143	11,914	22.0%
West Milford (T)	24,797	1,151	4.6%
Woodland Park (B)	13,291	1,341	10.1%
Passaic County (Total)	519,986	64,743	12.5%

Source: (US Census Bureau 2022); (NJGWS 2015); (NJOIT 2024); Microsoft 2019

Table 10-10 shows that 7,313 persons live in the Liquefaction Class 4 hazard area. The Township of Wayne has the greatest population in the hazard area with 2,409 people.

Table 10-10. Population in the Liquefaction Class 4 Hazard Area

Jurisdiction	Total Population (2022 ACS 5-Year Estimate)	Population in the Liquefaction Class 4 Hazard Area	
		Number of Persons	% of Jurisdiction Total
Bloomingdale (B)	7,726	0	0.0%
Clifton (C)	89,451	0	0.0%
Haledon (B)	8,945	411	4.6%
Hawthorne (B)	19,456	19	0.1%
Little Falls (T)	14,229	1,568	11.0%
North Haledon (B)	8,801	0	0.0%
Passaic (C)	70,048	920	1.3%
Paterson (C)	157,864	381	0.2%
Pompton Lakes (B)	11,052	1,487	13.5%
Prospect Park (B)	6,299	0	0.0%
Ringwood (B)	11,692	0	0.0%
Totowa (B)	10,975	62	0.6%
Wanaque (B)	11,217	0	0.0%
Wayne (T)	54,143	2,409	4.4%
West Milford (T)	24,797	0	0.0%
Woodland Park (B)	13,291	56	0.4%
Passaic County (Total)	519,986	7,313	1.4%

Source: (US Census Bureau 2022); (NJGWS 2015); (NJOIT 2024); Microsoft 2019

Hazus estimated the number of people who might be injured or killed by an earthquake, categorizing casualties into severity levels based on the extent of injuries. The analysis provided casualty estimates for three times of day—2:00 AM, 2:00 PM, and 5:00 PM—to reflect peak occupancy in different community sectors. The 2:00 AM estimate considers maximum residential occupancy, the 2:00 PM estimate accounts for peak occupancy in educational, commercial, and industrial sectors, and the 5:00 PM estimate represents peak commute time. This approach helps to understand the varying impact of an earthquake depending on the time of day and the corresponding occupancy levels in different sectors. The Hazus analysis was conducted for the 500- and 2,500-year MRP events; results for each are shown in Table 10-11.

Residents may be displaced or require temporary to long-term sheltering due to an earthquake. 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 after a disaster event. Hazus estimated no people with sheltering needs for Passaic County for an earthquake event with a 500-year MRP. For the 2,500-year MRP, 120 persons would require sheltering as shown in Table 10-12.

Table 10-11. Estimated Casualties from 500-Year and 2,500-Year MRP Earthquake Events

Time of Day Event Occurs	500-Year MRP Earthquake Event			2,500-Year MRP Earthquake Event		
	Non-Hospitalized Injuries	Hospitalizations	Fatalities	Non-Hospitalized Injuries	Hospitalizations	Fatalities
2:00 a.m.	2	0	0	37	2	0
2:00 p.m.	8	1	0	96	17	3
5:00 p.m.	2	0	0	28	3	0

Source: Hazus v6.1

Table 10-12. Person Seeking Sheltering, 500-Year and 2,500-Year MRP Earthquake Event

Jurisdiction	500-Year MRP Earthquake Event		2,500-Year MRP Earthquake Event	
	Displaced Households	Persons Seeking Short-Term Sheltering	Displaced Households	Persons Seeking Short-Term Sheltering
Bloomingdale (B)	0	0	0	0
Clifton (C)	0	0	17	9
Haledon (B)	0	0	0	0
Hawthorne (B)	0	0	3	1
Little Falls (T)	0	0	1	0
North Haledon (B)	0	0	0	0
Passaic (C)	0	0	16	13
Paterson (C)	0	0	31	24
Pompton Lakes (B)	0	0	0	0
Prospect Park (B)	0	0	0	0
Ringwood (B)	0	0	0	0
Totowa (B)	0	0	0	0
Wanaque (B)	0	0	1	0
Wayne (T)	0	0	3	1
West Milford (T)	0	0	0	0
Woodland Park (B)	0	0	0	0
Passaic County (Total)	0	0	72	48

Source: Hazus v6.1; (US Census Bureau 2022)
Note: Population rounded down; All results 0 for 500-year MRP event.

Landslides and Subsidence/Sinkholes

Generally, a landslide or subsidence event is an isolated incidence, impacting the populations within the immediate area. In addition to causing damage to residential buildings and displacing residents, landslides and subsidence events can block or damage major roadways and inhibit travel for emergency responders or populations trying to evacuate the area.

Table 10-13 summarizes the population living in the landslide class A and class B hazard areas. Overall, there are 842 people residing in the landslide class A hazard area and 466 in the landslide class B hazard area. The Borough of Woodland Park (232) and the Borough of Ringwood (161) have the greatest number of residents living in the landslide class A hazard area. The Borough of Wanaque (147) and the Township of Wayne (115) have the greatest number of residents living in the landslide class B hazard area.

Table 10-13. Estimated Population in the Landslide Class A and Class B Hazard Areas

Jurisdiction	Total Population (2022 ACS 5-Year Estimate)	Population in the Class A Hazard Area		Population in the Class B Hazard Area	
		Number of Persons	% of Jurisdiction Total	Number of Persons	% of Jurisdiction Total
Bloomingdale (B)	7,726	7	0.1%	11	0.1%
Clifton (C)	89,451	14	<0.1%	0	0.0%
Haledon (B)	8,945	5	0.1%	0	0.0%
Hawthorne (B)	19,456	7	<0.1%	103	0.5%
Little Falls (T)	14,229	0	0.0%	0	0.0%
North Haledon (B)	8,801	146	1.7%	0	0.0%
Passaic (C)	70,048	0	0.0%	0	0.0%
Paterson (C)	157,864	23	<0.1%	0	0.0%
Pompton Lakes (B)	11,052	30	0.3%	0	0.0%
Prospect Park (B)	6,299	7	0.1%	0	0.0%
Ringwood (B)	11,692	161	1.4%	5	<0.1%
Totowa (B)	10,975	121	1.1%	6	0.1%
Wanaque (B)	11,217	0	0.0%	147	1.3%
Wayne (T)	54,143	77	0.1%	115	0.2%
West Milford (T)	24,797	12	<0.1%	79	0.3%
Woodland Park (B)	13,291	232	1.7%	0	0.0%
Passaic County (Total)	519,986	842	0.2%	466	0.1%

Source: (US Census Bureau 2022); (NJOIT 2024); Microsoft 2019; (NJGWS 2015)

Table 10-14 summarizes the population living in areas with carbonate bedrock. Overall, 646 people are living on carbonate bedrock. There are two jurisdictions that contain residents living on carbonate bedrock: the Town of West Milford (618) and the Borough of Wanaque (28).

Socially Vulnerable Population

Research indicates that while some populations may not face higher hazard exposure, they can experience more severe impacts and longer recovery times if affected. This is due to factors like decreased mobility, limited financial resources to respond to hazards, and the quality and location of their housing. For instance, the elderly and those living in poverty are at greater risk during geological events due to potential limited access to mobilization or medical resources.

Table 10-14. Estimated Population in the Sinkhole Hazard Areas

Jurisdiction	Total Population (2022 ACS 5-Year Estimate)	Population in the Carbonate (Sinkholes/Karst) Hazard Area	
		Number of Persons	% of Jurisdiction Total
Bloomingdale (B)	7,726	0	0.0%
Clifton (C)	89,451	0	0.0%
Haledon (B)	8,945	0	0.0%
Hawthorne (B)	19,456	0	0.0%
Little Falls (T)	14,229	0	0.0%
North Haledon (B)	8,801	0	0.0%
Passaic (C)	70,048	0	0.0%
Paterson (C)	157,864	0	0.0%
Pompton Lakes (B)	11,052	0	0.0%
Prospect Park (B)	6,299	0	0.0%
Ringwood (B)	11,692	0	0.0%
Totowa (B)	10,975	0	0.0%
Wanaque (B)	11,217	28	0.2%
Wayne (T)	54,143	0	0.0%
West Milford (T)	24,797	618	2.5%
Woodland Park (B)	13,291	0	0.0%
Passaic County (Total)	519,986	646	0.1%

Source: (US Census Bureau 2022); (NJOIT 2024); Microsoft 2019; NJDEP 2023

Earthquake

Table 10-15 presents the estimated socially vulnerable populations located within the NEHRP Soils Class D and E hazard areas. There are 10,206 persons over the age of 65 years, 3,920 persons under the age of 5 years, 7,080 non-English speakers, 5,690 persons with a disability, and 7,348 living in poverty located in these areas. Table 10-16 presents the estimated socially vulnerable populations located within the Liquefaction Class 4 hazard area. There are 1,180 persons over the age of 65 years, 391 persons under the age of 5 years, 522 non-English speakers, 579 persons with a disability, and 573 living in poverty located in this hazard area.

Landslide and Subsidence/Sinkholes

Table 10-17 presents the estimated socially vulnerable populations living in the landslide class A and class B hazard areas. There are 160 persons over the age of 65 years, 40 persons under the age of 5 years, 33 non-English speakers, 68 persons with a disability, and 47 living in poverty located in the landslide class A hazard area. There are 93 persons over the age of 65 years, 20 persons under the age of 5 years, 11 non-English speakers, 43 persons with a disability, and 20 living in poverty located in the landslide class B hazard area.

Table 10-18 presents the estimated socially vulnerable populations located in landscapes with carbonate bedrock. There are 122 persons over the age of 65 years, 41 persons under the age of 5 years, 6 non-English speakers, 52 persons with a disability, and 19 living in poverty located in landscapes with carbonate bedrock throughout Passaic County.

Table 10-15. Estimated Vulnerable Persons Located in the NEHRP D & E Soils Hazard Area

Jurisdiction	Estimated Number of Vulnerable Persons Located in the NEHRP D & E Soils Hazard Area									
	Persons Over 65	% of Total	Persons Under 5	% of Total	Non-English Speaking Persons	% of Total	Persons with a Disability	% of Total	Persons in Poverty	% of Total
Bloomingdale (B)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Clifton (C)	1,738	11.1%	541	11.1%	1,177	11.1%	1,141	11.1%	714	11.1%
Haledon (B)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Hawthorne (B)	719	17.8%	133	17.8%	160	17.7%	325	17.8%	169	17.8%
Little Falls (T)	195	8.9%	41	8.7%	53	8.8%	95	8.9%	41	8.9%
North Haledon (B)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Passaic (C)	981	15.6%	903	15.6%	2,454	15.6%	857	15.6%	2,385	15.6%
Paterson (C)	1,219	6.7%	836	6.7%	2,345	6.7%	857	6.7%	2,496	6.7%
Pompton Lakes (B)	1,537	86.8%	490	86.7%	197	86.4%	693	86.7%	833	86.8%
Prospect Park (B)	4	0.6%	3	0.6%	4	0.6%	6	0.7%	7	0.6%
Ringwood (B)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Totowa (B)	500	23.5%	95	23.3%	80	23.3%	306	23.5%	98	23.3%
Wanaque (B)	427	17.1%	79	17.0%	50	16.9%	253	17.0%	118	17.0%
Wayne (T)	2,389	22.0%	630	22.0%	442	22.0%	956	22.0%	314	22.0%
West Milford (T)	216	4.6%	75	4.6%	12	4.6%	92	4.6%	35	4.6%
Woodland Park (B)	281	10.1%	94	10.0%	106	10.0%	109	10.1%	138	10.1%
Passaic County (Total)	10,206	13.0%	3,920	11.7%	7,080	10.3%	5,690	12.2%	7,348	10.7%

Source: (US Census Bureau 2022); (NJOIT 2024); (NJGWS 2015); Microsoft 2019

Table 10-16. Estimated Vulnerable Persons Located in the Liquefaction Class 4 Hazard Area

Jurisdiction	Estimated Number of Vulnerable Persons Located in the Liquefaction Class 4 Hazard Area									
	Persons Over 65	% of Total	Persons Under 5	% of Total	Non-English Speaking Persons	% of Total	Persons with a Disability	% of Total	Persons in Poverty	% of Total
Bloomingdale (B)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Clifton (C)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Haledon (B)	67	4.6%	25	4.5%	42	4.5%	47	4.6%	35	4.6%
Hawthorne (B)	3	0.1%	0	0.0%	0	0.0%	1	0.1%	0	0.0%
Little Falls (T)	241	11.0%	51	10.9%	66	11.0%	118	11.0%	50	10.8%
North Haledon (B)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Passaic (C)	82	1.3%	76	1.3%	206	1.3%	72	1.3%	200	1.3%
Paterson (C)	43	0.2%	30	0.2%	84	0.2%	30	0.2%	89	0.2%
Pompton Lakes (B)	238	13.4%	76	13.5%	30	13.2%	107	13.4%	129	13.4%
Prospect Park (B)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Ringwood (B)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Totowa (B)	12	0.6%	2	0.5%	1	0.3%	7	0.5%	2	0.5%
Wanaque (B)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Wayne (T)	483	4.4%	127	4.4%	89	4.4%	193	4.4%	63	4.4%
West Milford (T)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Woodland Park (B)	11	0.4%	4	0.4%	4	0.4%	4	0.4%	5	0.4%
Passaic County (Total)	1,180	1.5%	391	1.2%	522	0.8%	579	1.2%	573	0.8%

Source: (US Census Bureau 2022); (NJOIT 2024); (NJGWS 2015); Microsoft 2019

Table 10-17. Estimated Vulnerable Persons Located in the Landslide Hazard Areas

Jurisdiction	Estimated Number of Vulnerable Persons Located in the Class A Hazard Area					Estimated Number of Vulnerable Persons Located in the Class B Hazard Area				
	Persons Over 65	Persons Under 5	Non-English Speaking Persons	Persons with a Disability	Persons in Poverty	Persons Over 65	Persons Under 5	Non-English Speaking Persons	Persons with a Disability	Persons in Poverty
Bloomingdale (B)	1	0	0	0	0	1	0	0	0	1
Clifton (C)	2	0	1	1	1	0	0	0	0	0
Haledon (B)	0	0	0	0	0	0	0	0	0	0
Hawthorne (B)	1	0	0	0	0	21	3	4	9	5
Little Falls (T)	0	0	0	0	0	0	0	0	0	0
North Haledon (B)	35	8	3	13	5	0	0	0	0	0
Passaic (C)	0	0	0	0	0	0	0	0	0	0
Paterson (C)	2	1	5	1	5	0	0	0	0	0
Pompton Lakes (B)	4	1	0	2	2	0	0	0	0	0
Prospect Park (B)	0	0	0	1	1	0	0	0	0	0
Ringwood (B)	27	6	1	12	3	1	0	0	0	0
Totowa (B)	23	4	3	14	4	1	0	0	0	0
Wanaque (B)	0	0	0	0	0	32	6	3	19	9
Wayne (T)	15	4	2	6	2	23	6	4	9	3
West Milford (T)	2	0	0	0	0	14	5	0	6	2
Woodland Park (B)	48	16	18	18	24	0	0	0	0	0
Passaic County (Total)	160	40	33	68	47	93	20	11	43	20

Source: (US Census Bureau 2022); (NJOIT 2024); (NJGWS 2015); Microsoft 2019

Table 10-18. Estimated Vulnerable Persons Located in the Sinkholes Hazard Area

Jurisdiction	Number of Vulnerable Persons Living in the Carbonate (Sinkholes/Karst) Hazard Area				
	Persons Over 65	Persons Under 5	Non-English Speaking Persons	Persons with a Disability	Persons in Poverty
Bloomingdale (B)	0	0	0	0	0
Clifton (C)	0	0	0	0	0
Haledon (B)	0	0	0	0	0
Hawthorne (B)	0	0	0	0	0
Little Falls (T)	0	0	0	0	0
North Haledon (B)	0	0	0	0	0
Passaic (C)	0	0	0	0	0
Paterson (C)	0	0	0	0	0
Pompton Lakes (B)	0	0	0	0	0
Prospect Park (B)	0	0	0	0	0
Ringwood (B)	0	0	0	0	0
Totowa (B)	0	0	0	0	0
Wanaque (B)	6	1	0	3	1
Wayne (T)	0	0	0	0	0
West Milford (T)	116	40	6	49	18
Woodland Park (B)	0	0	0	0	0
Passaic County (Total)	122	41	6	52	19

Source: (US Census Bureau 2022); (NJOIT 2024); (NJGWS 2015); Microsoft 2019

10.2.2 General Building Stock

Earthquake

When earthquakes occur, the effects of ground shaking can extend over large areas. Older structures are particularly vulnerable due to less stringent building codes at the time of their construction and potential maintenance issues. The severity of the impacts also depends on occupancy and timing of the earthquake.

Location on Susceptible Soils

Table 10-19 summarizes the number of buildings built on the NEHRP D and E Soils hazard area and the total replacement cost of these buildings by jurisdiction. There are 15,022 buildings with a replacement cost value (RCV) of approximately $18.9 billion built on lands in the NEHRP D and E soils hazard area. The Township of Wayne has the greatest number of buildings built in the NEHRP D and E Soils hazard area; 3,894 buildings (25 percent of its total building stock) with an estimated replacement cost of $5.9 billion.

Table 10-20 summarizes the number of buildings built on the Liquefaction Class 4 hazard area and the total replacement cost of these buildings by jurisdiction. There are 2,133 buildings with an RCV of approximately $3.6 billion built on lands in the Liquefaction Class 4 hazard area. The Township of Wayne has the greatest number of buildings built in the Liquefaction Class 4 hazard area; 1,007 buildings (6.5-percent of its total building stock) with an estimated replacement cost of $1.6 billion.

Table 10-19. Number and Value of Buildings in the NEHRP D & E Soils Hazard Area

Jurisdiction	Jurisdiction Total Buildings		Buildings in the NEHRP D&E Soils Hazard Area			
			Number of Buildings		RCV	
	Count	RCV	Count	% of Jurisdiction Total	Value	% of Jurisdiction Total
Bloomingdale (B)	2,406	$1,358,262,927	0	0.0%	$0	0.0%
Clifton (C)	20,935	$15,833,226,790	2,459	11.7%	$2,490,585,729	15.7%
Haledon (B)	1,898	$1,277,354,659	0	0.0%	$0	0.0%
Hawthorne (B)	6,079	$3,946,342,797	1,142	18.8%	$952,274,341	24.1%
Little Falls (T)	2,915	$3,414,669,325	256	8.8%	$279,853,151	8.2%
North Haledon (B)	2,952	$2,161,286,853	0	0.0%	$0	0.0%
Passaic (C)	5,784	$11,383,166,371	952	16.5%	$3,226,794,645	28.3%
Paterson (C)	16,686	$18,630,913,440	1,183	7.1%	$2,381,965,768	12.8%
Pompton Lakes (B)	3,271	$1,954,260,257	2,811	85.9%	$1,447,486,690	74.1%
Prospect Park (B)	1,016	$492,237,246	6	0.6%	$8,718,987	1.8%
Ringwood (B)	4,369	$2,697,179,876	0	0.0%	$0	0.0%
Totowa (B)	3,765	$5,499,989,017	892	23.7%	$919,471,133	16.7%
Wanaque (B)	3,183	$2,352,891,840	598	18.8%	$479,884,648	20.4%
Wayne (T)	15,577	$15,872,014,112	3,894	25.0%	$5,946,715,728	37.5%
West Milford (T)	9,452	$5,622,763,478	470	5.0%	$289,102,833	5.1%
Woodland Park (B)	2,965	$3,101,377,870	359	12.1%	$450,161,439	14.5%
Passaic County (Total)	103,253	$95,597,936,857	15,022	14.5%	$18,873,015,092	19.7%

Source: Microsoft 2019; RS Means 2024; (NJGWS 2015); (NJOIT 2024)

Table 10-20. Number and Value of Buildings in the Liquefaction Class 4 Hazard Area

Jurisdiction	Jurisdiction Total Buildings		Buildings in the Liquefaction Class 4 Hazard Area			
			Number of Buildings		RCV	
	Count	RCV	Count	% of Jurisdiction Total	Value	% of Jurisdiction Total
Bloomingdale (B)	2,406	$1,358,262,927	0	0.0%	$0	0.0%
Clifton (C)	20,935	$15,833,226,790	10	<0.1%	$59,781,539	0.4%
Haledon (B)	1,898	$1,277,354,659	102	5.4%	$158,818,221	12.4%
Hawthorne (B)	6,079	$3,946,342,797	27	0.4%	$82,486,477	2.1%
Little Falls (T)	2,915	$3,414,669,325	308	10.6%	$148,136,012	4.3%
North Haledon (B)	2,952	$2,161,286,853	0	0.0%	$0	0.0%
Passaic (C)	5,784	$11,383,166,371	104	1.8%	$647,531,797	5.7%
Paterson (C)	16,686	$18,630,913,440	106	0.6%	$480,925,996	2.6%
Pompton Lakes (B)	3,271	$1,954,260,257	423	12.9%	$172,121,365	8.8%
Prospect Park (B)	1,016	$492,237,246	0	0.0%	$0	0.0%
Ringwood (B)	4,369	$2,697,179,876	0	0.0%	$0	0.0%
Totowa (B)	3,765	$5,499,989,017	31	0.8%	$215,562,469	3.9%
Wanaque (B)	3,183	$2,352,891,840	0	0.0%	$0	0.0%
Wayne (T)	15,577	$15,872,014,112	1,007	6.5%	$1,619,335,277	10.2%
West Milford (T)	9,452	$5,622,763,478	0	0.0%	$0	0.0%
Woodland Park (B)	2,965	$3,101,377,870	15	0.5%	$7,540,312	0.2%
Passaic County (Total)	103,253	$95,597,936,857	2,133	2.1%	$3,592,239,464	3.8%

Source: Microsoft 2019; RS Means 2024; (NJGWS 2015); (NJOIT 2024)

Table 10-21 displays the buildings located within the NEHRP D and E hazard area by general occupancy. The residential occupancy is the most exposed to this hazard area with 12,235 total buildings. The Township of Wayne holds the highest number of resident buildings (3,091) in the hazard area.

Table 10-21. Buildings in the NEHRP D & E Soils Hazard Area by General Occupancy

	Buildings in the NEHRP D&E Soils Hazard Area by General Occupancy Class			
Jurisdiction	Residential	Commercial	Industrial	Other[a]
Bloomingdale (B)	0	0	0	0
Clifton (C)	2,028	397	25	9
Haledon (B)	0	0	0	0
Hawthorne (B)	905	212	19	6
Little Falls (T)	215	41	0	0
North Haledon (B)	0	0	0	0
Passaic (C)	749	164	16	23
Paterson (C)	890	222	50	21
Pompton Lakes (B)	2,502	282	10	17
Prospect Park (B)	6	0	0	0
Ringwood (B)	0	0	0	0
Totowa (B)	745	135	9	3
Wanaque (B)	469	108	11	10
Wayne (T)	3,091	729	45	29
West Milford (T)	376	87	0	7
Woodland Park (B)	259	94	5	1
Passaic County (Total)	12,235	2,471	190	126

Source: Microsoft 2019; (NJOIT 2024); (NJGWS 2015)

a. Other = Government, Religion, Agricultural, and Education

Table 10-22 lists buildings in the Liquefaction Class 4 hazard area by general occupancy. The exposure analysis estimates that the residential occupancy is the most exposed to this hazard with a total of 1,479 residential buildings. The Township of Wayne has the highest number of residential buildings (625) in this hazard area.

Level of Damage by Occupancy Class

Table 10-23 summarizes the expected damage to various building types during the 500- and 2,500-year MRP events. For residential buildings, the majority are expected to sustain no damage, with 99.4 percent undamaged in the 500-year period and 92.0 percent in the 2,500-year MRP. Minor damage is expected in a small percentage, increasing from 0.6 percent in the 500-year MRP to 6.9 percent in the 2,500-year MRP. Moderate to severe damage and destruction are rare across all building types, with slightly higher percentages in the 2,500-year period. Commercial, industrial, and other buildings show similar trends, with most buildings remaining undamaged, and minor damage percentages increasing 0.3 percent in the 500-year MRP to 4.2 percent in the 2,500-year MRP. Severe damage and destruction remain minimal across all categories. Another key factor in degree of vulnerability is age of facilities and infrastructure, which correlates with building standards in place at times of construction.

Table 10-22. Buildings in the Liquefaction Class 4 Hazard Area by General Occupancy

Jurisdiction	Buildings in the Liquefaction Class 4 Hazard Area by General Occupancy Class			
	Residential	Commercial	Industrial	Other[a]
Bloomingdale (B)	0	0	0	0
Clifton (C)	0	7	3	0
Haledon (B)	71	29	2	0
Hawthorne (B)	5	18	3	1
Little Falls (T)	266	33	9	0
North Haledon (B)	0	0	0	0
Passaic (C)	63	32	6	3
Paterson (C)	32	62	12	0
Pompton Lakes (B)	388	26	7	2
Prospect Park (B)	0	0	0	0
Ringwood (B)	0	0	0	0
Totowa (B)	18	11	2	0
Wanaque (B)	0	0	0	0
Wayne (T)	625	355	23	4
West Milford (T)	0	0	0	0
Woodland Park (B)	11	4	0	0
Passaic County (Total)	1,479	577	67	10

Source: Microsoft 2019; (NJOIT 2024); (NJGWS 2015)

a. Other = Government, Religion, Agricultural, and Education

Table 10-23. Damage Severity by Occupancy Class

Total Number of Buildings in Occupancy	Severity of Expected Damage	500-Year MRP		2,500-Year MRP	
		Building Count	% Buildings in Occupancy Class	Building Count	% Buildings in Occupancy Class
Residential Exposure (Single and Multi-Family Dwellings)					
88,431	NONE	87,910	99.4%	81,360	92.0%
	MINOR	488	0.6%	6,075	6.9%
	MODERATE	32	<0.1%	946	1.1%
	SEVERE	0	0.0%	50	0.1%
	DESTRUCTION	0	0.0%	0	0.0%
Commercial Buildings					
13,055	NONE	13,009	99.6%	12,313	94.3%
	MINOR	40	0.3%	543	4.2%
	MODERATE	6	<0.1%	186	1.4%
	SEVERE	0	<0.1%	10	0.1%
	DESTRUCTION	0	<0.1%	2	<0.1%

Total Number of Buildings in Occupancy	Severity of Expected Damage	500-Year MRP		2,500-Year MRP	
		Building Count	% Buildings in Occupancy Class	Building Count	% Buildings in Occupancy Class
Industrial Buildings					
738	NONE	729	98.8%	670	90.8%
	MINOR	7	0.9%	45	6.1%
	MODERATE	2	0.3%	20	2.7%
	SEVERE	0	<0.1%	3	0.4%
	DESTRUCTION	0	<0.1%	0	0.1%
Other Buildings[a]					
1,029	NONE	1,014	98.6%	917	89.1%
	MINOR	12	1.1%	81	7.9%
	MODERATE	3	0.3%	25	2.5%
	SEVERE	0	<0.1%	4	0.4%
	DESTRUCTION	0	0.0%	1	0.1%

Source: Hazus v6.1; Microsoft 2019; (NJOIT 2024)

a. Other = Government, Religion, Agricultural, and Education

Estimated Losses

Table 10-24 and Table 10-25 provide an overview of the estimated losses in various jurisdictions within Passaic County during earthquakes with a 500-year and 2,500-year MRP. For the 500-year MRP event, the total estimated losses to residential, commercial, and other buildings is about $23 million, which is less than 0.1 percent of the total Couty RCV. For the 2,500-year MRP event, the total estimated loss is about $591 million, or 0.6 percent of the total Couty RCV. This includes significant losses across residential, commercial, and other buildings, with the City of Paterson experiencing the highest total loss of approximately $128 million.

Table 10-24. Estimated Losses Due to 500-Year MRP Earthquake Events

Jurisdiction	Total Replacement Cost Value (RCV)	Estimated Loss				
		Residential	Commercial	Other[a]	Total	
					Damage	% of RCV
Bloomingdale (B)	$1,358,262,927	$116,312	$23,885	$26,953	$167,149	<0.1%
Clifton (C)	$15,833,226,790	$2,223,980	$1,613,412	$1,252,332	$5,089,723	<0.1%
Haledon (B)	$1,277,354,659	$84,000	$28,590	$77,793	$190,383	<0.1%
Hawthorne (B)	$3,946,342,797	$665,432	$249,941	$295,491	$1,210,863	<0.1%
Little Falls (T)	$3,414,669,325	$368,308	$218,758	$253,203	$840,269	<0.1%
North Haledon (B)	$2,161,286,853	$315,617	$41,850	$37,491	$394,958	<0.1%
Passaic (C)	$11,383,166,371	$1,639,041	$722,667	$764,330	$3,126,038	<0.1%
Paterson (C)	$18,630,913,440	$1,566,767	$1,667,655	$2,054,100	$5,288,521	<0.1%
Pompton Lakes (B)	$1,954,260,257	$162,738	$34,884	$63,161	$260,783	<0.1%
Prospect Park (B)	$492,237,246	$80,715	$25,473	$34,560	$140,749	<0.1%
Ringwood (B)	$2,697,179,876	$225,555	$35,708	$45,201	$306,464	<0.1%

Jurisdiction	Total Replacement Cost Value (RCV)	Estimated Loss				
		Residential	Commercial	Other[a]	Total	
					Damage	% of RCV
Totowa (B)	$5,499,989,017	$353,152	$504,071	$315,929	$1,173,152	<0.1%
Wanaque (B)	$2,352,891,840	$315,794	$77,273	$266,495	$659,562	<0.1%
Wayne (T)	$15,872,014,112	$1,488,288	$1,071,757	$1,038,830	$3,598,875	<0.1%
West Milford (T)	$5,622,763,478	$497,904	$103,379	$119,378	$720,662	<0.1%
Woodland Park (B)	$3,101,377,870	$181,025	$76,371	$52,366	$309,762	<0.1%
Passaic County (Total)	$95,597,936,857	$10,284,626	$6,495,673	$6,697,613	$23,477,912	<0.1%

Source: Hazus v6.1; RS Means 2024; Microsoft 2019; (NJOIT 2024)

a. Other = Government, Religion, Agricultural, and Education

Table 10-25. Estimated Damage Costs Due to 2,500-Year MRP Earthquake Events

Jurisdiction	Total Replacement Cost Value (RCV)	Estimated Damage to Structure and Contents				
		Residential	Commercial	Other[a]	Total	
					Damage	% of RCV
Bloomingdale (B)	$1,358,262,927	$4,097,324	$1,064,840	$611,451	$5,773,614	0.4%
Clifton (C)	$15,833,226,790	$52,474,112	$38,403,141	$24,312,879	$115,190,132	0.7%
Haledon (B)	$1,277,354,659	$3,010,650	$1,417,293	$2,044,237	$6,472,180	0.5%
Hawthorne (B)	$3,946,342,797	$16,046,836	$6,598,261	$5,732,896	$28,377,993	0.7%
Little Falls (T)	$3,414,669,325	$8,861,114	$5,984,437	$5,306,507	$20,152,058	0.6%
North Haledon (B)	$2,161,286,853	$9,314,630	$1,689,932	$996,212	$12,000,773	0.6%
Passaic (C)	$11,383,166,371	$41,253,746	$22,077,829	$13,785,713	$77,117,288	0.7%
Paterson (C)	$18,630,913,440	$39,312,011	$42,448,658	$46,985,149	$128,745,818	0.7%
Pompton Lakes (B)	$1,954,260,257	$5,637,695	$1,781,074	$1,384,762	$8,803,531	0.5%
Prospect Park (B)	$492,237,246	$2,243,624	$652,706	$559,477	$3,455,807	0.7%
Ringwood (B)	$2,697,179,876	$7,712,829	$1,757,170	$1,534,834	$11,004,834	0.4%
Totowa (B)	$5,499,989,017	$9,092,316	$13,822,811	$8,541,204	$31,456,332	0.6%
Wanaque (B)	$2,352,891,840	$8,387,882	$2,293,365	$4,089,407	$14,770,654	0.6%
Wayne (T)	$15,872,014,112	$42,502,603	$27,494,799	$21,629,736	$91,627,137	0.6%
West Milford (T)	$5,622,763,478	$15,367,167	$4,142,362	$3,613,160	$23,122,689	0.4%
Woodland Park (B)	$3,101,377,870	$7,095,045	$4,298,553	$1,850,944	$13,244,543	0.4%
Passaic County (Total)	$95,597,936,857	$272,409,583	$175,927,231	$142,978,569	$591,315,383	0.6%

Source: Hazus v6.1; RS Means 2024; Microsoft 2019; (NJOIT 2024)

a. Other = Government, Religion, Agricultural, and Education

Landslide and Subsidence/Sinkholes

The built environment is vulnerable if built on soils/geology susceptible to landslides or sinkholes such as steep slopes or carbonate bedrock. Geological hazard areas may destabilize the foundation of structures resulting in monetary losses to businesses and residents.

Table 10-26 summarizes the number of buildings built on the Class A and Class B landslide hazard areas and the total replacement cost of these buildings by jurisdiction. There are 250 buildings, with an RCV of approximately $468 million, built on lands in the landslide Class A hazard area. There are 137 buildings, with an RCV of approximately $80 million, built in the landslide class B hazard area. The Borough of Ringwood has the greatest number of buildings in the landslide Class A hazard area—57 buildings (1.3 percent of its total building stock), with an estimated replacement cost of $28 million. The Borough of Wanaque has the greatest number of buildings in the landslide Class B hazard area—37 buildings (1.2 percent of its total building stock), with an estimated replacement cost of $18 million.

Table 10-27 lists the buildings in the landslide class A and Class B hazard area by general occupancy. The residential occupancy is the most exposed to landslide hazards, with 221 residential buildings in the landslide Class A hazard area, and 126 residential buildings in the landslide Class B hazard area. The Borough of Ringwood has the highest number of residential buildings (55) in the Class A hazard area, and the Borough of Wanaque has the highest number of residential buildings (36) in the Class B hazard area.

Table 10-28 summarizes the number of buildings built on carbonate bedrock and the total replacement cost of these buildings by jurisdiction. There are 245 buildings, with an RCV of approximately $126 million, built on lands with carbonate bedrock. The Township of Milford has the greatest number of buildings on carbonate bedrock—237 buildings (2.5 percent of its total building stock) with an estimated replacement cost of $122 million.

Table 10-29 lists the buildings located within the carbonate bedrock hazard area by general occupancy. The residential occupancy is the most exposed to the subsidence hazard area with 209 total buildings. The Township of West Milford holds the highest number of resident buildings (202) in the carbonate rock hazard area.

10.2.3 Community Lifelines and Other Critical Facilities

Earthquakes, landslides, and sinkholes can severely disrupt essential services such as power, water, transportation, and emergency response systems. When community lifelines and other critical facilities go offline, the community's ability to function and recover is significantly hindered. The following analysis explores the anticipated effects on various facilities and the extent of damage expected under different scenarios.

Earthquake

Table 10-30 shows the number of critical facilities located on NEHRP D and E soils. There are 254 facilities located in this hazard area, with the highest number among the safety and security lifeline (70). The Township of Wayne has the highest number of critical facilities (62) located in the NEHRP D and E soils hazard area.

Table 10-31 outlines the number of critical facilities in the Liquefaction Class 4 Hazard Area. The City of Paterson has the highest number of facilities in hazard areas (16), followed by the Township of Wayne (14). Overall, Passaic County has 69 facilities in the Liquefaction Class 4 hazard area, accounting for 5.2 percent of the jurisdictional total.

Table 10-26. Number and Value of Buildings in Landslide Hazard Area

Jurisdiction	Jurisdiction Total Buildings		Landslide Class A Hazard Area				Landslide Class B Hazard Area			
			Number of Buildings		RCV		Number of Buildings		RCV	
	Count	RCV	Count	% of Jurisdiction Total	Value	% of Jurisdiction Total	Count	% of Jurisdiction Total	Value	% of Jurisdiction Total
Bloomingdale (B)	2,406	$1,358,262,927	2	0.1%	$958,334	0.1%	3	0.1%	$1,078,377	0.1%
Clifton (C)	20,935	$15,833,226,790	3	<0.1%	$1,193,974	<0.1%	0	0.0%	$0	0.0%
Haledon (B)	1,898	$1,277,354,659	3	0.2%	$5,294,231	0.4%	0	0.0%	$0	0.0%
Hawthorne (B)	6,079	$3,946,342,797	2	<0.1%	$5,918,109	0.1%	27	0.4%	$15,103,481	0.4%
Little Falls (T)	2,915	$3,414,669,325	0	0.0%	$0	0.0%	0	0.0%	$0	0.0%
North Haledon (B)	2,952	$2,161,286,853	44	1.5%	$125,994,212	5.8%	0	0.0%	$0	0.0%
Passaic (C)	5,784	$11,383,166,371	0	0.0%	$0	0.0%	0	0.0%	$0	0.0%
Paterson (C)	16,686	$18,630,913,440	9	0.1%	$22,071,458	0.1%	0	0.0%	$0	0.0%
Pompton Lakes (B)	3,271	$1,954,260,257	8	0.2%	$4,017,888	0.2%	0	0.0%	$0	0.0%
Prospect Park (B)	1,016	$492,237,246	2	0.2%	$2,748,385	0.6%	0	0.0%	$0	0.0%
Ringwood (B)	4,369	$2,697,179,876	57	1.3%	$27,503,724	1.0%	2	<0.1%	$717,358	<0.1%
Totowa (B)	3,765	$5,499,989,017	38	1.0%	$34,325,140	0.6%	3	0.1%	$1,612,573	<0.1%
Wanaque (B)	3,183	$2,352,891,840	1	<0.1%	$147,715	<0.1%	37	1.2%	$18,246,241	0.8%
Wayne (T)	15,577	$15,872,014,112	20	0.1%	$14,925,704	0.1%	31	0.2%	$21,971,186	0.1%
West Milford (T)	9,452	$5,622,763,478	5	0.1%	$3,012,499	0.1%	34	0.4%	$20,789,964	0.4%
Woodland Park (B)	2,965	$3,101,377,870	56	1.9%	$219,864,650	7.1%	0	0.0%	$0	0.0%
Passaic County (Total)	103,253	$95,597,936,857	250	0.2%	$467,976,022	0.5%	137	0.1%	$79,519,181	0.1%

Source: Microsoft 2019; RS Means 2024; (NJGWS 2015); (NJOIT 2024)

Table 10-27. Buildings in the Landslide Hazard Area by General Occupancy Class

Jurisdiction	Landslide Class A Hazard Area				Landslide Class B Hazard Area			
	Residential	Commercial	Industrial	Other[a]	Residential	Commercial	Industrial	Other[a]
Bloomingdale (B)	2	0	0	0	3	0	0	0
Clifton (C)	3	0	0	0	0	0	0	0
Haledon (B)	1	1	1	0	0	0	0	0
Hawthorne (B)	2	0	0	0	27	0	0	0
Little Falls (T)	0	0	0	0	0	0	0	0
North Haledon (B)	43	1	0	0	0	0	0	0
Passaic (C)	0	0	0	0	0	0	0	0
Paterson (C)	2	7	0	0	0	0	0	0
Pompton Lakes (B)	8	0	0	0	0	0	0	0
Prospect Park (B)	1	1	0	0	0	0	0	0
Ringwood (B)	55	2	0	0	2	0	0	0
Totowa (B)	35	2	1	0	2	1	0	0
Wanaque (B)	0	1	0	0	36	1	0	0
Wayne (T)	20	0	0	0	30	1	0	0
West Milford (T)	4	1	0	0	26	5	1	2
Woodland Park (B)	45	11	0	0	0	0	0	0
Passaic County (Total)	221	27	2	0	126	8	1	2

Source: (NJGWS 2015); (NJOIT 2024); Microsoft 2019

a. Other = Government, Religion, Agricultural, and Education

Table 10-28. Number and Value of Buildings in the Carbonate Rock Hazard Area

Jurisdiction	Jurisdiction Total Buildings		Buildings in the Carbonate Rock Hazard Area			
			Number of Buildings		RCV	
	County	RCV	Count	% of Jurisdiction Total	Value	% of Jurisdiction Total
Bloomingdale (B)	2,406	$1,358,262,927	0	0.0%	$0	0.0%
Clifton (C)	20,935	$15,833,226,790	0	0.0%	$0	0.0%
Haledon (B)	1,898	$1,277,354,659	0	0.0%	$0	0.0%
Hawthorne (B)	6,079	$3,946,342,797	0	0.0%	$0	0.0%
Little Falls (T)	2,915	$3,414,669,325	0	0.0%	$0	0.0%
North Haledon (B)	2,952	$2,161,286,853	0	0.0%	$0	0.0%
Passaic (C)	5,784	$11,383,166,371	0	0.0%	$0	0.0%

Jurisdiction	Jurisdiction Total Buildings		Buildings in the Carbonate Rock Hazard Area			
			Number of Buildings		RCV	
	County	RCV	Count	% of Jurisdiction Total	Value	% of Jurisdiction Total
Paterson (C)	16,686	$18,630,913,440	0	0.0%	$0	0.0%
Pompton Lakes (B)	3,271	$1,954,260,257	0	0.0%	$0	0.0%
Prospect Park (B)	1,016	$492,237,246	0	0.0%	$0	0.0%
Ringwood (B)	4,369	$2,697,179,876	0	0.0%	$0	0.0%
Totowa (B)	3,765	$5,499,989,017	0	0.0%	$0	0.0%
Wanaque (B)	3,183	$2,352,891,840	8	0.3%	$3,992,663	0.2%
Wayne (T)	15,577	$15,872,014,112	0	0.0%	$0	0.0%
West Milford (T)	9,452	$5,622,763,478	237	2.5%	$122,352,578	2.2%
Woodland Park (B)	2,965	$3,101,377,870	0	0.0%	$0	0.0%
Passaic County (Total)	103,253	$95,597,936,857	245	0.2%	$126,345,240	0.1%

Source: Microsoft 2019; RS Means 2024; NJDEP 2023; (NJOIT 2024)

Table 10-29. Buildings in Carbonate Rock Hazard Aea by General Occupancy Class

Jurisdiction	Sinkholes (Carbonate Karst) Hazard Area			
	Residential	Commercial	Industrial	Other[a]
Bloomingdale (B)	0	0	0	0
Clifton (C)	0	0	0	0
Haledon (B)	0	0	0	0
Hawthorne (B)	0	0	0	0
Little Falls (T)	0	0	0	0
North Haledon (B)	0	0	0	0
Passaic (C)	0	0	0	0
Paterson (C)	0	0	0	0
Pompton Lakes (B)	0	0	0	0
Prospect Park (B)	0	0	0	0
Ringwood (B)	0	0	0	0
Totowa (B)	0	0	0	0
Wanaque (B)	7	1	0	0
Wayne (T)	0	0	0	0
West Milford (T)	202	35	0	0
Woodland Park (B)	0	0	0	0
Passaic County (Total)	209	36	0	0

Source: Microsoft 2019; NJDEP 2023; (NJOIT 2024)

a. Other = Government, Religion, Agricultural, and Education

Table 10-30. Number of Facilities in the NEHRP D & E Soils Hazard Area, by Lifeline Category

Jurisdiction	Number of Facilities in the NEHRP D & E Soils Hazard Area, by Lifeline Category									Total Facilities in Hazard Area	
	Communications	Energy	Food, Hydration, Shelter	Hazardous Materials	Health & Medical	Safety & Security	Transportation	Water Systems	Other Critical Facilities	Count	% of Jurisdiction Total
Bloomingdale (B)	0	0	0	0	0	0	0	0	0	0	0.0%
Clifton (C)	0	0	0	0	9	3	6	0	9	27	16.1%
Haledon (B)	0	0	0	0	0	0	0	0	0	0	0.0%
Hawthorne (B)	0	0	0	0	3	5	4	12	5	29	37.2%
Little Falls (T)	0	0	0	0	0	0	2	3	0	5	10.6%
North Haledon (B)	0	0	0	0	0	0	0	0	0	0	0.0%
Passaic (C)	0	0	0	0	0	4	7	0	8	19	20.4%
Paterson (C)	0	2	1	2	6	14	7	1	6	39	13.5%
Pompton Lakes (B)	1	0	0	0	1	12	6	4	4	28	77.8%
Prospect Park (B)	0	0	0	0	0	0	1	0	0	1	5.0%
Ringwood (B)	0	0	0	0	0	0	0	0	0	0	0.0%
Totowa (B)	0	0	0	2	0	2	1	2	3	10	13.7%
Wanaque (B)	0	0	0	0	3	8	0	5	1	17	34.0%
Wayne (T)	0	0	0	2	6	18	14	8	14	62	36.5%
West Milford (T)	0	0	0	1	0	1	1	4	1	8	7.0%
Woodland Park (B)	0	0	0	1	0	3	2	0	3	9	20.5%
Passaic County (Total)	1	2	1	8	28	70	51	39	54	254	19.1%

Source: (Passaic County HMP 2020); (NJGIN 2017, 2021, 2022); (HIFLD 2017, 2018, 2022, 2023); (NJGWS 2015); (Passaic County Department of Planning & Economic Development 2024); Passaic County 2024

Table 10-31. Number of Facilities in the Liquefaction Class 4 Hazard Area, by Lifeline Category

Jurisdiction	Number of Facilities in the Liquefaction Class 4 Hazard Area, by Lifeline Category									Total Facilities in Hazard Area	
	Communications	Energy	Food, Hydration, Shelter	Hazardous Materials	Health & Medical	Safety & Security	Transportation	Water Systems	Other Critical Facilities	Count	% of Jurisdiction Total
Bloomingdale (B)	0	0	0	0	0	0	0	0	0	0	0.0%
Clifton (C)	0	0	0	0	0	0	0	1	0	1	0.6%
Haledon (B)	0	0	0	0	0	0	7	0	0	7	23.3%
Hawthorne (B)	0	0	0	0	0	1	4	3	0	8	10.3%
Little Falls (T)	0	0	0	0	0	0	0	0	1	1	2.1%
North Haledon (B)	0	0	0	0	0	0	0	0	0	0	0.0%
Passaic (C)	0	0	0	0	0	0	6	0	1	7	7.5%
Paterson (C)	0	0	0	0	0	0	15	0	1	16	5.6%
Pompton Lakes (B)	1	0	0	0	1	0	4	3	0	9	25.0%
Prospect Park (B)	0	0	0	0	0	0	0	0	0	0	0.0%
Ringwood (B)	0	0	0	0	0	0	0	0	0	0	0.0%
Totowa (B)	0	0	0	0	1	1	2	0	1	5	6.8%
Wanaque (B)	0	0	0	0	0	0	0	0	0	0	0.0%
Wayne (T)	0	0	0	0	3	0	9	1	1	14	8.2%
West Milford (T)	0	0	0	0	0	0	0	0	0	0	0.0%
Woodland Park (B)	0	0	0	0	0	0	1	0	0	1	2.3%
Passaic County (Total)	1	0	0	0	5	2	48	8	5	69	5.2%

Source: (Passaic County HMP 2020); (NJGIN 2017, 2021, 2022); (HIFLD 2017, 2018, 2022, 2023); (NJGWS 2015); (Passaic County Department of Planning & Economic Development 2024); Passaic County 2024

Hazus assigned the average probability of each damage state category to the critical facilities in the County for the 500- and 2,500-year MRP events. In addition, Hazus estimates the time to restore critical facilities to fully functional use. Results are presented as a probability of being functional at specified time increments (days after the event). For example, Hazus might estimate that a facility has 5 percent chance of being fully functional on Day 3, and a 95 percent chance of being fully functional on Day 90. For percent probability of sustaining damage, the minimum and maximum damage estimated value for that facility type is presented.

Table 10-32 provides an analysis of the average percent probability of sustaining damage and the average percent functionality of various lifeline systems following a 500-year MRP earthquake. For most lifelines, the probability of sustaining no damage is very high, ranging from 96.4 percent to 99.8 percent. Slight damage is expected in a small percentage of cases, and moderate, extensive, and complete damage are rare. For instance, the transportation and communication systems have about 99 percent chance of sustaining no damage and less than a 0.1 percent chance of extensive or complete damage.

Table 10-32. Average Percent Probability of Sustaining Damage, 500-Year MRP

	Average Percent Probability of Sustaining Damage 500-Year MRP					Average Percent Functionality			
	None	Slight	Moderate	Extensive	Complete	Day 1	Day 7	Day 30	Day 90
Communications	99.1%	0.8%	0.1%	<0.1%	0.0%	99.9%	99.9%	99.9%	99.9%
Energy	97.6%	1.4%	0.8%	0.1%	0.0%	98.5%	99.8%	99.9%	99.9%
Food, Hydration, Shelter	96.4%	2.7%	0.8%	0.1%	0.0%	96.4%	99.0%	99.8%	99.9%
Hazardous Materials	96.9%	2.3%	0.7%	0.1%	0.0%	96.9%	99.1%	99.8%	99.9%
Health and Medical	98.9%	0.9%	0.2%	<0.1%	0.0%	98.8%	99.7%	99.9%	99.9%
Safety and Security	97.4%	2.0%	0.6%	0.1%	0.0%	97.3%	99.3%	99.9%	99.9%
Transportation	99.8%	0.2%	<0.1%	0.0%	0.0%	100.0%	100.0%	100.0%	100.0%
Water Systems	98.3%	1.0%	0.6%	0.1%	0.0%	99.1%	99.9%	99.9%	99.9%

Source: Hazus v6.1; Passaic County 2024; (Passaic County HMP 2020); (NJGIN 2017, 2021, 2022); (HIFLD 2017, 2018, 2022, 2023); (Passaic County Department of Planning & Economic Development 2024)

In terms of functionality, most lifelines are expected to recover quickly. By Day 1, functionality ranges from 96.4 percent to 100 percent, and by Day 7, it improves to between 99 percent and 100 percent. By Day 30 and Day 90, nearly all lifelines are expected to be fully functional, with percentages close to or at 100 percent.

Table 10-33 provides an analysis of the average percent probability of sustaining damage and the average percent functionality of various lifeline systems during a 2,500-year MRP earthquake. For most lifelines, the probability of sustaining no damage is high, though lower than in a 500-year event, ranging from 82.4 percent to 91.1 percent. Slight to moderate damage is more likely, with slight damage probabilities ranging from 6.3 percent to 13.9 percent and moderate damage probabilities from 2.2 percent to 7.0 percent. Extensive and complete damage remains rare but is slightly more probable than in the 500-year MRP event.

In terms of functionality, most lifelines are expected to recover significantly within the first week. By Day 1, functionality ranges from 77.5 percent to 91.0 percent, improving to between 91.3 percent and 97.3 percent by Day 7. By Day 30 and Day 90, nearly all lifelines are expected to be fully functional, with percentages close to or at 100 percent.

Table 10-33. Average Percent Probability of Sustaining Damage 2,500-Year MRP

	Average Percent Probability of Sustaining Damage 2,500-Year MRP					Average Percent Functionality			
	None	Slight	Moderate	Extensive	Complete	Day 1	Day 7	Day 30	Day 90
Communications	84.1%	10.2%	4.7%	0.8%	0.1%	84.1%	94.3%	99.0%	99.8%
Energy	79.9%	12.6%	6.2%	1.2%	0.1%	79.8%	92.4%	98.6%	99.8%
Food, Hydration, Shelter	77.6%	13.9%	7.0%	1.4%	0.1%	77.5%	91.3%	98.4%	99.8%
Hazardous Materials	80.4%	12.3%	6.0%	1.1%	0.1%	80.4%	92.6%	98.7%	99.8%
Health and Medical	91.1%	6.3%	2.2%	0.3%	0.0%	91.0%	97.3%	99.5%	99.9%
Safety and Security	82.4%	11.2%	5.3%	1.0%	0.1%	82.4%	93.4%	98.9%	99.5%
Transportation	83.1%	10.8%	5.0%	0.9%	0.1%	83.1%	93.8%	98.9%	99.8%
Water Systems	84.5%	9.6%	4.9%	1.0%	0.1%	85.1%	95.1%	99.0%	99.8%

Source: Hazus v6.1; Passaic County 2024; (Passaic County HMP 2020); (NJGIN 2017, 2021, 2022); (HIFLD 2017, 2018, 2022, 2023); (Passaic County Department of Planning & Economic Development 2024)

Landslide and Subsidence/Sinkholes

Table 10-34 and Table 10-35 show that there are two critical facilities each in the landslide Class A and Class B hazard areas. No critical facilities are located in the carbonate rock hazard area.

A significant amount of infrastructure can be exposed to mass movements of geological material (USGS 2023):

- *Roads*—Landslides and sinkholes can block egress and ingress on roads, causing isolation for neighborhoods, traffic problems, and delays for public and private transportation. This can result in economic losses for businesses. Portions of Interstate I-80, US Route US-206, and State Routes, including NJ-15, NJ-94, NJ-183, and NJ-23 run the mine subsidence hazard area.
- *Bridges*—Landslides can significantly impact road bridges. Mass movements can knock out bridge abutments or significantly weaken the soil supporting them, making them hazardous for use.
- *Power Lines*—A landslide could trigger failure of the soil underneath towers that support power lines, causing them to collapse and ripping down the lines. Sinkholes can swallow utility lines and cause impacts on underground pipes. Power and communication failures due to landslides and sinkholes can create problems for vulnerable populations and businesses.
- *Rail Lines*—Landslides can block travel along rail lines, which are more difficult to detour than roads and highways. Many residents rely on public transport to get to work around the County and into New York City, and a landslide event could prevent travel to and from work.

Table 10-34. Number of Facilities in the Landslide Class A Hazard Area, by Lifeline Category

Jurisdiction	Number of Facilities in the Landslide Class A Hazard Area, by Lifeline Category									Total Facilities in Hazard Area	
	Communications	Energy	Food, Hydration, Shelter	Hazardous Materials	Health & Medical	Safety & Security	Transportation	Water Systems	Other Critical Facilities	Count	% of Jurisdiction Total
Bloomingdale (B)	0	0	0	0	0	0	0	0	0	0	0.0%
Clifton (C)	0	0	0	0	0	0	0	0	0	0	0.0%
Haledon (B)	0	0	0	0	0	0	0	0	0	0	0.0%
Hawthorne (B)	0	0	0	0	0	0	0	0	0	0	0.0%
Little Falls (T)	0	0	0	0	0	0	0	0	0	0	0.0%
North Haledon (B)	0	0	0	0	0	0	0	0	0	0	0.0%
Passaic (C)	0	0	0	0	0	0	0	0	0	0	0.0%
Paterson (C)	0	0	0	0	0	0	0	0	0	0	0.0%
Pompton Lakes (B)	0	0	0	0	0	0	0	0	0	0	0.0%
Prospect Park (B)	0	0	0	1	0	0	0	0	0	1	5.0%
Ringwood (B)	0	0	0	0	0	0	0	0	0	0	0.0%
Totowa (B)	0	0	0	0	0	0	0	0	0	0	0.0%
Wanaque (B)	0	0	0	0	0	0	0	0	0	0	0.0%
Wayne (T)	0	0	0	0	0	0	0	0	0	0	0.0%
West Milford (T)	0	0	0	0	0	0	0	0	0	0	0.0%
Woodland Park (B)	0	0	0	0	0	0	0	1	0	1	2.3%
Passaic County (Total)	0	0	0	1	0	0	0	1	0	2	0.2%

Source: (Passaic County HMP 2020); (NJGIN 2017, 2021, 2022); (HIFLD 2017, 2018, 2022, 2023); (NJGWS 2015); (Passaic County Department of Planning & Economic Development 2024); Passaic County 2024

Table 10-35. Number of Facilities in the Landslide Class B Hazard Area, by Lifeline Category

Jurisdiction	Number of Facilities in the Landslide Class B Hazard Area, by Lifeline Category									Total Facilities in Hazard Area	
	Communications	Energy	Food, Hydration, Shelter	Hazardous Materials	Health & Medical	Safety & Security	Transportation	Water Systems	Other Critical Facilities	Count	% of Jurisdiction Total
Bloomingdale (B)	0	0	0	0	0	0	0	0	0	0	0.0%
Clifton (C)	0	0	0	0	0	0	1	0	0	1	0.6%
Haledon (B)	0	0	0	0	0	0	0	0	0	0	0.0%
Hawthorne (B)	0	0	0	0	0	0	0	0	0	0	0.0%
Little Falls (T)	0	0	0	0	0	0	0	0	0	0	0.0%
North Haledon (B)	0	0	0	0	0	0	0	0	0	0	0.0%
Passaic (C)	0	0	0	0	0	0	0	0	0	0	0.0%
Paterson (C)	0	0	0	0	0	0	0	0	0	0	0.0%
Pompton Lakes (B)	0	0	0	0	0	0	0	0	0	0	0.0%
Prospect Park (B)	0	0	0	0	0	0	0	0	0	0	0.0%
Ringwood (B)	0	0	0	0	0	0	0	0	0	0	0.0%
Totowa (B)	0	0	0	0	0	0	0	0	0	0	0.0%
Wanaque (B)	0	0	0	0	0	0	0	1	0	1	2.0%
Wayne (T)	0	0	0	0	0	0	0	0	0	0	0.0%
West Milford (T)	0	0	0	0	0	0	0	0	0	0	0.0%
Woodland Park (B)	0	0	0	0	0	0	0	0	0	0	0.0%
Passaic County (Total)	0	0	0	0	0	0	1	1	0	2	0.2%

Source: (Passaic County HMP 2020); (NJGIN 2017, 2021, 2022); (HIFLD 2017, 2018, 2022, 2023); (NJGWS 2015); (Passaic County Department of Planning & Economic Development 2024); Passaic County 2024

10.2.4 Economy

Geological hazards can cause direct and indirect impacts on the economy. Direct costs include the actual damage sustained by buildings, property, and infrastructure due to ground failure, which also threatens transportation corridors, fuel and energy conduits, and communication lines (USGS 2020). Indirect costs, such as clean-up costs, business interruption, damage to inventory, relocation costs, wage loss, and rental loss due to the repair/replacement of buildings loss of tax revenues, reduced property values, and loss of productivity may also occur, but are difficult to measure. Secondary effects, such as blocking access to roads, can isolate residents and businesses and delay commercial, public, and private transportation.

Table 10-36 outlines the estimated debris generated in Passaic County for the 500- and 2,500-year MRP events. For the 500-year MRP event, the total debris includes 2,989 tons of brick/wood and 449 tons of concrete/steel. In the 2,500-year MRP event, these amounts significantly increase to 27,476 tons of brick/wood and 9,718 tons of concrete/steel.

Table 10-36. 500-Year and 2,500-Year MRP Earthquake Event Debris

Jurisdiction	Debris Generated (tons)			
	500-Year MRP		2,500-Year MRP	
	Brick/Wood	Concrete/Steel	Brick/Wood	Concrete/Steel
Bloomingdale (B)	19	2	228	47
Clifton (C)	568	99	4,934	2,184
Haledon (B)	34	4	332	78
Hawthorne (B)	148	24	1,307	488
Little Falls (T)	116	18	1,059	397
North Haledon (B)	25	2	365	74
Passaic (C)	509	72	4,164	1,344
Paterson (C)	577	90	5,629	2,342
Pompton Lakes (B)	38	4	396	83
Prospect Park (B)	27	4	220	67
Ringwood (B)	30	3	417	72
Totowa (B)	65	12	663	413
Wanaque (B)	142	22	1,043	300
Wayne (T)	603	85	5,457	1,583
West Milford (T)	60	5	875	164
Woodland Park (B)	29	3	388	82
Passaic County (Total)	2,989	449	27,476	9,718

Source: Hazus v6.1, Microsoft 2019; (NJOIT 2024)

10.2.5 Natural, Historic and Cultural Resources

Natural

Earthquakes can cause damage to the surface of the earth in various forms depending on the magnitude and distribution of the event. Surface faulting is one of the major seismic components to earthquakes that can create

wide ruptures in the ground. Ruptures can have a direct impact on the natural environment because they can disconnect habitats for miles, isolating animal species and tearing apart plant roots (USGS n.d.).

Soil liquefaction can impact soil pores and retention of water resources. The greater the seismic activity and liquefaction properties of the soil, the more likely drainage of groundwater can occur, which depletes groundwater resources. In areas where there is higher pressure of groundwater retention, the pores can build up more pressure and make soil behave more like a fluid rather than a solid, increasing risk of localized flooding and deposition or accumulation of silt (USGS n.d.).

Landslide-susceptible steep slopes within the Highlands Region play an important ecological, recreational, scenic, and functional role. They provide specialized habitats for rare plant and animal species. Disturbance of areas containing steep slopes can trigger erosion and sedimentation, resulting in the loss of topsoil. The silting of wetlands, lakes, ponds, and streams damages and degrades wetland and aquatic habitats that are found throughout the region and receive the state's highest water quality protections. Steep slope disturbance can also result in the loss of habitat quality, degradation of surface water quality, silting of wetlands, and alteration of drainage patterns (NJ Highlands Council 2012).

Historic

The primary concern for historic resources in the event of an earthquake is the potential damage from ground shaking and soil liquefaction. Passaic County's historic landmarks and older buildings, many of which may not be built to modern seismic standards, are particularly vulnerable to earthquake damage.

Landslide impacts on historic resources within the County are highest in areas near hillsides that are characterized by unstable soil and erosion. Historic landmarks in these areas are highly susceptible to landslide occurrences.

Cultural

The primary concern for cultural resources in the event of an earthquake is the potential damage from ground shaking and soil liquefaction. The county's cultural landmarks and older buildings, many of which may not be built to modern seismic standards, are particularly vulnerable to earthquake damage.

Landslide impacts on cultural resources within the County are highest in areas near hillsides that are characterized by unstable soil and erosion. Cultural landmarks in these areas are highly susceptible to landslide occurrences.

10.3 FUTURE CHANGES THAT MAY AFFECT RISK

10.3.1 Potential or Planned Development

Areas targeted for future growth and development have been identified across the County. Development built in areas with softer NEHRP soil classes, liquefaction, and landslide-susceptible areas may experience shifting or cracking in the foundation during geological hazard events. However, current building codes require seismic provisions that should render new construction less vulnerable to seismic impacts than older, existing construction that may have been built to lower construction standards.

Any areas of growth could be impacted by geological hazards if located within the identified hazard areas or downslope of one of these areas. In general, development of slopes is not recommended due to the increased risk of erosion, stormwater runoff and flooding potential, and many municipalities already have local ordinances regulating development in steep or sloped areas. The additional runoff results in sedimentation of downslope surface waters, which damages habitat and has the potential to damage property. The Highlands Council has template ordinances available to define Steep Slope Protection Areas and protect from their disturbance. In addition, there are recommendations for site design for permitted disturbances to minimize impacts.

Recently, sinkholes have been correlated to land use practices, especially from groundwater pumping and from construction and development practices. Sinkholes may form when the land surface is changed, such as when industrial and runoff-storage ponds are created. The weight of new material can trigger an underground collapse of supporting material, causing a sinkhole. Additionally, the overburden sediments that cover buried cavities in the aquifer systems are balanced by groundwater fluid pressure. Groundwater helps keep the surface soil in place. Pumping groundwater for urban water supply and irrigation can produce new sinkholes. If pumping results in a lowering of groundwater levels, then underground structural failure, sinkholes may occur as well (USGS 2018). Geological make-up should be considered for future development; certain soils, such as limestone, are more prone to sinkholes.

10.3.2 Projected Changes in Population

An increase in population density can impact the number of persons exposed to geological hazard areas. Changes in density can create issues for local residents during evacuation of a landslide or ground failure event and affect commuters who travel into and out of the County for work, particularly during a geologic event (such as a sinkhole) that breaches major transportation corridors, which are also major commuter roads.

The New Jersey Department of Labor and Workforce Development produced population projections by County for 2029 and 2034. According to these projections, Passaic County is projected to have an increase in population in the upcoming years. These projections include a population of 536,100 by 2029 and 542,500 by 2034 (State of New Jersey 2017).

10.3.3 Climate Change

The County is expected to experience an increase in average annual temperatures and precipitation due to climate change. Severe storms and heavy rainfall events may elevate the likelihood of landslides in steep sloped areas, as precipitation may exceed the soil's absorption capacity. These changes depend on the development of steep slopes and other climate trends, such as seasonal precipitation and drought, which affect vegetation growth.

Higher temperatures and potentially more intense, less frequent summer rainfall may alter water resource availability and increase the frequency of droughts. Drought periods can intensify sinkhole activity in some karst areas, potentially increasing the number of sinkholes. Changes to the water balance, including over-withdrawal of groundwater, diverting surface water, creating artificial ponds, and drilling new wells, can accelerate bedrock degradation and sinkhole formation.

The impacts of climate change on earthquakes are not well understood, making it difficult to determine changes in the County's vulnerability. However, climate change may magnify secondary impacts of earthquakes. Consequently, the County's assets located on saturated soils and at the base of steep slopes are at higher risk of landslides and mudslides due to seismic activity.