5.7 GEOLOGICAL HAZARDS

SECTION 5.7 GEOLOGICAL HAZARDS

5.7.1 HAZARD DESCRIPTION

Geological Hazards can be classified into to geological events: Landslides and Land subsidence.

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.

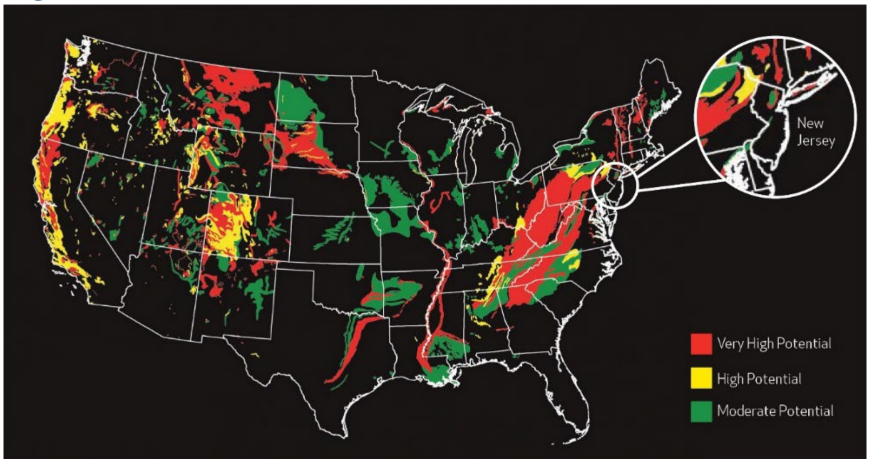
Both natural and man-made sinkholes can occur without warning. Slumping or falling fence posts, trees, or foundations, sudden formation of small ponds, wilting vegetation, discolored well water, and/or structural cracks in walls and floors, are all specific signs that a sinkhole is forming. Sinkholes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

5.7.2 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

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

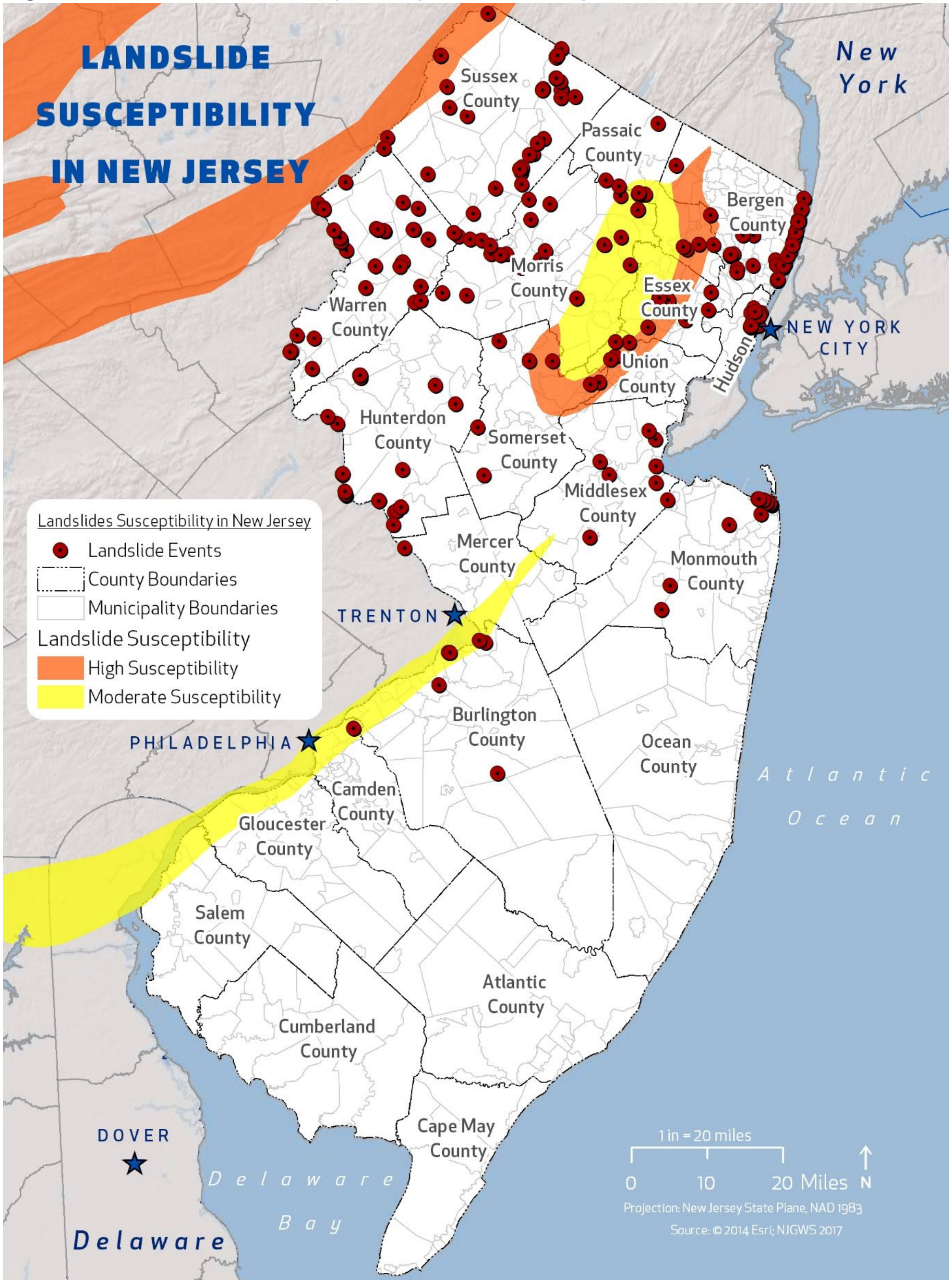
The New Jersey Geologic Survey (currently known as the New Jersey Geological and Water Survey) determined landslide susceptibility for nine counties in New Jersey (Bergen, Essex, Hudson, Middlesex, Monmouth, Morris, Passaic, Somerset, and Union). Areas within these counties are classified into Class 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.

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 (USGS). 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) data 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 M for each county's map.

Figure 5.7-3 Landslide Susceptibility in New Jersey



Source: USGS 2001; NJGWS 2017

Figure 5.7-4 Atlantic Highlands Slump Zone

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.

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

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.

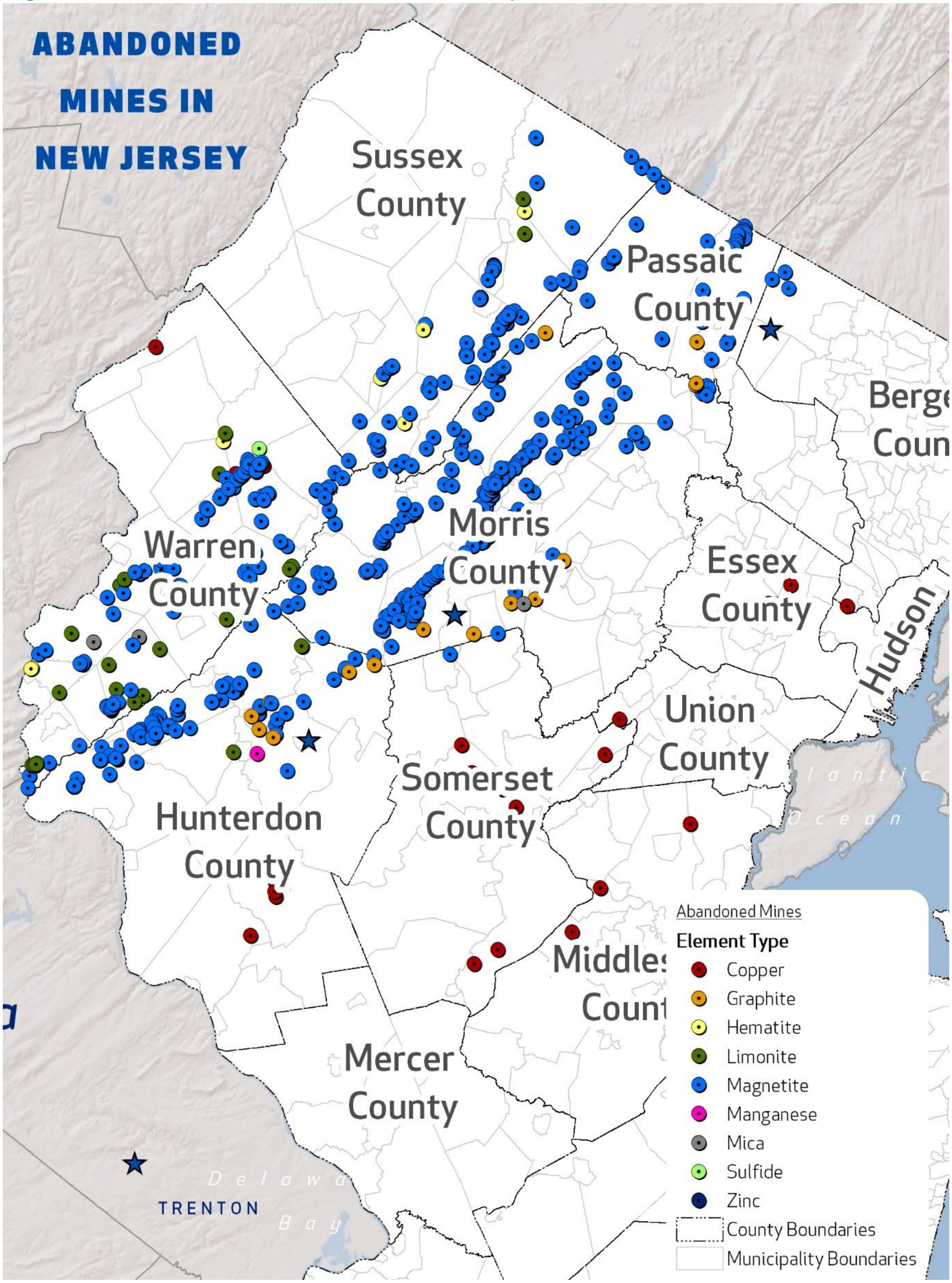
Subsidence/Sinkholes

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 5.7-7 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 M – Geologic Hazard Maps and Tables.

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.

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 5.7-6 Abandoned Mines in New Jersey

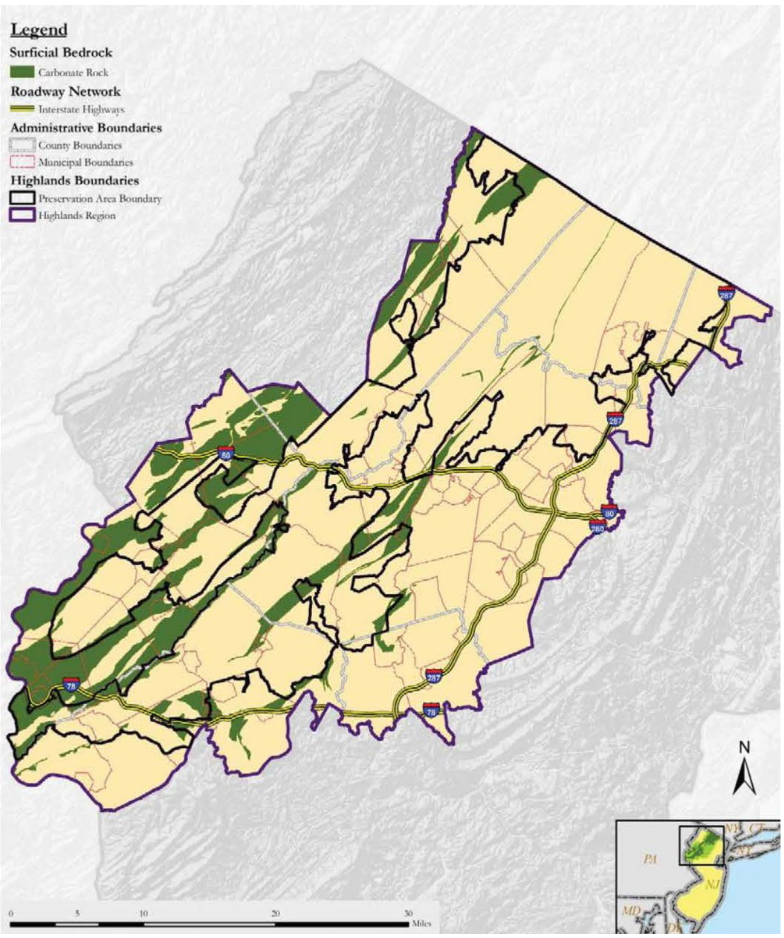


Source: NJGWS 2006

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).

Substantial areas of the New Jersey Highlands are underlain by carbonate rocks. 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 5.7-7 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 storm water 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 storm water 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.

5.7.3 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 caused by two watermain breaks.

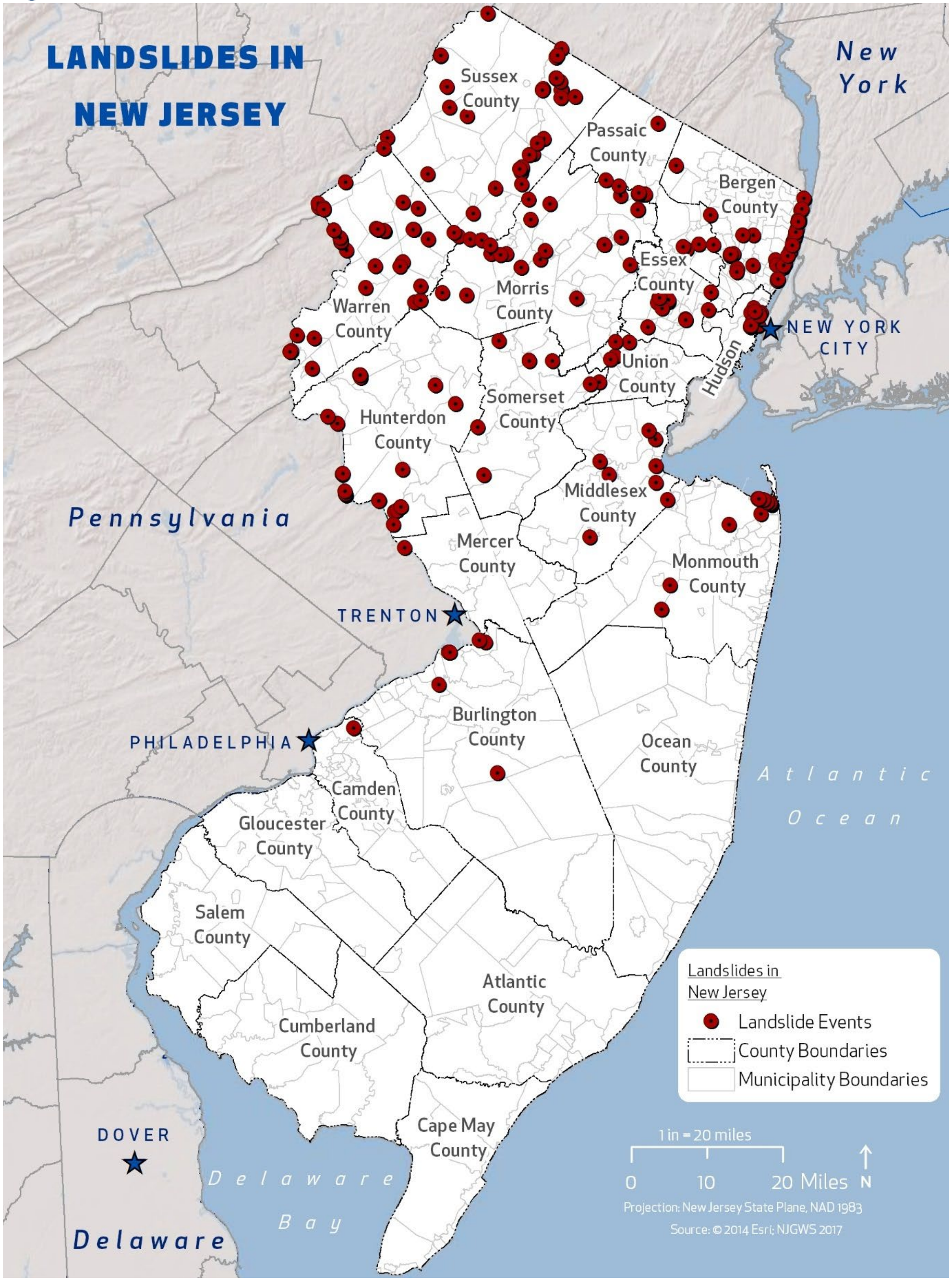
5.7.4 PREVIOUS OCCURRENCES AND LOSSES

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. Figure 5.7-8 illustrates the location of landslide events in New Jersey and Table 5.7-1 lists details of these historic landslides.

Figure 5.7-8 Historic Landslide Events



Source: NJGWS, 2017

Table 5.7-1 Past Occurrences of Landslides in New Jersey (1896 to 2017) By County

DATE	TYPE	COUNTY	TRIGGER	DAMAGE	COMMENTS
4/18/1896	Rockfall	Bergen	Weathering	No	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.
5/4/1893	Debris flow	Burlington	Heavy rain	Yes	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.
7/23/1887	Debris flow	Warren	Heavy rain/poor drainage	Yes	Two people killed, and railroad tracks damaged by a debris flow after heavy rains near Manunka Chunk Mountain, estimated location.
10/8/1903	Debris flow	Hudson	Heavy rain	No	Report of a landslide after heavy rain in Weehawken at the Weehawken tunnel, the railroad was closed. Estimated location.
10/8/1903	Debris flow	Monmouth	Heavy rain	Yes	Report of a big landslide at Waterwitch, just below the long pier, shut down the Central Railroad of NJ. Estimated location
10/8/1903	Debris flow	Morris	Heavy rain	No	Report of a big landslide near Stanhope, rock and sand slid onto railroad tracks. Estimated location.
11/16/1904	Slump	Monmouth	Atlantic Ocean wave action	Unknown	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.
5/25/1905	Debris flow	Monmouth	Heavy rain	No	Small landslide in 1972.
6/6/1905	Debris flow	Middlesex	Heavy rain	No	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.
6/15/1905	Rockfall	Hudson	Weathering	Yes	Large falling rock in 1993 demolished a car, numerous other past rockfalls in the same area.
7/6/1905	Rockfall	Sussex	Weathering	No	Small rockfall along old Susquehanna and Western railway bed which is now a hiking trail. Discovered in 2014, could have happened earlier.
7/6/1905	Rockfall	Morris	Weathering	No	Small rockfall adjacent to Timber Ridge Road.
7/6/1905	Rockfall	Warren	Weathering	No	Small rockfall along Rt. 80.
4/13/1915	Rockslide	Warren	Quarrying	No	A quarry worker at the Vulcanite Cement Works was killed by a slide of rock. Estimated location.

DATE	TYPE	COUNTY	TRIGGER	DAMAGE	COMMENTS
11/7/1915	Rockslide	Passaic	Vibration from railroad	Yes	Rockslide down Garret Mountain destroyed 200 feet of the D, L & W railroad tracks. Estimated location.
6/16/1925	Debris flow	Warren	Heavy rain	Yes	Passenger train derailed after hitting landslide material on railroad tracks caused by heavy rain. The train exploded causing multiple death and injuries.
7/5/1928	Rockslide	Bergen	Heavy rain	Yes	Report of a large rockslide: 100 feet of Henry Hudson Drive destroyed, $15,000 in damage in 1928. Estimated location.
7/11/1929	Rockslide	Warren	Quarrying	No	A rockslide killed one worker and injured five others at the Edison Portland cement quarry. Estimated location.
5/17/1935	Rockslide	Bergen	Weathering	Yes	A 50-ton rock fell from the Palisades onto Rt. 5. The road was closed for five hours.
12/10/1935	Rockslide	Hudson	Heavy rain/weathering	Yes	Rockslide from a promontory on the Palisades crashed into the L.O. Koven Fabricating Company in Hoboken. Many other rockslides in prior years.
3/11/1936	Debris flow	Passaic	Heavy rain	Yes	CCC camp cut off as a result of Rt. 23 landslide due to heavy rain, estimated location.
5/11/1936	Slump	Middlesex	Clay digging	Yes	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.
7/14/1936	Rockslide	Bergen	Heavy rain	No	A small rock slide occurred in the Palisades Interstate Park near the Yonkers-Alpine Ferry. Triggered by heavy rain from thunderstorms. Estimated location.
11/23/1936	Rockslide	Hudson	Construction	Yes	A large rock pile near the Lincoln Tunnel during its construction slide onto Boulevard East destroying a truck. Estimated location.
1/10/1937	Rockslide	Bergen	Weathering	No	A rockslide on the Alpine Approach Road closed traffic for one hour. Estimated location.
7/23/1938	Rockslide	Bergen	Heavy rain	No	Large rockslide north of Twombley's Landing. Estimated location.
7/23/1938	Debris flow	Bergen	Heavy rain	No	Report of Rt. 6 (now Rt. 46) closed for several hours by landslides after heavy rain. Estimated location.
7/23/1938	Debris flow	Bergen	Heavy rain	No	Report of a landslide, road restricted to one lane by a landslide of mud and stone. Estimated location.
7/23/1938	Rockslide	Bergen	Heavy rain	No	A rockslide on the Palisades creates the likeness of Hitler on the cliffs. Estimated location.
9/21/1938	Rockslide	Bergen	Heavy rain	Yes	Landslides caused by the rain from The Great Hurricane of 1938 closed Henry

DATE	TYPE	COUNTY	TRIGGER	DAMAGE	COMMENTS
					Hudson Drive between Alpine and the boat basin. Estimated location.
4/1/1939	Rockslide	Bergen	Heavy rain	No	Heavy rain caused a rockslide on Henry Hudson Drive covering 20 feet of the road. Estimated location.
3/5/1941	Rockslide	Hudson	Weathering	Yes	A boulder and rocks fell from the hillside blocking traffic on Holland Street for eight hours. Another rockslide in 1916 nearby. Estimated location.
7/10/1945	Debris flow	Warren	Heavy rain/poor drainage	Yes	Four people died when their apartment was destroyed by a debris flow after a retaining wall collapsed during heavy rain. Estimated location.
3/15/1947	Rockslide	Bergen	Weathering	No	Rockslide destroyed the likeness of Hitler on the Palisades. Estimated location.
11/12/1948	Rockslide	Mercer	Quarrying	No	A rockslide at the Lambertville Quarry killed two workers who were drilling holes in a cliff to insert dynamite when rockslide occurred. Estimated location.
8/6/1952	Rockslide	Bergen	Heavy rain	Yes	Heavy rains caused a rockslide on the Alpine Approach Road blocking the road for 28 hours. Estimated location.
12/13/1952	Rockslide	Sussex	Weathering	No	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	Heavy rain	Yes	Rt. 23 closed at Beaver Lake as a result of landslide due to heavy rain from Hurricane Diane. Estimated location.
8/19/1955	Debris flow	Warren	Heavy rain	Yes	Heavy rain from Hurricane Diane triggered a debris flow on Rt. 46 just west of Great Meadows closing Rt. 46.
6/18/1956	Rockslide	Morris	Quarrying	Yes	Three quarry workers, were buried and died in a quarry rockslide of many tons of rocks. Estimated location.
4/8/1957	Rockslide	Bergen	Heavy rain/weathering	Yes	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	Weathering	Yes	Large rockslide slid off the Palisades triggered by freezing and thawing, road closed. Estimated location.
3/6/1959	Rockfall	Bergen	Heavy rain	Yes	A rockfall blocked the Alpine Approach Road, heavy rains combined with early thawing caused the rockfall. Estimated location.
3/6/1959	Rockfall	Bergen	Heavy rain	Yes	A rockfall on Henry Hudson Drive just north of George Washington Bridge, traffic blocked, heavy rains and early thawing triggered rockfall. Estimated location.

DATE	TYPE	COUNTY	TRIGGER	DAMAGE	COMMENTS
8/6/1961	Rockslide	Bergen	Weathering	Yes	Rockslide caused thousands of dollars in damage, 100 feet of road destroyed, rocks stopped 100 feet short of 50 people at the water's edge. Estimated location.
11/10/1963	Rockslide	Passaic	Mining	No	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.
8/14/1967	Rockfall	Warren	Heavy rain	Unknown	A rockslide after heavy rain blocked part of Rt. 46 near the Delaware River. Estimated location.
8/28/1971	Debris flow	Passaic	Heavy rain	Yes	Debris flow triggered by heavy rains from Hurricane Doria, a large section of the Morris Canal slid onto Vetrone Drive causing substantial property damage.
9/12/1971	Debris flow	Bergen	Heavy rain	No	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	Heavy rain	No	A landslide on Rt. 4 blocked a westbound lane from the George Washington Bridge, estimated location.
9/3/1974	Debris flow	Hudson	Heavy rain	No	Report of landslides which delayed traffic at Grand Avenue and Union Turnpike. Estimated location.
9/26/1975	Debris flow	Passaic	Heavy rain	No	Four days of heavy rain triggered a debris flow on Rt. 80 at the ramp to Rt. 20 in Paterson. Estimated location.
12/31/1977	Rockslide	Hudson	Weathering	Yes	A rockslide in an area prone to rockslides from freeze and thaw weathering. $2,000 to clean up the rocks.
9/21/1989	Debris flow	Morris	Heavy rain	Yes	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	Heavy rain	Yes	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	Heavy rain	No	A report that Rt. 202 was closed temporarily because of a debris flow from Rt. 287 construction site after heavy rain. Estimated location.
8/17/1991	Debris flow	Union	Heavy rain	No	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.
11/9/1994	Rockslide	Somerset	Quarrying	No	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.

DATE	TYPE	COUNTY	TRIGGER	DAMAGE	COMMENTS
1/17/1995	Rockfall	Essex	Weathering	Unknown	Large rockfall, one lane closed for two days for rock removal.
7/2/1995	Debris flow	Morris	Weathering	Yes	Heavy rains caused a debris flow onto a back porch of a house, driveway and onto Forestdale Road.
10/21/1995	Debris flow	Warren	Heavy rain	No	Landslide after heavy rain, it was 600 feet long. Evidence of past landslides. Estimated location.
1/18/1996	Slump	Middlesex	Construction	Yes	A 40-foot high slope slid during road construction, undermining Old Bridge Turnpike, between Tices Lane and Edgeboro Road. The road was closed.
1/18/1996	Debris flow	Sussex	Heavy rain/snowmelt	No	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	Heavy rain/snowmelt	Yes	Two landslides after heavy rain and melting snow, house destroyed.
10/19/1996	Debris flow	Morris	Heavy rain	Unknown	In the Poets Peak development, a debris flow deposited considerable silt into the Ledgewood Brook after heavy rain. Estimated location.
3/18/1998	Rockslide	Bergen	Weathering	Yes	Rockslide on Rt. 95 Southbound local lanes, damage to one car from
6/13/1998	Debris flow	Essex	Heavy rain	Yes	Report of a minor debris flow of mud down a hill into a house after heavy rain. Estimated location.
1/3/1999	Debris flow	Monmouth	Heavy rain	Yes	Landslide, possibly due to fill material failure after heavy rain, one condominium unit destroyed, three others damaged.
9/5/1999	Debris flow	Monmouth	Fossil digging	No	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.
9/8/1999	Debris flow	Hunterdon	Heavy rain	No	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.
8/12/2000	Debris flow	Morris	Heavy rain	Yes	Landslide after heavy rain, sections of Rt.15 south collapsed. Estimated location.
8/12/2000	Debris flow	Sussex	Heavy rain	Yes	Massive landslide after heavy rain, property damage, railroad and Glen Road temporarily closed.
8/16/2000	Debris flow	Sussex	Heavy rain	Yes	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.

DATE	TYPE	COUNTY	TRIGGER	DAMAGE	COMMENTS
8/27/2000	Debris flow	Somerset	Heavy rain	No	Construction site related landslide during heavy rains on Rt. 22. Estimated location.
4/9/2001	Mudslide	Sussex	Heavy rain	N/A	Heavy rain caused a mudslide in Sparta; Main Street was closed for two hours. The mudslide spread across Spring Brook Trail.
8/5/2003	Debris flow	Bergen	Heavy rain	Unknown	Reported debris flow down the mountain triggered by heavy rain covered a 100-foot section of River Road.
11/20/2003	Debris flow	Warren	Heavy rain	Yes	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.
7/23/2004	Rockfall	Bergen	Heavy rain	Unknown	Rockslide after heavy rain.
2/5/2005	Rockfall	Morris	Weathering	Yes	A block of rock weighing an estimated 35 tons fell on Timber Ridge Road damaging a catch basin.
3/29/2005	Rockslide	Bergen	Weathering	No	Rockslide on Rt. 95 Southbound local lanes, right lane was closed for 65 minutes to remove debris. Estimated location.
4/3/2005	Debris flow	Hunterdon	Heavy rain	Yes	Two landslides after heavy rain, 40-feet by 30-feet along County Rt. 619, some utility and property damage.
4/3/2005	Debris flow	Morris	Heavy rain	Yes	Large debris flow occurred along Berkshire Valley Road (Morris County Rt. 699) across from Longwood Lake during heavy rains.
4/3/2005	Debris flow	Sussex	Heavy rain	No	Small debris flow along Macpeek Road after heavy rain.
7/17/2005	Debris flow	Middlesex	Heavy rain	Yes	Significant property damage from landslide, a swimming pool was filled in with mud.
10/8/2005	Debris flow	Bergen	Heavy rain	Yes	Landslide caused some property damage to a two-family house on Farnham Avenue.
10/8/2005	Slump	Monmouth	Heavy rain	Yes	Small backyard slump caused by water saturation after heavy rain, some property damage. Estimated location.
10/8/2005	Debris flow	Monmouth	Heavy rain	Yes	Landslide partially blocked road after heavy rain during road construction.
12/17/2005	Rockslide	Bergen	Weathering	Yes	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.
6/29/2006	Debris flow	Sussex	Heavy rain	Yes	Heavy rains caused a retaining wall to collapse triggering a debris flow, damaging a deck.
7/22/2006	Debris flow	Bergen	Heavy rain/broken sewer pipe	Yes	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	Heavy rain	Yes	Heavy rain triggered a debris flow on Rt. 208 Southbound near Lincoln Avenue which

DATE	TYPE	COUNTY	TRIGGER	DAMAGE	COMMENTS
					caused a multiple vehicle accident on the highway, road temporarily closed.
4/15/2007	Debris flow	Bergen	Heavy rain	No	A small debris flow at the bottom of Passaic Avenue and Burr Place was triggered by heavy rain.
4/15/2007	Debris flow	Bergen	Heavy rain	Yes	Landslide after heavy rain on Farnham Avenue. Some property damage, backyard covered in mud, 50 families displaced.
4/15/2007	Debris flow	Bergen	Heavy rain	Yes	Landslide after heavy rain on Farnham Avenue. Some property damage, backyard covered in mud, 50 families displaced.
4/15/2007	Debris flow	Bergen	Heavy rain	Yes	Landslide after heavy rain on Farnham Avenue. Some property damage, backyard covered in mud, 50 families displaced.
4/15/2007	Debris flow	Bergen	Heavy rain	Yes	Landslide onto two family homes 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	Heavy rain	Yes	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	Heavy rain	Yes	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	Heavy rain	Yes	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	Heavy rain	Yes	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	Heavy rain	Yes	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	Heavy rain	Yes	Heavy rain caused a landslide 150-feet wide near Ross Dock causing damage to retaining walls. Henry Hudson Drive closed for one month.
4/15/2007	Debris flow	Hudson	Heavy rain	No	Heavy rain triggered a small rockfall on Sinatra Drive which was closed temporarily.
4/15/2007	Debris flow	Hudson	Heavy rain	Yes	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.
4/15/2007	Slump	Monmouth	Heavy rain	Yes	Landslide on the bluff between Linden Avenue and Shore Drive, west of Waterwitch Drive in the Atlantic Highlands.

DATE	TYPE	COUNTY	TRIGGER	DAMAG E	COMMENTS
4/15/2007	Debris flow	Passaic	Heavy rain/broken sewer pipe	Yes	Debris flow after heavy rain on Riverview Drive along the Passaic River, road closed for repairs.
4/15/2007	Slump	Somerset	Heavy rain	No	Slump during heavy rain along the shoulder of the Southbound lanes of Rt. 287 during heavy rain.
4/15/2007	Rockfall	Warren	Heavy rain	Yes	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.
4/16/2007	Debris flow	Hudson	Heavy rain	Yes	Retaining wall collapse during heavy rain deposited rock and debris in the Doric Apartments parking lot, $225,000 in damages. Estimated location.
5/8/2008	Debris flow	Camden	Heavy rain	No	Debris Flow on U.S. 130 Southbound, right lane closed temporarily. Estimated location.
6/22/2008	Debris flow	Essex	Heavy rain	Yes	A contractor was buried to the waist and trapped for three hours
1/5/2009	Debris flow	Bergen	Heavy rain/snowmelt	Yes	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	Heavy rain	Yes	Landslide after heavy rain during Hurricane Floyd, three houses
9/16/2009	Debris flow	Hunterdon	Heavy rain	No	County Rt. 523 closed due to debris flow south of Dreahook Road. Estimated location.
3/13/2010	Debris flow	Sussex	Heavy rain	Yes	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	Heavy rain	Yes	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.
4/1/2010	Debris flow	Monmouth	Heavy rain	Yes	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.
5/5/2010	Rockfall	Bergen	Weathering	Yes	Rockslide closed Rt. 5 for two days at the Undercliff Avenue section. About 20 yards of rocks and some trees fell onto the road.
3/30/2011	Rockslide	Morris	Weathering	Yes	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.

DATE	TYPE	COUNTY	TRIGGER	DAMAGE	COMMENTS
4/17/2011	Debris flow	Hudson	Heavy rain	Yes	Backyard destroyed by debris flow after retaining wall collapses during heavy rain at 340 Ogden Avenue. Debris fell onto hill overlooking Paterson Plank Road.
8/15/2011	Debris flow	Sussex	Heavy rain	Yes	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	Bergen	Heavy rain	Yes	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	Heavy rain	Yes	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	Heavy rain	Yes	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	Hunterdon	Heavy rain	No	Small mudslide on steep embankment along Rt. 523.
8/28/2011	Debris flow	Hunterdon	Heavy rain	No	Small mudslide on steep embankment along Rt. 523.
8/28/2011	Debris flow	Hunterdon	Heavy rain	No	Small mudslide on steep embankment along Rt. 523.
8/28/2011	Debris flow	Hunterdon	Heavy rain	No	Small mudslide on steep embankment along Rt. 523.
8/28/2011	Debris flow	Hunterdon	Heavy rain	No	Small mudslide on steep embankment along Rt. 523.
8/28/2011	Debris flow	Monmouth	Heavy rain	Yes	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	Heavy rain	Yes	Large landslide above condo complex triggered by heavy rain from Tropical Storm Irene damages condo complex. Some damage to condominium.
8/28/2011	Debris flow	Morris	Heavy rain	No	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	Heavy rain	Yes	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	Heavy rain	No	Small debris flow on hillside along Segur Street in Dover due to Tropical Storm Irene.
8/28/2011	Debris flow	Morris	Heavy rain	Yes	Debris flow along Reservoir Avenue near reservoir outlet area due to Tropical Storm Irene.

DATE	TYPE	COUNTY	TRIGGER	DAMAGE	COMMENTS
8/28/2011	Slump	Morris	Heavy rain	Yes	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	Heavy rain	Yes	Small debris flow along Rt. 206 NB on steep slope.
8/28/2011	Debris flow	Somerset	Heavy rain	No	Debris flow on slope along Rt. 287 Southbound.
8/28/2011	Debris flow	Sussex	Heavy rain	No	Small debris flow along County Rt. 565 (Glenwood Road) near Lake Pochung Road. Triggered by Tropical Storm Irene.
8/28/2011	Debris flow	Sussex	Heavy rain	No	Debris flow near state line along Lake Wallkill Road. Triggered by
8/28/2011	Debris flow	Sussex	Heavy rain	No	Debris flow along Lake Wallkill Road triggered by Tropical Storm Irene.
8/28/2011	Debris flow	Sussex	Heavy rain	No	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	Heavy rain	No	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	Heavy rain	No	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	Heavy rain	No	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	Heavy rain	No	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	Heavy rain	Yes	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	Heavy rain	Yes	Large mudslide on Holland Circle due to Tropical Storm Irene. Temporary road closure and evacuations.
8/28/2011	Debris flow	Sussex	Heavy rain	Yes	Small mudslide on Holland Circle due to Tropical Storm Irene. Temporary road closure and evacuations.
8/28/2011	Debris flow	Sussex	Heavy rain	Yes	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	Heavy rain	Yes	A small debris flow triggered by Tropical Storm Irene.

DATE	TYPE	COUNTY	TRIGGER	DAMAGE	COMMENTS
8/28/2011	Debris flow	Sussex	Heavy rain	Yes	Moderate size debris flow on steep slope along Rt. 517 triggered by Tropical Storm Irene.
8/28/2011	Debris flow	Sussex	Heavy rain	No	Debris flow along Macpeek Road in Vernon. Temporary road closure.
8/28/2011	Debris flow	Sussex	Heavy rain	No	Debris flow along Drew Mountain. Road on steep slope triggered by Tropical Storm Irene.
8/28/2011	Debris flow	Sussex	Heavy rain	No	Debris flow along Owassa Road.
8/28/2011	Slump	Sussex	Heavy rain	No	Large slump on steep hill above Culvers Creek.
8/28/2011	Debris flow	Union	Heavy rain	Yes	NJ Transit rail road tracks in Summit south of Edgewood Road covered by a debris flow during Tropical Storm Irene. Temporary closure of tracks.
8/28/2011	Debris flow	Warren	Heavy rain	No	Debris flow on Rt. 519 due to Hurricane Irene.
8/28/2011	Debris flow	Warren	Heavy rain	Yes	Debris flow due to heavy rain from Tropical Storm Irene onto Alphano Road in area of construction near Panther Valley development. Temporary road closure.
8/29/2011	Debris flow	Morris	Heavy rain	No	Small landslide along Rt. 202 south east of Whiton Road on steep slope due to Tropical Storm Irene.
9/8/2011	Debris flow	Morris	Heavy rain	No	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	Heavy rain	Yes	Debris flow after heavy rain, temporary road closure of Stephensburg Road.
9/8/2011	Debris flow	Morris	Heavy rain	No	Debris flow along Naughtright Road.
9/8/2011	Debris flow	Sussex	Heavy rain	No	Debris flow along lower end of Holland Circle triggered by heavy rain from Tropical Storm Lee.
9/8/2011	Debris flow	Warren	Heavy rain	Yes	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.
March 2012	Rockfall	Essex	Weathering	No	Rockfall along Rt. 280 in East Orange off Ramp leading to Garden State parkway.
5/12/2012	Rockslide	Bergen	Weathering	Yes	A large chuck of the Palisades Interstate Park's cliff wall broke off 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.
February 2013	Rockfall	Warren	Weathering	No	Rockfall along Rt. 46
February 2013	Rockfall	Morris	Weathering	No	Rockfall along Rt. 10 west

DATE	TYPE	COUNTY	TRIGGER	DAMAGE	COMMENTS
11/27/2013	Debris flow	Hudson	Heavy Rain	No	Paterson Plan Road was closed from 9:03 am to 2 pm from Congress Street in Jersey City to Harrison Place in Hoboken due to debris flow after heavy rain
11/29/2013	Rockslide	Somerset	Heavy rain/ weathering	Yes	A portion of the cliff face behind the Watchung Department of Public Works garage on Somerset Street slid off the mountain sometime during the overnight on Thanksgiving night and crushed an old DPW truck. No one was hurt
December 2013	Rockfall	Hunterdon	Weathering	No	Rockfall from cliff along Rt. 29
December 2013	Rockfall	Hunterdon	Weathering	No	Rockfall from cliff along Rt. 29
1/15/2014	Debris flow	Hudson	Weathering	Yes	Landslide on the western side of Paterson Plank Road in North Bergen on Jan. 15, 2014. Road repairs estimated at $700.000 including shoring up the cliff below the roadway and to repair the road.
March 2014	Rockfall	Morris	Weathering		Rockfall along Rt. 15 in Jefferson Twp. estimated location. Exact location unknown.
March 2014	Rockfall	Warren	Weathering	No	Rockfall along Rt. 57 WB.
3/25/2014	Rockslide	Somerset	Quarrying	Yes	A quarry worker was trapped in an excavator by a large boulder that had fallen on his vehicle after a rockslide at the Gibralter Rock-Belle Mead Stone Quarry. He was medevaced to a hospital and treated for his injuries and in stable condition.
April 2014	Weathering	Essex	Quarrying	No	Rockfall along Rt. 280 in East Orange off ramp leading to Garden State Parkway, estimated location.
April 2014	Weathering	Warren	Weathering	No	Small Rockfall along Rt. 22.
April 2014	Rockfall	Hunterdon	Weathering	No	Small rockfall along Rt. 78 west in Bethlehem Township, estimated location.
4/27/2014	Rockfall	Hunterdon	Weathering	No	A massive boulder caused delays on Route 29 near Byram just north of Stockton. Traffic was stopped temporarily until the boulder was cleared.
4/30/2014	Slump	Monmouth	Heavy rain	Yes	A landslide at 160 Ocean Boulevard in Atlantic Highlands on April 30-May 1, 2014 during heavy rains that supposedly "sent hundreds of thousands of cubic yards of dirt, sand, and rock" onto the Henry Hudson Trail at the base of the slope.
12/6/2014	Rockfall	Essex	Heavy rain	Yes	A 3,000-4,000 lb. boulder rolled down a hill and crashed into a car. The rockfall was attributed to prior heavy rains earlier in the month. The boulder caused about $8,000 worth of damage to a Subaru Forrester.

DATE	TYPE	COUNTY	TRIGGER	DAMAG E	COMMENTS
3/23/2015	Slump	Middlesex	Water main Break	Yes	Erosion from a water main break is believed to have caused a road collapse on Gordon Street. An SUV vehicle had fallen into the ravine. A large section of road and front yard of a house slumped down. Gordon street east of Pine street was closed
4/20/2015	Slump	Burlington	Heavy rain	Yes	During heavy rain a landslide opened up a cavernous hole in the backyards of two houses on East Front Street in Florence. The landslide took out half of one backyard. Possible broken drainage pipe also contributed to landslide.
January 2016	Rockslide	Bergen	Weathering	No	Large Rockslide along the Palisades. A huge piece of rock had sheared away from the cliff.
April 2016	Rockslide	Bergen	Weathering	Yes	Small rockslide south of the state line lookout on the Alpine Approach Road.
May 2016	Rockslide	Bergen	Weathering	Yes	Large rockslide closed the Alpine Approach road for over a week. The Debris field that covered the road was 75 feet long by 20 feet wide.

Source: NJDEP 2012; NOAA-NCDC 2013, NJGWS 2017

Subsidence/Sinkholes

Sinkhole and subsidence activities occur primarily in Warren, Sussex, Passaic, Morris, Somerset, and Hunterdon Counties (NJGWS). The following events were discussed in the 2014 New Jersey HMP and provided below.

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 5.7-9 shows sinkholes that have occurred in different areas of New Jersey since the 2014 Plan Update.

Figure 5.7-9 Sinkholes New Jersey

Source: (clockwise) Courtesy of PIX 11 2013; Reuters, 2015; NBC, 2017

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. Table 5.7-2 below provides detail on the 66 sinkholes that were larger than 40,000 square feet.

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

MUNICIPALITY	AREA (SQ FT)	MUNICIPALITY	AREA (SQ FT)
Harmony Township	40,739	White Township	109,678
Hardwick Township	40,967	Hardwick Township	110,490

MUNICIPALITY	AREA (SQ FT)
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
Washington Township	100,472
Blairstown Township	100,896
Hardwick Township	103,506
White Township	105,050
Greenwich Township	109,602

MUNICIPALITY	AREA (SQ FT)
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
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

5.7.5 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 M 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 2017, there were 287 instances of recorded landslides in the State (NJGWS, 2017). 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 New Jersey. Therefore, the probability of a sinkhole forming in 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.

5.7.5.1 POTENTIAL EFFECTS OF CLIMATE CHANGE

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.

5.7.6 IMPACT ANALYSIS

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.

5.7.6.1 SEVERITY AND 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

5.7.6.2 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.

5.7.6.3 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.

5.7.7 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 is 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.

5.7.7.1 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 M 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 (USGS). 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 USGS 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 Located in the Landslide Areas

		NJGWS-Defined Landslide Susceptible Areas						Landslide Susceptible Areas (Godt 2001)			
County	Total Area (sq. mi)	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
Atlantic	610.7	-	-	-	-	-	-	0	0.0%	0	0.0%
Bergen	239.8	5.1	2.1%	1.5	0.6%	0	0.0%	0	0.0%	0	0.0%
Burlington	820.3	-	-	-	-	-	-	0	0.0%	49.4	6.0%
Camden	227.6	-	-	-	-	-	-	0	0.0%	24.5	10.7%
Cape May	286.1	-	-	-	-	-	-	0	0.0%	0	0.0%
Cumberland	501.8	-	-	-	-	-	-	0	0.0%	0	0.0%
Essex	129.7	0.4	0.3%	0.9	0.7%	0	0.0%	0	0.0%	0	0.0%
Gloucester	336.2	-	-	-	-	-	-	0	0.0%	42.7	14.9%
Hudson	51.5	0.4	0.7%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Hunterdon	437.3	-	-	-	-	-	-	0	0.0%	0	0.0%
Mercer	228.8	-	-	-	-	-	-	0	0.0%	27	11.8%
Middlesex	317	0	0.0%	0.6	0.2%	0.7	0.2%	0	0.0%	3.5	1.1%
Monmouth	485.7	0	0.0%	4.2	0.9%	0	0.0%	0	0.0%	0	0.0%
Morris	481.4	4.7	1.0%	6.9	1.4%	1	0.2%	0	0.0%	0	0.0%
Ocean	757.9	-	-	-	-	-	-	0	0.0%	0	0.0%
Passaic	198.3	6.3	3.2%	0.6	0.3%	0	0.0%	0	0.0%	0	0.0%
Salem	347.1	-	-	-	-	-	-	0	0.0%	22.2	6.4%
Somerset	304.9	1.4	0.5%	3.1	1.0%	0.6	0.2%	0	0.0%	0	0.0%
Sussex	535.5	-	-	-	-	-	-	51	9.5%	0	0.0%

Union	105.4	0.2	0.2%	0.8	0.8%	0	0.0%	0	0.0%	0	0.0%
Warren	362.6	-	-	-	-	-	-	0	0.0%	0	0.0%
Total	7765.7	18.4	0.2%	18.6	0.2%	2.3	0.0%	51	0.7%	169.2	2.2%

Source: NJGWS 2005; USGS 2001

Table 5.7-4 Total Land Located in the Subsidence/Sinkhole Areas

County	Total Area (sq. mi)	Sinkhole/ Subsidence Hazard Areas	
		Carbonate Rock Formation (sq. mi)	% Total
Atlantic	610.7	0	0.0%
Bergen	239.8	0	0.0%
Burlington	820.3	22.9	2.8%
Camden	227.6	0.8	0.3%
Cape May	286.1	0	0.0%
Cumberland	501.8	0	0.0%
Essex	129.7	0	0.0%
Gloucester	336.2	0.6	0.2%
Hudson	51.5	0	0.0%
Hunterdon	437.3	28	6.4%
Mercer	228.8	0	0.0%
Middlesex	317	0	0.0%
Monmouth	485.7	45	9.3%
Morris	481.4	32.7	6.8%
Ocean	757.9	6	0.8%
Passaic	198.3	1	0.5%
Salem	347.1	24.6	7.1%
Somerset	304.9	1.1	0.4%
Sussex	535.5	133.1	24.9%
Union	105.4	0	0.0%
Warren	362.6	153.1	0.0%
Total	7765.7	448.9	5.8%

Source: NJGWS 2005; USGS 2001

Sixteen 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 5.7-5 Number of Geologic Hazard Events and Abandoned Mines by County

County	Number of Landslide Events	Number of Sinkhole/ Subsidence Events	Number of Abandoned Mines
Atlantic	0	N/A	0
Bergen	59	N/A	4
Burlington	6	N/A	0
Camden	1	N/A	0
Cape May	0	N/A	0
Cumberland	0	N/A	0
Essex	13	N/A	3
Gloucester	0	N/A	0
Hudson	19	N/A	0
Hunterdon	29	N/A	103
Mercer	1	N/A	0
Middlesex	8	N/A	3
Monmouth	19	N/A	0
Morris	30	N/A	211
Ocean	0	N/A	0
Passaic	7	N/A	46
Salem	0	N/A	0
Somerset	9	N/A	12
Sussex	38	N/A	75
Union	4	N/A	0
Warren	44	1185	131
Total	287	1185	588

Source: NJGWS

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. To better understand life at risk, the landslide and sinkhole/subsidence hazard areas were overlaid upon the 2015 American Community Survey 5 Year Estimates population data (American Community Survey, 2015). 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. Refer to Table 5.7-6 and 5.7-7 below.

Based on the analysis of USGS landslide susceptibility data (USGS, 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 population based in the urban and suburban areas proximate to Philadelphia, adjacent to the Delaware River located in Burlington, Camden, and Gloucester Counties is vulnerable. 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 would be 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 5.7-6 Estimated Population Located in the Landslide Areas

County	Total Population	NJGWS-Defined Landslide Susceptible Areas						Landslide Susceptible Areas (Godt, 2001)			
		Class A	% Total	Class B	% Total	Class C	% Total	High Susceptibility	% Total	Moderate Susceptibility	% Total
Atlantic	275,376	551	0.2%	1,928	0.7%	0	0.0%	0	0.0%	0	0.0%
Bergen	926,330	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Burlington	450,556	0	0.0%	0	0.0%	0	0.0%	0	0.0%	109,485	24.3%
Camden	511,998	0	0.0%	0	0.0%	0	0.0%	0	0.0%	123,904	24.2%
Cape May	95,805	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Cumberland	157,035	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Essex	791,609	792	0.1%	2,375	0.3%	0	0.0%	0	0.0%	0	0.0%
Gloucester	290,298	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Hudson	662,619	2,650	0.4%	663	0.1%	0	0.0%	0	0.0%	0	0.0%
Hunterdon	126,250	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Mercer	370,212	0	0.0%	0	0.0%	0	0.0%	0	0.0%	61,455	16.6%
Middlesex	830,300	0	0.0%	1,661	0.2%	2,491	0.3%	0	0.0%	10,794	1.3%
Monmouth	629,185	0	0.0%	1,258	0.2%	1,258	0.2%	0	0.0%	0	0.0%
Morris	498,192	498	0.1%	4,982	1.0%	0	0.0%	0	0.0%	0	0.0%
Ocean	583,450	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Passaic	507,574	2,030	0.4%	508	0.1%	0	0.0%	0	0.0%	0	0.0%
Salem	65,120	0	0.0%	0	0.0%	0	0.0%	0	0.0%	16,931	26.0%
Somerset	330,604	331	0.1%	2,314	0.7%	661	0.2%	0	0.0%	0	0.0%
Sussex	145,930	0	0.0%	0	0.0%	0	0.0%	4,816	3.3%	0	0.0%
Union	548,744	549	0.1%	549	0.1%	0	0.0%	0	0.0%	0	0.0%
Warren	107,226	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Total	8,904,413	8,904	0.1%	17,809	0.2%	0	0.0%	8,904	0.1%	347,272	3.9%

Table 5.7-7 Estimated Population Located in the Subsidence/Sinkhole Hazard Areas

County	Total Population	Sinkhole/Subsidence Hazard Areas	
		Carbonate Rock Formation	% Total
Atlantic	275,376	0	0%

County	Total Population	Sinkhole/Subsidence Hazard Areas	
		Carbonate Rock Formation	% Total
Bergen	926,330	0	0%
Burlington	450,556	10,363	2%
Camden	511,998	11,776	2%
Cape May	95,805	0	0%
Cumberland	157,035	0	0%
Essex	791,609	0	0%
Gloucester	290,298	290	0%
Hudson	662,619	0	0%
Hunterdon	126,250	10,226	8%
Mercer	370,212	0	0%
Middlesex	830,300	0	0%
Monmouth	629,185	63,548	10%
Morris	498,192	18,433	4%
Ocean	583,450	4,084	1%
Passaic	507,574	1,015	0%
Salem	65,120	6,252	10%
Somerset	330,604	992	0%
Sussex	145,930	38,526	26%
Union	548,744	0	0%
Warren	107,226	71,734	67%
Total	8,904,413	231,515	3%

5.7.7.2 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 5.7-8 summarizes the state-owned and -leased facilities vulnerable to the landslide and sinkhole/subsidence hazards by county. Table 5.7-9 summarizes the facilities vulnerable by state agency.

Table 5.7-8 State-Owned and -Leased Buildings in the Landslide and Sinkhole/Subsidence Area by County

County	Total Number of Buildings	NJGWS-Defined Landslide Susceptible Areas			Landslide Susceptible Areas (GODT 2001)			Sinkhole/Subsidence Hazard Areas		
		Owned	Leased	Total	Owned	Leased	Total	Owned	Leased	Total
Atlantic	165	-	-	-	0	0	0	0	0	0
Bergen	79	67	12	79	0	0	0	17	1	18
Burlington	683	-	-	-	62	4	66	0	0	0

County	Total Number of Buildings	NJGWS-Defined Landslide Susceptible Areas			Landslide Susceptible Areas (GODT 2001)			Sinkhole/Subsidence Hazard Areas		
		Owned	Leased	Total	Owned	Leased	Total	Owned	Leased	Total
Camden	154	-	-	-	12	7	19	0	0	0
Cape May	191	-	-	-	0	0	0	0	0	0
Cumberland	464	-	-	-	0	0	0	0	0	0
Essex	102	80	22	102	20	6	26	0	0	0
Gloucester	55	-	-	-	6	1	7	0	0	0
Hudson	53	42	11	53	0	0	0	0	0	0
Hunterdon	501	-	-	-	0	0	0	231	0	231
Mercer	673	-	-	-	3	1	4	77	8	85
Middlesex	334	307	27	334	0	0	0	1	0	1
Monmouth	450	432	18	450	1	0	1	0	0	0
Morris	227	209	18	227	27	8	35	12	0	12
Ocean	244	-	-	-	8	0	8	0	0	0
Passaic	250	235	15	250	91	12	103	1	0	1
Salem	121	-	-	-	9	0	9	0	0	0
Somerset	138	133	5	138	9	0	9	1	0	1
Sussex	446	-	-	-	15	0	15	158	4	162
Union	53	35	18	53	9	4	13	0	0	0
Warren	225	-	-	-	0	0	0	122	4	126
Total	5,608	1,540	146	1,686.00	272	43	315	620	17	637

Source: NJOMB 2018; NJOMB 2013; USGS 2001; NJGWS 2005

Table 5.7-9 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			Landslide Susceptible Areas (GODT 2001)			Sinkhole/Subsidence Hazard Areas		
		Owned	Leased	Total	Owned	Leased	Total	Owned	Leased	Total
Agriculture	10	9	-	9	-	-	-	-	-	-
Banking and Insurance	1	-	-	-	-	-	-	-	-	-
Chief Executive	2	-	1	1	-	-	-	-	-	-
Children and Families	157	41	28	69	7	8	15	2	1	3
Community Affairs	10	-	4	4	-	-	-	-	1	1
Corrections	801	143	2	145	-	-	-	103	-	103
Education	66	7	2	9	1	2	3	-	-	-
Environmental Protection	2,004	492	5	497	38	2	40	306	1	307

Agency	Total Number of Buildings	NJGWS-Defined Landslide Susceptible Areas			Landslide Susceptible Areas (GODT 2001)			Sinkhole/Subsidence Hazard Areas		
		Owned	Leased	Total	Owned	Leased	Total	Owned	Leased	Total
Health	9	-	-	-	-	-	-	79	-	79
Human Services	729	170	3	173	61	1	62	-	-	-
Judiciary	92	29	17	46	7	7	14	3	1	4
Juvenile Justice Commission	199	101	1	102	36	-	36	-	-	-
Labor and Work Force Development	50	-	28	28	-	5	5	-	4	4
Law and Public Safety	27	4	2	6	-	1	1	1	1	2
Legislature	6	-	-	-	-	-	-	-	-	-
Military and Veterans Affairs	273	129	2	131	15	-	15	26	1	27
Miscellaneous Commissions	2	-	-	-	-	1	1	-	-	-
Motor Vehicles Commission	141	55	17	72	12	5	17	2	2	4
Personnel	2	-	-	-	-	-	-	-	-	-
State	19	-	1	1	-	-	-	2	-	2
State Police	141	24	14	38	9	5	14	37	2	39
Transportation	617	219	-	219	83	-	83	57	-	57
Treasury	250	117	19	136	3	6	9	2	3	5
Total	5,608	1,540	146	1,686	272	43	315	620	17	637

Source: NJOMB 2018; NJOMB 2013; USGS 2001; NJGWS 2005

Based on the analysis the USGS landslide susceptibility data (USGS, 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 5.7-10 and 5.7-11 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 5.7-10 Critical Facilities Exposed to the Landslide Hazard Areas

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	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bergen	1,148	-	-	-	-	13	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Burlington	747	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Camden	701	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cape May	229	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cumberland	251	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Essex	784	-	-	-	-	26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Gloucester	346	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hudson	493	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
Hunterdon	328	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mercer	538	-	-	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Middlesex	816	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Monmouth	905	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Morris	913	-	-	-	-	70	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ocean	621	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Passaic	648	-	-	-	-	46	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Salem	201	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Somerset	539	-	-	-	-	24	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Sussex	542	-	-	-	-	16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Union	607	-	-	-	-	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Warren	351	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	12,096	-	-	-	-	230	-	-	-	-	1	1	-	1	-	-	-	-	1	-	-	-	-	-	2	-	1

Table 5.7-11 Critical Facilities Exposed to the Sinkhole/Subsidence Hazard Areas

County	Total Number	Airport	Special Needs	Communication	orrectional 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	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bergen	1,148	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Burlington	747	-	-	-	-	-	-	3	-	-	1	-	-	-	3	-	-	-	1	-	-	-	-	5	5	-	3
Camden	701	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cape May	229	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cumberland	251	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Essex	784	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gloucester	346	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hudson	493	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hunterdon	328	-	-	-	1	32	-	7	-	-	4	-	-	-	-	-	-	-	2	-	-	-	-	8	6	-	-
Mercer	538	-	-	-	-	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Middlesex	816	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Monmouth	905	-	-	-	-	-	1	4	1	-	12	-	-	-	6	1	-	-	4	-	-	1	-	42	9	-	1
Morris	913	-	-	-	-	18	1	4	-	-	5	-	-	-	3	1	-	-	-	-	-	-	-	12	3	-	2
Ocean	621	-	-	-	-	-	-	2	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	4	3	-	-
Passaic	648	-	-	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Salem	201	-	-	-	-	-	-	1	-	-	4	-	-	-	-	-	-	-	2	-	-	-	-	6	6	-	1
Somerset	539	-	-	-	-	7	-	1	-	-	1	-	-	-	-	-	-	-	1	-	-	1	-	-	2	-	-
Sussex	542	1	-	-	-	42	-	20	-	-	21	-	-	-	5	-	-	-	9	-	-	-	-	39	46	-	2
Union	607	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Warren	351	-	-	1	1	41	-	25	1	-	26	2	-	-	13	-	-	-	13	-	-	1	-	45	61	-	2
Total	12,096	1	-	1	2	171	2	67	2	-	75	2	-	-	30	2	-	-	33	-	-	3	-	161	141	-	11

5.7.7.3 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 5.7-12 through 5.7-14 identifies a potential total risk exposure of buildings vulnerable to landslides, and 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 5.7-12 Estimated Building Replacement Cost Vulnerable to the Landslide (NJGWS) Hazards by County

		NJGWS-Defined Landslide Susceptible Areas		
County	Total RCV	Owned	Leased	Total
Atlantic	$ 437,234,696	$ -	$ -	$ -
Bergen	$ 167,418,063	$ 117,835,865	$ 49,582,198	$ 167,418,063
Burlington	$ 638,782,952	$ -	$ -	$ -
Camden	$ 498,714,249	$ -	$ -	$ -
Cape May	$ 114,971,807	$ -	$ -	$ -
Cumberland	$ 643,881,700	$ -	$ -	$ -
Essex	$ 822,674,560	$ 293,884,559	$ 528,790,001	$ 822,674,560
Gloucester	$ 105,866,503	$ -	$ -	$ -
Hudson	$ 280,805,250	$ 159,090,356	$ 121,714,894	$ 280,805,250
Hunterdon	$ 260,655,560	$ -	$ -	$ -
Mercer	$ 2,952,671,103	$ -	$ -	$ -
Middlesex	$ 632,983,190	$ 412,486,406	$ 220,496,783	$ 632,983,190
Monmouth	$ 463,386,037	$ 351,311,438	$ 112,074,600	$ 463,386,037
Morris	$ 385,747,921	$ 244,543,130	$ 141,204,791	$ 385,747,921
Ocean	$ 310,626,835	$ -	$ -	$ -
Passaic	$ 299,429,912	$ 171,973,957	$ 127,455,955	$ 299,429,912
Salem	$ 134,460,134	$ -	$ -	$ -
Somerset	$ 226,685,451	$ 130,922,009	$ 95,763,442	$ 226,685,451
Sussex	$ 98,346,368	$ -	$ -	$ -
Union	$ 164,566,538	$ 112,222,819	$ 52,343,719	$ 164,566,538
Warren	$ 79,870,209	$ -	$ -	$ -
Total	$9,719,779,039	$1,994,270,540	$1,449,426,382	$ 3,443,696,923

Source: NJOMB 2018; NJGWS 2005; USGS, 2001

Table 5.7-13 Estimated Building Replacement Cost Vulnerable to the Landslide (GODT) Hazards by County

County	Total RCV	Landslide Susceptible Areas		
		Owned	Leased	Total
Atlantic	$ 437,234,696	$ -	$ -	$ -
Bergen	$ 167,418,063	$ -	$ -	$ -
Burlington	$ 638,782,952	$ 97,652,011	$ 8,037,829	$105,689,840
Camden	$ 498,714,249	$ 36,145,078	$ 41,750,670	$ 77,895,748
Cape May	$ 114,971,807	$ -	$ -	$ -
Cumberland	$ 643,881,700	$ -	$ -	$ -
Essex	$ 822,674,560	$ 19,104,014	$ 55,175,145	$ 74,279,159
Gloucester	$ 105,866,503	$ 886,610	$ 10,771,922	$ 11,658,532
Hudson	$ 280,805,250	$ -	$ -	$ -
Hunterdon	$ 260,655,560	$ -	$ -	$ -
Mercer	$ 2,952,671,103	$ 4,590,281	$ 5,965,569	$ 10,555,850
Middlesex	$ 632,983,190	$ -	$ -	$ -
Monmouth	$ 463,386,037	$ 15,017,130	$ -	$ 15,017,130
Morris	$ 385,747,921	$ 11,293,759	$ 59,659,644	$ 70,953,403
Ocean	$ 310,626,835	$ 585,229	$ -	$ 585,229
Passaic	$ 299,429,912	$112,928,985	$ 115,233,898	$ 228,162,882
Salem	$ 134,460,134	$ 2,640,981	$ -	$ 2,640,981
Somerset	$ 226,685,451	$ 30,116,324	$ -	$ 30,116,324
Sussex	$ 98,346,368	$ 1,565,573	$ -	$ 1,565,573
Union	$ 164,566,538	$ 8,705,686	$ 11,310,001	$ 20,015,687
Warren	$ 79,870,209	$ -	$ -	$ -
Total	$9,719,779,039	$ 341,231,661	$307,904,677	$ 649,136,338

Source: NJOMB 2018; NJGWS 2005; USGS, 2001

Table 5.7-14 Estimated Building Replacement Cost Vulnerable to the Subsidence/Sinkhole Hazards by County

County	Total RCV	Sinkhole/Subsidence Hazard Areas		
		Owned	Leased	Total
Atlantic	$ 437,234,696	$ -	$ -	$ -
Bergen	$ 167,418,063	$ -	$ 955,527	$ 955,527
Burlington	$ 638,782,952	$ -	$ -	$ -
Camden	$ 498,714,249	$ -	$ -	$ -
Cape May	$ 114,971,807	$ -	$ -	$ -
Cumberland	$ 643,881,700	$ -	$ -	$ -
Essex	$ 822,674,560	$ 18,554,013	$ -	$ 18,554,013
Gloucester	$ 105,866,503	$ -	$ -	$ -
Hudson	$ 280,805,250	$ -	$ -	$ -
Hunterdon	$ 260,655,560	$ 139,183,005	$ -	$ 139,183,005
Mercer	$ 2,952,671,103	$ 146,227,195	$ 51,783,789	$198,010,984

County	Total RCV	Sinkhole/Subsidence Hazard Areas		
		Owned	Leased	Total
Middlesex	$ 632,983,190	$ 346,517	$ -	$ 346,517
Monmouth	$ 463,386,037	$ -	$ -	$ -
Morris	$ 385,747,921	$ 776,345	$ -	$ 776,345
Ocean	$ 310,626,835	$ -	$ -	$ -
Passaic	$ 299,429,912	$ 3,353,201	$ -	$ 3,353,201
Salem	$ 134,460,134	$ -	$ -	$ -
Somerset	$ 226,685,451	$ 322,901	$ -	$ 322,901
Sussex	$ 98,346,368	$ 54,949,826	$ 7,392,669	$ 62,342,495
Union	$ 164,566,538	$ -	$ -	$ -
Warren	$ 79,870,209	$ 62,367,205	$ 7,028,540	$ 69,395,746
Total	$9,719,779,039	$426,080,207	$ 67,160,526	$493,240,733

Source: NJOMB 2018; NJGWS 2005; USGS, 2001

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.

5.7.7.4 ESTIMATING POTENTIAL LOSSES TO STATE FACILITIES

The vulnerability of each individual state building and critical facility will differ based on the topography and underlying geology. Tables 5.7-15 through 5.7-17 below summarize the estimated loss by 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.

Table 5.7-15 Estimated Building Replacement Cost Vulnerable to the Landslide (NJGWS) Hazards by Agency

Agency	Total RCV	NJGWS-Defined Landslide Susceptible Areas		
		Owned	Leased	Total
Agriculture	$ 8,096,184	$ 3,021,682	$ -	$ 3,021,682
Banking and Insurance	$ 58,349,889	$ -	$ -	$ -
Chief Executive	$ 41,711,042	$ -	$ 6,803,870	$ 6,803,870
Children and Families	$ 710,790,282	$ 27,380,788	$ 413,620,211	$ 441,000,999
Community Affairs	$ 133,856,589	$ -	$ 75,839,984	$ 75,839,984
Corrections	$ 1,159,804,016	$ 295,725,716	$ 3,963,378	$ 299,689,094
Education	$ 177,472,231	$ 25,209,326	$ 3,470,064	$ 28,679,390

Agency	Total RCV	NJGWS-Defined Landslide Susceptible Areas		
		Owned	Leased	Total
Environmental Protection	$ 756,535,586	$ 267,939,010	$ 22,155,132	$ 290,094,142
Health	$ 187,466,620	$ -	$ -	$ -
Human Services	$ 1,120,601,472	$ 304,123,151	$ 6,892,301	$ 311,015,452
Judiciary	$1,096,424,568	$ 432,995,476	$ 142,648,801	$ 575,644,277
Juvenile Justice Commission	$ 246,910,955	$ 81,339,381	$ 822,656	$ 82,162,036
Labor and Work Force Development	$ 328,156,420	$ -	$ 151,799,736	$ 151,799,736
Law and Public Safety	$ 284,215,262	$ 11,953,749	$ 99,369,320	$ 111,323,069
Legislature	$ 120,556,954	$ -	$ -	$ -
Military And Veterans Affairs	$ 737,946,664	$ 318,619,796	$ 1,182,771	$ 319,802,566
Miscellaneous Commissions	$ 18,027,989	$ -	$ -	$ -
Motor Vehicles Commission	$ 563,493,240	$ 37,234,454	$ 81,789,875	$ 119,024,329
Personnel	$ 9,656,017	$ -	$ -	$ -
State	$ 152,151,016	$ -	$ 2,625,851	$ 2,625,851
State Police	$ 432,772,085	$ 48,683,845	$ 34,254,858	$ 82,938,703
Transportation	$ 320,748,453	$ 81,745,497	$ -	$ 81,745,497
Treasury	$ 1,054,035,504	$ 58,298,671	$ 402,187,573	$ 460,486,244
Total	$ 9,719,779,039	$1,994,270,540	$1,449,426,38 2	$ 3,443,696,922

Source: NJOMB 2018; NJGWS 2005; USGS, 2001

Table 5.7-16 Estimated Building Replacement Cost Vulnerable to the Landslide (GODT) Hazards by Agency

Agency	Total RCV	Landslide Susceptible Areas		
		Owned	Leased	Total
Agriculture	$ 8,096,184	$ -	$ -	$ -
Banking and Insurance	$ 58,349,889	$ -	$ -	$ -
Chief Executive	$ 41,711,042	$ -	$ -	$ -
Children and Families	$ 710,790,282	$ 2,450,782	$ 109,899,228	$ 112,350,010
Community Affairs	$ 133,856,589	$ -	$ -	$ -
Corrections	$ 1,159,804,016	$ -	$ -	$ -
Education	$ 177,472,231	$ 4,505,881	$ 3,470,064	$ 7,975,945
Environmental Protection	$ 756,535,586	$ 7,278,417	$ 13,676,211	$ 20,954,628
Health	$ 187,466,620	$ -	$ -	$ -
Human Services	$ 1,120,601,472	$ 86,737,846	$ 2,092,032	$ 88,829,878
Judiciary	$1,096,424,568	$ 53,987,191	$ 70,409,578	$ 124,396,769

Agency	Total RCV	Landslide Susceptible Areas		
		Owned	Leased	Total
Juvenile Justice Commission	$ 246,910,955	$79,905,096	$ -	$ 79,905,096
Labor and Work Force Development	$ 328,156,420	$ -	$ 22,617,645	$ 22,617,645
Law and Public Safety	$ 284,215,262	$ -	$ 5,204,211	$ 5,204,211
Legislature	$ 120,556,954	$ -	$ -	$ -
Military And Veterans Affairs	$ 737,946,664	$ 24,824,216	$ -	$ 24,824,216
Miscellaneous Commissions	$ 18,027,989	$ -	$ 8,415,544	$ 8,415,544
Motor Vehicles Commission	$ 563,493,240	$ 4,841,461	$ 18,726,167	$ 23,567,628
Personnel	$ 9,656,017	$ -	$ -	$ -
State	$ 152,151,016	$ -	$ -	$ -
State Police	$ 432,772,085	$38,435,844	$ 12,072,248	$ 50,508,092
Transportation	$ 320,748,453	$ 22,894,297	$ -	$ 22,894,297
Treasury	$ 1,054,035,504	$ 15,370,629	$ 41,321,751	$ 56,692,380
Total	$ 9,719,779,039	$ 341,231,661	$307,904,677	$649,136,338

Source: NJOMB 2018; NJGWS 2005; USGS, 2001

Table 5.7-17 Estimated Building Replacement Cost Vulnerable to the Subsidence/Sinkhole Hazards by Agency

Agency	Total RCV	Sinkhole/Subsidence Hazard Areas		
		Owned	Leased	Total
Agriculture	$ 8,096,184	$ -	$ -	$ -
Banking and Insurance	$ 58,349,889	$ -	$ -	$ -
Chief Executive	$ 41,711,042	$ -	$ -	$ -
Children and Families	$ 710,790,282	$ 1,303,316	$ 3,725,740	$ 5,029,056
Community Affairs	$ 133,856,589		$ 1,385,871	$ 1,385,871
Corrections	$ 1,159,804,016	$ 69,874,333		$ 69,874,333
Education	$ 177,472,231	$ -	$ -	$ -
Environmental Protection	$ 756,535,586	$ 76,541,778	$ 6,484,639	$ 83,026,417
Health	$ 187,466,620	$ -	$ -	$ -
Human Services	$ 1,120,601,472	$ 67,881,453	$ -	$ 67,881,453
Judiciary	$1,096,424,568	$ 25,466,292	$ 10,914,542	$ 36,380,834
Juvenile Justice Commission	$ 246,910,955	$ -	$ -	$ -
Labor and Work Force Development	$ 328,156,420	$ -	$ 7,413,626	$ 7,413,626
Law and Public Safety	$ 284,215,262	$ 2,272,730	$ 3,308,592	$ 5,581,323
Legislature	$ 120,556,954	$ -	$ -	$ -

Agency	Total RCV	Sinkhole/Subsidence Hazard Areas		
		Owned	Leased	Total
Military and Veterans Affairs	$ 737,946,664	$ 32,053,817	$ 21,639,775	$ 53,693,592
Miscellaneous Commissions	$ 18,027,989	$ -	$ -	$ -
Motor Vehicles Commission	$ 563,493,240	$ 620,470	$ 2,113,450	$ 2,733,920
Personnel	$ 9,656,017	$ -	$ -	$ -
State	$ 152,151,016	$ 19,505	$ -	$ 19,505
State Police	$ 432,772,085	$ 127,347,685	$ 2,421,508	$ 129,769,194
Transportation	$ 320,748,453	$ 11,668,985		$ 11,668,985
Treasury	$ 1,054,035,504	$ 11,029,843	$ 7,752,781	$ 18,782,624
Total	$ 9,719,779,039	$426,080,207	$ 67,160,526	$ 493,240,733

Source: NJOMB 2018; NJGWS 2005; USGS, 2001

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