Section 5. Risk Assessment

5.7 Geological Hazards

2014 Plan Update Changes

- Previous occurrences were updated including a listing of landslide and sinkhole occurrences throughout New Jersey. The previous occurrences of landslides were developed using 2012 NJGWS data.
- Figures and maps were updated. At the request of the New Jersey Geological and Water Survey, Figures 4.4.9.5-2 and 4.4.9.5-3 of the 2011 Plan were removed. These figures showed several geologic units as being carbonate bedrock and sinkhole-prone which are not carbonate units.
- Potential change in climate and its impacts on geological hazards are discussed.
- The vulnerability assessment now directly follows the hazard profile.
- An exposure analysis of the population, general building stock, State-owned and leased buildings, critical facilities and infrastructure was conducted using best available hazard data.
- Environmental impacts is a new subsection.

For the 2014 Plan update, the geologic hazards profile and vulnerability assessment were significantly enhanced to include updated information and best available data on landslides and subsidence/sinkholes. The hazard descriptions and locations that are vulnerable to these hazards were enhanced to reflect best available data. Additionally, previous occurrences of both landslides and subsidence/sinkholes events were updated with new information not previously included in the 2011 Hazard Mitigation Plan (HMP). The vulnerability assessment of these hazards was updated to incorporate 2010 United States Census, state building, and updated critical facility data.

5.7.1 Profile

Hazard Description

Landslides

According to the United States Geological Survey (USGS), the term landslide includes a wide range of ground movement, such as rock falls, deep failure of slopes, and shallow debris flows. Although gravity acting on an over steepened slope is the primary reason for a landslide, there are other contributing factors (USGS 2013). Among the contributing factors are: (1) erosion by rivers, glaciers, or ocean waves which create over-steepened slopes; (2) rock and soil slopes weakened through saturation by snowmelt or heavy rains; (3) earthquakes which create stresses making weak slopes fail; and (4) excess weight from rain/snow accumulation, rock/ore stockpiling, waste piles, or man-made structures. Scientists from the USGS also monitor stream flow, noting changes in sediment load in rivers and streams that may result from landslides. All of these types of landslides are considered aggregately in USGS landslide mapping.

In New Jersey, there are four main types of landslides: slumps, debris flows, rockfalls, and rockslides. Slumps are coherent masses that move downslope by rotational slip on surfaces that underlie and penetrate the landslide deposit (Briggs et al 1975). 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 the movement of newly detached segments of bedrock sliding on bedrock, joint, or fault surfaces (Delano and Wilshusen 2001).

Subsidence/Sinkholes

Land subsidence can be defined as 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 2000). Subsidence often occurs through the loss of subsurface support in karst terrain, which may result from a number of natural- and human-caused occurrences. Karst describes a distinctive topography that indicates 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 stream, enlarged bedrock fractures, caves, and underground streams.

Sinkholes, the type of subsidence most frequently seen in the New Jersey, are a natural and common geologic feature in areas with underlying limestone, carbonate rock, salt beds, or other rocks that are soluble in water. Over periods of time, measured in thousands of years, the carbonate bedrock can be dissolved through acidic rain water moving in fractures or cracks in the bedrock. This creates larger openings in the rock through which water and overlying soil materials will travel. Over time the voids will enlarge until the roof over the void is unable to support the land above will collapse forming a sinkhole. In this example the sinkhole occurs naturally, but in other cases the root causes of a sinkhole are anthropogenic. These anthropogenic causes can include those that involve changes to the water balance of an area such as: over-withdrawal of 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 serve to accelerate the natural processes of creation of soil voids, which can have a direct impact on sinkhole creation.

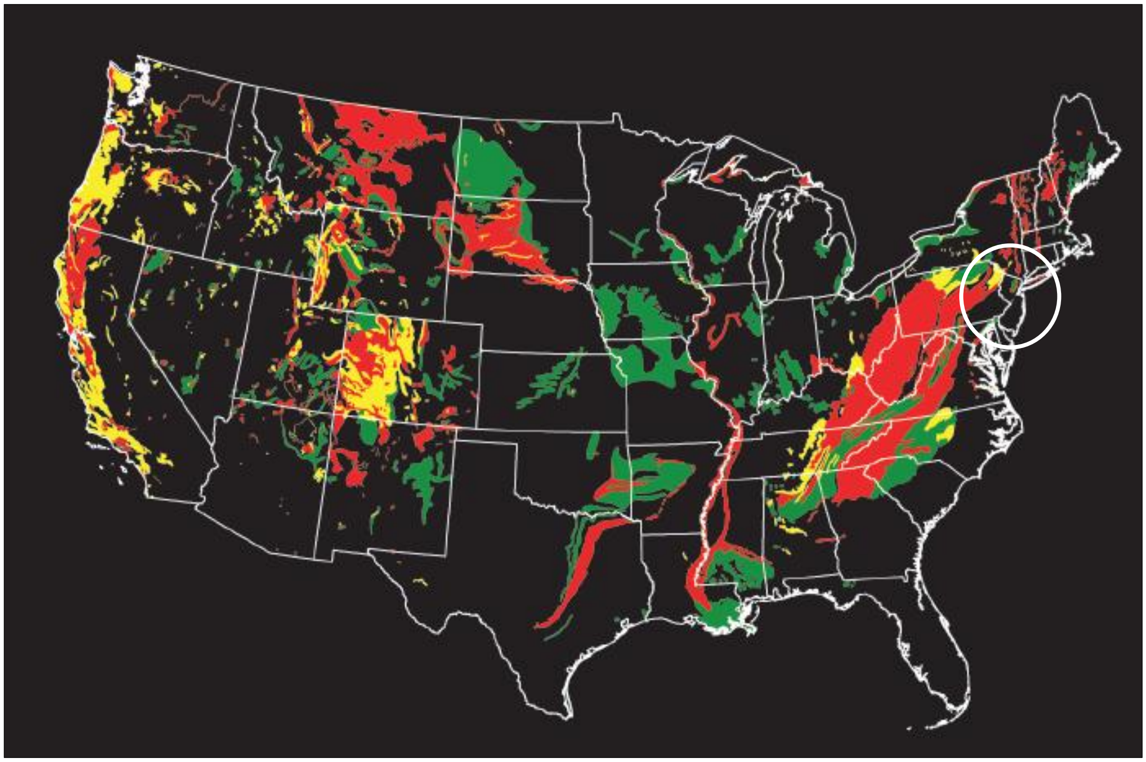
Both natural and man-made sinkholes can occur without warning. Slumping or falling fence posts, trees, or foundations, sudden formation of small ponds, wilting vegetation, discolored well water, and/or structural cracks in walls and floors, are all specific signs that a sinkhole is forming. Sinkholes can range in form 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.

Location

Landslides

The entire United States experiences landslides, with 36 states having moderate to highly severe landslide hazards. Expansion of urban and recreational developments into hillside areas exposes more people to the threat of landslides each year. Figure 5.7-1 illustrates the potential for landslides in the United States.

Figure 5.7-1. Landslide Potential of the Conterminous U.S



Source: USGS 2005

Note: Red areas have very high potential, yellow areas have high potential, and green areas have moderate potential. Landslides can and do occur in the black areas, but the potential is low. Map not to scale. Circle indicates the approximate location of New Jersey.

Landslides are common in New Jersey, primarily in the northern region of the State. As noted in the previous occurrences section, New Jersey has an extensive history of landslides, and the landslides occur for a variety of reasons. Figure 5.7-2 shows a landslide in an unidentified residential area of New Jersey.

Figure 5.7-2. Landslide in New Jersey

Source: New Jersey HMP 2011

The New Jersey Geologic Survey (currently known as the New Jersey Geological and Water Survey) determined landslide susceptibility for nine counties in New Jersey (Bergen, Essex, Hudson, Middlesex, Monmouth, Morris, Passaic, Somerset, and Union). Areas within these counties are classified into Class A, B, and C landslide susceptible classes, and several subclasses within the main classifications. These classes are consistent with HAZUS User Manual Table 9.2. Class A areas in New Jersey include classes AII, AIV, AVI which is strongly cemented rock at varying slope angles; Class B includes classes BIII, BIV, BV, and BVI which includes weakly cemented rock and soil at varying slope angles; and Class C includes classes CV, CVI, CVII, CIX, and CX which includes shale and clayey soil at varying slope angles. Refer to Appendix Q for a more detailed map for each county.

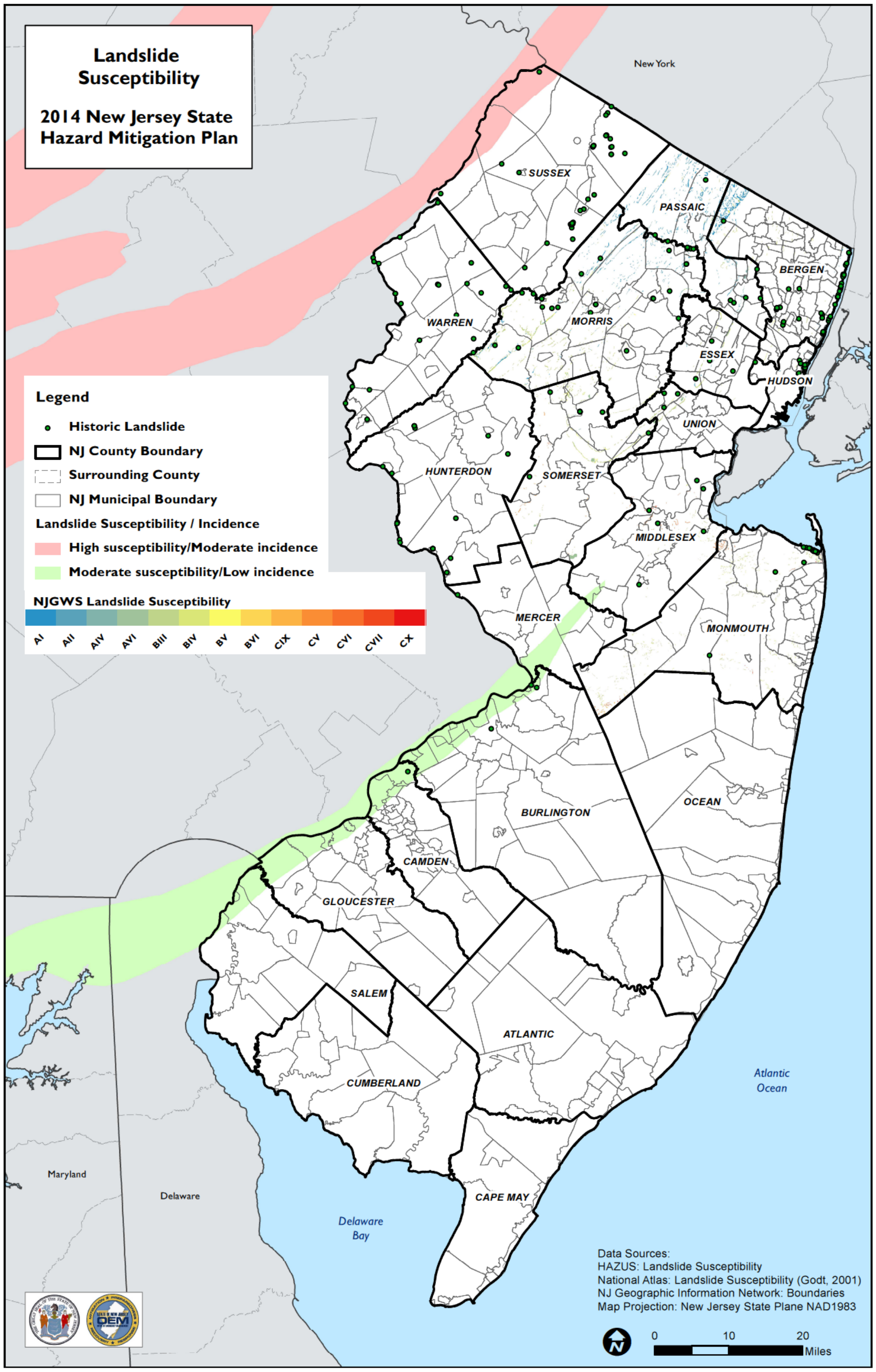
For the remainder of the State, the National Landslide Incidence and Susceptibility layer of the conterminous United States can be used to coarsely define the general landslide susceptible areas (Godt 2001). It is recognized that this data is highly generalized and is not suitable for local planning. According to Radbruch-Hall et al., the Landslide Incidence and Susceptibility Geographic Information System (GIS) layer from National Atlas:

> "….was prepared by evaluating formations or groups of formations shown on the geologic map of the United States (King and Beikman 1974) and classifying them as having high, medium, or low landslide incidence (number of landslides) and being of high, medium, or low susceptibility to landsliding. Thus, those map units or parts of units

> with more than 15 percent of their area involved in landsliding were classified as having high incidence; those with 1.5 to 15 percent of their area involved in landsliding, as having medium incidence; and those with less than 1.5 percent of their area involved, as having low incidence. This classification scheme was modified where particular lithofacies are known to have variable landslide incidence or susceptibility. In continental glaciated areas, additional data were used to identify surficial deposits that are susceptible to slope movement. Susceptibility to landsliding was defined as the probable degree of response of the areal rocks and soils to natural or artificial cutting or loading of slopes or to anomalously high precipitation. High, medium, and low susceptibility are delimited by the same percentages used in classifying the incidence of landsliding. For example, it was estimated that a rock or soil unit characterized by high landslide susceptibility would respond to widespread artificial cutting by some movement in 15 percent or more of the affected area. We did not evaluate the effect of earthquakes on slope stability, although many catastrophic landslides have been generated by ground shaking during earthquakes. Areas susceptible to ground failure under static conditions would probably also be susceptible to failure during earthquakes: (Radbruch-Hall 1982).

Figure 5.7-3 illustrates the landslide susceptible areas in New Jersey using these two datasets (New Jersey Geological and Water Survey where applicable, and the National Landslide Incidence and Susceptibility data for the remainder of the State). Due to the scale of the map, the NJGWS landslide susceptible areas are difficult to see; refer to Appendix Q for each county’s map.

Figure 5.7-3. Landslide Susceptibility in New Jersey



Source: *Godt 2001; NJGWS 2000-2009*

Notes: *Due to the scale of the map, the NJGWS landslide susceptible areas are difficult to see; refer to Appendix Q for each county's map.*

NJGWS *New Jersey Geological and Water Survey*

Located in the Sandy Hook Bay, the Atlantic Highlands Slump Zone has a long history of slumping that extends back a couple hundred years and continues today. Most of the older slumps in this region were caused by the Atlantic Ocean wave action when the Raritan Bay was open to the ocean hundreds of years ago. Today there are two active slump zones: the western slump block is 400 feet wide and 2,500 feet long, and the eastern slump is 450 feet wide and 1,400 feet long (Minard 1969). The eastern slump is the result of two large landslides in the past. The first slump included an entire mass; the second slump included a smaller section. Figure 5.7-4 illustrates the location and extent of the western and eastern slump zones.

Figure 5.7-4. Atlantic Highlands Slump Zone

Source: Pallis 2009

In addition to this region, one of the most active landslide areas is the Palisades along the Hudson River. In this region, large rockfalls and rockslides occur along the high cliffs bordering the Hudson River. These landslides are most common in the winter and spring months after freeze-thaw cycles occur and loosen pieces of rock along joints and fractures. Surface water also seeps into joints and cracks along the rock, increasing the weight of the rocks and causing the expansion of joints when it freezes, thus prying blocks away from the main cliff (Hansen 1995). Figure 5.7-5 illustrates a significant rockslide along a section of the Palisades.

Figure 5.7-5. Rockslide in the Palisades in 1938

Source: Palisades Interstate Park

Another active landslide region in New Jersey is a location known as "the narrows". This area is located across the state in Hunterdon County along the Delaware River. Both small and large rockslides are an ongoing problem in this area. Heavy rains and excessive saturation often exacerbate the condition in this region.

Subsidence/Sinkholes

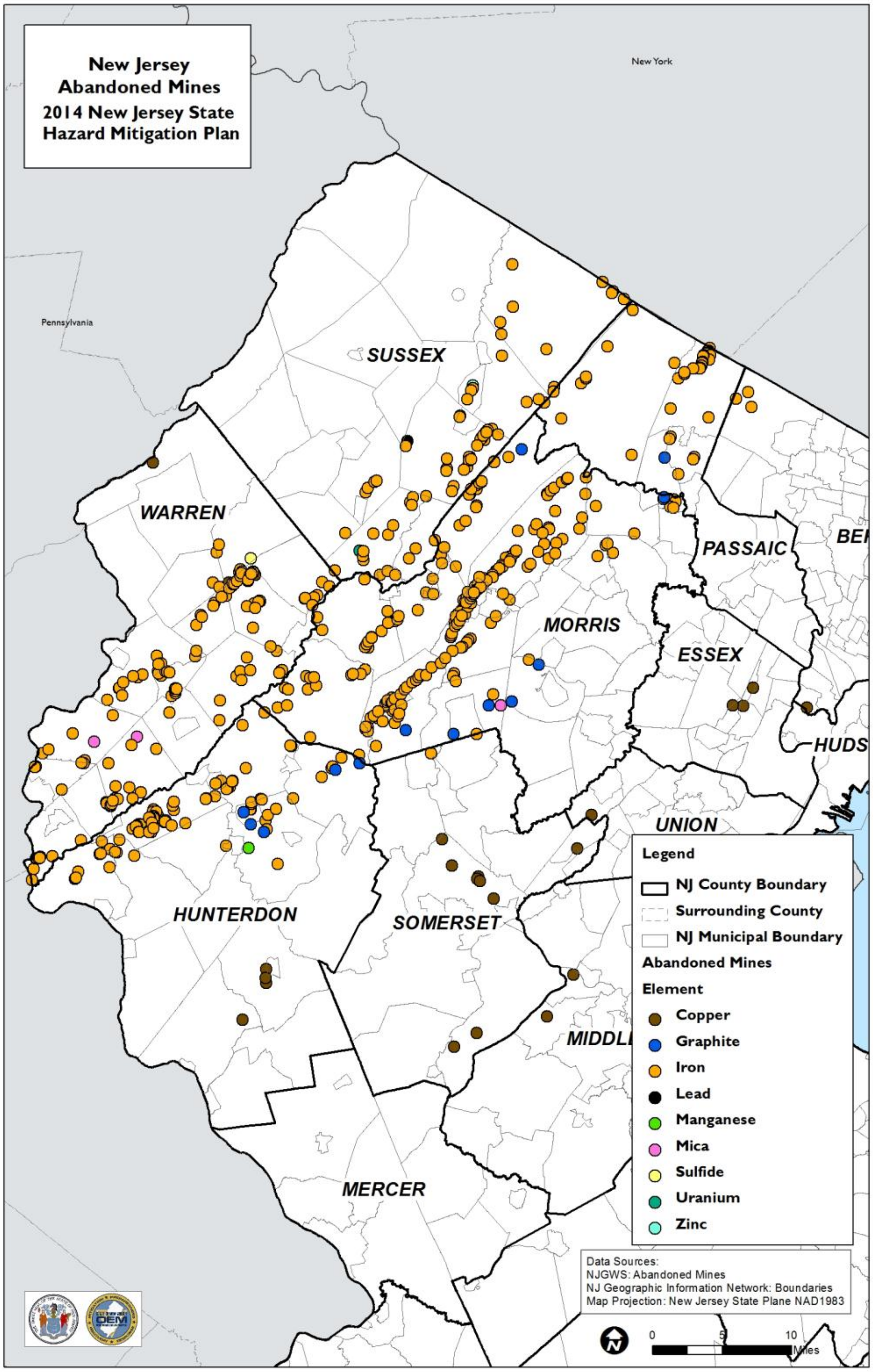
New Jersey may be susceptible to the effects of subsidence and sinkholes, primarily in the northern region of the State. The State's susceptibility to subsidence is due in part to the number of abandoned mines throughout New Jersey. The State historically was an iron-producing state and the first mines in New Jersey were drilled in the early 1700s, with operations continuing until 1986 when the last active mine was closed. Although mines have closed in New Jersey, continued development in the northern part of the State could prove problematic because of the extensive mining there which has caused widespread subsidence. One problem is that the mapped locations of some of the abandoned mines are not accurate. Another issue is that 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. Figure 5.7-6 shows a collapse adjacent to an abandoned mine. Additionally, Figure 5.7-7 shows the approximate locations of abandoned mines in New Jersey. A table listing of all of the abandoned mines in New Jersey can be found in Appendix Q – Geologic Hazard Maps and Tables.

On September 30, 2013, New Jersey Geological and Water Survey completed a risk analysis of abandoned mines for a FEMA pre-disaster mitigation grant performed under the auspices of NJOEM. About 2700 sites where mining or prospecting occurred were ranked "high" "medium" or "low" for risk of subsidence. Many of these locations were also field inspected and photographed. This data will be published in 2014 and incorporated into the next State HMP update.

Figure 5.7-6. Collapse Along the White Meadow Mine Workings in Morris County

Source: Volkert 2008

Figure 5.7-7. Abandoned Mines in New Jersey



Source: NJGWS 2006

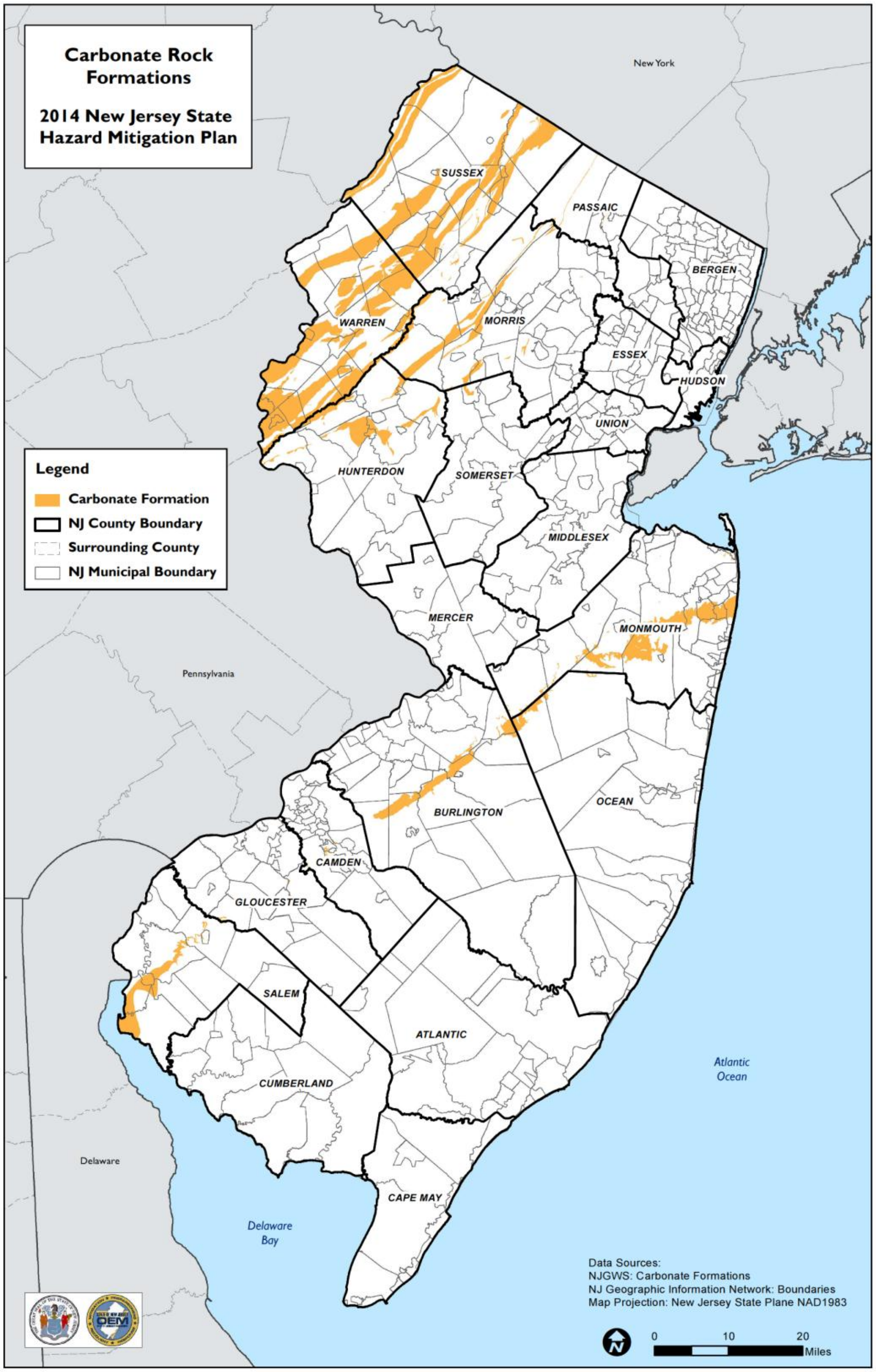
Naturally occurring subsidence and sinkholes in New Jersey occur within bands of carbonate bedrock. In northern New Jersey, there are more than 225 square miles that are underlain by limestone, dolomite, and marble. In some areas, no sinkholes have appeared, while in others, sinkholes are common. In southern New Jersey, there are approximately 100 miles that are locally underlain by a lime sand with thin limestone layers. No collapse sinkholes have been identified; however, there are some features which could be either very shallow solution depressions or wind blowout features. Sinkholes in New Jersey are generally concentrated in the northwestern part of the State as show in Figure 5.7-8.

Areas underlain by carbonate rock may contain surface depressions and open drainage passages making such 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 (Piefer 2006).

Figure 5.7-8 illustrates the locations of carbonate-bearing geologic formations of New Jersey. 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 may be 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 so various karst features, including sinkholes, may be found on any of these units.

The only spatial coverage for historic sinkholes is in Warren County. This data is mainly based on 1960s and 1979 aerial photography with some limited field checking in 1999.

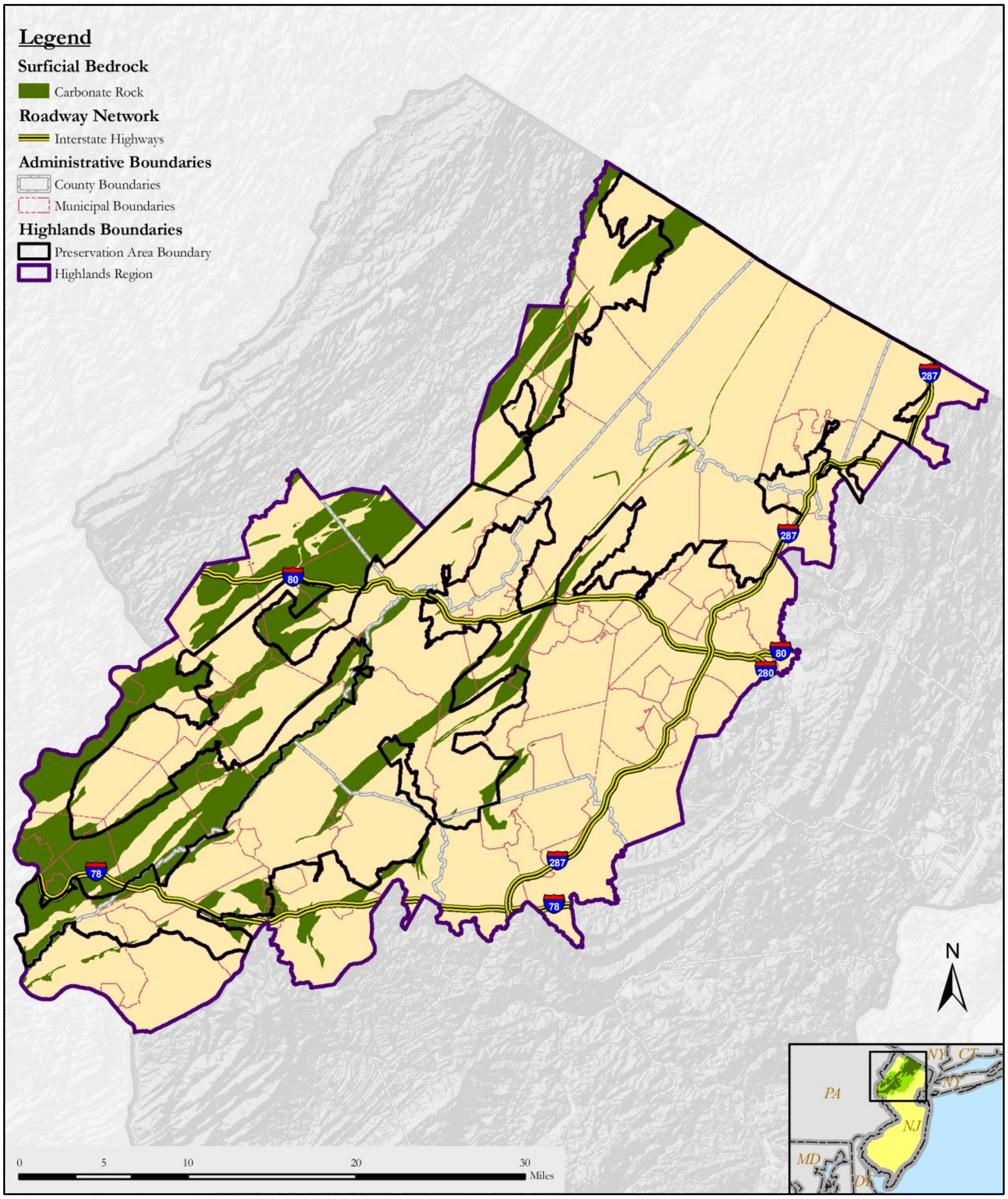
Figure 5.7-8. Carbonate Rock Regions of New Jersey



Source: New Jersey Geological Survey (NJGS) 2004

Substantial areas of the New Jersey Highlands are underlain by carbonate rocks (Figure 5.7-9). These rock formations, consisting primarily of limestone, dolomite, and marble, have unique characteristics that require responses to both the policy level and in specific technical guidance to municipalities. According to the NJDEP, 59 of the 88 municipalities within the Highlands region contain carbonate rocks. Eleven of these municipalities are in Hunterdon County. Fourteen municipalities are in Morris County. Four municipalities are in Passaic County, three are in Somerset. Eight municipalities are in Sussex and 19 are in Warren. Far from being an isolated geologic condition, the widespread presence of carbonate rocks in the regulated area indicates that their presence is a matter of regional concern.

Figure 5.7-9. Carbonate Rock in the New Jersey Highlands



Source: New Jersey Highlands Council 2007

While fewer karst features have been mapped in existing urban areas, human activity can often be the cause of a subsidence or sinkhole event. Furthermore, the lack of karst features exhibited in maps of urban areas is likely a result of development activities that disguise, cover, or fill existing features rather than an absence of the features themselves. Leaking water pipes or structures that convey stormwater runoff may also result in areas of subsidence as the water dissolves substantial amounts of rock over time. In some cases, construction, land grading, or earthmoving activities that cause changes in stormwater flow can trigger sinkhole events. Subsidence or sinkhole events may occur in the presence of mining activity, especially in areas where the cover of a mine is thin, even in areas where bedrock is not necessarily conducive to their formation. Piggott and Eynon (1978) indicated that sinkhole development normally occurs where the interval to the ground surface is less than three to five times the thickness of the extracted seam, and the maximum interval is up to 10 times the thickness of the extracted seam. Sub-surface (i.e., underground) extraction of materials such as oil, gas, coal, metal ores (copper, iron, and zinc), clay, shale, limestone, or water may result in slow-moving or abrupt shifts in the ground surface.

Extent

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 any particular area include soil properties, topographic position and slope, and historical incidence. Predicting a landslide is difficult, even under ideal conditions and with reliable information. As a result, the Geological Survey of Alabama indicates that the landslide hazard is often represented by landslide incidence and/or susceptibility, as defined below:

- Landslide incidence is the number of landslides that have occurred in a given geographic area. High incidence means greater than 15% of a given area has been involved in landsliding; medium incidence means that 1.5 to 15% of an area has been involved; and low incidence means that less than 1.5% of an area has been involved.
- Landslide susceptibility is defined as 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 in areas where rocks and soils have experienced numerous landslides in the past. Landslide susceptibility depends on slope angle and the geologic material underlying the slope. Landslide susceptibility only identifies areas potentially affected and does not imply a time frame when a landslide might occur. High, medium, and low susceptibility are delimited by the same percentages used for classifying the incidence of landsliding.

Subsidence/Sinkhole

Landslide subsidence occurs slowly and continuously over time or abruptly for various reasons. Subsidence and sinkholes can occur due to either natural processes (karst sinkholes in areas underlain by soluble bedrock) or as a result of human activities such as the Hoboken, New Jersey sinkhole outbreak in 2013.

Previous Occurrences and Losses

Landslides

Nationwide, landslides constitute a major geologic hazard as they are widespread, occur in all 50 states, and cause between approximately $1 and $2 billion in damages and more than 25 fatalities on average each year. In

New Jersey, landslides are a hazard in areas with steep to moderate slopes or geologic units prone to failure. Landslides can damage utilities, property, and transportation routes. The current average annual cost of landslides in New Jersey is hundreds of thousands of dollars and over 60 fatalities have been attributed to landslide events (New Jersey Geological and Water Survey 2012).

In New Jersey, there have been numerous landslide occurrences. The size and extent of each event varies from minor to extensive. Table 5.7-1 lists historic landslides in New Jersey, and Figure 5.7-10 illustrates the location of these landslide events.

Table 5.7-1. Past Occurrences of Landslides in New Jersey (1896 to 2012) By County

Date	Type	County	Municipality	Trigger	Damage	Fatalities	Injuries	Comments
4/18/1896	Rockfall	Bergen	Alpine	Weathering	No	0	0	A large boulder fell on the south side of the Blackledge Kearney House. It has an inscription on it that the rock fell on April 18, 1896.
7/5/1928	Rockslide	Bergen	Alpine	Heavy rain	Yes	0	0	Report of a large rockslide: 100 feet of Henry Hudson Drive destroyed, $15,000 in damage in 1928. Estimated location.
5/17/1935	Rockslide	Bergen	Edgewater	Weathering	Yes	0	0	A 50-ton rock fell from the Palisades onto Rt. 5. The road was closed for five hours.
7/14/1936	Rockslide	Bergen	Alpine	Heavy rain	No	0	0	A small rock slide occurred in the Palisades Interstate Park near the Yonkers-Alpine Ferry. Triggered by heavy rain from thunderstorms. Estimated location.
1/10/1937	Rockslide	Bergen	Alpine	Weathering	No	0	0	A rockslide on the Alpine Approach Road closed traffic for one hour. Estimated location.
7/23/1938	Rockslide	Bergen	Alpine	Heavy rain	No	0	0	Large rockslide north of Twombley's Landing. Estimated location.
7/23/1938	Debris flow	Bergen	Lodi	Heavy rain	No	0	0	Report of Rt. 6 (now Rt. 46) closed for several hours by landslides after heavy rain. Estimated location.
7/23/1938	Debris flow	Bergen	Paramus	Heavy rain	No	0	0	Report of a landslide, road restricted to one lane by a landslide of mud and stone. Estimated location.
7/23/1938	Rockslide	Bergen	Alpine	Heavy rain	No	0	0	A rockslide on the Palisades creates the likeness of Hitler on the cliffs. Estimated location.
9/21/1938	Rockslide	Bergen	Alpine	Heavy rain	Yes	0	0	Landslides caused by the rain from The Great Hurricane of 1938 closed Henry Hudson Drive between Alpine and the boat basin. Estimated location.
4/1/1939	Rockslide	Bergen	Tenafly Boro	Heavy rain	No	0	0	Heavy rain caused a rockslide on Henry Hudson Drive covering 20 feet of the road. Estimated location.
3/15/1947	Rockslide	Bergen	Englewood Cliffs	Weathering	No	0	0	Rockslide destroyed the likeness of Hitler on the Palisades. Estimated location.
8/6/1952	Rockslide	Bergen	Alpine	Heavy rain	Yes	0	0	Heavy rains caused a rockslide on the Alpine Approach Road blocking the road for 28 hours. Estimated location.
4/8/1957	Rockslide	Bergen	Alpine	Heavy rain/ weathering	Yes	0	0	Report of a rockslide triggered by weathering from rain and melting snow, Henry Hudson Drive closed for two days. Estimated location.
1/27/1959	Rockslide	Bergen	Tenafly	Weathering	Yes	0	0	Large rockslide slid off the Palisades triggered by freezing and thawing, road closed. Estimated location.
3/6/1959	Rockfall	Bergen	Alpine	Heavy rain	Yes	0	0	A rockfall blocked the Alpine Approach Road, heavy rains combined with early thawing caused the rockfall. Estimated location.

Table 5.7-1. Past Occurrences of Landslides in New Jersey (1896 to 2012) By County

Date	Type	County	Municipality	Trigger	Damage	Fatalities	Injuries	Comments
3/6/1959	Rockfall	Bergen	Fort Lee Boro	Heavy rain	Yes	0	0	A rockfall on Henry Hudson Drive just north of George Washington Bridge, traffic blocked, heavy rains and early thawing triggered rockfall. Estimated location.
8/6/1961	Rockslide	Bergen	Alpine	Weathering	Yes	0	0	Rockslide caused thousands of dollars in damage, 100 feet of road destroyed, rocks stopped 100 feet short of 50 people at the waters edge. Estimated location.
9/12/1971	Debris flow	Bergen	Wood Ridge	Heavy rain	No	1	0	A 24-year-old man was killed when the earth collapsed on the cliffside parking lot where he worked burying him under three feet of mud and rocks.
9/3/1974	Debris flow	Bergen	Fort Lee Boro	Heavy rain	No	0	0	A landslide on Rt. 4 blocked a westbound lane from the George Washington Bridge, estimated location.
3/18/1998	Rockslide	Bergen	Fort Lee Boro	Weathering	Yes	0	0	Rockslide on Rt. 95 Southbound local lanes, damage to one car from debris in the roadway, right lane closed to install fencing and remove debris.
8/5/2003	Debris flow	Bergen	Edgewater	Heavy rain	Unknown	0	0	Reported debris flow down the mountain triggered by heavy rain covered a 100-foot section of River Road.
7/23/2004	Rockfall	Bergen	Fort Lee Boro	Heavy rain	Unknown	0	0	Rockslide after heavy rain.
3/29/2005	Rockslide	Bergen	Englewood	Weathering	No	0	0	Rockslide on Rt. 95 Southbound local lanes, right lane was closed for 65 minutes to remove debris. Estimated location.
10/8/2005	Debris flow	Bergen	Lodi	Heavy rain	Yes	0	0	Landslide caused some property damage to a two family house on Farnham Avenue.
12/17/2005	Rockslide	Bergen	Alpine	Weathering	Yes	0	0	Significant rockslide, road closed for repairs, location taken at the toe of the landslide in the parking lot where a large boulder bounced into the Hudson River.
7/22/2006	Debris flow	Bergen	River Edge	Heavy rain/ broken sewer pipe	Yes	0	0	Heavy rain caused a storm sewer line to break triggering a debris flow which damaged a fence and closed Kinderkemack Road for two days.
4/15/2007	Debris flow	Bergen	Glen Rock	Heavy rain	Yes	0	0	Heavy rain triggered a debris flow on Rt. 208 Southbound near Lincoln Avenue which caused a multiple vehicle accident on the highway, road temporarily closed.
4/15/2007	Debris flow	Bergen	Hasbrouck Heights	Heavy rain	No	0	0	A small debris flow at the bottom of Passaic Avenue and Burr Place was triggered by heavy rain.
4/15/2007	Debris flow	Bergen	Lodi	Heavy rain	Yes	0	0	Landslide after heavy rain on Farnham Avenue. Some property damage, backyard covered in mud, 50 families displaced.

Table 5.7-1. Past Occurrences of Landslides in New Jersey (1896 to 2012) By County

Date	Type	County	Municipality	Trigger	Damage	Fatalities	Injuries	Comments
4/15/2007	Debris flow	Bergen	Lodi	Heavy rain	Yes	0	0	Landslide after heavy rain on Farnham Avenue. Some property damage, backyard covered in mud, 50 families displaced.
4/15/2007	Debris flow	Bergen	Lodi	Heavy rain	Yes	0	0	Landslide after heavy rain on Farnham Avenue. Some property damage, backyard covered in mud, 50 families displaced.
4/15/2007	Debris flow	Bergen	Lodi	Heavy rain	Yes	0	0	Landslide onto two family house on Farnham Avenue. Inside of house destroyed, 70-foot retaining wall collapsed, backyard covered in mud, 50 families displaced.
4/15/2007	Debris flow	Bergen	Alpine	Heavy rain	Yes	0	0	Heavy rain triggered a landslide on Henry Hudson Drive which was closed for one month, damage to road and retaining walls.
4/15/2007	Debris flow	Bergen	Alpine	Heavy rain	Yes	0	0	Heavy rain triggered a landslide on Henry Hudson Drive which was closed for one month, damage to road and retaining walls.
4/15/2007	Debris flow	Bergen	Alpine	Heavy rain	Yes	0	0	Heavy rain triggered a landslide on Henry Hudson Drive which was closed for one month, damage to road and retaining walls.
4/15/2007	Debris flow	Bergen	Alpine	Heavy rain	Yes	0	0	Heavy rain triggered a landslide on Henry Hudson Drive which was closed for one month, damage to road and retaining walls.
4/15/2007	Debris flow	Bergen	Fort Lee Boro	Heavy rain	Yes	0	0	Heavy rain caused a small landslide near Ross Dock causing damage to retaining walls. Henry Hudson Drive closed for one month.
4/15/2007	Debris flow	Bergen	Englewood Cliffs	Heavy rain	Yes	0	0	Heavy rain caused a landslide 150-feet wide near Ross Dock causing damage to retaining walls. Henry Hudson Drive closed for one month.
1/5/2009	Debris flow	Bergen	Tenafly	Heavy rain/ snowmelt	Yes	0	0	Rock slide on Henry Hudson Drive at Englewood Cliffs, Tenafly border triggered by rain and snow. Road closed for cleanup. Estimated location.
9/16/2009	Debris flow	Bergen	Oakland	Heavy rain	Yes	0	0	Landslide after heavy rain during Hurricane Floyd, three houses damaged, 100 people evacuated. Estimated location.
5/5/2010	Rockfall	Bergen	Edgewater	Weathering	Yes	0	0	Rockslide closed Rt. 5 for two days at the Undercliff Avenue section. About 20 yards of rocks and some trees fell onto the road.
8/28/2011	Debris flow	Bergen	Englewood Cliffs Boro	Heavy rain	Yes	0	0	Debris flow of mud, rock and trees triggered by Tropical Storm Irene. Temporary road closure of River Road up to one week.
8/28/2011	Debris flow	Bergen	Tenafly Boro	Heavy rain	Yes	0	0	Debris flow of mud, rock and trees triggered by Tropical Storm Irene. Temporary road closure of River Road up to one week.
8/28/2011	Debris flow	Bergen	Alpine Boro	Heavy rain	Yes	0	0	Debris flow of mud, rock and trees triggered by Tropical Storm Irene. Temporary road closure of River Road up to one week.
5/12/2012	Rockslide	Bergen	Alpine Boro	Weathering	Yes	0	0	A large chuck of the Palisades Interstate Park's cliff wall broke off

Table 5.7-1. Past Occurrences of Landslides in New Jersey (1896 to 2012) By County

Date	Type	County	Municipality	Trigger	Damage	Fatalities	Injuries	Comments
								Saturday, May 12, at about 7:45 p.m., causing a rock slide into the Hudson River at the State Line Lookout. The Shore Trail was closed temporarily.
Unknown	Rockslide	Bergen	Alpine	Weathering	No	0	0	Historic rockslide area, thousands of rockslides and rockfalls over the years created a talus slope called the Giant Stairs.
Unknown	Debris flow	Bergen	Hackensack	Clay digging	No	1	0	A laborer, while digging in a brick yard pit, at Hackensack, was crushed to death by a mass of clay which fell upon him. Estimated location.
Unknown	Rockfall	Bergen	Edgewater Boro	Weathering	Unknown	0	0	Small rockfall.
Unknown	Rockfall	Bergen	Alpine	Weathering	Yes	0	0	Roadway damage. Estimated location.
Unknown	Rockfall	Bergen	Edgewater Boro	Weathering	Unknown	0	0	Small rockfall.
Unknown	Rockfall	Bergen	Tenafly	Weathering	Yes	0	0	Roadway damage. Estimated location.
Unknown	Rockfall	Bergen	Fort Lee Boro	Weathering	Unknown	0	0	Small rockfall.
Unknown	Rockfall	Bergen	Tenafly	Weathering	Yes	0	0	Roadway damage. Estimated location.
Unknown	Rockfall	Bergen	Alpine	Weathering	Yes	0	0	Roadway damage. Estimated location.
5/4/1893	Debris flow	Burlington	Bordentown	Heavy rain	Yes	0	0	A two-story home was buried and totally destroyed in a landslide. Heavy rain caused a landslide of a 50-foot bank above the house to fall on the house and knock it off its foundation.
Unknown	Debris flow	Burlington	Bordentown Township	Heavy rain	Yes	0	0	Heavy rain caused a landslide at the Irondale school. Tons of earth gave way, a portion covered the last-bound track of the Amboy Division Railroad. Estimated location.
Unknown	Debris flow	Burlington	Burlington Township	Quarrying	No	1	0	A quarry worker/civil war veteran was crushed to death under a landslide of hundreds of tons of earth in the Bowen gravel pit. Estimated location.
Unknown	Debris flow	Burlington	Southampton Township	Heavy rain	Yes	0	0	Heavy rains caused a debris flow at the BEMS Big Hill Landfill causing damage to some nearby homes.
5/8/2008	Debris flow	Camden	Pennsauken Township	Heavy rain	No	0	0	Debris Flow on U.S. 130 Southbound, right lane closed temporarily. Estimated location.
1/17/1995	Rockfall	Essex	West Orange Township	Weathering	Unknown	0	0	Large rockfall, one lane closed for two days for rock removal.

Table 5.7-1. Past Occurrences of Landslides in New Jersey (1896 to 2012) By County

Date	Type	County	Municipality	Trigger	Damage	Fatalities	Injuries	Comments
6/13/1998	Debris flow	Essex	West Orange Township	Heavy rain	Yes	0	0	Report of a minor debris flow of mud down a hill into a house after heavy rain. Estimated location.
6/22/2008	Debris flow	Essex	West Orange Township	Heavy rain	Yes	0	1	A contractor was buried to the waist and trapped for three hours when a storm caused a mudslide in the trench he was digging. Estimated location.
Unknown	Rockfall	Essex	West Orange Township	Weathering	No	0	0	Rockfall area, the roadway cut is highly fractured causing loose rock fragments to fall onto the road. Estimated location.
Unknown	Rockfall	Essex	West Orange Township	Weathering	No	0	0	Rockfall area along Interstate 280.
Unknown	Rockfall	Essex	East Orange	Weathering	Unknown	0	0	Rockfall along Interstate 280. Estimated location.
Unknown	Rockfall	Essex	West Orange Township	Weathering	Unknown	0	0	Large rockfall during the night, fragments spilled onto the shoulder and into half of the middle lane.
Unknown	Rockfall	Essex	West Orange Township	Weathering	Unknown	0	0	Small rockfall.
Unknown	Rockfall	Essex	West Orange Township	Weathering	Unknown	0	0	Small rockfall.
Unknown	Slump	Essex	Millburn Township	Heavy rain	No	0	0	Sixty-foot tall, 200-foot long streambank slump area was reactivated during heavy rains. The slumps here were active since at least 1970s.
10/8/1903	Debris flow	Hudson	Weehawken	Heavy rain	No	0	0	Report of a landslide after heavy rain in Weehawken at the Weehawken tunnel, the railroad was closed. Estimated location.
12/10/1935	Rockslide	Hudson	Jersey City	Heavy rain/ weathering	Yes	0	0	Rockslide from a promontory on the Palisades crashed into the L.O. Koven Fabricating Company in Hoboken. Many other rockslides in prior years.
11/23/1936	Rockslide	Hudson	Weehawken	Construction	Yes	0	0	A large rock pile near the Lincoln Tunnel during its construction slide onto Boulevard East destroying a truck. Estimated location.
3/5/1941	Rockslide	Hudson	Jersey City	Weathering	Yes	0	0	A boulder and rocks fell from the hillside blocking traffic on Holland Street for eight hours. Another rockslide in 1916 nearby. Estimated location.
9/3/1974	Debris flow	Hudson	North Bergen	Heavy rain	No	0	0	Report of landslides which delayed traffic at Grand Avenue and Union Turnpike. Estimated location.
12/31/1977	Rockslide	Hudson	Weehawken	Weathering	Yes	0	0	A rockslide in an area prone to rockslides from freeze and thaw weathering. $2,000 to clean up the rocks.
1993	Rockfall	Hudson	Weehawken	Weathering	Yes	0	0	Large falling rock in 1993 demolished a car, numerous other past rockfalls in the same area.

Table 5.7-1. Past Occurrences of Landslides in New Jersey (1896 to 2012) By County

Date	Type	County	Municipality	Trigger	Damage	Fatalities	Injuries	Comments
4/15/2007	Debris flow	Hudson	Hoboken	Heavy rain	No	0	0	Heavy rain triggered a small rockfall on Sinatra Drive which was closed temporarily.
4/15/2007	Debris flow	Hudson	Union City	Heavy rain	Yes	0	0	Rock and debris from a 50-foot high retaining wall collapse during heavy rain covered the north wing of the 14th Street Viaduct, road closed.
4/16/2007	Debris flow	Hudson	Union City	Heavy rain	Yes	0	0	Retaining wall collapse during heavy rain deposited rock and debris in the Doric Apartments parking lot, $225,000 in damages. Estimated location.
4/17/2011	Debris flow	Hudson	Jersey City	Heavy rain	Yes	0	0	Backyard destroyed by debris flow after retaining wall collapses during heavy rain at 340 Ogden Avenue. Debris fell onto hill overlooking Paterson Plank Road.
Unknown	Debris flow	Hudson	Kearny	Heavy rain	Yes	0	0	Police reported major damage to Passaic Avenue between W. Midland and Laurel Avenues, where an embankment slid across the roadway.
Unknown	Rockfall	Hudson	Union City	Weathering	Unknown	0	0	Rockfall along road cut.
Unknown	Rockslide	Hudson	Weehawken	Tree removal from slope	No	0	0	Rockslide occurred a few years after trees were removed from the bottom of the cliff.
Unknown	Rockfall	Hudson	Hoboken	Weathering	Yes	0	0	Falling boulder totaled illegally parked car.
Unknown	Rockfall	Hudson	Union City	Weathering	Unknown	0	0	Rockfall along road cut.
9/8/1999	Debris flow	Hunterdon	Lambertville	Heavy rain	No	0	0	Heavy rains swamped some of the city's streets Wednesday afternoon, causing a minor mudslide on Swan Street then onto Rt. 29. The downpour started about 1 p.m. and lasted about an hour. Estimated location.
4/3/2005	Debris flow	Hunterdon	Alexandria Township	Heavy rain	Yes	0	0	Two landslides after heavy rain, 40-feet by 30-feet along County Rt. 619, some utility and property damage.
9/16/2009	Debris flow	Hunterdon	Readington Township	Heavy rain	No	0	0	County Rt. 523 closed due to debris flow south of Dreahook Road during Hurricane Floyd. Estimated location.
8/28/2011	Debris flow	Hunterdon	Delaware Township	Heavy rain	No	0	0	Small mudslide on steep embankment along Rt. 523.
8/28/2011	Debris flow	Hunterdon	Delaware Township	Heavy rain	No	0	0	Small mudslide on steep embankment along Rt. 523.
8/28/2011	Debris flow	Hunterdon	Delaware Township	Heavy rain	No	0	0	Small mudslide on steep embankment along Rt. 523.
8/28/2011	Debris flow	Hunterdon	Delaware Township	Heavy rain	No	0	0	Small mudslide on steep embankment along Rt. 523.

Table 5.7-1. Past Occurrences of Landslides in New Jersey (1896 to 2012) By County

Date	Type	County	Municipality	Trigger	Damage	Fatalities	Injuries	Comments
8/28/2011	Debris flow	Hunterdon	Delaware Township	Heavy rain	No	0	0	Small mudslide on steep embankment along Rt. 523.
Unknown	Rockfall	Hunterdon	Bethlehem Township	Weathering	Unknown	0	0	Rockfall along Interstate 78.
Unknown	Slump	Hunterdon	Bethlehem Township	Quarrying	Yes	0	0	Quarry landslide 250-feet long after the toe of the slope was removed for quarrying. Bellwood Farm Road was destroyed and never rebuilt.
Unknown	Rockfall	Hunterdon	Kingwood Township	Weathering	Unknown	0	0	Small rockfall.
Unknown	Rockfall	Hunterdon	Kingwood Township	Weathering	Unknown	0	0	Small rockfall.
Unknown	Rockfall	Hunterdon	Kingwood Township	Weathering	Unknown	0	0	Small rockfall.
Unknown	Rockslide	Hunterdon	Milford Boro	Weathering	Yes	0	0	Rockslide, road closed temporarily for cleanup and repairs.
Unknown	Rockfall	Hunterdon	Bethlehem Township	Weathering	No	0	0	Rockfall along Interstate78
Unknown	Rockfall	Hunterdon	Kingwood Township	Weathering	Unknown	0	0	Small rockfall.
Unknown	Rockfall	Hunterdon	Kingwood Township	Weathering	Unknown	0	0	Small rockfall.
Unknown	Rockfall	Hunterdon	Kingwood Township	Weathering	Unknown	0	0	Small rockfall.
Unknown	Rockfall	Hunterdon	West Amwell Township	Weathering	Unknown	0	0	Large rockfall.
Unknown	Rockslide	Hunterdon	Clinton Township	Weathering	No	0	0	Small rockslide.
11/12/1948	Rockslide	Mercer	Hopewell	Quarrying	No	2	0	A rockslide at the Lambertville Quarry killed two workers who were drilling holes in a cliff to insert dynamite when rockslide occurred. Estimated location.
5/11/1936	Slump	Middlesex	Perth Amboy	Clay digging	Yes	0	3	A boy and two men were buried alive in clay landslide while digging for clay at the Valentine Brothers Clay pit. They were trapped for 30 minutes but were rescued and survived. Estimated location.
1984	Debris flow	Middlesex	Old Bridge Township	Heavy rain	No	0	0	In April 1984, after heavy rains and high tides, the southern side of a landfill collapsed and slid into wetlands. New Jersey Department of Environmental Protection closed the landfill later in 1984.
1/18/1996	Slump	Middlesex	South River Boro	Construction	Yes	0	0	A 40-foot high slope slid during road construction, undermining Old Bridge Turnpike, between Tices Lane and Edgeboro Road. The road was closed.
7/17/2005	Debris flow	Middlesex	Monroe Township	Heavy rain	Yes	0	0	Significant property damage from landslide, a swimming pool was

Table 5.7-1. Past Occurrences of Landslides in New Jersey (1896 to 2012) By County

Date	Type	County	Municipality	Trigger	Damage	Fatalities	Injuries	Comments
								filled in with mud.
Unknown	Slump	Middlesex	New Brunswick	Heavy rain	No	0	0	Five acre landslide on Raritan River bluff. Estimated location.
Unknown	Slump	Middlesex	Woodbridge	Fill material failure	No	0	0	Man-made slope, fill material failure.
1782	Slump	Monmouth	Highlands Boro	Atlantic Ocean wave action	Unknown	0	0	1782 landslide from newspaper account possibly triggered by undercutting Atlantic Ocean wave action. Noise from the slump was heard for several miles. The block that slumped measured about 400-feet wide and 2,500 feet long.
10/8/1903	Debris flow	Monmouth	Highlands Boro	Heavy rain	Yes	0	0	Report of a big landslide at Waterwitch, just below the long pier, shut down the Central Railroad of NJ. Estimated location.
1/3/1999	Debris flow	Monmouth	Highlands Boro	Heavy rain	Yes	0	2	Landslide, possibly due to fill material failure after heavy rain, one condominium unit destroyed, three others damaged.
9/5/1999	Debris flow	Monmouth	Middletown	Fossil digging	No	0	1	A 36-year-old man was seriously injured when he was buried alive in a landslide while digging for fossils in a 45-foot embankment along Big Brook. Estimated location.
10/8/2005	Slump	Monmouth	Atlantic Highlands Boro	Heavy rain	Yes	0	0	Small backyard slump caused by water saturation after heavy rain, some property damage. Estimated location.
10/8/2005	Debris flow	Monmouth	Freehold Township	Heavy rain	Yes	0	0	Landslide partially blocked road after heavy rain during road construction.
4/15/2007	Slump	Monmouth	Highlands Boro	Heavy rain	Yes	0	0	Landslide on the bluff between Linden Avenue and Shore Drive, west of Waterwitch Drive in the Atlantic Highlands.
4/1/2010	Debris flow	Monmouth	Highlands Boro	Heavy rain	Yes	0	0	Triggered by Nor'Easter of March 31 to April, 1, located on bluff between Linden Avenue and Shore Drive west of Waterwitch Drive. 50-feet wide 170-feet long. Deck and house threatened.
8/28/2011	Debris flow	Monmouth	Highlands Boro	Heavy rain	Yes	0	0	Large landslide above condo complex triggered by heavy rain from Tropical Storm Irene damages condo complex. Some damage to condominium. Reactivation of prior landslide.
8/28/2011	Debris flow	Monmouth	Highlands Boro	Heavy rain	Yes	0	0	Large landslide above condo complex triggered by heavy rain from Tropical Storm Irene damages condo complex. Some damage to condominium.
Unknown	Slump	Monmouth	Atlantic Highlands Boro	Atlantic Ocean wave action	No	0	0	Historic slump area, older landslide, probably hundreds of years old. Estimated location.
1972	Debris flow	Monmouth	Highlands Boro	Heavy rain	No	0	0	Small landslide in 1972.

Table 5.7-1. Past Occurrences of Landslides in New Jersey (1896 to 2012) By County

Date	Type	County	Municipality	Trigger	Damage	Fatalities	Injuries	Comments
Unknown	Slump	Monmouth	Highlands Boro	Heavy rain	No	0	0	Landslide after heavy rain.
Unknown	Slump	Monmouth	Middletown	Heavy rain	No	0	0	Recent small slump in slump block possibly hundreds of years old on Navesink River bluff.
Unknown	Slump	Monmouth	Howell Township	River erosion	Yes	0	0	River bank slumping on 26-foot high bank due to undercutting from the Manasquan River along 200 feet of Bergerville Road, some damage to road.
Unknown	Debris flow	Monmouth	Atlantic Highlands Boro	Heavy rain	Yes	0	0	Exact date unknown, first noticed in early April 2010 after back to back Nor'Easters in March and April.
Unknown	Debris flow	Monmouth	Atlantic Highlands Boro	Heavy rain	Yes	0	0	Exact date unknown, first noticed in early April 2010 after back to back Nor'Easters in March and April.
Unknown	Slump	Monmouth	Atlantic Highlands Boro	Heavy rain	No	0	0	Reactivation of old slump block in Atlantic Highlands Boro.
10/8/1903	Debris flow	Morris	Netcong	Heavy rain	No	0	0	Report of a big landslide near Stanhope, rock and sand slid onto railroad tracks. Estimated location.
6/18/1956	Rockslide	Morris	Riverdale	Quarrying	Yes	3	0	Three quarry workers, were buried and died in a quarry rockslide of many tons of rocks. Estimated location.
9/21/1989	Debris flow	Morris	Pequannock	Heavy rain	Yes	0	0	Landslide of fill material from Rt. 287 construction triggered by heavy rain buried the fifteenth green and sixteenth tee of Sunset Valley golf course with mud, $75,000 in damages.
5/16/1990	Debris flow	Morris	Pequannock	Heavy rain	Yes	0	0	Landslide of fill material from Rt. 287 construction triggered by heavy rain buried the eleventh hole and fairway of Sunset Valley golf course with mud, $125,000 in damages.
5/16/1990	Debris flow	Morris	Montville Township	Heavy rain	No	0	0	A report that Rt. 202 was closed temporarily because of a debris flow from Rt. 287 construction site after heavy rain. Estimated location.
7/2/1995	Debris flow	Morris	Kinnelon	Weathering	Yes	0	0	Heavy rains caused a debris flow onto a back porch of a house, driveway and onto Forestdale Road.
10/19/1996	Debris flow	Morris	Roxbury Township	Heavy rain	Unknown	0	0	In the Poets Peak development, a debris flow deposited considerable silt into the Ledgewood Brook after heavy rain. Estimated location.
8/12/2000	Debris flow	Morris	Jefferson Township	Heavy rain	Yes	0	0	Landslide after heavy rain, sections of Rt.15 south collapsed. Estimated location.
2/5/2005	Rockfall	Morris	Riverdale	Weathering	Yes	0	0	A block of rock weighing an estimated 35 tons fell on Timber Ridge Road damaging a catch basin.
4/3/2005	Debris flow	Morris	Jefferson Township	Heavy rain	Yes	0	0	Large debris flow occurred along Berkshire Valley Road (Morris County Rt. 699) across from Longwood Lake during heavy rains.

Table 5.7-1. Past Occurrences of Landslides in New Jersey (1896 to 2012) By County

Date	Type	County	Municipality	Trigger	Damage	Fatalities	Injuries	Comments
3/30/2011	Rockslide	Morris	Riverdale	Weathering	Yes	0	0	Large 100-foot long rockslide during the late night hours of March 30 blocked access to the Enclave at Riverdale housing development. Road closed for one week.
8/28/2011	Debris flow	Morris	Boonton	Heavy rain	No	0	0	Debris flow along the Rockaway River triggered by heavy rain from Tropical Storm Irene. Two houses on Harrison Street declared uninhabitable due to slope instability after the slide.
8/28/2011	Debris flow	Morris	Mount Olive Township	Heavy rain	Yes	0	0	Debris flow along off-ramp of Rt. 206. Some fence damage. Area formerly in the path of the Morris Canal.
8/28/2011	Debris flow	Morris	Dover	Heavy rain	No	0	0	Small debris flow on hillside along Segur Street in Dover due to Tropical Storm Irene.
8/28/2011	Debris flow	Morris	Randolph Township	Heavy rain	Yes	0	0	Debris flow along Reservoir Avenue near reservoir outlet area due to Tropical Storm Irene.
8/28/2011	Slump	Morris	Boonton	Heavy rain	Yes	0	0	Rt 287 NB slump. Roadway collapsed due to Rockaway River washing out the riverbank during heavy rain from Tropical Storm Irene.
8/28/2011	Debris flow	Morris	Roxbury Township	Heavy rain	Yes	0	0	Small debris flow along Rt. 206 NB on steep slope.
8/29/2011	Debris flow	Morris	Branchburg Township	Heavy rain	No	0	0	Small landslide along Rt. 202 south east of Whiton Road on steep slope due to Tropical Storm Irene.
9/8/2011	Debris flow	Morris	Dover	Heavy rain	No	0	0	Heavy rain from Tropical Storm Lee triggered a reactivation of a repaired mudslide on Segur Street from 10 days prior during Tropical Storm Irene.
9/8/2011	Debris flow	Morris	Washington Township	Heavy rain	Yes	0	0	Debris flow after heavy rain, temporary road closure of Stephensburg Road.
9/8/2011	Debris flow	Morris	Washington Township	Heavy rain	No	0	0	Debris flow along Naughtright Road.
Unknown	Rockfall	Morris	Montville Township	Weathering	No	0	0	Rockfall area, the roadway cut is highly fractured causing loose rock fragments to fall onto the road. Estimated location.
Unknown	Debris flow	Morris	Mount Olive Township	Heavy rain	Yes	0	0	Report of landslides near Waterloo on the Morris and Essex Railroad with many trains delayed. Estimated location.
Unknown	Debris flow	Morris	Morristown	Heavy rain	Yes	0	0	Heavy rain during construction of the 1776 office building caused a debris flow that washed out five historic graves from a cemetery at a church.
Unknown	Debris flow	Morris	Riverdale Boro	Heavy rain	Yes	0	0	A small debris flow along Rt. 287 during its construction deposited mud in the backyards of some homes on Greenwich Street. .

Table 5.7-1. Past Occurrences of Landslides in New Jersey (1896 to 2012) By County

Date	Type	County	Municipality	Trigger	Damage	Fatalities	Injuries	Comments
								Estimated location.
Unknown	Rockfall	Morris	Randolph Township	Weathering	Unknown	0	0	Small rockfall.
Unknown	Rockfall	Morris	Roxbury Township	Weathering	Unknown	0	0	Rockfall in road cut.
Unknown	Rockfall	Morris	Washington Township	Weathering	No	0	0	Small rockfall along Schooley's Mountain Road.
11/7/1915	Rockslide	Passaic	Paterson	Vibration from railroad	Yes	0	0	Rockslide down Garret Mountain destroyed 200 feet of the D, L & W railroad tracks. Estimated location.
3/11/1936	Debris flow	Passaic	West Milford Township	Heavy rain	Yes	0	0	CCC camp cut off as a result of Rt. 23 landslide due to heavy rain, estimated location.
11/10/1963	Rockslide	Passaic	Ringwood Boro	Mining	No	1	0	A 15-year-old boy died when he was buried in a large rockslide inside an abandoned open pit iron mine (The Hard Mine). Estimated location.
8/28/1971	Debris flow	Passaic	West Paterson	Heavy rain	Yes	0	0	Debris flow triggered by heavy rains from Hurricane Doria, a large section of the Morris Canal slid onto Vetrone Drive causing substantial property damage.
9/26/1975	Debris flow	Passaic	Paterson	Heavy rain	No	0	0	Four days of heavy rain triggered a debris flow on Rt. 80 at the ramp to Rt. 20 in Paterson. Estimated location.
4/15/2007	Debris flow	Passaic	Totowa	Heavy rain/broken sewer pipe	Yes	0	0	Debris flow after heavy rain on Riverview Drive along the Passaic River, road closed for repairs.
Unknown	Rockfall	Passaic	West Milford Township	Weathering	Unknown	0	0	Rockslide mixed with soil.
11/9/1994	Rockslide	Somerset	Bernards Township	Quarrying	No	0	2	Two men injured, one critically when a ledge collapsed where the men were working, they fell 100 feet into a rock quarry. GPS location at front gate of quarry.
8/27/2000	Debris flow	Somerset	North Plainfield Boro	Heavy rain	No	0	0	Construction site related landslide during heavy rains on Rt. 22. Estimated location.
4/15/2007	Slump	Somerset	Bernards Township	Heavy rain	No	0	0	Slump during heavy rain along the shoulder of the Southbound lanes of Rt. 287 during heavy rain.
8/28/2011	Debris flow	Somerset	Bernards Township	Heavy rain	No	0	0	Debris flow on slope along Rt. 287 Southbound.
Unknown	Slump	Somerset	Bernards Township	Heavy rain	Yes	0	0	Slumps in clayey pre-Illinoian till that came out onto the shoulder of the northbound lanes of Rt. 287.

Table 5.7-1. Past Occurrences of Landslides in New Jersey (1896 to 2012) By County

Date	Type	County	Municipality	Trigger	Damage	Fatalities	Injuries	Comments
Unknown	Rockfall	Somerset	Peapack-Gladstone Boro	Weathering	No	0	0	Small rockfall along Rt. 206 south.
12/13/1952	Rockslide	Sussex	Byram Township	Weathering	No	1	1	A rockslide killed a 10-year-old boy. Another 10-year-old boy suffered a broken ankle while playing on Panther Mountain. Estimated location.
8/19/1955	Debris flow	Sussex	Hardyston Township	Heavy rain	Yes	0	0	Rt. 23 closed at Beaver Lake as a result of landslide due to heavy rain from Hurricane Diane. Estimated location.
1/18/1996	Debris flow	Sussex	Vernon Township	Heavy rain/snowmelt	No	0	0	Debris flow during heavy rain and melting snow on Curtis Drive, school buses could not get through for several days. Estimated location.
1/19/1996	Debris flow	Sussex	Sparta Township	Heavy rain/snowmelt	Yes	0	0	Two landslides after heavy rain and melting snow, house destroyed.
8/12/2000	Debris flow	Sussex	Sparta Township	Heavy rain	Yes	0	0	Massive landslide after heavy rain, property damage, railroad and Glen Road temporarily closed.
8/16/2000	Debris flow	Sussex	Sparta Township	Heavy rain	Yes	0	0	Massive landslide at least 2000-feet long and over 100-feet deep occurred in Sparta Glen during heavy rain causing much damage to parts of downtown Sparta.
4/9/2001	Mudslide	Sussex	Sparta	Heavy rain	N/A	0	0	Heavy rain caused a mudslide in Sparta; Main Street was closed for two hours. The mudslide spread across Spring Brook Trail.
4/3/2005	Debris flow	Sussex	Vernon Township	Heavy rain	No	0	0	Small debris flow along Macpeek Road after heavy rain.
6/29/2006	Debris flow	Sussex	Franklin Boro	Heavy rain	Yes	0	0	Heavy rains caused a retaining wall to collapse triggering a debris flow, damaging a deck.
3/13/2010	Debris flow	Sussex	Ogdensburg Boro	Heavy rain	Yes	0	0	A mudslide about 70-feet long and 40-feet wide forced a three-quarter mile section of Edison Avenue to be closed. The debris flow damaged the road and the guardrail on the side of the tracks and covered the railroad tracks.
3/13/2010	Debris flow	Sussex	Sparta Township	Heavy rain	Yes	0	0	A mudslide about 40-feet deep and 40-feet wide occurred near the intersection of Rt. 517 and Station Road. A quarter mile section of Rt. 517 was closed for three days for cleanup and repairs.
8/15/2011	Debris flow	Sussex	Vernon Township	Heavy rain	Yes	0	0	Massive landslide in Great Gorge Village along Steamboat Drive near the Minerals resort and at ski slope due to heavy rain in area of underground pipeline work.
8/28/2011	Debris flow	Sussex	Vernon Township	Heavy rain	No	0	0	Small debris flow along County Rt. 565 (Glenwood Road) near Lake Pochung Road. Triggered by Tropical Storm Irene.

Table 5.7-1. Past Occurrences of Landslides in New Jersey (1896 to 2012) By County

Date	Type	County	Municipality	Trigger	Damage	Fatalities	Injuries	Comments
8/28/2011	Debris flow	Sussex	Vernon Township	Heavy rain	No	0	0	Debris flow near state line along Lake Wallkill Road. Triggered by Tropical Storm Irene. Temporary road closure.
8/28/2011	Debris flow	Sussex	Vernon Township	Heavy rain	No	0	0	Debris flow along Lake Wallkill Road triggered by Tropical Storm Irene.
8/28/2011	Debris flow	Sussex	Vernon Township	Heavy rain	No	0	0	Small debris flow along County Rt. 565 (Glenwood Road) Between Babtown Road and Lake Pochung Road. Triggered by Tropical Storm Irene.
8/28/2011	Debris flow	Sussex	Vernon Township	Heavy rain	No	0	0	Small debris flow along County Rt. 565 (Glenwood Road) Between Babtown Road and Lake Pochung Road. Triggered by Tropical Storm Irene.
8/28/2011	Debris flow	Sussex	Vernon Township	Heavy rain	No	0	0	Small debris flow along County Rt. 565 (Glenwood Road) Between Babtown Road and Lake Pochung Road. Triggered by Tropical Storm Irene.
8/28/2011	Debris flow	Sussex	Vernon Township	Heavy rain	No	0	0	Small debris flow along County Rt. 565 (Glenwood Road) Between Babtown Road and Lake Pochung Road. Triggered by Tropical Storm Irene.
8/28/2011	Debris flow	Sussex	Vernon Township	Heavy rain	No	0	0	Small debris flow along County Rt. 565 (Glenwood Road) Between Babtown Road and Lake Pochung Road. Triggered by Tropical Storm Irene.
8/28/2011	Debris flow	Sussex	Vernon Township	Heavy rain	Yes	0	0	Second massive landslide in Great Gorge Village near due to heavy rain from Tropical Storm Irene in area of underground pipeline work.
8/28/2011	Debris flow	Sussex	Sparta Township	Heavy rain	Yes	0	0	Large mudslide on Holland Circle due to Tropical Storm Irene. Temporary road closure and evacuations.
8/28/2011	Debris flow	Sussex	Sparta Township	Heavy rain	Yes	0	0	Small mudslide on Holland Circle due to Tropical Storm Irene. Temporary road closure and evacuations.
8/28/2011	Debris flow	Sussex	Vernon Township	Heavy rain	Yes	0	0	A debris flow triggered by Tropical Storm Irene on Lake Wallkill Road near Owens Station Road, temporary road closure.
8/28/2011	Debris flow	Sussex	Vernon Township	Heavy rain	Yes	0	0	A small debris flow triggered by Tropical Storm Irene.
8/28/2011	Debris flow	Sussex	Ogdensburg Boro	Heavy rain	Yes	0	0	Moderate size debris flow on steep slope along Rt. 517 triggered by Tropical Storm Irene.
8/28/2011	Debris flow	Sussex	Vernon Township	Heavy rain	No	0	0	Debris flow along Macpeek Road in Vernon. Temporary road closure.
8/28/2011	Debris flow	Sussex	Vernon Township	Heavy rain	No	0	0	Debris flow along Drew Mountain. Road on steep slope triggered by Tropical Storm Irene.

Table 5.7-1. Past Occurrences of Landslides in New Jersey (1896 to 2012) By County

Date	Type	County	Municipality	Trigger	Damage	Fatalities	Injuries	Comments
8/28/2011	Debris flow	Sussex	Frankford Township	Heavy rain	No	0	0	Debris flow along Owassa Road.
8/28/2011	Slump	Sussex	Branchville Boro	Heavy rain	No	0	0	Large slump on steep hill above Culvers Creek.
9/8/2011	Debris flow	Sussex	Sparta Township	Heavy rain	No	0	0	Debris flow along lower end of Holland Circle triggered by heavy rain from Tropical Storm Lee.
Unknown	Slump	Sussex	Montague Township	Weathering	No	0	0	Older landslide. Estimated location.
Unknown	Rockfall	Sussex	Sparta Township	Weathering	No	0	0	Rockfall of small boulders along roadway cut.
Unknown	Debris flow	Sussex	Walpack Township	Weathering	No	0	0	Two small landslides thirty feet apart onto the road.
Unknown	Debris flow	Sussex	Sparta Township	Heavy rain	Yes	0	0	Small landslide in development lot of new housing development approximately 40-feet long by 20-feet deep.
8/17/1991	Debris flow	Union	Summit	Heavy rain	No	0	0	NJ Transit railroad operations were shut down between Murray Hill and Summit when a debris flow triggered by heavy rain covered railroad tracks. Estimated location.
8/28/2011	Debris flow	Union	Summit	Heavy rain	Yes	0	0	NJ Transit rail road tracks in Summit south of Edgewood Road covered by a debris flow during Tropical Storm Irene. Temporary closure of tracks.
Unknown	Slump	Union	Berkeley Heights	Heavy rain	No	0	0	Two hundred-foot long slump, fill material failure after heavy rain during construction of Interstate 78. Trees were knocked down. Estimated location.
7/23/1887	Debris flow	Warren	Knowlton Township	Heavy rain/poor drainage	Yes	2	0	Two people killed and railroad tracks damaged by a debris flow after heavy rains near Manunka Chunk Mountain, estimated location.
4/13/1915	Rockslide	Warren	Alpha Boro	Quarrying	No	1	0	A quarry worker at the Vulcanite Cement Works was killed by a slide of rock. Estimated location.
6/16/1925	Debris flow	Warren	Mansfield Township	Heavy rain	Yes	50	38	Passenger train derailed after hitting landslide material on railroad tracks caused by heavy rain. The train exploded causing multiple death and injuries.
7/11/1929	Rockslide	Warren	Oxford	Quarrying	No	1	5	A rockslide killed one worker and injured five others at the Edison Portland cement quarry. Estimated location.
7/10/1945	Debris flow	Warren	Phillipsburg	Heavy rain/poor drainage	Yes	4	0	Four people died when their apartment was destroyed by a debris flow after a retaining wall collapsed during heavy rain. Estimated location.

Table 5.7-1. Past Occurrences of Landslides in New Jersey (1896 to 2012) By County

Date	Type	County	Municipality	Trigger	Damage	Fatalities	Injuries	Comments
8/19/1955	Debris flow	Warren	Liberty Township	Heavy rain	Yes	0	0	Heavy rain from Hurricane Diane triggered a debris flow on Rt. 46 just west of Great Meadows closing Rt. 46.
8/14/1967	Rockfall	Warren	Knowlton Township	Heavy rain	Unknown	0	0	A rockslide after heavy rain blocked part of Rt. 46 near the Delaware River. Estimated location.
10/21/1995	Debris flow	Warren	Hardwick Township	Heavy rain	No	0	0	Landslide after heavy rain, it was 600 feet long. Evidence of past landslides. Estimated location.
11/20/2003	Debris flow	Warren	Liberty Township	Heavy rain	Yes	0	0	A 5-foot high and 75-foot wide wall of mud, debris and trees slid onto Rt. 46 after heavy rain, road closed for repairs, 20 yards of guardrail destroyed.
4/15/2007	Rockfall	Warren	Hardwick Township	Heavy rain	Yes	0	0	A car was damaged when it ran into a landslide as it fell onto Rt. 80 westbound near the Delaware River after heavy rain. Rt. 80 Westbound closed. Estimated location.
8/28/2011	Debris flow	Warren	Lopatcong Township	Heavy rain	No	0	0	Debris flow on Rt. 519 due to Hurricane Irene.
8/28/2011	Debris flow	Warren	Allamuchy Township	Heavy rain	Yes	0	0	Debris flow due to heavy rain from Tropical Storm Irene onto Alphano Road in area of construction near Panther Valley development. Temporary road closure.
9/8/2011	Debris flow	Warren	Liberty Township	Heavy rain	Yes	0	0	Large landslide triggered by rain from Tropical Storm Lee destroyed two houses and damaged another building in near Lewis Lane in Mountain Lake. 50 people evacuated.
Unknown	Rockfall	Warren	Hardwick Township	Weathering	No	0	0	Rockfall area along Rt. 80.
Unknown	Rockfall	Warren	Allamuchy Township	Weathering	No	0	0	Rockfall area, the roadway cut is highly fractured causing loose rock fragments to fall onto the road. Estimated location.
Unknown	Rockfall	Warren	Frelinghuysen Township	Weathering	No	0	0	Rockfall area along Rt. 80, the roadway cut is highly fractured causing loose rock fragments to fall onto the road. Estimated location.
Unknown	Rockfall	Warren	Hope Township	Weathering	No	0	0	Small rockfall along Rt.80 Eastbound. Estimated location.
Unknown	Rockfall	Warren	Hope Township	Weathering	No	0	0	Small rockfall along Rt.80 Eastbound. Estimated location.
Unknown	Rockslide	Warren	Frelinghuysen Township	Weathering	Yes	0	0	Rockslide blocked the main rail line near Johnsonburg train station, track eventually redug and rerouted.
Unknown	Rockfall	Warren	Hardwick Township	Weathering	Yes	0	0	Roadway damage from rockfall.
Unknown	Rockfall	Warren	Hardwick Township	Road construction	Yes	0	0	Rock fall partially blocked Old Mine Road.

Table 5.7-1. Past Occurrences of Landslides in New Jersey (1896 to 2012) By County

Date	Type	County	Municipality	Trigger	Damage	Fatalities	Injuries	Comments
				removed toe				
Unknown	Rockfall	Warren	Knowlton Township	Weathering	No	0	0	Small rockslide.
Unknown	Rockfall	Warren	Harmony Township	Weathering	No	0	0	Roadway (County Rt. 621) blocked temporarily by fallen boulders. Estimated location.
Unknown	Rockfall	Warren	Allamuchy Township	Weathering	No	0	0	Small rockfall in roadway cut in center median across from rest area. Estimated location.

Source: NJDEP 2012; NOAA-NCDC 2013

BEMS Burlington Environmental Management Services Incorporated

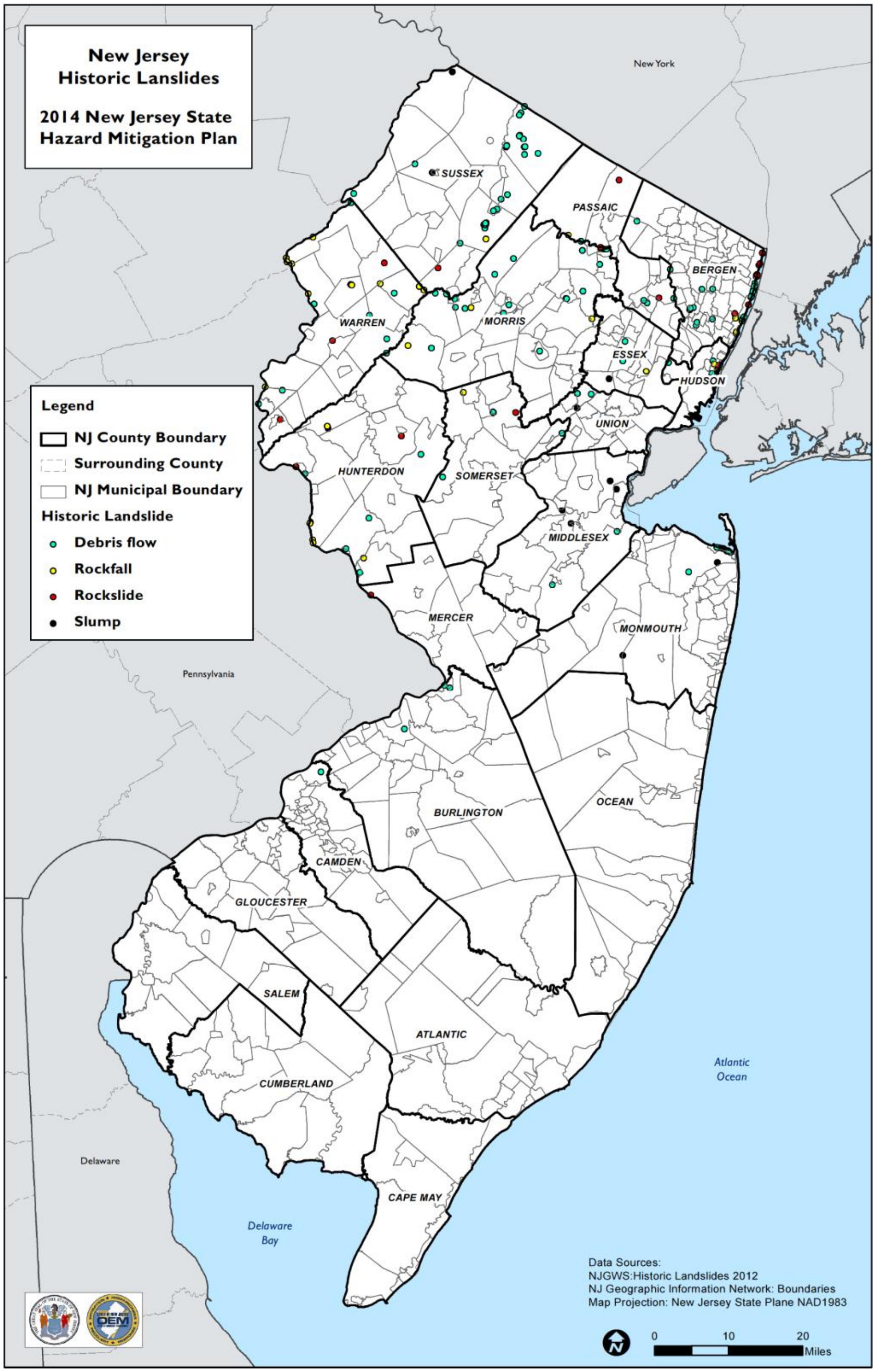
N/A Not applicable

NCDC National Climatic Data Center

NJDEP New Jersey Department of Environmental Protection

NOAA National Oceanic and Atmospheric Administration

Figure 5.7-10. Historic Landslide Events



Source: NJGWS 2012

Detailed information regarding several of the historic landslide events with fatalities or significant property damaged listed in Table 5.7-1 is provided below.

In 1887, a landslide demolished a house and a quarter mile of railroad, killing two people in Warren County. In July 1929, a rockslide killed a quarry worker and injured five others in Warren County. Another person was killed in 1936 when a Work Progress Administration (WPA) worker was killed while working on a road project below Henry Hudson Drive in Palisades Interstate Park in Bergen County. Four people were killed and their apartment was destroyed when a retaining wall collapsed triggering a landslide in Wayne County in 1945. In November 1948, two men were killed when they were buried in a landslide in Hunterdon County (Pallis 2009).

In December 1952, a 10-year-old boy was killed in a rockslide while playing outside a cave in Panther Mountain. Another fatality occurred in November 1963 when a 15-year-old boy was killed as a result of a landslide. The boy was buried under several hundred tons of debris in Passaic County. Despite best efforts the boy's body was never recovered (Pallis 2009).

In September 1971, a 24-year-old man was killed when heavy rains in Bergen County triggered the earth to collapse on the cliffside parking lot of the restaurant where he worked. The subsequent landslide buried him under three feet of rocks (Pallis 2009).

In September 1999, three homes were damaged in Bergen County by a landslide triggered by the heavy rains of Hurricane Floyd. Also during 1999, heavy rains triggered a landslide and destroyed a condominium and damaged three others in Monmouth County (Pallis 2009).

In August 2000, a slow moving storm dumped more than a foot of rain in New Jersey. The torrential rain triggered large landslides that damaged homes and businesses and blocked Route 15 south in Morris County (Pallis 2009).

Between April 15 and 16, 2007, a series of landslides occurred during a Nor'Easter. The most destructive landslide occurred in Bergen County and caused over fifty families to be displaced from six homes and an apartment building. Additionally, the incident caused a traffic accident. Another six landslides occurred along the Palisades in Bergen County as well as a small landslide in Hudson County (Pallis 2009).

Subsidence/Sinkholes

As stated in the 2011 New Jersey HMP, sinkhole and subsidence activities occur primarily in Warren, Sussex, Passaic, Morris, Somerset, and Hunterdon Counties (NJ HMP 2011). The following events were discussed in the 2011 New Jersey HMP and provided below.

- June 16, 1983 – Phillipsburg, Warren County – This one of the largest documented sinkholes to occur in the State of New Jersey. The sinkhole was large enough to cause a two-story home to rotate on its foundation util the front part of the house had sunk to the second story and the back was 10 or more feet off its foundation. A second hole over 20 feet wide opened between the house and the street. This all occurred within a few hours as a result of a broken water main in the street (NJ HMP 2011).
- March 17, 2010 – Mansfield Township, Warren County – A large sinkhole which was 15 feet by 18 feet by 25 feet deep and opened up on Brantwood Terrace. It took five truckloads of concrete to fill the throat of the hole in the bedrock. The sinkhole was then backfilled with several truckloads of stone and soil (NJ HMP 2011).

- 2006 – Trenton, Mercer County – A sinkhole near the New Jersey State Department of Human Resources building occurred; however, it was not considered a true sinkhole because the area is not underlain by carbonate rock (NJ HMP 2011). Figure 5.7-11 shows this incident.

Figure 5.7-11. Sinkhole in Trenton, New Jersey

Source: NJ HMP 2011

Non-karst sinkholes occur throughout New Jersey for various reasons. The 2011 Plan discussed specific sinkhole events that occurred in New Jersey, as described above. For this 2014 Plan update, sinkhole events were summarized between January 1, 2010, and December 31, 2012.

This sinkhole occurrence was not included in the 2011 New Jersey HMP; however, it did result in a fatality and will be included in this Plan Update. In April 1993, a seven year old boy was killed when a sinkhole suddenly opened up in the yard of the boy's North Brunswick home. The boy, who was playing in the yard at the time, was consumed by the hole. More than 100 rescuers attempted to save the boy but were unsuccessful (AP 1993).

A significant sinkhole occurred in Hoboken (Hudson County) in October 2011. A 60-foot long by 15-foot wide sinkhole formed along Sinatra Drive. To repair the hole, the New Jersey Department of Transportation provided a $1.5 million grant to the City to repair the damage of the sinkhole. The sinkhole was blamed on a combination of age of infrastructure, traffic, and damage from mollusks (AP 2011).

Sinkholes are often a problem along the Jersey Shore. In April 2012, a dozen or so sinkholes emerged at a beach in Monmouth County. One beachgoer was caught in a sinkhole and submerged waste deep in sand. The cause of the sinkholes was heavy rains that triggered unconsolidated sand to subside. The trapped individual was freed after 15 minutes (Thompson 2012).

On February 21, 2013, a recent sinkhole appeared suddenly on the Garden State Parkway, damaging 18 vehicles and causing eight miles of traffic delays. The six-by-four foot sinkhole occurred as a result of an underground drainage pipe separating and subsequently weakening the road surface. Most vehicles suffered flat tires and bent rims. Fifteen vehicles had to be towed from the Parkway (Frassanelli 2013).

Also in 2013, a sinkhole caused several water main breaks in Hoboken and prompted boil water advisories across the City. In addition to causing several water main breaks, the sinkhole swallowed a car. The sinkhole was caused by a construction crew that accidently struck a water main, washing out loose subsurface fill and also leading to several sinkholes and additional water main breaks throughout the City. The original sinkhole occurred at approximately 3 a.m. on March 28, 2013 (Gilliam 2013). Figure 5.7-12 shows the Hoboken sinkhole from March 2013.

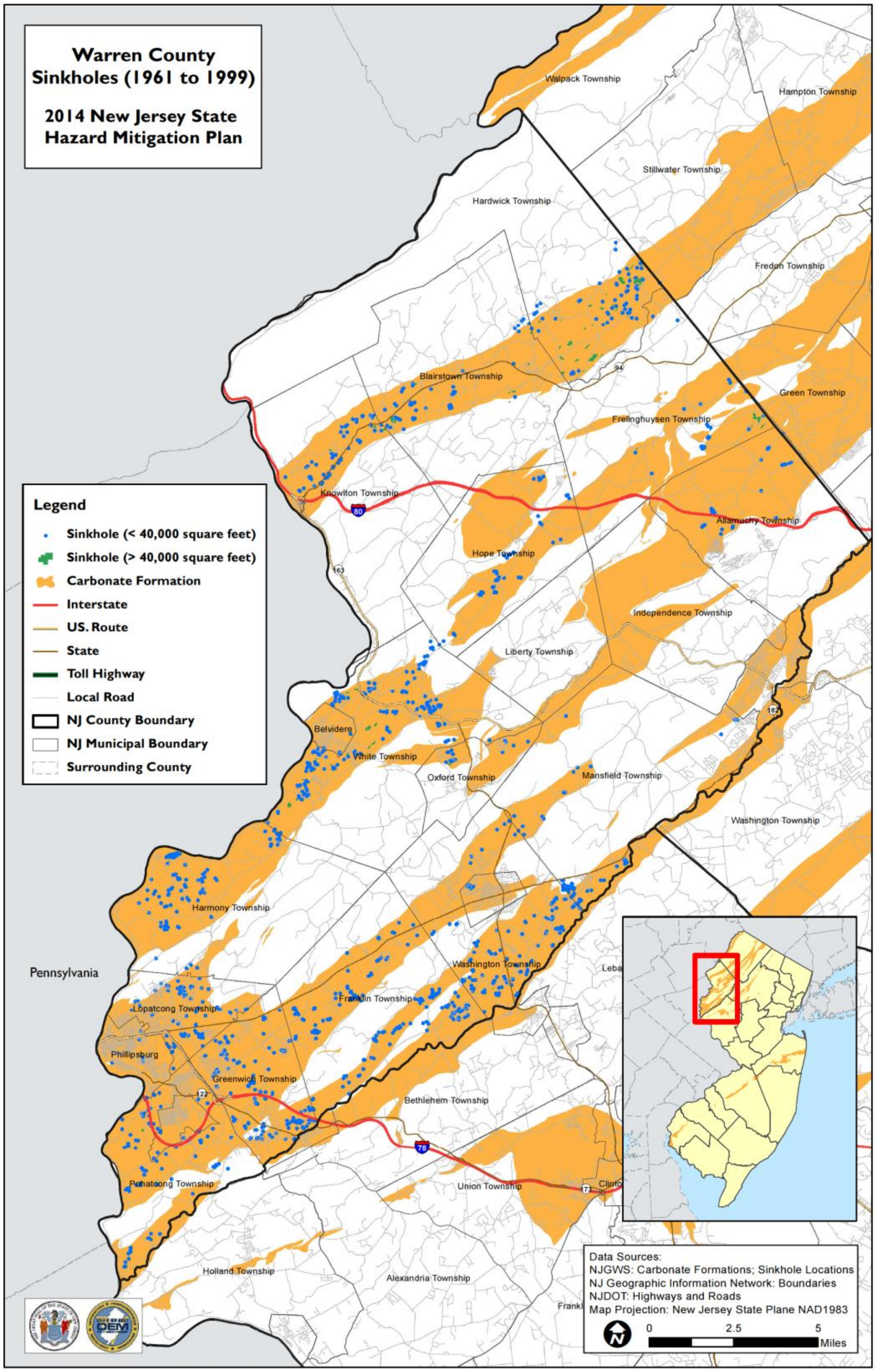
Figure 5.7-12. March 2013 Hoboken Sinkhole

Source: PIX 11 2013

There is a limited amount data available for natural (karst) sinkholes; however, the New Jersey Geological and Water Survey did compile data for Warren County. Warren County had 1,251 sinkholes between 1961 and 1999. Sixty-six of the sinkholes were more than 40,000 square feet in areas and the remaining 1,185 were less than 40,000 square feet (Figure 5.7-13). Table 5.7-2 below provides detail on the 66 sinkholes that were larger than 40,000 square feet.

On September 30, 2013, New Jersey Geological and Water Survey completed a risk analysis of abandoned mines for a FEMA pre-disaster mitigation grant performed under the auspices of NJOEM. About 2700 sites where mining or prospecting occurred were ranked “high” “medium” or “low” for risk of subsidence. Many of these locations were also field inspected and photographed. This data will be published in 2014 and incorporated into the next State HMP update.

Figure 5.7-13. Warren County Sinkholes (1961 to 1999)



Source: New Jersey Geological Survey 1999; 2004

Table 5.7-2. Reported Sinkholes in Warren County, New Jersey (1961 to 1999)

Municipality	Area (sq ft)
Harmony Township	40,739
Hardwick Township	40,967
Belvidere	42,147
Hardwick Township	42,950
Hardwick Township	43,575
Blairstown Township	45,509
Hope Township	46,244
Hardwick Township	52,142
Frelinghuysen Township	52,262
White Township	52,273
Washington Township	52,282
Lopatcong Township	53,310
Hardwick Township	53,543
Hardwick Township	54,249
Franklin Township	55,211
White Township	58,629
Knowlton Township	60,522
Frelinghuysen Township	62,021
Blairstown Township	62,734
Hardwick Township	67,333
Frelinghuysen Township	68,791
Hardwick Township	71,818
Hardwick Township	76,965
Blairstown Township	83,452
White Township	84,070
Hardwick Township	84,451
Hardwick Township	88,146
Hardwick Township	92,362

Table 5.7-2. Reported Sinkholes in Warren County, New Jersey (1961 to 1999)

Municipality	Area (sq ft)
Washington Township	100,472
Blairstown Township	100,896
Hardwick Township	103,506
White Township	105,050
Greenwich Township	109,602
White Township	109,678
Hardwick Township	110,490
Knowlton Township	111,898
Oxford Township	125,436
White Township	125,854
Hardwick Township	126,642
Phillipsburg	130,118
Hardwick Township	138,277
Pohatcong Township	139,081
Blairstown Township	157,228
Hardwick Township	163,010
Hardwick Township	166,171
White Township	167,063
Hardwick Township	168,440
White Township	169,467
Hardwick Township	178,416
White Township	180,111
Frelinghuysen Township	180,122
Knowlton Township	184,861
Hardwick Township	188,850
Hardwick Township	204,533
White Township	211,532
Hardwick Township	211,986
White Township	217,081

Table 5.7-2. Reported Sinkholes in Warren County, New Jersey (1961 to 1999)

Municipality	Area (sq ft)
Blairstown Township	242,894
White Township	351,632
White Township	434,477
Hardwick Township	450,093
Blairstown Township	644,516
Hardwick Township	676,562
Hardwick Township	818,448
Frelinghuysen Township	852,588
Hardwick Township	1,035,560

Source: NJGWS 2007
sq ft square feet

Probability of Future Occurrences

Landslide

Landslides are often triggered by other natural hazards such as earthquakes, heavy rain, floods, or wildfires. Therefore, landslide frequency is often related to the frequency of these other hazards. In general, landslides are most likely during periods of higher than average rainfall. The ground must be saturated prior to the onset of a major storm for significant landsliding to occur.

Landslide probabilities are a function of surface geology and are also influenced by weather and human activities. The NJGWS determined landslide susceptibility for nine counties in the State of New Jersey (Bergen, Essex, Hudson, Middlesex, Monmouth, Morris, Passaic, Somerset, and Union). Refer to Appendix Q for detailed maps of each county.

For the purposes of this plan, the probability of future occurrences is defined by the number of events over a specified period of time. There was one federally declared disaster (DR-1337) as a result of mudslides impacting Sussex and Morris Counties. It is noted that the historic record may underestimate the true number of events that have taken place in the State. Looking at the recent record, from 1782 to 2012, there were 233 instances of landslides in the State. Based upon past instances it is reasonable to project that landslides could continue to impact New Jersey, primarily in the northern counties. Landslides may also continue to be a geologic hazard in the State of New Jersey as more land is developed.

Subsidence/Sinkholes

Sinkhole occurrence is a continuing phenomenon and is fairly common in the carbonate areas of the New Jersey. Therefore, the probability of a sinkhole forming in the New Jersey may be high. As these areas become increasingly developed, and as more people move out of the cities, the strain on underground aquifers could increase. This may pose an even greater threat for sinkholes in those areas resulting from groundwater depletion. Based on geological conditions, subsidence events are likely to occur in the future in areas of New Jersey underlain by carbonate bedrock and experiencing increased development.

Severity

Landslides destroy property and infrastructure and can cause fatalities. Slope failures in the United States result in an average of 25 fatalities per year and an annual cost of about $1.5 billion.

The average annual damages and losses from subsidence in the United States are estimated to be at least $125 million. In New Jersey, it is estimated the annual losses from sinkholes is less than $1 million per year.

Warning Time

Landslides

Mass movements of geological material can occur suddenly or slowly. The velocity of movement may range from a slow creep of inches per year to many feet per second, depending on slope angle, material, and water content. Some methods used to monitor mass movements can provide an idea of the type of movement and the amount of time prior to failure. It is also possible to determine what areas are at risk during general time periods. Assessing the geology, vegetation, and amount of predicted precipitation for an area can help in these predictions. However, there is no practical warning system for individual landslides. The current standard operating procedure is to monitor situations on a case-by-case basis, and respond after the event has occurred. According to the United States Search and Rescue Task Force, generally accepted warning signs for landslide activity include:

- Springs, seeps, or saturated ground in areas that have not typically been wet before
- New cracks or unusual bulges in the ground, street pavements, or sidewalks
- Soil moving away from foundations
- Ancillary structures, such as decks and patios, tilting and/or moving relative to the main house
- Concrete floors and foundations tilting or cracking
- Broken water lines and other underground utilities
- Leaning telephone poles, trees, retaining walls or fences
- Offset fence lines
- Sunken or down-dropped road beds
- Rapid increase in creek water levels, possibly accompanied by increased turbidity (soil content)
- Sudden decrease in creek water levels though rain is still falling or just recently stopped
- Sticking doors and windows, and visible open spaces indicating jams and frames out of plumb
- A faint rumbling sound that increases in volume as the landslide nears
- Unusual sounds, such as trees cracking or boulders knocking together

Subsidence/Sinkholes

Subsidence and sinkholes can occur gradually or abruptly without warning. Geologists have a firm understanding of the risk factors that lead to sinkholes, thus areas of concern are highlighted on the risk maps. Additionally, human activities may have exacerbated the sinkhole risk for the State. Although specific warning signs may not be present, there are some general warning signs that may indicate a sinkhole is about to occur.

The Southwest Florida Water Management District explains that there are several warning signs for sinkholes, that include:

- Fresh exposure on fence posts, foundations and trees that result when the ground sinks
- Slumping, sagging or slanting fence posts, trees or other objects
- Ponding (small ponds of rainfall forming where water has not been collected before)
- Wilting of small, circular areas of vegetation because the moisture that normally supports vegetation in the area is draining into the sinkhole developing below the surface
- Turbidity of water in nearby wells during early stages of sinkhole development
- Structural cracks in walls, floors and pavement; cracks in the ground surface

Secondary Hazards

Landslides

Landslides can cause several types of secondary effects, such as blocking access to roads, which can isolate residents and businesses and delay commercial, public, and private transportation. This could result in economic losses for businesses. Other potential problems resulting from landslides are power and communication failures. Vegetation or poles on slopes can be knocked over, resulting in possible losses to power and communication lines. Landslides also have the potential of destabilizing the foundation of structures, which may result in monetary loss for residents. They also can damage rivers or streams, potentially harming water quality, fisheries, and spawning habitat.

Subsidence/Sinkholes

Like landslides, subsidence/sinkholes can cause several types of secondary effects such as blocking roadways and access points to businesses and critical infrastructure. As noted in the previous occurrences section, subsidence/sinkholes have impacted major roadways in New Jersey, including the Garden State Parkway. This impact can cause traffic accidents, especially on major routes. Sinkholes may also cause utility failures, as was the case in Hoboken where several water mains were broken as a result of a sinkhole. Sinkholes also have the potential to cause damage to chemical infrastructures such as pipelines and facilities that store or transport hazardous materials. The result from a breach of one of these systems may result in a hazardous materials release and damage the environment.

Climate Change Impacts

Landslides

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 New Jersey Climate Adaptation Alliance is a network of policymakers, public and private-sector practitioners, academics, non-governmental organizations (NGO), and business leaders aligned to build climate change preparedness in the state of New Jersey. The Alliance is facilitated by Rutgers University, which provides science and technical support, facilitates the Alliance's operations and advances its recommendations. A document titled Change in New Jersey: Trends and Projections was developed to identify recommendations for State and local public policy that will be designed to enhance climate change preparedness and resilience in New Jersey (Rutgers 2013).

Temperatures in the Northeast United States have increased 1.5 degrees Fahrenheit (°F) on average since 1900. Most of this warming has occurred since 1970. The State of New Jersey, for example, has observed an increase in average annual temperatures of 1.2°F between the period of 1971-2000 and the most recent decade of 2001-2010 (ONJSC, 2011). Winter temperatures across the Northeast have seen an increase in average temperature of 4°F since 1970 (Northeast Climate Impacts Assessment [NECIA] 2007). By the 2020s, the average annual temperature in New Jersey is projected to increase by 1.5°F to 3°F above the statewide baseline (1971 to 2000), which was 52.7°F. By 2050, the temperature is projected to increase 3°F to 5°F (Sustainable Jersey Climate Change Adaptation Task Force 2013).

Both northern and southern New Jersey have become wetter over the past century. Northern New Jersey's 1971-2000 precipitation average was over 5" (12%) greater than the average from 1895-1970. Southern New Jersey became 2" (5%) wetter late in the 20th century (Office of New Jersey State Climatologist).

Future climate change may impact storm patterns, increasing the probability of more frequent, intense storms with varying duration. Increase in global temperature could affect the snowpack and its ability to hold and store water. Warming temperatures also could increase the occurrence and duration of droughts, which could increase the probability of wildfire, reducing the vegetation that helps to support steep slopes. All of these factors could increase the probability for landslide occurrences.

Subsidence/Sinkholes

Similar to landslides, future climate change could affect subsidence and sinkholes in New Jersey. As discussed throughout this profile, one of the triggers for subsidence and sinkholes is an abundance of moisture which has the potential to permeate the bedrock causing an event. Climatologists predict an increase in annual precipitation amounts. Both northern and southern New Jersey have become wetter over the past century. Northern New Jersey's 1971-2000 precipitation average was over 5" (12%) greater than the average from 1895-1970. Southern New Jersey became 2" (5%) wetter late in the 20th century (Office of New Jersey State Climatologist). Average annual precipitation is projected to increase in the region by 5% by the 2020s and up to 10% by the 2050s. Most of the additional precipitation is expected to come during the winter months (New York City Panel on Climate Change [NYCPCC] 2009). This increase will coincide with an increased potential risk in subsidence and sinkholes in vulnerable areas.

5.7.2 Vulnerability Assessment

To understand risk, a community must evaluate what assets are exposed or vulnerable in the identified hazard area. For geological hazards, the known landslide and subsidence/sinkhole vulnerable areas as identified by the New Jersey Geologic and Water Survey have been identified as the hazard area. The following text evaluates and estimates potential impact of geological hazards to jurisdictions and state facilities in New Jersey.

To determine vulnerability, a spatial analysis was conducted in GIS using the landslide susceptibility datasets discussed below. When the analysis determined the hazard area would impact the area in a jurisdiction, or the location of state buildings and critical facilities, these locations were deemed vulnerable to the hazard.

Assessing Vulnerability by Jurisdiction

The New Jersey Geologic Survey (currently known as the New Jersey Geological and Water Survey) determined landslide susceptibility for nine counties in New Jersey (Bergen, Essex, Hudson, Middlesex, Monmouth, Morris, Passaic, Somerset, and Union). Figure 5.7-3 earlier in this section illustrates the classifications statewide. Refer to Appendix Q for a more detailed map for each county. In addition to the analysis conducted using NJGWS data, a statewide analysis was conducted using the Landslide Incidence and Susceptibility national spatial layer was used to coarsely define the general landslide susceptible areas (Godt 2001). The limitations of this data set and analysis are recognized and are only used to provide a general estimate until higher resolution data is available statewide. The total land area located in each class using these two datasets was calculated for each county, as presented in Table 5.7-3 below. Based upon the analysis using NJGWS data, Bergen, Passaic, Morris and Hudson Counties have the greatest area delineated with landslide susceptible soils. Using the Godt data, northwestern Sussex County is also identified as being highly susceptible to landslide.

As discussed earlier, naturally occurring subsidence and sinkholes in New Jersey occur within bands of carbonate bedrock. Table 5.7-3 below summarizes the total land area in each county with carbonate rock formations. Primarily the northern region of New Jersey may be susceptible to natural subsidence and sinkholes. In addition, due to at least 588 abandoned mines, the northern part of the State may have a greater potential for significant surface collapse than the southern part. Figure 5.7-6 earlier in this section illustrates the locations of abandoned mines in the State. These mines are located in the following 10 counties: Bergen, Essex, Hunterdon, Middlesex, Morris, Passaic, Somerset, Sussex, Union, and Warren.

Table 5.7-3. Total Land Area Located in the Landslide and Subsidence/Sinkhole Hazard Areas

County	Total Area (sq mi)	NJGWS-Defined Landslide Susceptible Areas						Landslide Susceptible Areas (Godt 2001)				Sinkhole/Subsidence Hazard Areas	
		Class A (sq mi)	% Total	Class B (sq mi)	% Total	Class C (sq mi)	% Total	High Susceptibility /Moderate Incidence	% Total	Moderate Susceptibility/ Low Incidence	% Total	Carbonate Rock Formation (sq mi)	% Total
Atlantic	610.7	-	-	-	-	-	-	0.0	0.0%	0.0	0.0%	0.0	0.0%
Bergen	239.8	5.1	2.10%	1.5	0.60%	0	0.00%	0.0	0.0%	0.0	0.0%	0.0	0.0%
Burlington	820.3	-	-	-	-	-	-	0.0	0.0%	49.4	6.0%	22.9	2.8%
Camden	227.6	-	-	-	-	-	-	0.0	0.0%	24.5	10.7%	0.8	0.3%
Cape May	286.1	-	-	-	-	-	-	0.0	0.0%	0	0.0%	0.0	0.0%
Cumberland	501.8	-	-	-	-	-	-	0.0	0.0%	0.0	0.0%	0.0	0.0%
Essex	129.7	0.4	0.30%	0.9	0.70%	0	0.00%	0.0	0.0%	0.0	0.0%	0.0	0.0%
Gloucester	336.2	-	-	-	-	-	-	0.0	0.0%	42.7	14.9%	0.6	0.2%
Hudson	51.5	0.4	0.70%	0	0.00%	0	0.00%	0.0	0.0%	0.0	0.0%	0.0	0.0%
Hunterdon	437.3	-	-	-	-	-	-	0.0	0.0%	0.0	0.0%	28.0	6.4%
Mercer	228.8	-	-	-	-	-	-	0.0	0.0%	27.0	11.8%	0.0	0.0%
Middlesex	317.0	0	0.00%	0.6	0.20%	0.7	0.20%	0.0	0.0%	3.5	1.1%	0.0	0.0%
Monmouth	485.7	0	0.00%	4.2	0.90%	0	0.00%	0.0	0.0%	0.0	0.0%	45.0	9.3%
Morris	481.4	4.7	1.00%	6.9	1.40%	1	0.20%	0.0	0.0%	0.0	0.0%	32.7	6.8%
Ocean	757.9	-	-	-	-	-	-	0.0	0.0%	0.0	0.0%	6.0	0.8%
Passaic	198.3	6.3	3.20%	0.6	0.30%	0	0.00%	0.0	0.0%	0.0	0.0%	1.0	0.5%
Salem	347.1	-	-	-	-	-	-	0.0	0.0%	22.2	6.4%	24.6	7.1%
Somerset	304.9	1.4	0.50%	3.1	1.00%	0.6	0.20%	0.0	0.0%	0.0	0.0%	1.1	0.4%
Sussex	535.5	-	-	-	-	-	-	51.0	9.5%	0.0	0.0%	133.1	24.9%
Union	105.4	0.2	0.20%	0.8	0.80%	0	0.00%	0.0	0.0%	0.0	0.0%	0.0	0.0%
Warren	362.6	-	-	-	-	-	-	0.0	0.0%	0.0	0.0%	153.1	0.0%
Total	**7765.7**	**18.4**	**0.20%**	**18.6**	**0.20%**	**2.3**	**0.00%**	**51.0**	**0.7%**	**169.2**	**2.2%**	**448.9**	**5.8%**

Source: NJGWS 2005; Godt 2001

% *percent*

sq mi *square miles*

- *No data available to conduct the analysis. NJGWS data was only available for nine counties in New Jersey (Bergen, Essex, Hudson, Middlesex, Monmouth, Morris, Passaic, Somerset, and Union).*

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

Total area includes land and water.

Seventeen New Jersey counties included geologic hazards as a hazard of concern in their hazard mitigation plans. Refer to Table 5.1-2 in Section 5.1 (State Risk Assessment Overview) of this update for more information on the hazards included in these plans. Table 5.7-4 below summarizes the number of landslide and subsidence/sinkhole events from 1782 to 2006 by county. Based on the best available data, Bergen, Essex, Hudson, Hunterdon, Monmouth, Morris, Sussex, and Warren Counties have had the highest number of landslide events. As stated earlier, sinkhole event data is only available for Warren County. Abandoned mines in Bergen, Essex, Hunterdon, Morris, Passaic, Somerset, and Sussex Counties could make these locations vulnerable to the subsidence/sinkhole hazard as well.

Table 5.7-4. Number of Geologic Hazard Events and Abandoned Mines by County from 1782 to 2006

County	Number of Landslide Events	Number of Sinkhole/ Subsidence Events	Number of Abandoned Mines
Atlantic	0	N/A	0
Bergen	55	N/A	4
Burlington	4	N/A	0
Camden	1	N/A	0
Cape May	0	N/A	0
Cumberland	0	N/A	0
Essex	10	N/A	3
Gloucester	0	N/A	0
Hudson	16	N/A	0
Hunterdon	20	N/A	103
Mercer	1	N/A	0
Middlesex	6	N/A	0
Monmouth	18	N/A	0
Morris	28	N/A	211
Ocean	0	N/A	0
Passaic	7	N/A	46
Salem	0	N/A	0
Somerset	6	N/A	12
Sussex	34	N/A	75
Union	3	N/A	0
Warren	24	1,185	131
Total	**233**	**1,185**	**585**

Source: NJGWS 2005
N/A Not available

The population within the landslide and sinkhole/subsidence hazard areas may be vulnerable. Specifically, the population located downslope of the landslide hazard areas are particularly vulnerable to this hazard. Due to the nature of Census block data, it is difficult to determine demographics of populations vulnerable to mass movements of geological material.

To better understand life at risk, the landslide and sinkhole/subsidence hazard areas were overlaid upon the 2010 Census population data (United States Census 2010). Please note the Census blocks do not align exactly with the hazard areas and, therefore, these estimates should be considered for planning purposes only. Further, some areas did not have a defined landslide hazard category assigned due to the differences in extent of the polygon datasets. In these cases, the adjacent landslide hazard area classification was assigned to the Census block. The Census blocks with their centroid located in each zone were used to calculate the estimated population exposed to the landslide hazard. In New Jersey, there are an estimated 377,374 people potentially exposed to landslides and an estimated 229,989 people potentially exposed to sinkholes or subsidence. Refer to Table 5.7-5 below.

Based on the analysis the USGS landslide susceptibility data (Godt 2001) the largest percentage of the New Jersey population vulnerable to landslides is located in the areas identified having moderate susceptibility and low incidence. The main population base in the urban and suburban areas is proximate to Philadelphia adjacent to the Delaware River located in Burlington, Camden, and Gloucester Counties make up the majority of the potential population impacts. Highly populated areas in Mercer County are also vulnerable. The area of the State that has a high susceptibility and moderate incidence is located in area of Sussex County, which is sparsely populated, so the potential population impacts are minimal.

Based upon the analysis using NJGWS data, the areas of landslide susceptibility are specific to hilly or mountainous areas with steep slopes and erodible soils. Gradually more and more individual municipalities have implemented steep slope ordinances which prohibit development in these areas. Therefore, potential to develop these vulnerable areas are decreasing. However, the existing populations in these areas remain potentially vulnerable. Similar to landslides, subsidence and sinkholes pose a danger to populations living in high risk areas, including loss of life. Compounding the vulnerability of populations to subsidence/sinkholes is the vast array of abandoned mines and the geological makeup of much of northern New Jersey, coupled with recent growth in the region. Naturally, as populations move into high hazard areas, the vulnerability of said population will increase.

Table 5.7-5. Estimated Population Located in the Landslide and Subsidence/Sinkhole Hazard Areas

		NJGWS-Defined Landslide Susceptible Areas						Landslide Susceptible Areas (Godt 2001)				Sinkhole/Subsidence Hazard Areas	
County	Total Population	Class A	% Total	Class B	% Total	Class C	% Total	High Susceptibility /Moderate Incidence	% Total	Moderate Susceptibility/ Low Incidence	% Total	Carbonate Rock Formation	% Total
Atlantic	274,549	-	-	-	-	-	0.0%	0	0.0%	0	0.0%	0	0.0%
Bergen	905,116	1,818	0.2%	6,290	0.7%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Burlington	448,734	-	-	-	-	-	-	0	0.0%	109,139	24.3%	10,337	2.3%
Camden	513,657	-	-	-	-	-	-	0	0.0%	124,476	24.2%	2,252	2.3%
Cape May	97,265	-	-	-	-	-	-	0	0.0%	0	0.0%	0	0.0%
Cumberland	156,898	-	-	-	-	-	-	0	0.0%	0	0.0%	0	0.0%
Essex	783,969	730	0.1%	2,618	0.3%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Gloucester	288,288	-	-	-	-	-	-	0	0.0%	17,182	6.0%	171	0.1%
Hudson	634,266	2,786	0.4%	346	0.1%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Hunterdon	128,349	-	-	-	-	-	-	0	0.0%	0	0.0%	10,460	8.1%
Mercer	366,513	-	-	-	-	-	-	0	0.0%	60,779	16.6%	0	0.0%
Middlesex	809,858	0	0.0%	1,295	0.2%	2,153	0.3%	0	0.0%	10,743	1.3%	0	0.0%
Monmouth	630,380	0	0.0%	1,435	0.2%	1,487	0.2%	0	0.0%	0	0.0%	63,951	10.1%
Morris	492,276	312	0.1%	5,009	1.0%	0	0.0%	0	0.0%	0	0.0%	18,112	3.7%
Ocean	576,567	-	-	-	-	-	-	0	0.0%	0	0.0%	4,151	0.7%
Passaic	501,226	2,188	0.4%	297	0.1%	0	0.0%	0	0.0%	0	0.0%	1,232	0.2%
Salem	66,083	-	-	-	-	-	-	0	0.0%	17,202	26.0%	6,322	9.6%
Somerset	323,444	326	0.1%	2,268	0.7%	686	0.2%	0	0.0%	0	0.0%	863	0.3%
Sussex	149,265	-	-	-	-	-	-	4,952	3.3%	0	0.0%	39,422	26.4%
Union	536,499	324	0.1%	533	0.1%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Warren	108,692	-	-	-	-	-	-	0	0.0%	0	0.0%	72,716	66.9%
Total	**8,791,894**	**8,484**	**0.1%**	**20,091**	**0.2%**	**4,326**	**0.0%**	**4,952**	**0.1%**	**339,521**	**3.9%**	**229,989**	**2.6%**

Source: United States Census 2010; NJGWS, 2005 Godt 2001

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

% percent

NJGWS New Jersey Geological Water Survey

- No data available to conduct the analysis. NJGWS data was only available for nine counties in New Jersey (Bergen, Essex, Hudson, Middlesex, Monmouth, Morris, Passaic, Somerset, and Union).

Assessing Vulnerability to State Facilities

To assess the vulnerability of the state-owned and leased facilities provided by the New Jersey Office of Management and Budget (NJOMB), an analysis was conducted with the landslide and sinkhole/subsidence susceptible areas. Using ArcMap, GIS software, these hazard areas were overlaid with the state facility data to determine the number of vulnerable state facilities. Table 5.7-6 summarizes the state-owned and -leased facilities vulnerable to the landslide and sinkhole/subsidence hazards by county. Table 5.7-7 summarizes the facilities vulnerable by state agency.

Table 5.7-6. State-Owned and -Leased Buildings in the Landslide and Sinkhole/Subsidence Hazard Area by County

County	Total Number of Buildings	NJGWS-Defined Landslide Susceptible Areas (Classes A through C)			Landslide Susceptible Areas (High and Moderate Susceptibility) (Godt 2001)			Sinkhole/Subsidence Hazard Areas		
		Owned	Leased	Total	Owned	Leased	Total	Owned	Leased	Total
Atlantic	87	-	-	-	0	0	0	0	0	0
Bergen	46	0	0	0	0	0	0	0	0	0
Burlington	345	-	-	-	55	3	58	4	0	4
Camden	70	-	-	-	5	2	7	0	0	0
Cape May	114	-	-	-	0	0	0	0	0	0
Cumberland	367	-	-	-	0	0	0	0	0	0
Essex	74	0	0	0	0	0	0	0	0	0
Gloucester	46	-	-	-	6	0	6	0	0	0
Hudson	22	0	0	0	0	0	0	0	0	0
Hunterdon	333	-	-	-	0	0	0	181	0	181
Mercer	390	-	-	-	2	0	2	0	0	0
Middlesex	264	0	0	0	0	0	0	0	0	0
Monmouth	163	1	0	1	0	0	0	3	0	3
Morris	103	0	0	0	0	0	0	13	0	13
Ocean	103	-	-	-	0	0	0	0	0	0
Passaic	71	0	0	0	0	0	0	0	0	0
Salem	56	-	-	-	12	0	12	0	2	2
Somerset	38	0	0	0	0	0	0	0	0	0
Sussex	63	-	-	-	5	0	5	16	1	17
Union	35	0	0	0	0	0	0	0	0	0
Warren	120	-	-	-	0	0	0	55	3	58
Total	**2,910**	**1**	**0**	**1**	**85**	**5**	**90**	**272**	**6**	**278**

Source: NJOMB 2013; Godt 2001; NJGWS 2005

Note: NJGWS New Jersey Geological Water Survey

- No data available to conduct the analysis. NJGWS data was only available for nine counties in New Jersey (Bergen, Essex, Hudson, Middlesex, Monmouth, Morris, Passaic, Somerset, and Union).

Table 5.7-7. State-Owned and -Leased Buildings in the Landslide and Sinkhole/Subsidence Hazard Area by Agency

Agency	Total Number of Buildings	NJGWS-Defined Landslide Susceptible Areas (Classes A through C)			Landslide Susceptible Areas (High and Moderate Susceptibility) (Godt 2001)			Sinkhole/Subsidence Hazard Areas		
		Owned	Leased	Total	Owned	Leased	Total	Owned	Leased	Total
Agriculture	1	0	0	0	0	0	0	0	0	0
Banking and Insurance	1	0	0	0	0	0	0	0	0	0
Chief Executive	1	0	0	0	0	0	0	0	0	0
Children and Families	90	0	0	0	0	1	1	0	3	3
Community Affairs	9	0	0	0	0	0	0	0	0	0
Corrections	696	0	0	0	0	0	0	69	0	69
Education	64	0	0	0	1	0	1	0	0	0
Environmental Protection	330	0	0	0	7	1	8	69	0	69
Health	3	0	0	0	0	0	0	0	0	0
Human Services	463	0	0	0	0	0	0	77	0	77
Judiciary	4	0	0	0	0	0	0	0	0	0
Juvenile Justice Commission	181	0	0	0	36	0	36	0	0	0
Labor and Work Force Dev.	6	0	0	0	0	0	0	0	0	0
Law And Public Safety	11	0	0	0	0	0	0	0	0	0
Legislature	4	0	0	0	0	0	0	0	0	0
Military And Veterans Affairs	262	0	0	0	9	0	9	10	0	10
Miscellaneous Commissions	1	0	0	0	0	1	1	0	0	0
Motor Vehicles Commission	69	0	0	0	1	1	2	3	3	6
Personnel	1	0	0	0	0	0	0	0	0	0
State	9	0	0	0	0	0	0	0	0	0
State Police	122	0	0	0	4	1	5	1	0	1
Transportation	565	1	0	1	27	0	27	43	0	43
Treasury	17	0	0	0	0	0	0	0	0	0
Total	**2,910**	**1**	**0**	**1**	**85**	**5**	**90**	**272**	**6**	**278**

Source: NJOMB 2013; Godt 2001; NJGWS 2005
Note: NJGWS New Jersey Geological Water Survey

Based on the analysis the USGS landslide susceptibility data (Godt 2001) the majority of State buildings vulnerable to landslides are located in the areas identified having moderate susceptibility and low incidence. More specifically, the facilities most vulnerable are located in the urban and suburban areas proximate to Philadelphia, adjacent to the Delaware River located in Burlington, as well as Camden and Gloucester Counties. Highly populated areas in Mercer County are also vulnerable. Northwest Sussex County has a high susceptibility and moderate incidence; therefore, state-owned or -leased facilities in this area are also vulnerable. Based on the NJGWS data, which is more specific to New Jersey, one transportation facility in Monmouth County is vulnerable.

Similar to landslides, subsidence and sinkholes pose a risk to state facilities in high risk areas. The most vulnerable areas are located in the mountainous areas of northwestern New Jersey. Hunterdon County has the highest number of state facilities vulnerable to this risk.

For the purposes of this planning effort, the critical facilities located in the landslide and sinkhole/subsidence hazard areas are exposed and vulnerable. To assess the vulnerability of the critical facilities, an analysis was conducted with the landslide and sinkhole/subsidence susceptible areas. Using ArcMap, GIS software, these hazard areas were overlaid with the critical facility data to determine the number of vulnerable facilities. Tables 5.7-8 and 5.7-9 identify the number of critical facilities vulnerable to these geologic hazards in the State, summarized by county.

In terms of the landslide hazard, the following Counties have critical facilities located in the defined hazard areas: Bergen (fire and highway bridge), Essex (dam and shelter), Hudson (light rail facility and wastewater facility), Middlesex (dam), Monmouth (dam), Morris (three dams), Passaic (dams and shelter) and Somerset (two dams and police). For the sinkhole/subsidence hazard, the following Counties have critical facilities located on carbonate rock: Bergen, Hunterdon, Monmouth, Morris, Ocean, Salem, Somerset, Sussex and Warren.

In addition to critical facilities, a significant amount of infrastructure can be exposed to mass movements of geological material:

- *Roads*—Access to major roads is crucial to life-safety after a disaster event and to response and recovery operations. Landslides 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.
- *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*—Power lines are generally elevated above steep slopes; but the towers supporting them can be subject to landslides. A landslide could trigger failure of the soil underneath a tower, causing it to collapse and ripping down the lines. Power and communication failures due to landslides can create problems for vulnerable populations and businesses.

Several other types of infrastructure may also be exposed to landslides and/or sinkholes/subsidence, including water and sewer infrastructure. Vulnerable landslide areas of the State include: mountain and coastal roads; transportation infrastructure; vulnerable sinkhole/subsidence areas with karst geography make up; and areas with underground abandoned mines and carbonate rock formations. At this time all critical facilities, infrastructure, and transportation corridors located within the hazard areas are considered vulnerable until more information becomes available.

Table 5.7-8. Critical Facilities Exposed to the Landslide Hazard Areas (Classes A through C or High to Moderate Susceptibility)

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	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
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	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
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	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Monmouth	905	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Morris	913	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
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	2	0	0	0	0	0	0	0	0	0	0	0	0	1	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	0	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**	**0**	**0**	**0**	**0**	**9**	**0**	**0**	**0**	**0**	**1**	**1**	**0**	**1**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**2**	**0**	**1**

Table 5.7-9. Critical Facilities Exposed to the Sinkhole/Subsidence Hazard Areas

County	Total Count	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	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
Burlington	747	0	0	0	0	7	0	3	0	0	1	0	0	0	3	0	0	0	1	0	0	0	0	5	5	0	3
Camden	701	0	0	0	0	2	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	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
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	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
Hunterdon	328	0	0	0	1	22	0	7	0	0	4	0	0	0	0	0	0	0	2	0	0	0	0	8	6	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	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
Monmouth	905	0	0	0	0	8	1	4	1	0	12	0	0	0	6	1	0	0	4	0	0	1	0	42	9	0	1
Morris	913	0	0	0	0	14	1	4	0	0	5	0	0	0	3	1	0	0	0	0	0	0	0	12	3	0	2
Ocean	621	0	0	0	0	3	0	2	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	4	3	0	0
Passaic	648	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
Salem	201	0	0	0	0	0	0	1	0	0	4	0	0	0	0	0	0	0	2	0	0	0	0	6	6	0	1
Somerset	539	0	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0	2	0	0
Sussex	542	1	0	0	0	55	0	20	0	0	21	0	0	0	5	0	0	0	9	0	0	0	0	39	46	0	2
Union	607	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
Warren	351	0	0	1	1	34	0	25	1	0	26	2	0	0	13	0	0	0	13	0	0	1	0	45	61	0	2
Total	**12,096**	**1**	**0**	**1**	**2**	**146**	**2**	**67**	**2**	**0**	**75**	**2**	**0**	**0**	**30**	**2**	**0**	**0**	**33**	**0**	**0**	**3**	**0**	**161**	**141**	**0**	**11**

EOC *Emergency Operations Center*
EMS *Emergency Medical Services*

Estimating Potential Losses by Jurisdiction

Geologic hazards can impose direct and indirect impacts on society. Direct costs include the actual damage sustained by buildings, property and infrastructure. Indirect costs, such as clean-up costs, business interruption, loss of tax revenues, reduced property values, and loss of productivity are difficult to measure. Additionally, ground failure threatens transportation corridors, fuel and energy conduits, and communication lines (USGS 2003).

An exposure analysis methodology was used to grossly estimate potential losses. To estimate the general building stock vulnerable to this hazard, the associated building replacement values (buildings and contents) were determined for the identified census blocks within the approximate hazard areas. Potential losses to buildings include the costs to repair or replace the damage caused to the building. These dollar value losses to the building inventory replacement value would impact the local tax base and economy.

Table 5.7-10 identifies a potential total risk exposure of greater than $45 billion for buildings vulnerable to landslides, and $33 billion for buildings vulnerable to sinkholes/subsidence in New Jersey. The limitations of this analysis are recognized because this figure assumes 100% loss to each structure and its contents. This potential loss estimate is considered high given it is not likely that the geologic hazard events discussed would occur across the entire hazard area at the same time from one event. As more current replacement cost data becomes available at the structure level, and standardized methodologies for the landslide/subsidence/sinkhole hazards become available to estimate potential losses, this section of the plan will be updated with new information and the potential loss estimates will be further refined.

Table 5.7-10. Estimated Building Replacement Cost Vulnerable to the Landslide and Subsidence/Sinkhole Hazards

County	Total RCV	NJGWS-Defined Landslide Susceptible Areas						Landslide Susceptible Areas (Godt 2001)				Sinkhole/Subsidence Hazard Areas	
		Class A	% Total	Class B	% Total	Class C	% Total	High Susceptibility / Moderate Incidence	% Total	Moderate Susceptibility/ Low Incidence	% Total	Carbonate Rock Formation	% Total
Atlantic	$38,043,171,000	-	-	-	-	-	-	$0	0.0%	$0	0.0%	$0	0.0%
Bergen	$154,077,482,000	$235,743,000	0.2%	$730,653,000	0.5%	$0	0.00%	$0	0.0%	$0	0.0%	$0	0.0%
Burlington	$62,700,794,000	-	-	-	-	-	-	$0	0.0%	$14,027,309,000	22.4%	$1,347,735,000	2.1%
Camden	$70,467,051,000	-	-	-	-	-	-	$0	0.0%	$17,081,933,000	24.2%	$260,765,000	0.4%
Cape May	$24,665,528,000	-	-	-	-	-	-	$0	0.0%	$0	0.0%	$0	0.0%
Cumberland	$18,128,613,000	-	-	-	-	-	-	$0	0.0%	$0	0.0%	$0	0.0%
Essex	$113,124,687,000	$149,712,000	0.1%	$460,823,000	0.4%	$0	0.00%	$0	0.0%	$0	0.0%	$0	0.0%
Gloucester	$33,534,660,000	-	-	-	-	-	-	$0	0.0%	$2,415,295,000	7.2%	$15,703,000	0.0%
Hudson	$82,290,184,000	$878,094,000	1.1%	$134,022,000	0.2%	$0	0.00%	$0	0.0%	$0	0.0%	$0	0.0%
Hunterdon	$21,720,513,000	-	-	-	-	-	-	$0	0.0%	$0	0.0%	$1,918,926,000	8.8%
Mercer	$56,194,660,000	-	-	-	-	-	-	$0	0.0%	$8,473,419,000	15.1%	$0	0.0%
Middlesex	$119,947,782,000	$0	0.0%	$122,818,000	0.1%	$302,629,000	0.25%	$0	0.0%	$1,353,874,000	1.1%	$0	0.0%
Monmouth	$96,235,266,000	$0	0.0%	$421,809,000	0.4%	$262,500,000	0.27%	$0	0.0%	$0	0.0%	$10,033,287,000	10.4%
Morris	$86,634,810,000	$214,777,000	0.2%	$969,937,000	1.1%	$0	0.00%	$0	0.0%	$0	0.0%	$3,059,145,000	3.5%
Ocean	$73,559,915,000	-	-	-	-	-	-	$0	0.0%	$0	0.0%	$358,892,000	0.5%
Passaic	$66,705,864,000	$318,508,000	0.5%	$35,670,000	0.1%	$0	0.00%	$0	0.0%	$0	0.0%	$106,138,000	0.2%
Salem	$8,092,037,000	-	-	-	-	-	-	$0	0.0%	$1,914,651,000	23.7%	$870,327,000	10.8%
Somerset	$52,513,253,000	$132,408,000	0.3%	$534,379,000	1.0%	$268,150,000	0.51%	$0	0.0%	$0	0.0%	$207,066,000	0.4%
Sussex	$20,979,595,000	-	-	-	-	-	-	$638,596,000	3.0%	$0	0.0%	$5,647,131,000	26.9%
Union	$79,329,736,000	$5,451,000	0.0%	$61,804,000	0.1%	$0	0.00%	$0	0.0%	$0	0.0%	$0	0.0%
Warren	$14,442,755,000	-	-	-	-	-	-	$0	0.0%	$0	0.0%	$10,017,144,000	69.4%

Table 5.7-10. Estimated Building Replacement Cost Vulnerable to the Landslide and Subsidence/Sinkhole Hazards

		NJGWS-Defined Landslide Susceptible Areas						Landslide Susceptible Areas (Godt 2001)				Sinkhole/Subsidence Hazard Areas	
County	Total RCV	Class A	% Total	Class B	% Total	Class C	% Total	High Susceptibility / Moderate Incidence	% Total	Moderate Susceptibility/ Low Incidence	% Total	Carbonate Rock Formation	% Total
Total	$1,293,388,356,000	$1,934,693,000	0.1%	$3,471,915,000	0.3%	$833,279,000	0.06%	$638,596,000	0.0%	$45,266,481,000	3.5%	$33,842,259,000	2.6%

Source: HAZUS-MH 2.1; NJGWS 2005; Godt 2001
Notes:

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

The total building replacement cost values (RCV) are for all occupancy types (residential, commercial, industrial, religious, government, and education) and represent both structure and contents.

% percent
NJGWS New Jersey Geological Water Survey
RCV Replacement cost value
- No data available to conduct the analysis. NJGWS data was only available for nine counties in New Jersey (Bergen, Essex, Hudson, Middlesex, Monmouth, Morris, Passaic, Somerset, and Union).

As discussed in earlier in this section, based on an assessment of the New Jersey-specific data, the areas of landslide susceptibility are hilly or mountainous areas with steep slopes and erodible soils. Gradually more and more individual municipalities have implemented steep slope ordinances which prohibit development in these areas. Therefore, the potential to develop these vulnerable areas is decreasing. However, existing building infrastructure in these areas remain potentially vulnerable.

As noted in the Previous Occurrences and Losses section, there is a history of subsidence/sinkholes causing losses to building infrastructure. Compounding the vulnerability of building infrastructure to subsidence/ sinkholes is the vast array of abandoned mines and the geological makeup of much of northern New Jersey, coupled with recent growth in the region.

Estimating Potential Losses to State Facilities

An exposure analysis methodology was used to grossly estimate potential losses to state facilities. Table 5.7-11 below identifies a potential total risk exposure of $560 million for state buildings vulnerable to the geologic hazards. The limitations of this methodology are recognized because the figures assume 100% loss to each structure and its contents. This potential loss estimate is considered high given it is not likely a landslide or sinkhole/subsidence event would occur across the entire State's hazard area at the same time from one event. As more current replacement cost data becomes available at the structure level, and standardized methodologies for the landslide/subsidence/sinkhole hazards become available to estimate potential losses, this section of the plan will be updated with new information and the potential loss estimates will be further refined.

The vulnerability of each individual state building and critical facility will differ based on the topography and underlying geology. Tables 5.7-11 and 5.7-12 below summarize the potential loss by county and state agency. The replacement cost values for critical facilities were not available for this planning effort. Refer to the discussion in 'Assessing Vulnerability to State Facilities' presented earlier which summarizes the critical facility exposure analysis results.

Environmental Impacts

A landslide or sinkhole/subsidence event will alter the landscape. In addition to changes in topography, vegetation and wildlife habitats may be damaged or destroyed, and soil and sediment runoff will accumulate downslope potentially blocking waterways and roadways and impacting quality of streams and other water bodies. Additional environmental impacts include loss of agricultural and forest productivity. Refer to Section 5.15 (Crop Failure) for the environmental impacts regarding agricultural losses.

Table 5.7-11. Estimated Potential Loss of State-Owned and -Leased Buildings in the Geologic Hazard Areas by County

County	Total Number of Buildings	NJGWS-Defined Landslide Susceptible Areas (Classes A through C)			Landslide Susceptible Areas (High and Moderate Susceptibility) (Godt 2001)			Sinkhole/Subsidence Hazard Areas		
		Owned	Leased	Total	Owned	Leased	Total	Owned	Leased	Total
Atlantic	87	-	-	-	$0	$0	$0	$0	$0	$0
Bergen	46	$0	$0	$0	$0	$0	$0	$0	$0	$0
Burlington	345	-	-	-	$126,381,707	$6,346,326	$132,728,033	$3,891,872	$0	$3,891,872
Camden	70	-	-	-	$38,723,993	$24,970,421	$63,694,414	$0	$0	$0
Cape May	114	-	-	-	$0	$0	$0	$0	$0	$0
Cumberland	367	-	-	-	$0	$0	$0	$0	$0	$0
Essex	74	$0	$0	$0	$0	$0	$0	$0	$0	$0
Gloucester	46	-	-	-	$1,648,857	$0	$1,648,857	$0	$0	$0
Hudson	22	$0	$0	$0	$0	$0	$0	$0	$0	$0
Hunterdon	333	-	-	-	$0	$0	$0	$234,234,781	$0	$234,234,781
Mercer	390	-	-	-	$8,395,839	$0	$8,395,839	$0	$0	$0
Middlesex	264	$0	$0	$0	$0	$0	$0	$0	$0	$0
Monmouth	163	$172,834	$0	$172,834	$0	$0	$0	$12,898,708	$0	$12,898,708
Morris	103	$0	$0	$0	$0	$0	$0	$3,000,257	$0	$3,000,257
Ocean	103	-	-	-	$0	$0	$0	$0	$0	$0
Passaic	71	$0	$0	$0	$0	$0	$0	$0	$0	$0
Salem	56	-	-	-	$5,450,792	$0	$5,450,792	$0	$23,366,937	$23,366,937
Somerset	38	$0	$0	$0	$0	$0	$0	$0	$0	$0
Sussex	63	-	-	-	$1,775,545	$0	$1,775,545	$18,467,936	$2,153,428	$20,621,363
Union	35	$0	$0	$0	$0	$0	$0	$0	$0	$0
Warren	120	-	-	-	$0	$0	$0	$29,425,578	$19,510,379	$48,935,957
Total	**2,910**	**$172,834**	**$0**	**$172,834**	**$182,376,734**	**$31,316,747**	**$213,693,481**	**$301,919,132**	**$45,030,744**	**$346,949,876**

Source: NJOMB 2013; NJGWS, 2005; Godt 2001; Note: NJGWS New Jersey Geological Water Survey; - = No data available to conduct the analysis. NJGWS data was only available for nine counties in New Jersey (Bergen, Essex, Hudson, Middlesex, Monmouth, Morris, Passaic, Somerset, and Union).

Table 5.7-12. Estimated Potential Loss of State-Owned and -Leased Buildings in the Geologic Hazard Areas by Agency

Agency	Total RCV	NJGWS-Defined Landslide Susceptible Areas (Classes A through C)			Landslide Susceptible Areas (High and Moderate Susceptibility) (Godt 2001)			Sinkhole/Subsidence Hazard Areas		
		Owned	Leased	Total	Owned	Leased	Total	Owned	Leased	Total
Agriculture	$2,876,615	$0	$0	$0	$0	$0	$0	$0	$0	$0
Banking and Insurance	$83,777,640	$0	$0	$0	$0	$0	$0	$0	$0	$0
Chief Executive	$12,653,376	$0	$0	$0	$0	$0	$0	$0	$0	$0
Children and Families	$855,320,877	$0	$0	$0	$0	$3,955,681	$3,955,681	$0	$29,456,940	$29,456,940
Community Affairs	$142,133,954	$0	$0	$0	$0	$0	$0	$0	$0	$0
Corrections	$1,705,111,918	$0	$0	$0	$0	$0	$0	$99,755,758	$0	$99,755,758
Education	$313,825,668	$0	$0	$0	$8,379,732	$0	$8,379,732	$0	$0	
Environmental Protection	$466,946,331	$0	$0	$0	$1,904,065	$1,715,366	$3,619,431	$27,849,192	$0	$27,849,192
Health	$146,433,703	$0	$0	$0	$0	$0	$0	$0	$0	$0
Human Services	$1,689,928,602	$0	$0	$0	$0	$0	$0	$126,562,056	$0	$126,562,056
Judiciary	$114,021,053	$0	$0	$0	$0	$0	$0	$0	$0	$0
Juvenile Justice Commission	$258,880,851	$0	$0	$0	$106,000,156	$0	$106,000,156	$0	$0	$0
Labor and Work Force Dev.	$242,663,875	$0	$0	$0	$0	$0	$0	$0	$0	$0
Law And Public Safety	$498,665,653	$0	$0	$0	$0	$0	$0	$0	$0	$0
Legislature	$165,085,389	$0	$0	$0	$0	$0	$0	$0	$0	$0
Military And Veterans Affairs	$954,650,961	$0	$0	$0	$15,554,873	$0	$15,554,873	$17,310,681	$0	$17,310,681
Miscellaneous Commissions	$15,650,656	$0	$0	$0	$0	$15,650,656	$15,650,656	$0	$0	$0
Motor Vehicles Commission	$928,029,459	$0	$0	$0	$2,100,325	$9,319,764	$11,420,090	$12,898,708	$15,573,804	$28,472,512
Personnel	$8,513,417	$0	$0	$0	$0	$0	$0	$0	$0	$0
State	$208,816,705	$0	$0	$0	$39,359,349	$0	$39,359,349	$0	$0	$0
State Police	$473,621,856	$0	$0	$0		$675,279	$675,279	$1,897,935	$0	$1,897,935

Table 5.7-12. Estimated Potential Loss of State-Owned and -Leased Buildings in the Geologic Hazard Areas by Agency

Agency	Total RCV	NJGWS-Defined Landslide Susceptible Areas (Classes A through C)			Landslide Susceptible Areas (High and Moderate Susceptibility) (Godt 2001)			Sinkhole/Subsidence Hazard Areas		
		Owned	Leased	Total	Owned	Leased	Total	Owned	Leased	Total
Transportation	$512,199,066	$172,834	$0	$172,834	$9,078,234		$9,078,234	$15,644,804	$0	$15,644,804
Treasury	$400,714,935	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total	**$10,200,522,559**	**$172,834**	**$0**	**$172,834**	**$182,376,734**	**$31,316,747**	**$213,693,481**	**$301,919,132**	**$45,030,744**	**$346,949,876**

Source: NJOMB 2013; NJGWS 2005; Godt 2001

Note: NJGWS New Jersey Geological Water Survey

RCV Replacement cost value