11. GEOLOGICAL HAZARDS

11.1 HAZARD PROFILE

11.1.1 Hazard Description

For the purpose of Sussex County's HMP update, geological hazards include landslides and land subsidence/sinkholes.

Landslides

A landslide is a downslope movement of earthen materials. Landslides destroy property and infrastructure and can take the lives of people. When landslides deform and tilt the ground surface, the result can be destruction of foundations, offset of roads, breaking of underground pipes, or overriding of downslope property and structures.

Landslide Types

Figure 11-1 shows common landslide types as classified by the USGS. All these types of landslides are considered aggregately in USGS landslide mapping.

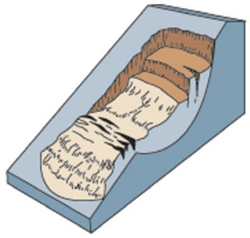
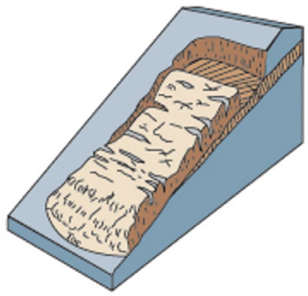
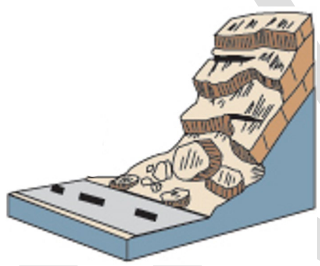
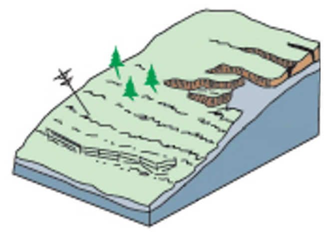
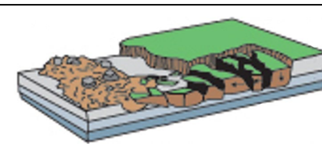
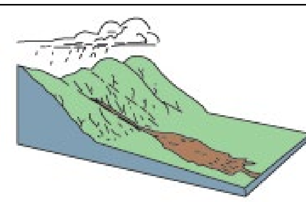
Landslide Causes

Landslides are caused by a combination of geological and climate conditions and the influence of urbanization. They can be initiated by storms, earthquakes, fires, volcanic eruptions, or human modification of the land. While small landslides are frequently a result of human activity, the largest landslides are often naturally occurring phenomena with little or no human contribution. Landslides are associated primarily with the following factors (USGS 2004):

- **Water—**Intense rainfall, changes in groundwater level, and water level changes along coastlines, earthen dams, and the banks of lakes, reservoirs, and rivers are the primary triggers of landslides.
- **Seismic Activity—**Earthquakes in landslide-prone areas greatly increase the likelihood that landslides will occur, either due to ground shaking alone or shaking-caused dilation of soil materials.
- **Mining—**Large vibrations, including blasting, reach yards under the soil surface, which poses a greater threat to areas that are already at risk for sliding.
- **Other Human Activity—**Construction activity that undercuts or overloads dangerous slopes or that redirects the flow of surface or groundwater can trigger slope failures.

Landslides are typically a function of soil type and slope steepness. Soil type is a key indicator for landslide potential and is used by geologists and geotechnical engineers to determine soil stability for construction standards.

Figure 11-1. Common Landslides Types

Rotational slides—Slides in which the surface of rupture is curved upward, and the slide movement rotates parallel to the ground surface. 	**Debris avalanches—** Debris flows that travel faster than about 10 miles per hour (mph). Speeds in excess of 20 mph are not uncommon, and speeds in excess of 100 mph, although rare, can occur. The slurry can travel miles from its source, growing as it descends, picking up trees, boulders, cars, and anything else in its path. 
Translational slides— Slides in which the mass moves along a roughly flat surface with little rotation. 	**Earthflows—**Landslides with an "hourglass" shape. The slope material liquefies and runs out, forming a bowl or depression at the head. A **mudflow** is an earthflow consisting of material that is wet enough to flow rapidly and that contains at least 50 percent sand-, silt-, and clay-sized particles. 
Falls—Abrupt movements of geologic materials, such as rocks and boulders, that become detached from steep slopes or cliffs. Falls are strongly influenced by gravity, weathering, and the presence of water in a mineral's pores. 	**Creep—**Slow, steady, downward movements of slope-forming soil or rock. Creep is indicated by curved tree trunks, bent fences, or retaining walls, tilted poles or fences, and small soil ripples or ridges. 
Topples—Slides involving the forward rotation of a unit about some point under the actions of gravity and forces exerted by surrounding objects or by fluids in cracks. 	**Lateral Spreads—**Slides on very gentle slopes or flat terrain caused by liquefaction, the process whereby saturated, loose, sediments are transformed from a solid into a liquefied state. The failure starts suddenly in a small area and spreads rapidly. 
Debris flows—Rapid landslides in which loose soil, rock, organic matter, air, and water mobilize as a slurry that flows downslope. Commonly caused by intense surface water flow due to heavy rain or rapid snowmelt that erodes loose soil or rock on steep slopes. 	

Source: (U.S. Geological Survey 2006, USGS 2004)

Subsidence/Sinkholes

Subsidence is any lowering of the earth's surface, from small or local collapses (sinkholes) to broad regional areas of lowering (USGS 2019). Subsidence and sinkholes can occur due to natural processes or because of human activities. The most common causes of subsidence include the following (USGS 2019):

- Aquifer-system compaction associated with groundwater withdrawals
- Drainage of organic soils
- Fracking and underground mining
- Earthquakes and erosion
- Natural compaction or collapse
- Expansive soils
- Hydrocompaction

In the United States, more than 17,000 square miles in 45 states, an area roughly the size of New Hampshire and Vermont combined, have been directly affected by subsidence (USGS 2018). Consequences of land subsidence include the following (USGS 2019):

- Reduced ability to store water in an aquifer
- Partially or completely submerged land
- Collapsed water well casings
- Disruption of collector drains and irrigation ditches
- Altered flow in creeks, which may increase the frequency and severity of flooding
- Damage to roadways, bridges, building foundations, and other infrastructure

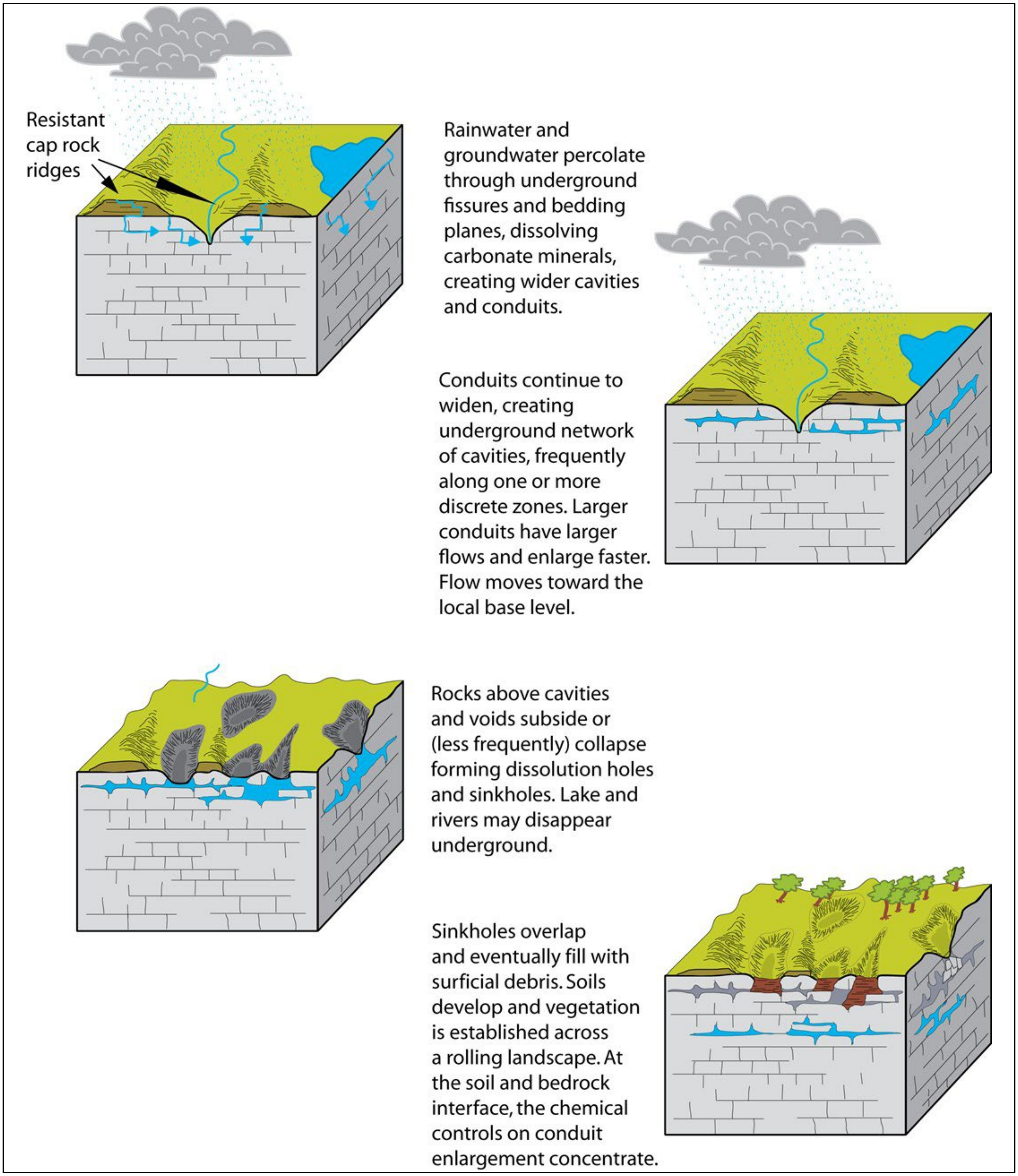
Both natural and man-made sinkholes can occur without warning. Slumping or falling fence posts, trees, or foundations, sudden formation of small ponds, wilting vegetation, discolored well water, and/or structural cracks in walls and floors are all signs that a sinkhole is forming.

Subsidence Due to Dissolving Bedrock (Karst)

Subsidence often occurs through the loss of subsurface support in areas underlain with soluble carbonate rocks (e.g., limestone and dolomite) that are gradually dissolving due to surface water or groundwater (NPS 2022). Such areas, called karst terrain, may result from several natural- and human-caused occurrences. The dissolution process causes surface depressions and the development of sinkholes, sinking streams, enlarged bedrock fractures, caves, and underground streams (NJOEM 2019). Figure 11-2 illustrates the development of karst terrain. Over 20 percent of the United States is underlain by karst terrain, but 40 percent of the nation's groundwater used for drinking is sourced from karst aquifers, increasing the potential for land subsidence and sinkholes (NPS 2022).

Sinkholes are the type of subsidence most frequently seen in New Jersey. They are a natural and common geologic feature in areas with underlying karst terrain. Over thousands of years, acidic rainwater traveling through fractures in the bedrock, slowly dissolves the bedrock, creating larger openings through which water and overlying soil materials will travel. The openings, called voids, enlarge until the ground is unable to support the land above, resulting in a collapse that forms a sinkhole (USGS 2018).

Figure 11-2. Formation of Sinkholes in Karst Terrain



Source: NPS 2022

Human Causes of Subsidence

Anthropogenic activities can accelerate the natural processes that result in soil voids and sinkholes (NJOEM 2019):

- 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
- Drilling new water wells

Leaking water pipes or structures that convey stormwater runoff may result in areas of subsidence as the water dissolves rock over time. In some cases, construction, land grading, or earth-moving activities that cause changes in stormwater flow can trigger subsidence events. Subsidence events may occur during mining activities, especially where the cover of a mine is thin. Underground extraction of materials such as oil, gas, coal, metal ores, clay, shale, limestone, or water may result in slow-moving or abrupt shifts in the ground surface (Whittaker and Reddish 1989).

According to the USGS, sinkholes are linked to groundwater pumping, construction, and development. Sinkholes can form when natural water drainage patterns are changed, and new water diversion systems are developed. Some sinkholes form when the land surface is changed, such as when industrial and runoff-storage ponds are created. The weight of the new material can trigger a collapse of supporting material, causing a sinkhole (USGS 2018).

Groundwater Withdrawal

Land subsidence can occur when groundwater is withdrawn from an area characterized predominantly by fine-grained sediment rocks. These types of rocks contain water, which is partially responsible for holding the rock's structure and form. When the water is removed, the open spaces between the fine sediments cause a partial collapse (USGS 2018). Figure 11-3 illustrates the land subsidence process, where soil layers become more compact and unstable due to the loss of groundwater.

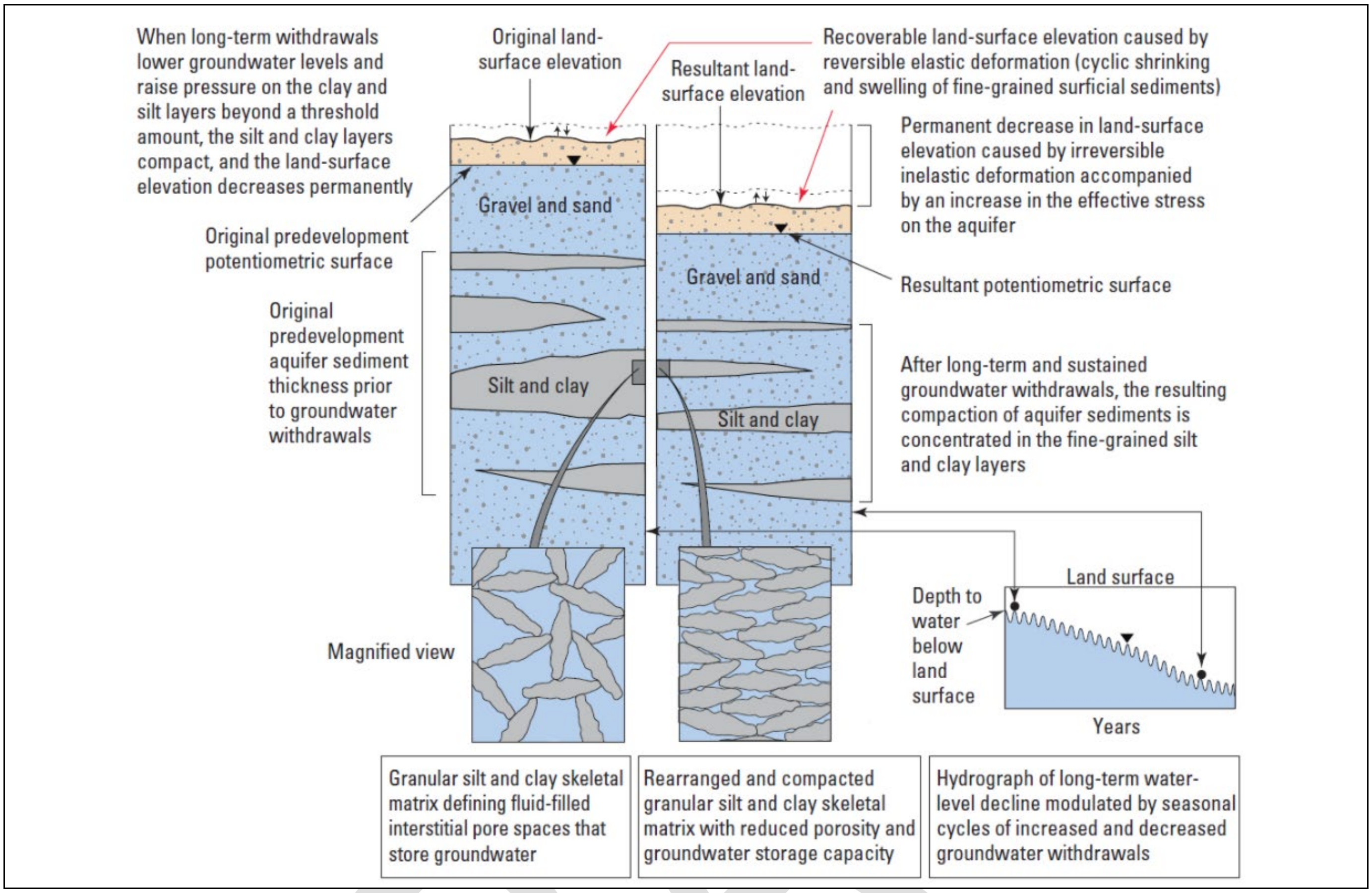
The overburdened sediments that cover underground areas in aquifer systems are balanced by groundwater pressure. The water below ground helps keep the surface soil in place. Groundwater pumping for urban water supply can produce new sinkholes. If pumping results in the lowering of groundwater levels, then underground structural failure, such as sinkholes, can occur (USGS 2018).

Abandoned Mines

New Jersey's susceptibility to subsidence is due in part to abandoned mines throughout the region. The mining industry in the state dates to the early 1600s when cooper was mined by Dutch settlers along the Delaware River in Warren County. There are almost 600 abandoned mines in New Jersey (NJDEP 2011).

The extensive mining that previously occurred in the northern part of the state has caused widespread subsidence. Many of the surface openings were improperly filled in, and roads and structures have been built adjacent to or on top of these former mine sites (NJOEM 2019). Mines create voids under the earth's surface, making areas above them more susceptible to land subsidence. Sinkholes and subsidence occur from the collapse of a mine roof into a mine opening. Areas most vulnerable to sinkholes are those where mining occurred less than 50 feet below the surface (PADEP 1999).

Figure 11-3. Subsidence Process Due to Groundwater Removal



Source: USGS n.d.

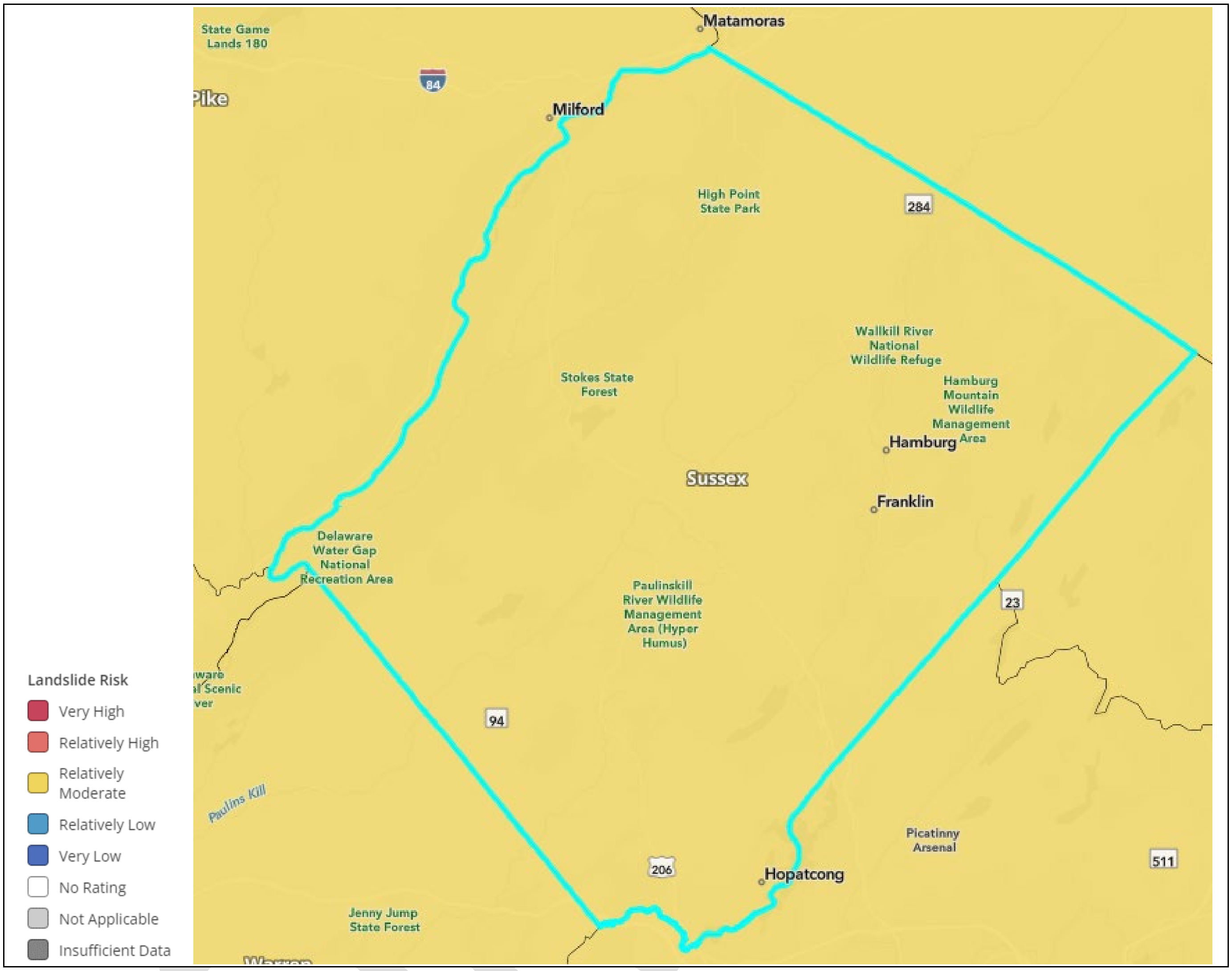
11.1.2 Location

Landslides

Landslides are common in New Jersey, primarily in northern regions. Expansion of urban and recreational developments into hillside areas exposes more people to the threat of landslides each year. Local landslide susceptibility mapping is available from multiple sources:

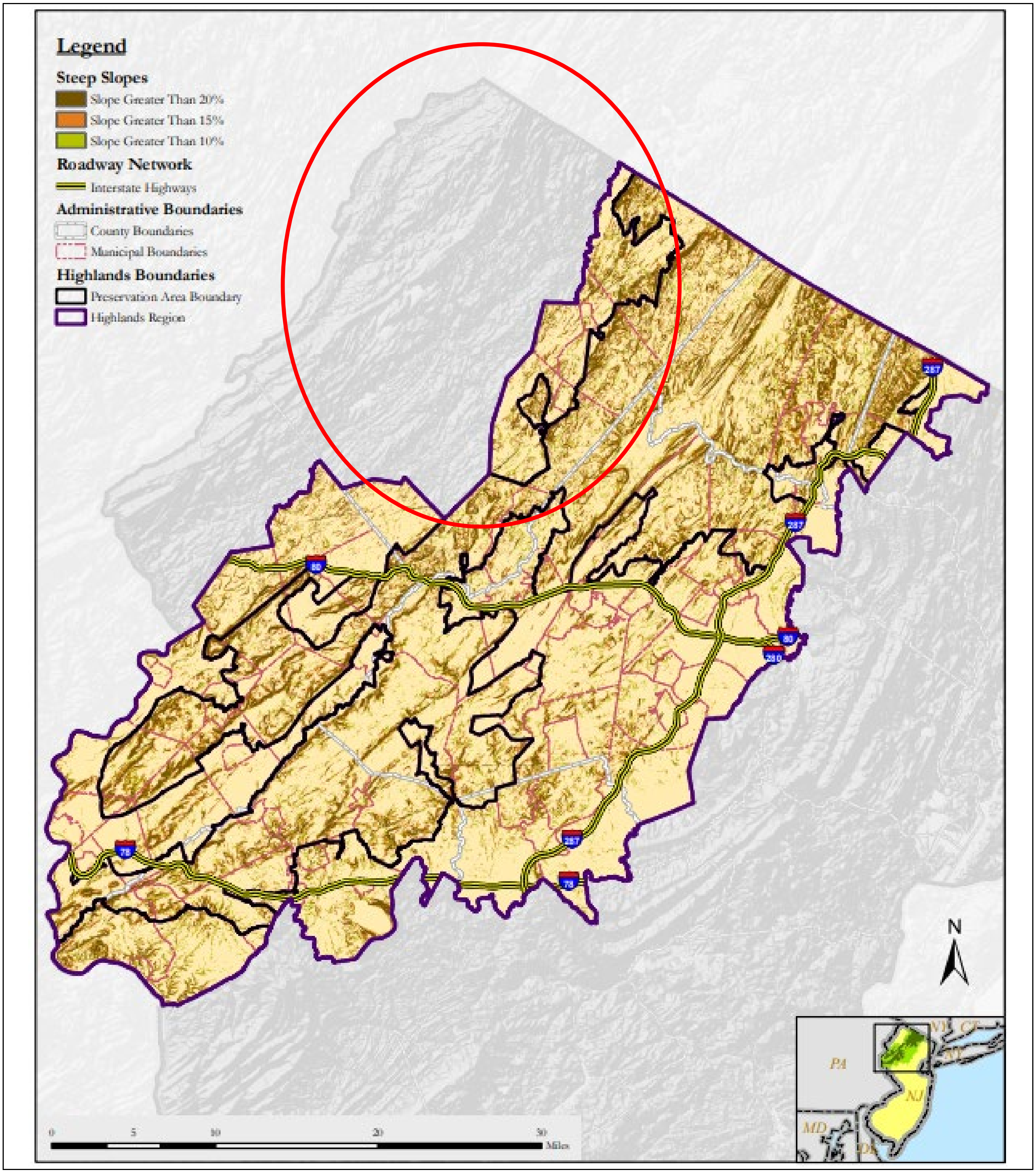
- The USGS reports a range of very high to moderate landslide potential in Sussex County (USGS 2005).
- Figure 11-4 shows a relatively moderate Landslide Risk Index for Sussex County from FEMA's National Risk Index (FEMA 2019).
- Figure 11-5 shows steep slopes in the portion of Sussex County that is within the Highlands Council Steep Stope Protection Area (New Jersey Highlands Council 2006).
- Figure 11-6 shows historical landslide locations in Sussex County. Landslides have occurred throughout Sussex County, with a large number in Vernon and Sparta. Many of the documented landslide were the result of Hurricane Irene storm damage destabilizing roads and causing debris flows. This demonstrates how landslides can become a secondary hazard during another disaster event.

Figure 11-4. National Risk Index, Landslide Index Score



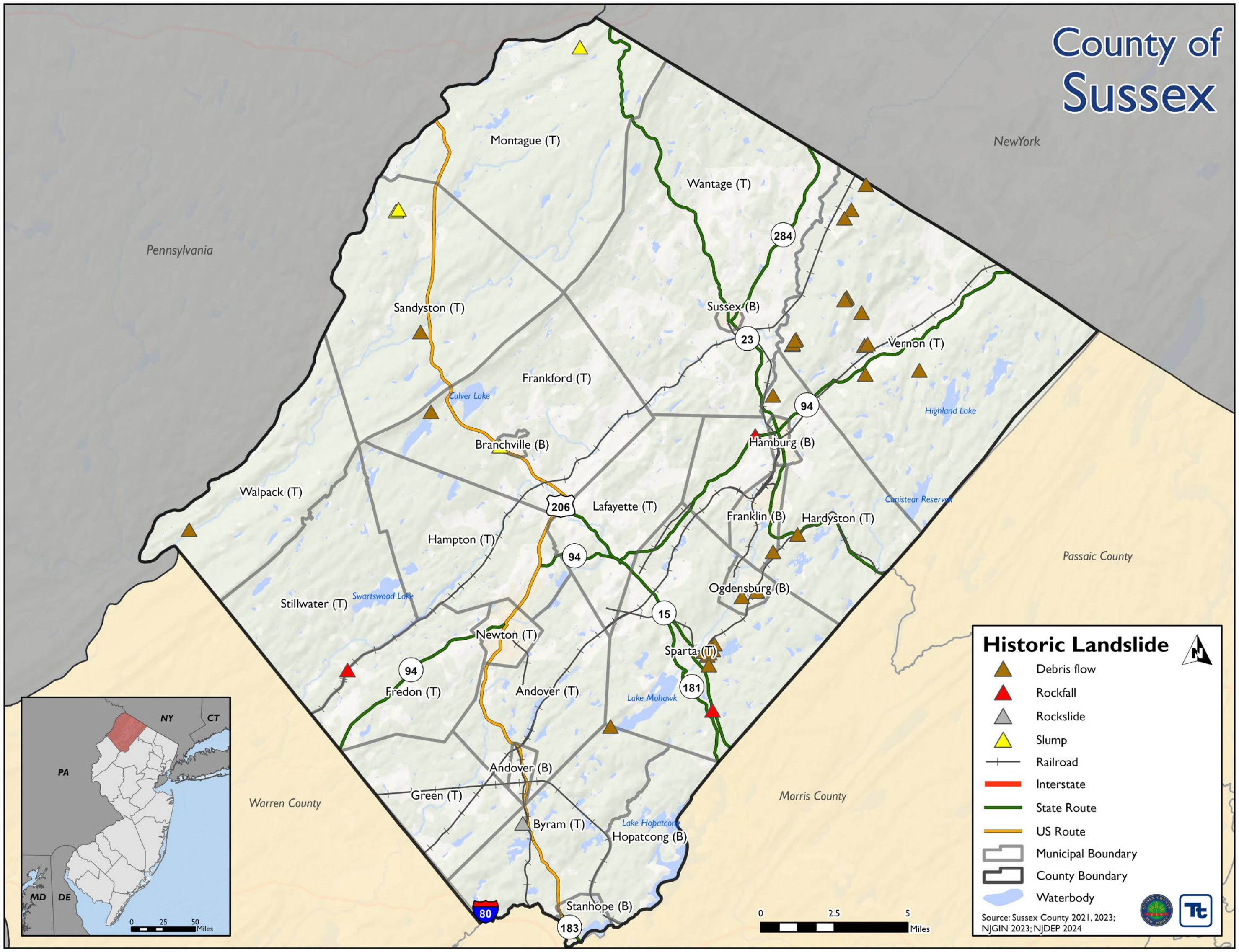
Source: FEMA 2019

Figure 11-5. Highlands Council Steep Stope Protection Area



Source: Highlands Council 2007
Note: The red circle indicates the approximate location of Sussex County.

Figure 11-6. Historical Landslides in Sussex County



Subsidence/Sinkholes

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 (NJOEM 2019). The State has recorded 382 carbonate bedrock formations, most of which (39 percent) are characterized as dolomite and minor limestone formations (NJGIN 2008). Sussex County has bands of carbonate rock running throughout the County; the only areas not containing notable bands of carbonate rock are along the southwestern border and part of the northern section. Figure 11-7 illustrates areas of carbonate bedrock located in Sussex County.

According to NJDEP, 59 of the 88 municipalities in the Highlands region contain carbonate rocks; eight of those municipalities are in Sussex County. As seen in Figure 11-8, large areas of carbonate rock formations and karst features exist in some, but not all, of these areas (Highlands Regional Master Plan 2008).

Figure 11-9 shows the location of mapped abandoned mines in Sussex County. Sussex County has 75 abandoned mines, principally in the eastern and southern portions of the County (NJDEP 2011).

11.1.3 Extent

Landslide

The extent of a landslide can be measured by the characteristics of the affected area (susceptibility) and the history of landslides (incidence). Landslide susceptibility is defined as the likely response of a geologic formation to natural or artificial cutting, to loading of slopes, or to unusually high precipitation. 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.

The “Landslide Overview Map of the Conterminous United States” classifies areas as having high, medium, or low landslide incidence and high, medium, or low susceptibility to landsliding (Radbruch-Hall, et al. 1982):

- Incidence:
  - High—More than 15 percent of a location’s area has been involved in landsliding
  - Medium—1.5 to 15 percent of a location’s area has been involved in landsliding
  - Low—Less than 1.5 percent of a location’s area has been involved in landsliding
- Susceptibility:
  - High—More than 15 percent of a location’s area would move in response to cutting or heavy rainfall
  - Medium—1.5 to 15 percent of a location’s area would move in response to cutting or heavy rainfall
  - Low—Less than 1.5 percent of a location’s area would move in response to cutting or heavy rainfall

Figure 11-10 shows USGS mapping of landslide incidence and susceptibility in the northern New Jersey region. Most of Sussex County is mapped as low incidence and susceptibility. The only exception is the northwest corner, which is mapped as moderate susceptibility and low incidence.

Figure 11-7. Carbonate Rock in Sussex County

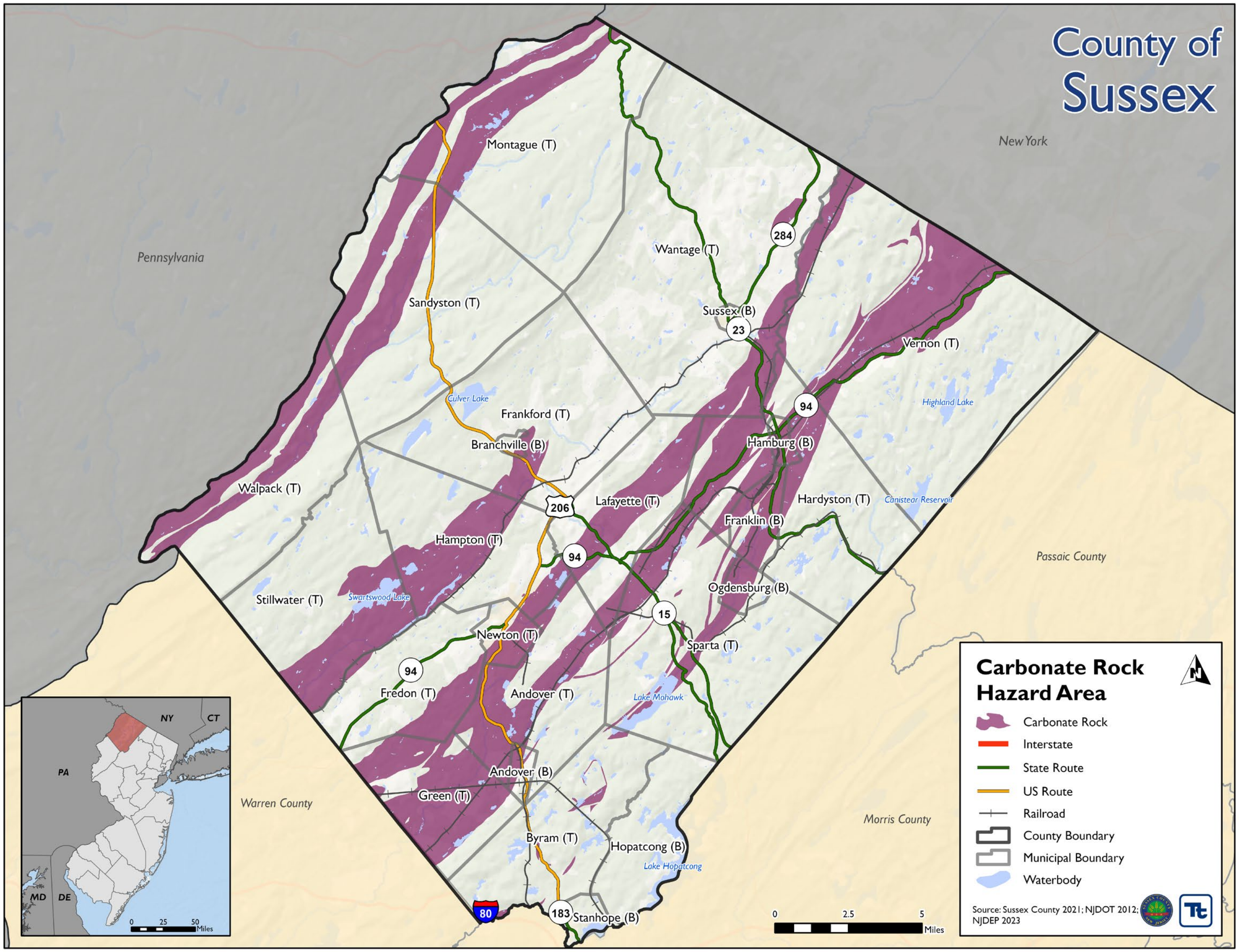
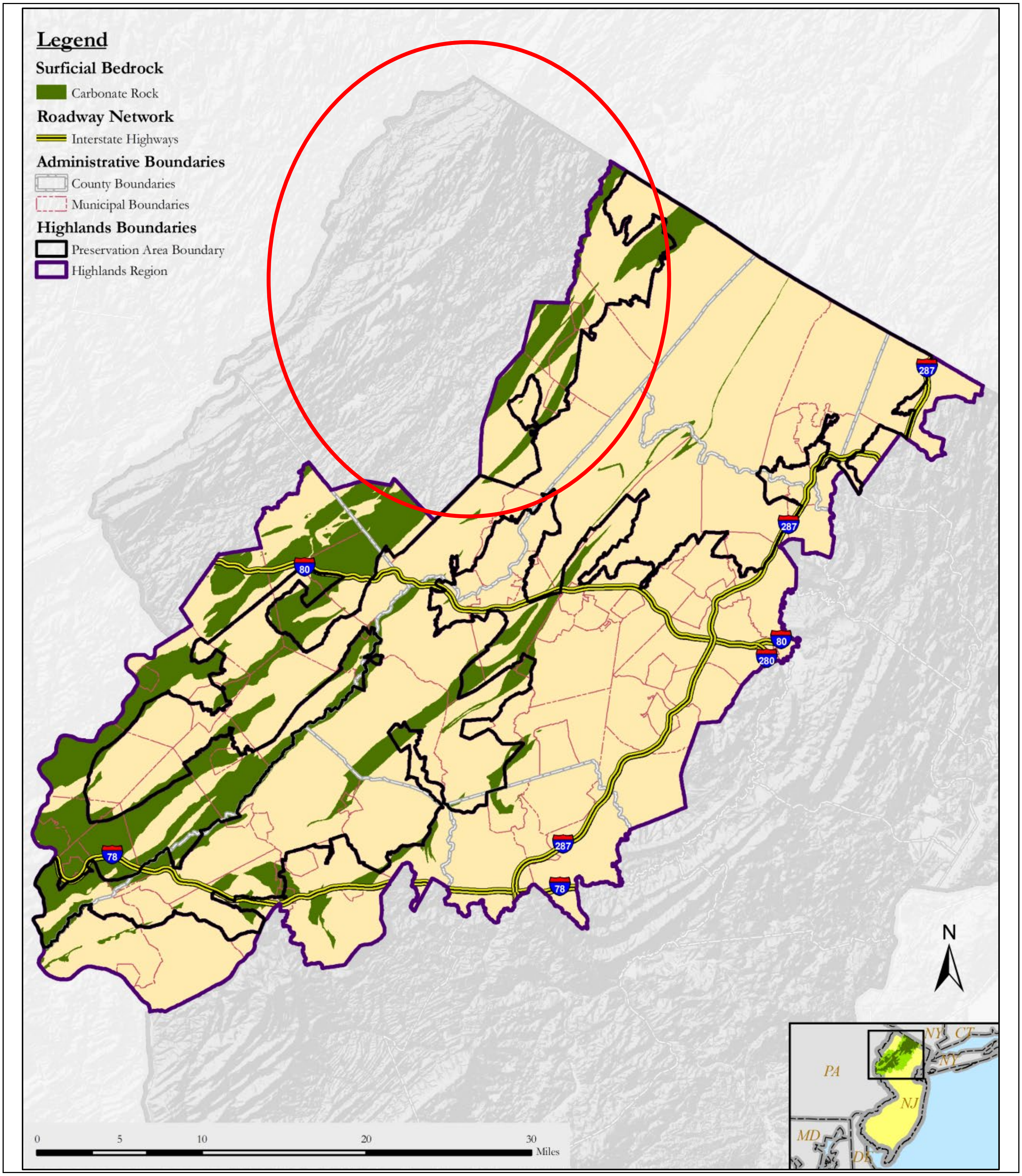


Figure 11-8. Carbonate Rock in the New Jersey Highlands



Source: New Jersey Highlands Council 2008
Note: The red circle indicates the approximate location of Sussex County.

Figure 11-9. Abandoned Mines in Sussex County

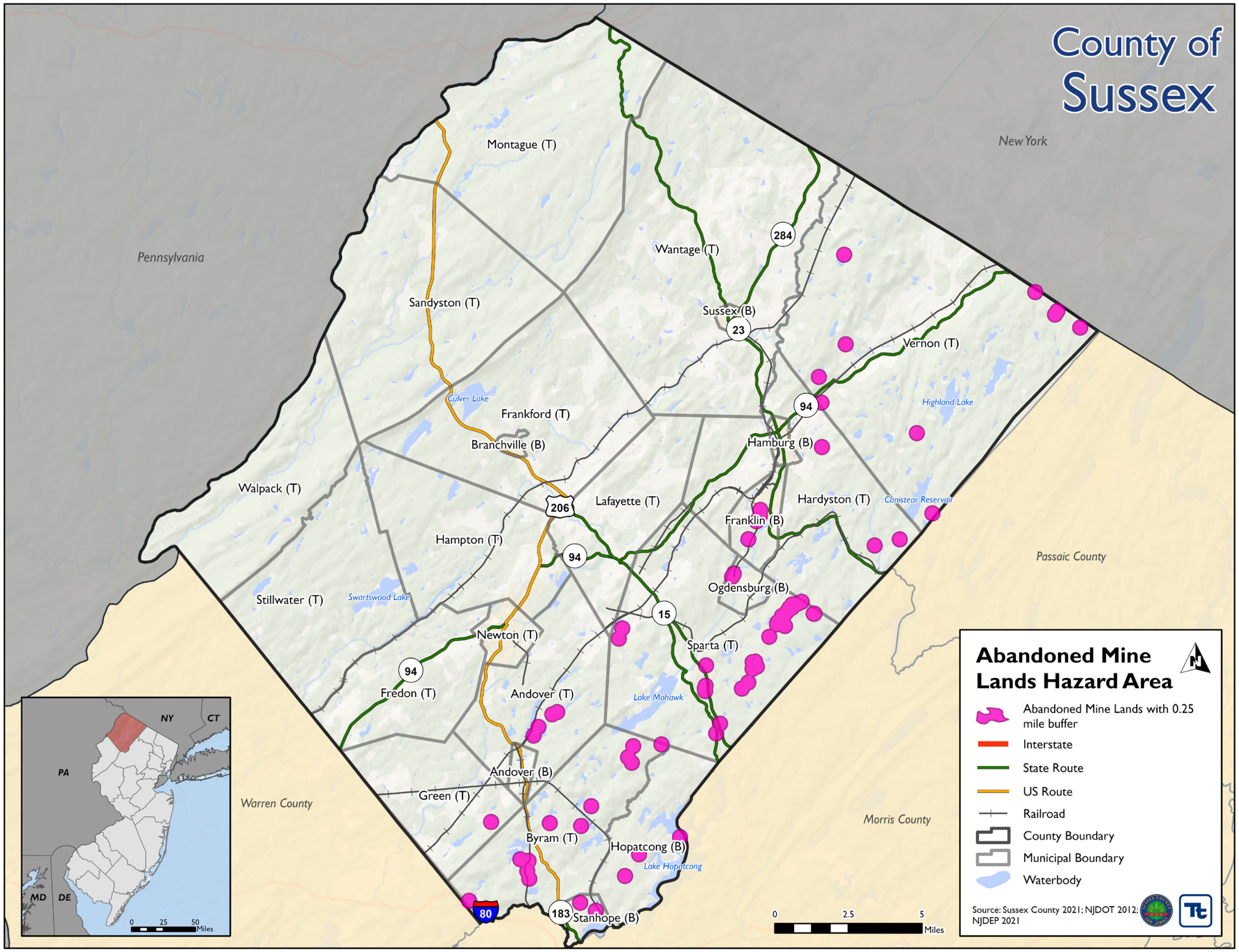
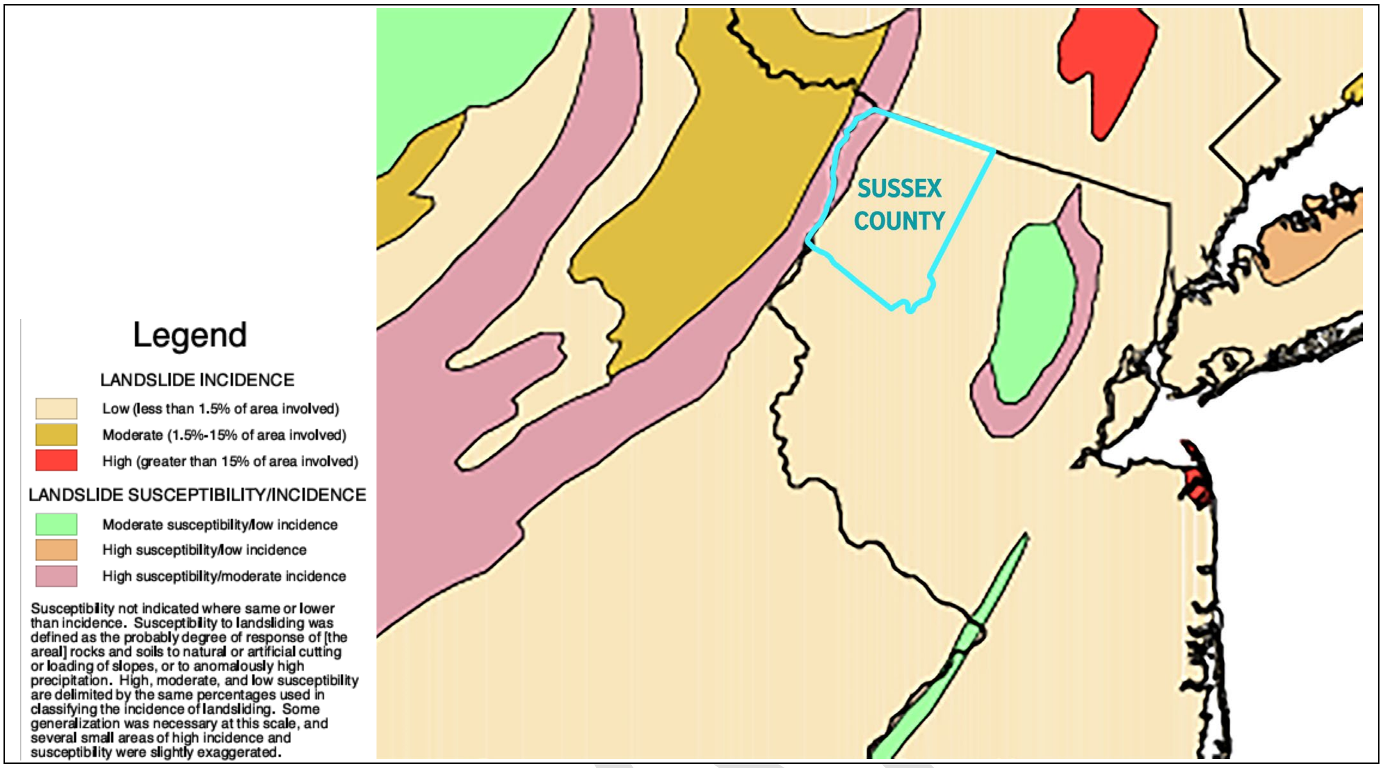


Figure 11-10. Sussex County Landslide Incidence and Susceptibility



Source: USGS 1982

A landslide also can be measured using the volume of material moved during the event. This is affected by the velocity of the landslide. The rate at which materials move ranges from inches per year to tens of miles per hour (mph) (USGS n.d.-c). A debris flow—a fast-moving slurry of water, rock, soil, vegetation, boulders, and trees—is triggered by short, intense periods of rainfall or rapid snowmelt, and can cause serious property damage and loss of life. A debris flow typically travels at about 10 mph but can exceed 35 mph in extreme cases (USGS 2022).

Subsidence/Sinkhole

Subsidence can occur abruptly or slowly and continuously over time. Sinkholes can range from steep-walled holes, to bowl, or cone-shaped depressions. When sinkholes occur in developed areas they can cause severe property damage, disruption of utilities, damage to roadways, injury, and loss of life (NJOEM 2019). There are several methods used to measure land subsidence:

- Global Positioning System (GPS) is used to monitor subsidence on a regional scale.
- USGS uses radar images from Earth-orbiting satellites to monitor subsidence by mapping land-surface deformation.
- Interferometric Synthetic Aperture Radar (InSAR) is a tool used to measure land subsidence by utilizing radar signals to track deformation in the earth's crust. USGS is using InSAR to map and monitor subsidence caused by compaction of aquifer systems (USDI, USGS 2000). Assessments of the InSAR data can be done to improve understanding of subsidence processes (USGS 2019).

11.1.4 Previous Occurrences

FEMA Major Disaster and Emergency Declarations

Sussex County has been included in one major disaster (DR) or emergency (EM) declaration specifically related to a geological hazard event (FEMA 2024). In addition, Sussex County was included in the FEMA disaster declaration for the remnants of Tropical Storm Lee in 2011 and Hurricane Ida in 2021. These disasters resulted in flood-induced landslides and mudslides. Sussex County experienced a debris flow along the lower end of Holland Circle a result of Tropical Storm Lee, as well as mudslides causing lane closures from Hurricane Ida; other minor events may have also occurred. Table 11-1 lists these declarations.

Table 11-1. FEMA Declarations for Geological Hazard Events in Sussex County

Event Date	Declaration Date	Declaration Number	Description
August 12 - 21, 2000	August 17, 2000	DR-1337	Severe Storms, Flooding, and Mudslides
September 8, 2011 - October 6, 2011	October 14, 2011	DR-4039	Remnants of Tropical Storm Lee
September 1 –3, 2021	September 5, 2021	DR-4614; EM-3573	Remnants of Hurricane Ida

Sources: FEMA 2024

USDA Declarations

The U.S. Secretary of Agriculture is authorized to designate counties as disaster areas to make emergency loans from the U.S. Department of Agriculture (USDA) to producers suffering losses in those counties and in contiguous counties. Since the previous Sussex County HMP, the County has not been included in any USDA agricultural disaster declarations related to geological hazards (USDA 2024).

Previous Events

Known geological hazard events that impacted Sussex County between January 2020 and June 2024 are listed in Table 11-2. For events prior to 2020, refer to the 2021 Sussex County HMP.

11.1.5 Probability of Future Occurrences

Probability Based on Previous Occurrences

Information on previous geological hazard occurrences in the County was used to calculate the probability of future occurrence of such events, as summarized in Table 11-3. Based on historical records and input from the Steering Committee, the probability of occurrence for geological hazards in the County is considered "rare."

Table 11-2. Geological Hazard Events in Sussex County (2020 to 2024)

Event Date	FEMA Declaration or State Proclamation Number	Sussex County included in declaration?	Location Impacted	Description
March 2021	N/A	N/A	Township of Vernon	The Township of Vernon had a relatively small sinkhole form as a result of heavy rain, snow melt and lake run off at the National Winter Activity Center. It was approximately 30" x 24" and 6' deep, connected to a spillway basin that ties into a stream. It was kept under watch and was remediated with a dam replacement project.
September 27, 2023	N/A	N/A	Township of Union	Ramsey Avenue in Township of Union was blocked off due to a sinkhole that affected a significant portion of the main road. The sinkhole occurred below the I-78 overpass. A project to mitigate the impacts from this event occurred in March 2023.

Source: NOAA-NCEI 2023; FEMA 2024

Table 11-3. Probability of Future Geological Hazard Events in Sussex County

Hazard Type	Number of Occurrences Between 1996[a] and 2023	Percent Chance of Occurring in Any Given Year
Debris Flows	27	100%
Mudslide	1	3.57%
Rockfalls	3	10.71%
Slump	3	10.71%
Sinkhole	2	7.14%
Total	**36**	**100%**

Source: NJOEM 2019; NOAA NCEI 2024; NJGWS 2024

a. *Events prior to 1996 are not included because sources of earlier data are not considered to be complete.*

Effect of Climate Change on Future Probability

Landslides

Projections of climate change for New Jersey predict increases in total annual precipitation, more intense rainfall events in fall, winter, and spring, and increased summer dry weather that can lead to wildfires that destroy vegetation growth that helps to support steep slopes (see Section 3.3.4). All these factors would increase the probability for landslide occurrences.

Northern New Jersey's 1971-2000 precipitation average was over 5 inches (12 percent) greater than the average from 1895-1970 (Office of New Jersey State Climatologist). Annual precipitation in New Jersey increased by 4.1 inches over the previous 100 years and was 8 percent above average from 2010 through 2020 (NJDEP 2019).

Subsidence/Sinkholes

One of the triggers for subsidence and sinkholes is an abundance of moisture permeating and dissolving the bedrock. Climatologists expect an increase in annual precipitation amounts, which will coincide with an increased risk in subsidence and sinkholes in vulnerable areas.

11.1.6 Cascading Impacts on Other Hazards

Landslides can cause secondary effects such as blocking roads, which can isolate residents and businesses and delay commercial, public, and private transportation. Other potential problems can result from landslides if vegetation or poles on slopes are knocked over, causing 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 can damage rivers or streams, potentially harming water quality, fisheries, and spawning habitat. Landslides can contribute to instances of flooding if the collapsed soil and sediment block streams, causing waters to flow outside of their banks. Sinkholes can pull down utility poles, structures, and vehicles. They can also impact underground pipes.

11.2 VULNERABILITY AND IMPACT ASSESSMENT

To evaluate the geological hazard, the following areas were defined as hazard areas:

- Landslide hazard areas:
  - Moderate slopes—15 to 20 percent
  - High slopes—greater than 20 percent
- Subsidence/sinkhole hazard areas:
  - 2023 NJDEP carbonate rock layer
  - Abandoned mine locations buffered by 0.25 miles

11.2.1 Life, Health, and Safety

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

Overall Population

Table 11-4 summarizes the population living in the high and moderate slope landslide hazard areas. Overall, 20,921 persons are living in the high landslide area and 16,335 persons live in the moderate landslide area. The Township of Vernon (4,883) and Township of Sparta (3,456) have the greatest number of residents living in the high landslide area. The Township of Sparta (2,801) and Township of Vernon (1,025) have the greatest number of residents living in the moderate landslide area.

Table 11-5 summarizes the population living on landscapes with carbonate karst bedrock or within 0.25 miles of an abandoned mine. Overall, 41,329 persons are living on carbonate karst bedrock and 6,369 persons live within 0.25 miles of an abandoned mine. The Town of Newton (5,550) and the Township of Vernon (4,899) have the greatest number of residents living on carbonate karst bedrock. The Borough of Hopatcong (1,916) and the Borough of Stanhope (1,025) have the greatest number of residents living within 0.25 miles of an abandoned mine.

Table 11-4. Estimated Population in the Landslide Hazard Areas

	Total Population (US Census Bureau Decennial 2020)	Population in the High Slope Landslide Hazard Area		Population in the Moderate Slope Landslide Hazard Area	
		Number of Persons	% of Jurisdiction Total	Number of Persons	% of Jurisdiction Total
Andover (B)	595	63	10.6%	45	7.6%
Andover (Twp)	5,996	704	11.7%	536	8.9%
Branchville (B)	791	67	8.5%	65	8.2%
Byram (Twp)	8,028	1,396	17.4%	847	10.6%
Frankford (Twp)	5,302	490	9.2%	494	9.3%
Franklin (B)	4,912	375	7.6%	339	6.9%
Fredon (Twp)	3,235	362	11.2%	332	10.3%
Green (Twp)	3,627	274	7.6%	271	7.5%
Hamburg (B)	3,266	254	7.8%	252	7.7%
Hampton (Twp)	4,893	381	7.8%	405	8.3%
Hardyston (Twp)	8,125	1,189	14.6%	1,269	15.6%
Hopatcong (B)	14,362	2,662	18.5%	1,909	13.3%
Lafayette (Twp)	2,358	191	8.1%	169	7.2%
Montague (Twp)	3,792	356	9.4%	462	12.2%
Newton (T)	8,374	794	9.5%	816	9.7%
Ogdensburg (B)	2,258	196	8.7%	156	6.9%
Sandyston (Twp)	1,977	359	18.2%	197	10.0%
Sparta (Twp)	19,600	3,456	17.6%	2,801	14.3%
Stanhope (B)	3,526	433	12.3%	411	11.7%
Stillwater (Twp)	4,004	475	11.9%	410	10.2%
Sussex (B)	2,024	303	15.0%	252	12.5%
Vernon (Twp)	22,358	4,883	21.8%	2,646	11.8%
Walpack (Twp)	7	0	0.0%	0	0.0%
Wantage (Twp)	10,811	1,258	11.6%	1,251	11.6%
Sussex County (Total)	**144,221**	**20,921**	**14.5%**	**16,335**	**11.3%**

Source: U.S. Census Bureau 2020, 2021; NJDEP Bureau of GIS; NJ Office of GIS NJOIT, USGS 2023; CDC/ATSDR 2020
Note: Results for population are rounded down.

Table 11-5. Estimated Population in the Subsidence/Sinkhole Hazard Areas

\	Total Population (US Census Bureau Decennial 2020)	Population in the Carbonate Karst Subsidence/Sinkhole Hazard Area		Population in the Abandoned Mine Subsidence/Sinkhole Hazard Area	
		Number of Persons	% of Jurisdiction Total	Number of Persons	% of Jurisdiction Total
Andover (B)	595	205	34.5%	595	0
Andover (Twp)	5,996	2,257	37.6%	5,996	164
Branchville (B)	791	296	37.4%	791	0
Byram (Twp)	8,028	475	5.9%	8,028	878
Frankford (Twp)	5,302	217	4.1%	5,302	0
Franklin (B)	4,912	3,677	74.9%	4,912	562
Fredon (Twp)	3,235	258	8.0%	3,235	0
Green (Twp)	3,627	2,672	73.7%	3,627	26
Hamburg (B)	3,266	2,736	83.8%	3,266	0
Hampton (Twp)	4,893	1,828	37.4%	4,893	0
Hardyston (Twp)	8,125	4,770	58.7%	8,125	100
Hopatcong (B)	14,362	0	0.0%	14,362	1,916
Lafayette (Twp)	2,358	1,375	58.3%	2,358	0
Montague (Twp)	3,792	2,169	57.2%	3,792	0
Newton (T)	8,374	5,550	66.3%	8,374	0
Ogdensburg (B)	2,258	1,741	77.1%	2,258	248
Sandyston (Twp)	1,977	577	29.2%	1,977	0
Sparta (Twp)	19,600	3,169	16.2%	19,600	558
Stanhope (B)	3,526	0	0.0%	3,526	1,025
Stillwater (Twp)	4,004	2,125	53.1%	4,004	0
Sussex (B)	2,024	0	0.0%	2,024	0
Vernon (Twp)	22,358	4,899	21.9%	22,358	892
Walpack (Twp)	7	5	71.4%	7	0
Wantage (Twp)	10,811	328	3.0%	10,811	0
Sussex County (Total)	**144,221**	**41,329**	**28.7%**	**144,221**	**6,369**

Source: U.S. Census Bureau 2020, 2021; NJGIN 2023; Sussex County 2021, 2023; NJDEP 2023; CDC/ATSDR 2020
Note: Results for population are rounded down.

Socially Vulnerable Population

Persons over the age of 65 and people below the poverty level are most vulnerable to geological hazards because of the potential limited access to mobilization or medical resources if a landslide or subsidence event occurs.

Table 11-6 presents the estimated socially vulnerable populations living in the high slope and moderate slope landslide hazard areas. There are 3,516 persons over the age of 65 years, 951 persons under the age of 5 years, 231 non-English speakers, 2,185 persons with a disability, and 985 living in poverty located in the high slope landslide hazard area. There are 2,806 persons over the age of 65 years, 732 persons under the age of 5 years, 194 non-English speakers, 1,736 persons with a disability, and 804 living in poverty located in the moderate slope landslide hazard area.

Table 11-7 presents the estimated socially vulnerable populations located in landscapes with carbonate karst bedrock or within 0.25 miles of an abandoned mine. There are 8,144 persons over the age of 65 years, 1,748 persons under the age of 5 years, 802 non-English speakers, 4,808 persons with a disability, and 2,326 living in poverty located in landscapes with carbonate karst bedrock. There are 986 persons over the age of 65 years, 307 persons under the age of 5 years, 82 non-English speakers, 638 persons with a disability, and 224 living in poverty located within 0.25-miles of an abandoned mine.

11.2.2 General Building Stock

Table 11-8 summarizes the number of buildings in the landslide hazard areas and the total replacement cost of these buildings by municipality. There are 10,107 buildings with a replacement cost value of approximately $6.8 trillion built on lands in the high landslide area. Furthermore, there are 7,714 buildings with a replacement cost value of approximately $6.1 trillion built in the moderate landslide area. The Township of Vernon has the greatest number of buildings built in the high landslide area; 2,530 buildings (21-percent of its total building stock) with an estimated replacement cost of $1 trillion. The Township of Vernon also has the greatest number of buildings built in the moderate landslide area; 1,388 buildings (11.5-percent of its total building stock) with an estimated replacement cost of $686 million.

Table 11-9 summarizes the number of buildings built in the subsidence/sinkhole hazard areas and the total replacement cost of these buildings by municipality. There are 20,634 buildings on lands with carbonate karst bedrock, with a replacement cost value of $23.9 billion. There are 3,035 buildings within 0.25 miles of an abandoned mine, with a replacement cost value of $1.6 billion. The Township of Vernon has the greatest number of buildings built on carbonate karst bedrock; 2,857 buildings (23.7-percent of its total building stock) with an estimated replacement cost of $2.4 billion. The Borough of Hopatcong has the greatest number of buildings built within 0.25-miles of an abandoned mine; 1,031 buildings (12.9-percent of its total building stock) with an estimated replacement cost of $339 million.

Table 11-10 summarizes buildings in the landslide hazard areas by general occupancy located. The exposure analysis estimates that across all subsidence hazard areas, the residential occupancy is the most exposed to landslide hazards, accounting for 91.8 percent and 92.4 percent of the buildings in the high slope landslide area and moderate slope landslide area, respectively.

Table 11-11 summarizes buildings in the subsidence/sinkhole hazard areas by general occupancy. The exposure analysis estimates that across all subsidence hazard areas, the residential occupancy is the most exposed to geological hazards, accounting for 83.2 percent and 95.1 percent of buildings on carbonate karst bedrock or within 0.25 miles of an abandoned mine, respectively.

Table 11-6. Estimated Vulnerable Persons Located in the Landslide Hazard Areas

	Vulnerable Population in the High Slope Landslide Hazard Area					Vulnerable Population in the Moderate Slope Landslide Hazard Area				
	Persons Over 65	Persons Under 5	Non-English Speaking Persons	Persons with a Disability	Persons in Poverty	Persons Over 65	Persons Under 5	Non-English Speaking Persons	Persons with a Disability	Persons in Poverty
Andover (B)	8	2	1	6	3	6	2	1	4	2
Andover (Twp)	160	28	0	61	31	122	21	0	46	23
Branchville (B)	13	3	2	7	2	13	3	2	6	2
Byram (Twp)	193	77	17	106	30	117	46	10	64	18
Frankford (Twp)	92	21	0	51	13	93	21	0	51	13
Franklin (B)	89	17	10	64	21	81	15	9	58	19
Fredon (Twp)	71	14	3	32	19	65	13	2	30	18
Green (Twp)	55	9	3	35	11	55	9	3	35	11
Hamburg (B)	35	11	25	18	13	34	11	25	18	13
Hampton (Twp)	90	15	7	57	27	95	16	8	61	28
Hardyston (Twp)	240	47	14	135	67	256	50	15	144	72
Hopatcong (B)	371	111	62	281	116	266	79	45	201	83
Lafayette (Twp)	41	13	2	20	16	36	12	2	18	14
Montague (Twp)	79	19	7	37	16	102	25	9	48	21
Newton (T)	169	24	19	113	69	174	25	19	116	71
Ogdensburg (B)	32	6	3	16	11	25	4	2	13	8
Sandyston (Twp)	58	20	0	40	13	31	10	0	22	7
Sparta (Twp)	462	204	23	273	132	374	165	19	221	107
Stanhope (B)	59	27	0	37	3	56	26	0	35	3
Stillwater (Twp)	123	11	0	65	32	106	9	0	56	28
Sussex (B)	44	13	1	52	54	37	10	0	43	45
Vernon (Twp)	805	216	20	506	191	436	117	11	274	103
Walpack (Twp)	0	0	0	0	0	0	0	0	0	0
Wantage (Twp)	227	43	12	173	95	226	43	12	172	95
Sussex County (Total)	**3,516**	**951**	**231**	**2,185**	**985**	**2,806**	**732**	**194**	**1,736**	**804**

Source: U.S. Census Bureau 2021; NJDOT 2012; Sussex County 2021
Note: Results for population are rounded down.

Table 11-7. Estimated Vulnerable Persons Located in the Subsidence/Sinkhole Hazard Areas

	Vulnerable Population in the Carbonate Karst Subsidence/Sinkhole Hazard Area					Vulnerable Population in the Abandoned Mine Subsidence/Sinkhole Hazard Area				
	Persons Over 65	Persons Under 5	Non-English Speaking Persons	Persons with a Disability	Persons in Poverty	Persons Over 65	Persons Under 5	Non-English Speaking Persons	Persons with a Disability	Persons in Poverty
Andover (B)	28	9	4	21	11	0	0	0	0	0
Andover (Twp)	515	91	0	197	100	37	6	0	14	7
Branchville (B)	61	14	10	31	13	0	0	0	0	0
Byram (Twp)	65	26	6	36	10	121	48	11	66	19
Frankford (Twp)	41	9	0	22	6	0	0	0	0	0
Franklin (B)	879	170	98	637	213	134	26	15	97	32
Fredon (Twp)	50	10	2	23	14	0	0	0	0	0
Green (Twp)	544	92	36	347	110	5	0	0	3	1
Hamburg (B)	377	119	278	201	145	0	0	0	0	0
Hampton (Twp)	431	75	36	275	130	0	0	0	0	0
Hardyston (Twp)	964	189	58	543	271	20	3	1	11	5
Hopatcong (B)	0	0	0	0	0	267	80	45	202	84
Lafayette (Twp)	298	99	19	147	116	0	0	0	0	0
Montague (Twp)	482	120	46	226	100	0	0	0	0	0
Newton (T)	1,184	172	134	792	485	0	0	0	0	0
Ogdensburg (B)	288	55	31	149	97	41	7	4	21	13
Sandyston (Twp)	93	32	0	65	22	0	0	0	0	0
Sparta (Twp)	423	187	21	250	121	74	33	3	44	21
Stanhope (B)	0	0	0	0	0	140	65	0	88	8
Stillwater (Twp)	550	51	0	294	145	0	0	0	0	0
Sussex (B)	0	0	0	0	0	0	0	0	0	0
Vernon (Twp)	807	217	20	507	192	147	39	3	92	34
Walpack (Twp)	5	0	0	0	0	0	0	0	0	0
Wantage (Twp)	59	11	3	45	25	0	0	0	0	0
Sussex County (Total)	**8,144**	**1,748**	**802**	**4,808**	**2,326**	**986**	**307**	**82**	**638**	**224**

Source: U.S. Census Bureau 2021; NJDOT 2012; Sussex County 2021
Note: Results for population are rounded down.

Table 11-8. Number and Value of Buildings Built in the Landslide Hazard Areas, by Municipality

	Jurisdiction Total Buildings		High Slope Landslide Hazard Area				Moderate Slope Landslide Hazard Area			
			Number of Buildings		Replacement Cost Value		Number of Buildings		Replacement Cost Value	
	Count	Replacement Cost Value	Count	% of Jurisdiction Total	Value	% of Jurisdiction Total	Count	% of Jurisdiction Total	Value	% of Jurisdiction Total
Andover (B)	326	$693,607,785	30	9.2%	$84,851,904	12.2%	22	6.7%	$14,937,299	2.2%
Andover (Twp)	2,577	$4,012,892,721	287	11.1%	$429,401,649	10.7%	218	8.5%	$489,814,622	12.2%
Branchville (B)	426	$598,388,025	30	7.0%	$22,831,953	3.8%	31	7.3%	$21,203,392	3.5%
Byram (Twp)	3,676	$3,162,144,221	603	16.4%	$394,980,945	12.5%	375	10.2%	$549,573,138	17.4%
Frankford (Twp)	3,529	$3,491,793,002	303	8.6%	$189,028,522	5.4%	308	8.7%	$336,138,928	9.6%
Franklin (B)	2,058	$2,227,977,138	158	7.7%	$270,405,197	12.1%	139	6.8%	$173,759,118	7.8%
Fredon (Twp)	1,615	$1,542,422,915	174	10.8%	$117,580,742	7.6%	150	9.3%	$106,536,412	6.9%
Green (Twp)	1,697	$1,821,582,866	130	7.7%	$104,158,588	5.7%	115	6.8%	$96,438,967	5.3%
Hamburg (B)	1,593	$1,809,235,911	131	8.2%	$200,223,008	11.1%	122	7.7%	$260,564,737	14.4%
Hampton (Twp)	2,761	$2,474,023,610	216	7.8%	$128,537,181	5.2%	220	8.0%	$164,434,727	6.6%
Hardyston (Twp)	4,401	$3,681,458,622	610	13.9%	$272,210,653	7.4%	640	14.5%	$341,801,016	9.3%
Hopatcong (B)	8,004	$3,432,619,930	1,457	18.2%	$509,910,100	14.9%	1,048	13.1%	$376,504,480	11.0%
Lafayette (Twp)	1,463	$2,142,628,709	115	7.9%	$103,828,169	4.8%	89	6.1%	$76,864,103	3.6%
Montague (Twp)	2,175	$1,659,675,649	196	9.0%	$86,148,793	5.2%	239	11.0%	$105,538,715	6.4%
Newton (T)	2,676	$5,699,120,026	240	9.0%	$363,498,898	6.4%	246	9.2%	$310,627,969	5.5%
Ogdensburg (B)	992	$954,409,603	87	8.8%	$46,086,565	4.8%	66	6.7%	$24,652,221	2.6%
Sandyston (Twp)	1,526	$1,350,071,503	234	15.3%	$274,764,211	20.4%	138	9.0%	$81,770,500	6.1%
Sparta (Twp)	8,127	$10,316,900,290	1,362	16.8%	$1,037,361,205	10.1%	1,106	13.6%	$976,202,794	9.5%
Stanhope (B)	1,552	$1,228,753,628	186	12.0%	$85,342,689	6.9%	175	11.3%	$97,522,202	7.9%
Stillwater (Twp)	2,487	$1,611,608,776	290	11.7%	$155,280,322	9.6%	230	9.2%	$121,387,915	7.5%
Sussex (B)	677	$2,187,092,184	103	15.2%	$368,327,856	16.8%	83	12.3%	$362,896,317	16.6%
Vernon (Twp)	12,039	$6,816,863,576	2,530	21.0%	$1,042,734,539	15.3%	1,388	11.5%	$686,404,866	10.1%
Walpack (Twp)	51	$68,015,712	7	13.7%	$27,328,302	40.2%	4	7.8%	$5,048,870	7.4%
Wantage (Twp)	5,509	$5,527,803,803	628	11.4%	$508,755,997	9.2%	562	10.2%	$392,530,176	7.1%
Sussex County (Total)	**71,937**	**$68,511,090,204**	**10,107**	**14.0%**	**$6,823,577,988**	**10.0%**	**7,714**	**10.7%**	**$6,173,153,486**	**9.0%**

Source: Sussex County 2023; NJOGIS, Civil Solutions, Spatial Data Logic; RS Means 2022; NJDEP 2023; NJDEP Bureau of GIS; NJ Office of GIS NJOIT, USGS 2023

Table 11-9. Number and Value of Buildings Built in the Subsidence/Sinkhole Hazard Areas, by Municipality

	Jurisdiction Total Buildings		Carbonate Karst Subsidence/Sinkhole Hazard Area				Abandoned Mine Subsidence/Sinkhole Hazard Area			
			Number of Buildings		Replacement Cost Value		Number of Buildings		Replacement Cost Value	
	Count	Replacement Cost Value	Count	% of Jurisdiction Total	Value	% of Jurisdiction Total	Count	% of Jurisdiction Total	Value	% of Jurisdiction Total
Andover (B)	326	$693,607,785	121	37.1%	$320,267,859	46.2%	0	0.0%	$0	0.0%
Andover (Twp)	2,577	$4,012,892,721	1,013	39.3%	$1,115,273,725	27.8%	61	2.4%	$28,403,619	0.7%
Branchville (B)	426	$598,388,025	145	34.0%	$184,636,652	30.9%	0	0.0%	$0	0.0%
Byram (Twp)	3,676	$3,162,144,221	241	6.6%	$143,006,808	4.5%	388	10.6%	$247,533,203	7.8%
Frankford (Twp)	3,529	$3,491,793,002	174	4.9%	$312,081,741	8.9%	0	0.0%	$0	0.0%
Franklin (B)	2,058	$2,227,977,138	1,568	76.2%	$1,715,235,362	77.0%	242	11.8%	$314,908,179	14.1%
Fredon (Twp)	1,615	$1,542,422,915	128	7.9%	$128,671,683	8.3%	0	0.0%	$0	0.0%
Green (Twp)	1,697	$1,821,582,866	1,270	74.8%	$1,518,168,438	83.3%	15	0.9%	$9,984,538	0.5%
Hamburg (B)	1,593	$1,809,235,911	1,323	83.1%	$1,470,386,117	81.3%	0	0.0%	$0	0.0%
Hampton (Twp)	2,761	$2,474,023,610	1,018	36.9%	$752,201,778	30.4%	0	0.0%	$0	0.0%
Hardyston (Twp)	4,401	$3,681,458,622	2,591	58.9%	$2,464,946,699	67.0%	50	1.1%	$32,357,056	0.9%
Hopatcong (B)	8,004	$3,432,619,930	0	0.0%	$0	0.0%	1,031	12.9%	$339,413,809	9.9%
Lafayette (Twp)	1,463	$2,142,628,709	789	53.9%	$915,626,081	42.7%	0	0.0%	$0	0.0%
Montague (Twp)	2,175	$1,659,675,649	1,263	58.1%	$1,056,880,331	63.7%	0	0.0%	$0	0.0%
Newton (T)	2,676	$5,699,120,026	1,677	62.7%	$2,105,906,361	37.0%	0	0.0%	$0	0.0%
Ogdensburg (B)	992	$954,409,603	780	78.6%	$849,309,854	89.0%	114	11.5%	$61,470,836	6.4%
Sandyston (Twp)	1,526	$1,350,071,503	530	34.7%	$535,685,808	39.7%	0	0.0%	$0	0.0%
Sparta (Twp)	8,127	$10,316,900,290	1,572	19.3%	$4,266,097,281	41.4%	232	2.9%	$233,229,672	2.3%
Stanhope (B)	1,552	$1,228,753,628	0	0.0%	$0	0.0%	441	28.4%	$185,991,698	15.1%
Stillwater (Twp)	2,487	$1,611,608,776	1,268	51.0%	$857,062,613	53.2%	0	0.0%	$0	0.0%
Sussex (B)	677	$2,187,092,184	0	0.0%	$0	0.0%	0	0.0%	$0	0.0%
Vernon (Twp)	12,039	$6,816,863,576	2,857	23.7%	$2,441,115,486	35.8%	461	3.8%	$151,997,698	2.2%
Walpack (Twp)	51	$68,015,712	45	88.2%	$55,790,111	82.0%	0	0.0%	$0	0.0%
Wantage (Twp)	5,509	$5,527,803,803	261	4.7%	$755,058,868	13.7%	0	0.0%	$0	0.0%
Sussex County (Total)	**71,937**	**$68,511,090,204**	**20,634**	**28.7%**	**$23,963,409,656**	**35.0%**	**3,035**	**4.2%**	**$1,605,290,309**	**2.3%**

Source : Sussex County 2023; NJOGIS, Civil Solutions, Spatial Data Logic; RS Means 2022; NJDEP 2021; NJDEP 2023

Table 11-10. Buildings on Lands in the Landslide Hazard Areas, by General Occupancy Class

	High Slope Landslide Hazard Area				Moderate Slope Landslide Hazard Area			
	Residential	Commercial	Industrial	Other[a]	Residential	Commercial	Industrial	Other[a]
Andover (B)	25	4	0	1	18	2	0	2
Andover (Twp)	252	8	1	26	192	9	0	17
Branchville (B)	29	1	0	0	28	2	0	1
Byram (Twp)	582	6	0	15	353	11	0	11
Frankford (Twp)	257	8	0	38	259	9	0	40
Franklin (B)	138	12	1	7	125	9	0	5
Fredon (Twp)	136	2	0	36	125	2	0	23
Green (Twp)	104	4	0	22	103	2	0	10
Hamburg (B)	115	15	1	0	114	7	0	1
Hampton (Twp)	180	4	0	32	191	2	0	27
Hardyston (Twp)	580	14	0	16	619	5	1	15
Hopatcong (B)	1,417	25	0	15	1,016	16	0	16
Lafayette (Twp)	78	7	2	28	69	7	0	13
Montague (Twp)	176	4	0	16	228	3	0	8
Newton (T)	213	16	0	11	219	13	1	13
Ogdensburg (B)	79	5	0	3	63	1	0	2
Sandyston (Twp)	199	8	1	26	109	7	0	22
Sparta (Twp)	1,299	30	1	32	1,053	33	1	19
Stanhope (B)	178	7	0	1	169	4	0	2
Stillwater (Twp)	235	11	0	44	203	3	0	24
Sussex (B)	83	15	1	4	69	14	0	0
Vernon (Twp)	2,441	42	3	44	1,323	27	1	37
Walpack (Twp)	0	1	0	6	0	3	0	1
Wantage (Twp)	486	11	0	131	483	5	0	74
Sussex County (Total)	**9,282**	**260**	**11**	**554**	**7,131**	**196**	**4**	**383**

Source: Sussex County 2023; NJOGIS, Civil Solutions, Spatial Data Logic; NJDEP 2023; NJDEP Bureau of GIS; NJ Office of GIS NJOIT, USGS 2023

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

Table 11-11. Buildings on Lands in the Subsidence/Sinkhole Hazard Areas, by General Occupancy Class

	Carbonate Karst Subsidence/Sinkhole Hazard Area				Abandoned Mine Subsidence/Sinkhole Hazard Area			
	Residential	Commercial	Industrial	Other[a]	Residential	Commercial	Industrial	Other[a]
Andover (B)	81	29	0	11	0	0	0	0
Andover (Twp)	808	73	8	124	59	0	0	2
Branchville (B)	127	15	1	2	0	0	0	0
Byram (Twp)	198	7	0	36	366	6	0	16
Frankford (Twp)	114	13	0	47	0	0	0	0
Franklin (B)	1,353	141	10	64	207	14	3	18
Fredon (Twp)	97	0	4	27	0	0	0	0
Green (Twp)	1,014	28	4	224	10	0	0	5
Hamburg (B)	1,234	68	6	15	0	0	0	0
Hampton (Twp)	862	16	0	140	0	0	0	0
Hardyston (Twp)	2,327	123	16	125	49	0	0	1
Hopatcong (B)	0	0	0	0	1,020	9	0	2
Lafayette (Twp)	560	32	20	177	0	0	0	0
Montague (Twp)	1,070	61	2	130	0	0	0	0
Newton (T)	1,488	132	14	43	0	0	0	0
Ogdensburg (B)	702	50	0	28	100	7	0	7
Sandyston (Twp)	319	29	2	180	0	0	0	0
Sparta (Twp)	1,191	235	32	114	210	9	2	11
Stanhope (B)	0	0	0	0	421	14	0	6
Stillwater (Twp)	1,050	71	0	147	0	0	0	0
Sussex (B)	0	0	0	0	0	0	0	0
Vernon (Twp)	2,449	171	21	216	446	7	6	2
Walpack (Twp)	9	21	0	15	0	0	0	0
Wantage (Twp)	127	76	1	57	0	0	0	0
Sussex County (Total)	**17,180**	**1,391**	**141**	**1,922**	**2,888**	**66**	**11**	**70**

Source: Sussex County 2023; NJOGIS, Civil Solutions, Spatial Data Logic; NJDEP 2023

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

11.2.3 Community Lifelines and Other Critical Facilities

A significant amount of infrastructure can be exposed to geological hazards (USGS 2023):

- *Roads*—Access to major roads is crucial to life-safety after a disaster event and to response and recovery operations. Landslides and sinkholes can block egress and ingress on roads, causing isolation for neighborhoods, traffic problems, and delays for public and private transportation. This can result in economic losses for businesses. Portions of Interstate I-80, US Route US-206, and State Routes, including NJ-15, NJ-94, NJ-183, and NJ-23 are in the mine subsidence hazard area.
- *Bridges*—Landslides 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. Sinkholes can swallow utility lines and cause impacts on underground pipes. Resulting power and communication failures can create problems for vulnerable populations and businesses.
- *Rail Lines*—Rail lines are important for response and recovery operations after a disaster. Landslides can block travel along the rail lines A detour for a rail line is not as easy as a detour for a local road or highway. Many residents rely on public transport to get to work around the County and into New York City, and a landslide event could prevent travel to and from work.

Water and sewer infrastructure also may be exposed to geological hazards.

11.2.4 Economy

Geological hazards can impose direct and indirect impacts on society. Direct costs include the damage sustained by buildings, property, and infrastructure due to a hazard event. Such events also threaten transportation corridors, fuel and energy conduits, and communication lines (USGS 2020). Indirect costs, such as clean-up costs, business interruption, loss of tax revenues, reduced property values, and loss of productivity may also occur. Building damage impacts the local tax base and economy. Subsidence and sinkholes can block access to roads, which can isolate residents and businesses and delay commercial, public, and private transportation.

11.2.5 Natural, Historic and Cultural Resources

Natural

Steep slopes in the Highlands Region play an important ecological, recreational, scenic, and functional role. They provide specialized habitats for rare plant and animal species. Areas of steep slope provide recreational opportunities and contribute to the rural character of the Highlands Region and Sussex County. Disturbance of areas containing steep slopes can trigger erosion and sedimentation, resulting in the loss of topsoil. Silting of water bodies degrades wetland and aquatic habitats that are found throughout the region and receive the state's highest water quality protections. Steep slope disturbance can result in the loss of habitat quality, degradation of surface water quality, silting of wetlands, and alteration of drainage patterns (NJ Highlands Council 2012).

Historic

Landslide impacts on historic resources within the County are highest in areas near hillsides that are characterized by unstable soil and erosion. Historical landmarks in these areas are highly susceptible to landslides, especially following seismic activity.

Cultural

Landslide impacts on cultural resources within the County are highest in areas near hillsides that are characterized by unstable soil and erosion. Cultural landmarks in these areas are highly susceptible to landslides, especially following seismic activity.

11.3 CHANGE OF VULNERABILITY SINCE 2021 HMP

Overall, the County's vulnerability to geological hazards has not changed, and the entire County will continue to be vulnerable to these hazards. Any change in vulnerability since the previous HMP would be attributed to changes in population density and new development. This updated HMP used updated building stock and critical asset inventories to assess the County's risk to these assets. The building inventory was updated using RSMeans 2022 values, which are more current and reflect replacement cost rather than the building stock improvement values reported in the 2021 HMP. Further, the 2021 5-year population estimates from the American Community Survey were used to evaluate the population exposed to the geological hazard areas.

11.4 FUTURE CHANGES THAT MAY AFFECT RISK

Understanding future changes that affect vulnerability can assist in planning for future development and ensure establishment of appropriate mitigation, planning, and preparedness measures. The following sections examine potential conditions that may affect hazard vulnerability.

11.4.1 Potential or Planned Development

Any areas of growth could be impacted by the geological hazard if located within the identified hazard areas or downslope. In general, development of slopes is not recommended due to the increased risk of erosion, stormwater runoff, and flooding. The Highlands Council has template ordinances available to define Steep Slope Protection Areas and protect against their disturbance. In addition, there are recommendations for site design for permitted disturbances to minimize impacts. Geological make-up should also be considered for future development; certain soils, such as limestone, are more prone to sinkholes.

Sinkholes may form when the land surface is changed, such as when industrial and runoff-storage ponds are created. The weight of new material can trigger an underground collapse of supporting material, causing a sinkhole. Additionally, the overburden sediments that cover buried cavities in the aquifer systems are balanced by groundwater fluid pressure. Groundwater is helping keep the surface soil in place. Pumping groundwater for urban water supply and irrigation can produce new sinkholes. If pumping results in a lowering of groundwater levels, then underground structural failure may occur (USGS 2018).

11.4.2 Projected Changes in Population

The New Jersey Department of Labor and Workforce Development produced population projections by County from 2014 to 2019, 2024, 2029, and 2034. According to these projections, Sussex County is projected to have a decrease in population in the upcoming years. These projection totals include a population of 140,400 by 2024, 137,300 by 2029, and 136,600 by 2034 (State of New Jersey 2017).

Changes in density can create issues for local residents during evacuation of a landslide or ground failure event and can have an effect on commuters that travel into and out of the County for work, particularly during a geologic event (such as a sinkhole) that breaches major transportation corridors, which are also major commuter roads.

11.4.3 Climate Change

The County is expected to see an increase in average annual temperatures and precipitation due to climate change. Increased severe storm and heavy rainfall events may elevate the likelihood of a landslide occurring in steep sloped areas because precipitation may fall faster or in larger quantities than the soil can absorb in a given timeframe. However, these changes depend on to what degree steep sloped areas are developed and other climate trends, such as seasonal precipitation and drought, which affect vegetation growth.

Higher temperatures and the possibility of more intense, less frequent summer rainfall may lead to changes in water resource availability. Increase in average temperatures may lead to an increase in the frequency of droughts. Sinkhole activity intensifies in some karst areas during periods of drought. With an increase in drought periods, the number of sinkholes could increase. Additionally, changes to the water balance of an area including 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 will cause sinkholes. These actions can also serve to accelerate the natural processes of bedrock degradation, which can have a direct impact on sinkhole creation.