5.4.4 Land Failure

This section provides a profile and vulnerability assessment for the land failure hazard.

5.4.4.1 Hazard Profile

This section provides profile information including description, extent, location, previous occurrences and losses and the probability of future occurrences.

Description

According to the U.S. Geological Survey (USGS), land failure or "ground failure" is the term used to describe zones of ground cracking, fissuring, and localized horizontal and vertical permanent ground displacement that can form by a variety of mechanisms on gently sloping valley floors. Land failure may be caused by surface rupture along faults, secondary movement on shallow faults, shaking-induced compaction of natural deposits in sedimentary basins and river valleys, and liquefaction of loose, sandy sediment (USGS, 2005).

These types of land failures, particularly landslides and land subsidence, impose many direct and indirect costs on a community. Direct costs include the actual damage sustained by buildings and property. Indirect costs are harder to measure and include business disruption, loss of tax revenues, reduced property values, loss of productivity, losses in tourism, and losses from litigation. They have a significant adverse effect on infrastructure and threaten transportation corridors, fuel and energy conduits, and communications linkages. Land failure events have devastating economic effects on Federal, State, local, and private roads, bridges, and tunnels every year. Railroads, pipelines, electric and telecommunication lines, dams, offshore oil and gas production facilities, port facilities, and waste repositories are continually affected by land movement. Road building and construction often exacerbate the landslide problem in hilly areas by altering the landscape, slopes, and drainages and by changing runoff directions and causing channeling, thereby increasing the potential for landslides. Landslides and others forms of land failure also have adverse environmental consequences, such as dramatically increased soil erosion, siltation of streams and reservoirs, blockage of stream drainages, and loss of valuable watershed, grazing, and timber lands (Spiker and Gori, 2000).

The historic record indicates Putnam County has been impacted by land failure, more specifically landslide, land subsidence, and sinkholes in the past. The County is still vulnerable to this natural hazard. For the purpose of this HMP, only these three types of land failure will be discussed in more detail. Few incidences of other types of land failures were found; therefore, no further assessments of erosion or mudslides were deemed necessary, unless they are linked with a landslide, land subsidence, or sinkhole incident.

Landslide

According to the U.S. 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.

Landslide materials may be composed of natural rock, soil, artificial fill, or a combination of these materials. They can be caused by numerous factors such as volcanic eruptions, earthquakes, fire, storms, and by human land modifications. Landslides can transpire quickly with little to no warning. Depending on the location of a landslide, they can pose significant risks to health, safety, transportation, as well as other services. Annually, landslides in the U.S. cause approximately $3.5 billion in damages and between 25 and 50 fatalities (NYS HMP 2014).

Subsidence/Sinkholes

Land subsidence is the sudden sinking or gradual downward settling of land with little or no horizontal motion, caused by a loss of subsurface support which may result from a number of natural and human caused occurrences including subsurface mining, pumping of oil, or groundwater. These events, depending on their location, can pose significant risks to health and safety, interruption to transportation, and other services (NYS HMP 2014).

Depressions, cracks, and sinkholes in the earth's surface can threaten people and property. Subsidence depressions, which normally occur over many days to a few years, may damage structures with low strain tolerances such as dams, factories, nuclear reactors, and utility lines. The sudden collapse of the ground surface to form sinkholes, many yards wide and deep, within the span of a few minutes to a few hours poses immediate threat to life and property (NYS HMP 2014).

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.

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. As a result, the landslide hazard is often represented by landslide incidence and/or susceptibility, defined below:

- Landslide incidence is the number of landslides that have occurred in a given geographic area. High incidence means greater than 15-percent of a given area has been involved in landsliding; medium incidence means that 1.5 to 15-percent of an area has been involved; and low incidence means that less than 1.5-percent of an area has been involved. (Geological Hazards Program, Date Unknown).
- 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 (Geological Hazards Program, Date Unknown; OAS, 1991).

Land Subsidence/Sinkholes

Several methods are available to monitor the extent and severity of land subsidence. The most basic approaches use repeated surveys with conventional or Global Positioning System (GPS) leveling. Another approach is to use permanent compaction recorders, or vertical extensometers. These devices use a pipe or a cable inside a well casing. The pipe inside the casing extends from land surface to some depth through compressible sediments. A table at land surface holds instruments that monitor change in distance between the top of the pipe and the table. If the inner pipe and casing go through the entire thickness of compressible sediments, then the device measures actual land subsidence. If both groundwater levels and compaction of sediments are measured, then the data can be analyzed to determine properties that can be used to predict future subsidence (Leake, 2013).

A mapping tool called Interferometric Synthetic Aperture Radar (InSAR) is a powerful tool that uses radar signals to measure deformation of the earth's crust. This is a critical element in the assessment and mitigation of subsidence. InSAR is capable of remotely sensing small changes in land surface elevation. InSAR is being used by the USGS and others to map and monitor land subsidence caused by the compaction of aquifer systems. The new displacement maps enhance the capabilities of monitoring and managing subsidence caused by the compaction of susceptible aquifer systems (Galloway et al., 2000).

The predominant conditions that lend to the overall risk of sinkhole occurrence include, as mentioned previously, underlying soil and rock type, natural and human impact on ground water, and occurrence of underground mining (natural and human caused). These conditions affect the location and probability of where a sinkhole event would occur, and can be generally classified as either underlying rock type or triggers.

Human activity can often be the cause of a sinkhole. Leaking water pipes or structures that convey stormwater runoff may also result in sinkholes as the water dissolves substantial amounts of rock over time. In some cases, construction, land grading, or earthmoving activities that cause changes in stormwater flow can trigger sinkhole events. Sinkhole events may occur in the presence of mining activity, especially in areas where the cover of a mine is thin, or in areas where bedrock is not necessarily conducive to their formation. In their article titled "Sinkholes are Bad," authors Piggott and Eynon 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 ten times the thickness of the extracted seam. Subsurface (i.e. underground) extraction of materials such as oil, gas, coal, metal ores (i.e. copper, iron, and zinc), clay, shale, limestone, or water may result in slow-moving or abrupt shifts in the ground surface (Piggott and Eynon 1978).

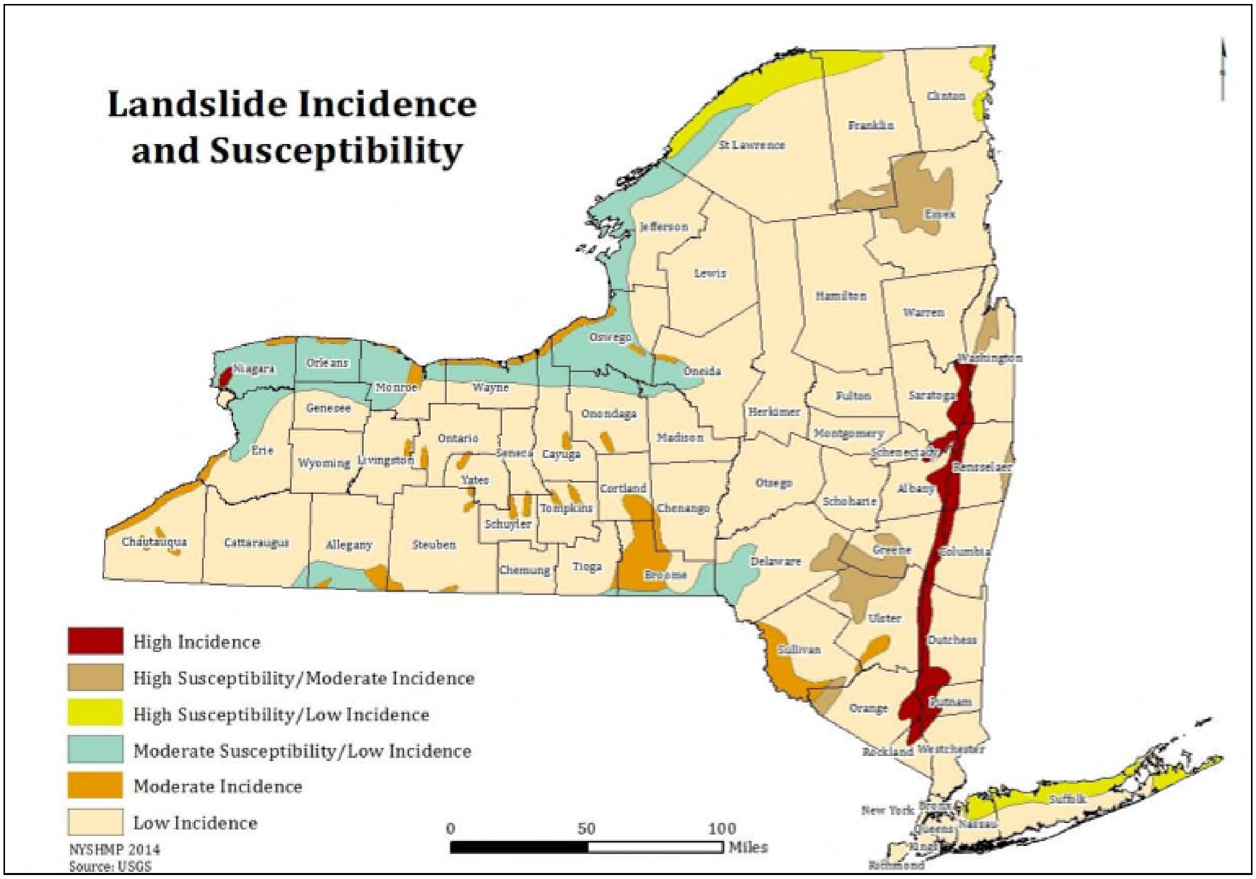
Location

Landslide

The potential for landslides exists across the entire State and the entire northeast region of the U.S. Scientific and historical data exists for New York State which indicates that some areas of the State have a substantial landslide risk. It is estimated that 80% of New York State has a low susceptibility to the landslide hazard. In general, the highest potential for landslides can be found along major rivers and lake valleys that were formerly occupied by glacial lakes resulting in glacial lake deposits and usually associated with steeper slopes (for example, the Hudson and Mohawk River Valleys). Some natural variables such as soil properties, topographic position and slope, and historical incidence all contribute to determining the overall risk of landslide activity in any particular area (NYS HMP 2014).

According to the NYS HMP Update, over 18,000 people in Putnam County live in a high incidence of landslide area, while over 81,000 live in a low incidence area.

Figure 5.4.4-1. Landslide Susceptibility in New York State



Source: *NYSHMP 2014*
Note: *The circle indicates the approximate location of Putnam County.*

As illustrated in Figure 5.4.4-1above, the western section of Putnam County has a high incidence of landslide. These areas within the County are classified as such because of their steep slopes, resulting in bed rock topples and soil slides (also known as debris slides). The remainder of the County has a low landslide incidence.

Land Subsidence and Sinkholes

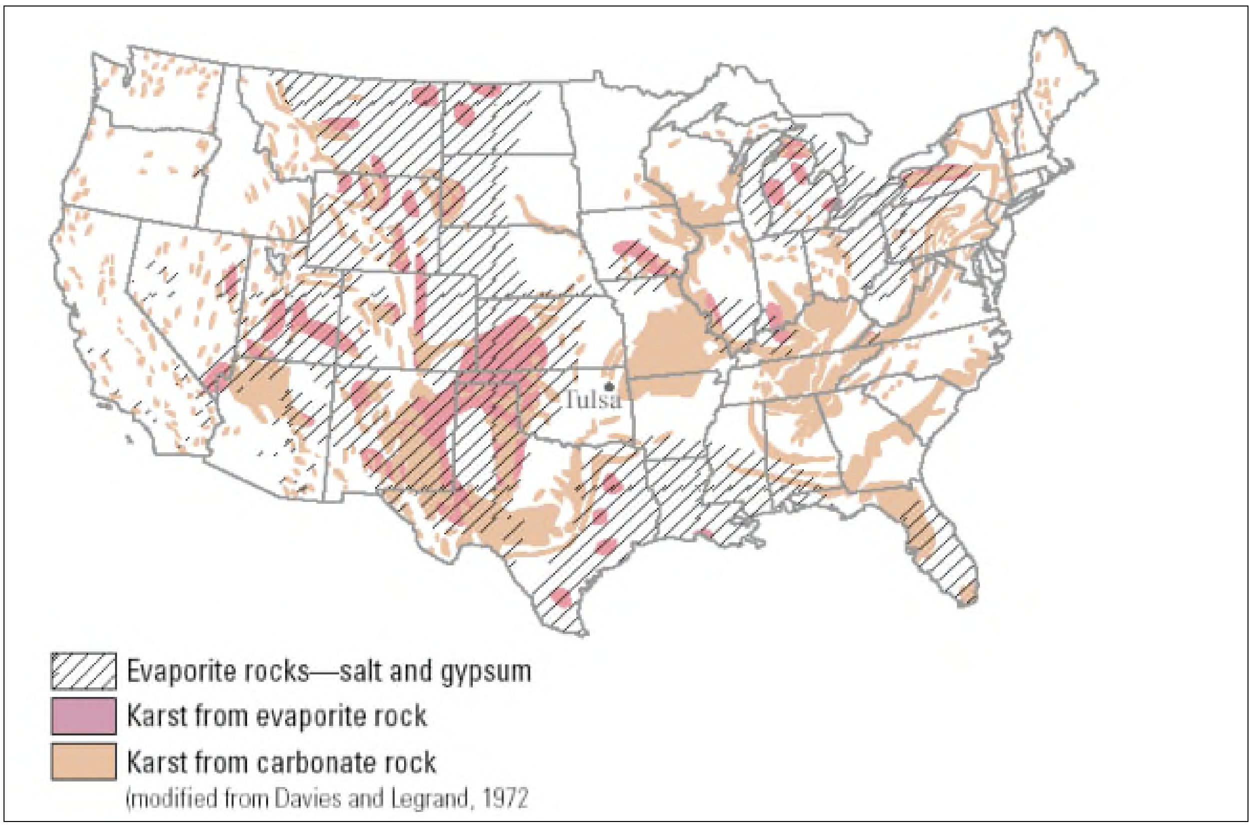
In the U.S., more than 17,000 square miles in 45 states have been directly affected by many types of land subsidence (Galloway et al., 2000). Figure 5.4.4-5 shows the distribution, major types and losses of subsidence affecting the U.S. The costs displayed on this figure are a loss estimate over an unspecified period of time and have only relative magnitudes for each state (Leake, 2013). Land subsidence occurrence can be expected where it has occurred previously. The potential for land subsidence exists across New York State, with areas having potentially higher risk than others (NYS HMP 2014).

Salt and gypsum underlie nearly 40% of the U.S. According to the USGS, karst is found throughout the country. Karst is the landscape of largely shaped dissolving action of water on carbonate bedrock. Carbonate karst landscapes constitute about 40% of the U.S. east of Oklahoma. Karst landscapes imply the existence of land subsidence, generally in the form of sinkholes, brought on by sinking soils resulting from caves or simply cavities below. In New York State, there is karst topography which is in a narrow band along the Helderberg Escarpment in Schoharie and Albany Counties (NYS HMP 2014).

As stated in the 2014 NYS HMP Update, land subsidence (better known as sinkholes) have a tendency to occur more often than not due to manmade influences (for example, mining). These occurrences are found more commonly underground made from evaporate rock. Evaporated rock is soluble in water and can potentially cause large cavity formations to occur. Sinkholes occur when underground holes are created either naturally or artificially, and collapse due to induced force. Carbonate rock (limestone and dolomite) are also prone to void formation but are less soluble (NYS HMP 2014). The potential for land subsidence to occur across New York State is particularly a result of underground mining, sinkholes and drainage of organic soils (Leake, 2013). In Putnam County, the Tilly Foster Mine was an iron mine located in the Town of Southeast. It was 600 feet deep and produced approximately 700,000 tons of ore until it closed in 1897.

Figure 5.4.4-6 indicates that most of western and central New York State consists of subsurface Karst landscapes from evaporative rock types, increasing the potential risk of land subsidence and sinkholes to occur in this region of the State.

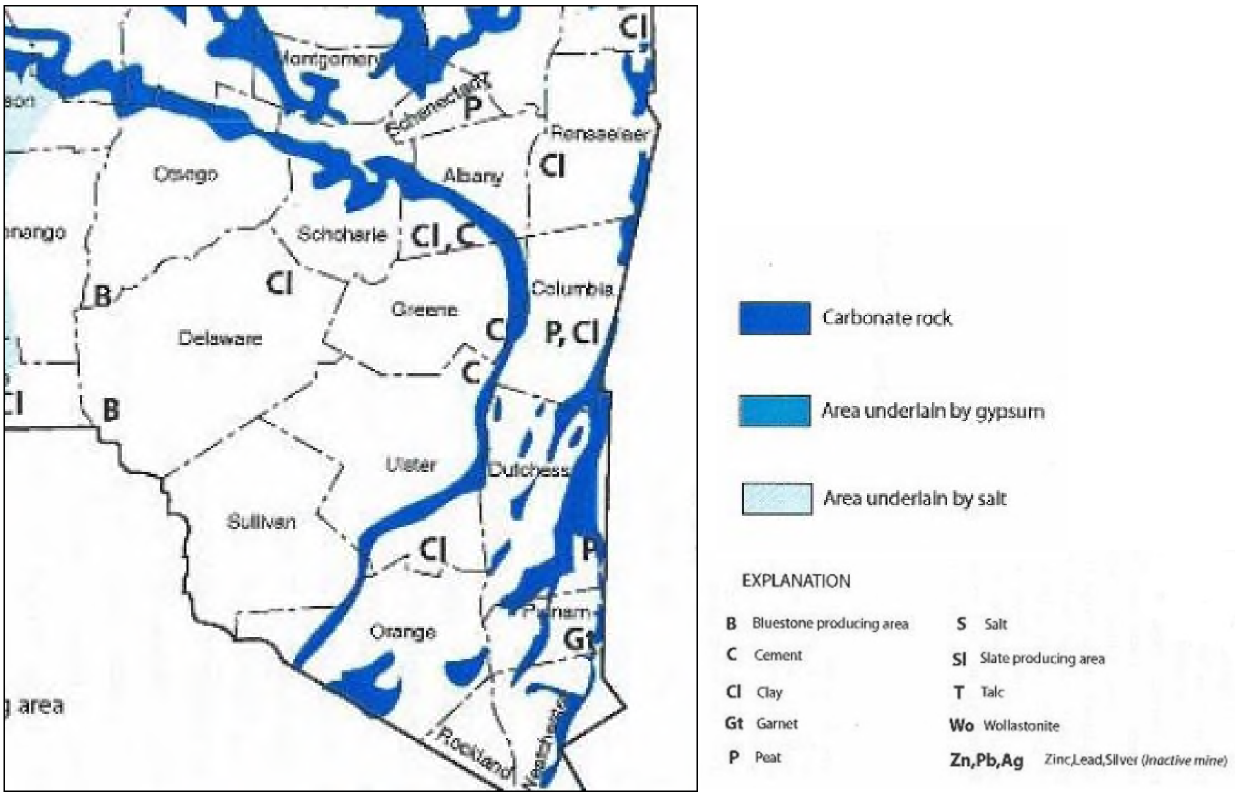
Figure 5.4.4-2. Land Subsidence in the United States



Source: NYS HMP 2014

Human activities can expedite cavity formation and collapse in these susceptible materials or even trigger the collapse of pre-existing subsurface cavities. Though the collapsed features tend to be highly localized, their impacts can extend beyond the collapse zone via the potential introduction of contaminants to the groundwater system (NYSDPC, 2008; Galloway et al., 2000). Within the eastern section of the State, Karst landscapes exist from carbonate rock, including areas located within Putnam County (Figure 5.4.4-3). The figure illustrates the mineral composition in the area of Putnam County. Mineral composition is considered when determining vulnerability to land subsidence.

Figure 5.4.4-3. Mineral Resources in Southeastern New York State



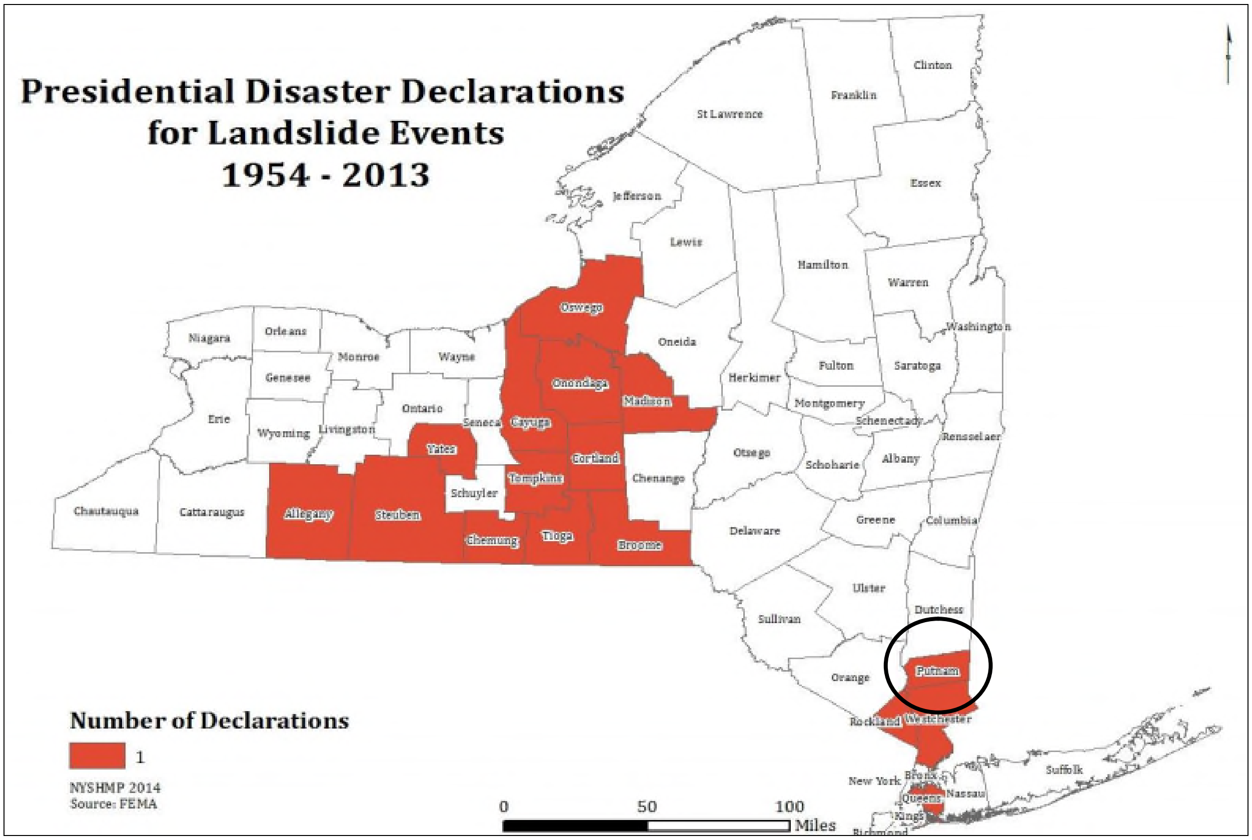
Source: NYS DHSES, 2014

Previous Occurrences and Losses

Between 1953 and 2014, New York State was included in one landslide major disaster declaration. It was classified as a severe storm, heavy rain, landslides and flooding. Generally, these disasters cover a wide region of the State; therefore, they may have impacted many counties. However, not all counties were included in the disaster declarations and emergencies. Of those events, the NYS HMP and other sources indicate that Putnam County has been declared as a disaster or emergency area as a result of one landslide declaration (FEMA, 2014).

Table 5.4.4-1 shows the FEMA disaster declarations (DR) (and does not indicate emergency (EM) declarations) for landslide events in New York State, from 1954 to 2013. This figure indicates that Putnam County was included in one disaster declaration which is in agreement with FEMA data.

Figure 5.4.4-4. Presidential Disaster Declarations for Flooding Events, 1954 to 2013



Source: *NYS DHSES, 2014*
Note: *The black oval indicates the approximate location of Putnam County.*

For this HMP, known landslide events that have impacted Putnam County between 1950 and 2014 are identified. Many sources were researched for historical information regarding land failure events in Putnam County; however, little information was found. Major land failure events that have impacted the County are summarized in Table 5.4.4-1.

Table 5.4.4-1. Land Failure Events in Putnam County

Dates of Event	Event Type	FEMA Declaration Number	County Declared?	Losses / Impact
October 2, 1975	Storms, Rain, Landslides and Flooding	DR-487	Yes	A week long rainfall event resulted in considerable flooding in the area. Hardest hit counties included: Broome, Cayuga, Chemung, Chenango, Madison, Onondaga, Oswego, and Tioga. Rainfall totals ranged from four to seven inches, with totals over 10 inches in southeastern New York State (including Putnam County). New York State experienced approximately $25 million in property damages and two fatalities. Damage estimates in Putnam County were not available.
August 7, 1990	Landslide	N/A	N/A	$1,000 in property damages
December 16, 2009	Sinkhole	N/A	N/A	Kent and Lake Carmel firefighters were called to rescue a horse that got its leg stuck in a sinkhole
August 28-30, 2011	Hurricane Irene	DR-4020	Yes	Rain from Hurricane Irene caused erosion and a mud slide that partially closed Route 9D in Philipstown, just north of Cold Spring

Sources: SHELDUS; Groom; FEMA 2014
NYSDPC New York State Disaster Preparedness Commission
USGS U.S. Geological Survey

Probability of Future Events

Based upon risk factors for and past occurrences, it is likely that geological hazards will occur in Putnam County in the future. It is estimated that Putnam County will continue to experience direct and indirect impacts of geological hazards and its impacts on occasion, with the secondary effects causing potential disruption or damage to communities.

As indicated in the NYS HMP, given the history of landslide occurrences in New York State, it is certain that future landslides will occur (NYS DHSES, 2014). Therefore, the probability of future landslides in New York State, including in Putnam County, is considered high. However, due to sparse records and the fact that many landslides occur away from human development (and may not be observed), the likely severity of future landslides cannot be determined.

While records of subsidence and sinkhole events in Putnam County are sparse, based on geological conditions, subsidence and sinkhole events are likely to occur in the future for the areas of Putnam County underlain by carbonate bedrock and experiencing increased development and/or mining.

In Section 5.3, the identified hazards of concern for Putnam County were ranked. The probability of occurrence, or likelihood of the event, is one parameter used for hazard rankings. Based on historical records and input from the Planning Committee, the probability of occurrence for geological hazards in the County is considered 'occasional' (likely to occur within 100 years, as presented in Table 5.3-3).

Climate Change Impacts

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 would increase the probability of wildfire, reducing the vegetation that helps to support steep slopes. All of these factors would increase the probability for landslide occurrences.

Similar to landslides, climate change will affect subsidence and sinkholes in New York State. 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 expect an increase in annual precipitation amounts. This increase will coincide with an increased risk in subsidence and sinkholes in vulnerable areas.

5.4.4.2 VULNERABILITY ASSESSMENT

To understand risk, a community must evaluate what assets are exposed or vulnerable in the identified hazard area. The following section discusses the potential impact of the land failure hazard on Putnam County including:

- Overview of vulnerability
- Data and methodology used for the evaluation
- Impact, including: (1) impact on life, safety and health of County residents, (2) general building stock, (3) critical facilities, (4) economy and (5) future growth and development
- Further data collections that will assist understanding of this hazard over time
- Overall vulnerability conclusion

Overview of Vulnerability

Vulnerability to landslide hazards is a function of location, type of human activity, use, and frequency of landslide events. The effects of landslides on people and structures can be lessened by total avoidance of landslide hazard areas or by restricting, prohibiting, or imposing conditions on hazard-zone activity. Local governments can reduce landslide effects through land use policies and regulations. Individuals can reduce their exposure to hazards by educating themselves on past hazard history of the site and by making inquiries to planning and engineering departments of local governments (National Atlas, 2007).

As discussed in the County's Vision 2010 document, more than nine-tenths of Putnam County's land area is part of the Hudson Highlands and most of Putnam's highest elevations are in the Town of Philipstown. The following describes the topography in the County with potentially steep slopes vulnerable to the landslide hazard.

'*The Towns of Philipstown and Putnam Valley and the western part of the Town of Kent have the most rugged terrain, with many high peaks having elevations of 1,000 feet or more. There are several ranges in these towns which are significant because they form a natural east-west barrier. These ranges, situated primarily in Putnam Valley, are separated by Peekskill Hollow Creek. The first range is known as Granite Mountain and is located west of the creek. Moving northward, the elevations increase up to 1,100 feet above sea level. The northern border of Putnam is similar to the west because of the number of high peaks. These peaks range from Mount Nimham in Kent, with an elevation of 1,270 feet above sea level, to Birch Hill in Patterson, reaching 1,260 above sea level. The Towns of Carmel, Southeast, and Patterson, and the eastern part of the Town of Kent, while retaining still relatively high peaks and variable relief, maintain more of a consistent terrain characterized by a greater number of more level parcels' (Putnam County Division of Planning and Development, 2010).*

According to the New York State Academy of Mineralogy, the Tilly Foster Mine was an iron mine 600 feet deep located in the Town of Southeast. The mine produced approximately 700,000 tons of ore until it closed in 1897. The presence of this mine is a concern to the County due the potential for sinkholes in this area.

Data and Methodology

In an attempt to estimate Putnam County's vulnerability to land failure due to landslides, the Geology - Landslide Incidence and Susceptibility GIS layer from National Atlas was used to coarsely define the general landslide susceptible area. The Geology - Landslide Incidence and Susceptibility GIS layer was overlaid upon the Putnam County municipalities, 2010 Census population data, custom building inventory and Putnam County's critical facility inventory to estimate exposure.

According to Radbruch-Hall et.al., the Landslide Incidence and Susceptibility GIS layer from National Atlas '….was prepared by evaluating formations or groups of formations shown on the geologic map of the United States (King and Beikman, 1974) and classifying them as having high, medium, or low landslide incidence (number of landslides) and being of high, medium, or low susceptibility to landsliding. Thus, those map units or parts of units with more than 15 percent of their area involved in landsliding were classified as having high incidence; those with 1.5 to 15 percent of their area involved in landsliding, as having medium incidence; and those with less than 1.5 percent of their area involved, as having low incidence. This classification scheme was modified where particular lithofacies are known to have variable landslide incidence or susceptibility. In continental glaciated areas, additional data were used to identify surficial deposits that are susceptible to slope movement. Susceptibility to landsliding was defined as the probable degree of response of the areal rocks and soils to natural or artificial cutting or loading of slopes or to anomalously high precipitation. High, medium, and low susceptibility are delimited by the same percentages used in classifying the incidence of landsliding. For example, it was estimated that a rock or soil unit characterized by high landslide susceptibility would respond to widespread artificial cutting by some movement in 15 percent or more of the affected area. We did not evaluate the effect of earthquakes on slope stability, although many catastrophic landslides have been generated by ground shaking during earthquakes. Areas susceptible to ground failure under static conditions would probably also be susceptible to failure during earthquakes' (Radbruch-Hall, 1982).

To estimate Putnam County's vulnerability to ground failure due to karst environments, the Engineering Aspects of Karst GIS layer from National Atlas, released in April 2005, was used. This national data set shows areas of karst, as well as features analogous to karst (sometimes referred to as "pseudokarst", which is karst-like terrain produced by processes other than the dissolution of rocks). This data set is a digital representation of USGS Open-File Report 2004-1352. This GIS layer was overlaid upon the 2010 Census population data, custom building inventory and Putnam County's critical facility inventory to estimate exposure. Table 5.4.4-2 summarizes the karst types found in Putnam County in accordance with this dataset.

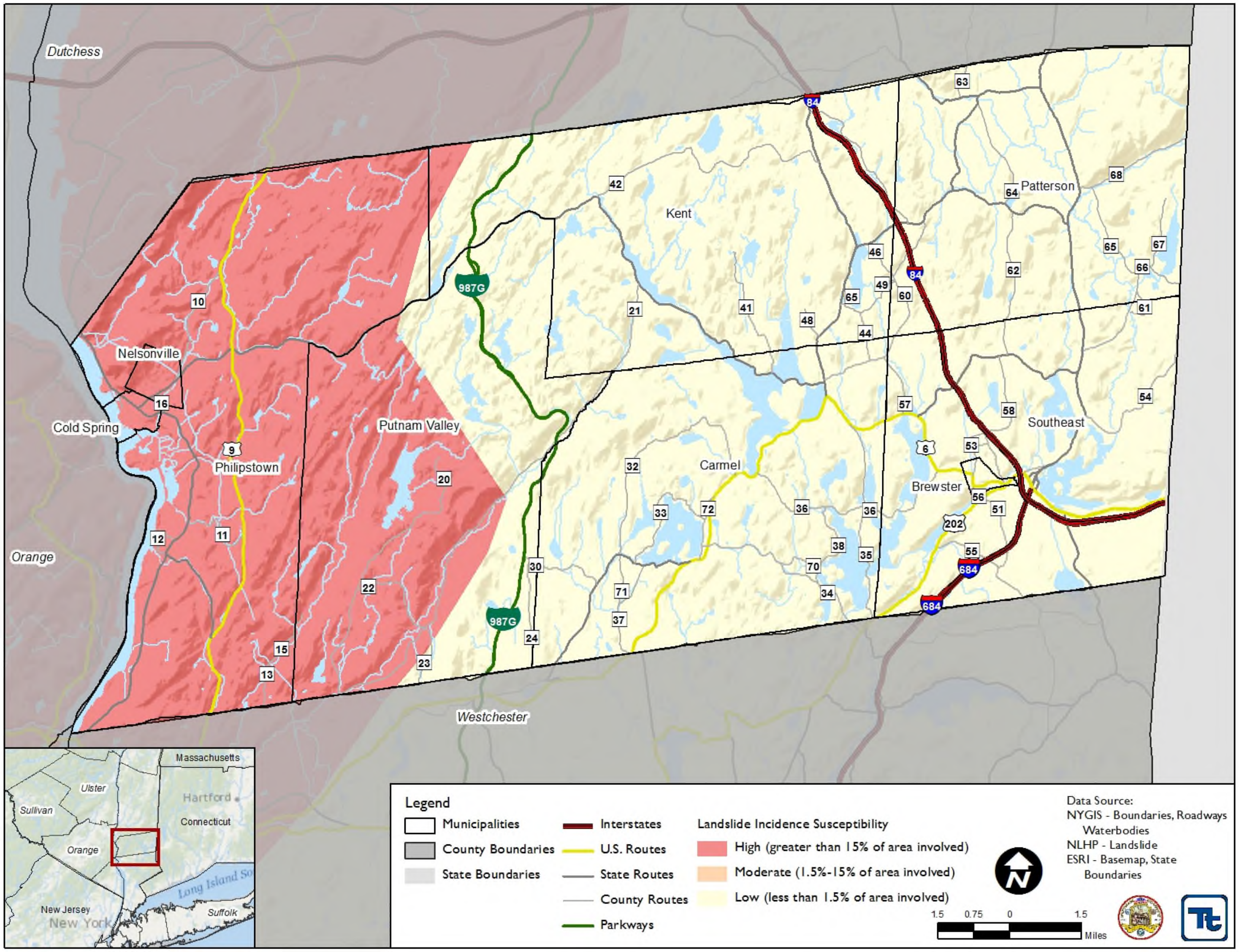
Table 5.4.4-2. Karst Types

Karst 11Type	Description
Long 1	Fissures, tubes, and caves over 1,000 ft (300 m) long; 50 ft (15 m) to over 250 ft (75 m) vertical extent; in gently dipping to flat-lying beds of carbonate rock
Short 3	Fissures, tubes, and caves generally less than 1,000 ft (300 m) long; 50 ft (15 m) or less vertical extent; in crystalline, highly siliceous, intensely folded carbonate rock

Source: Tobin and Weary, 2005
Note: ft = feet

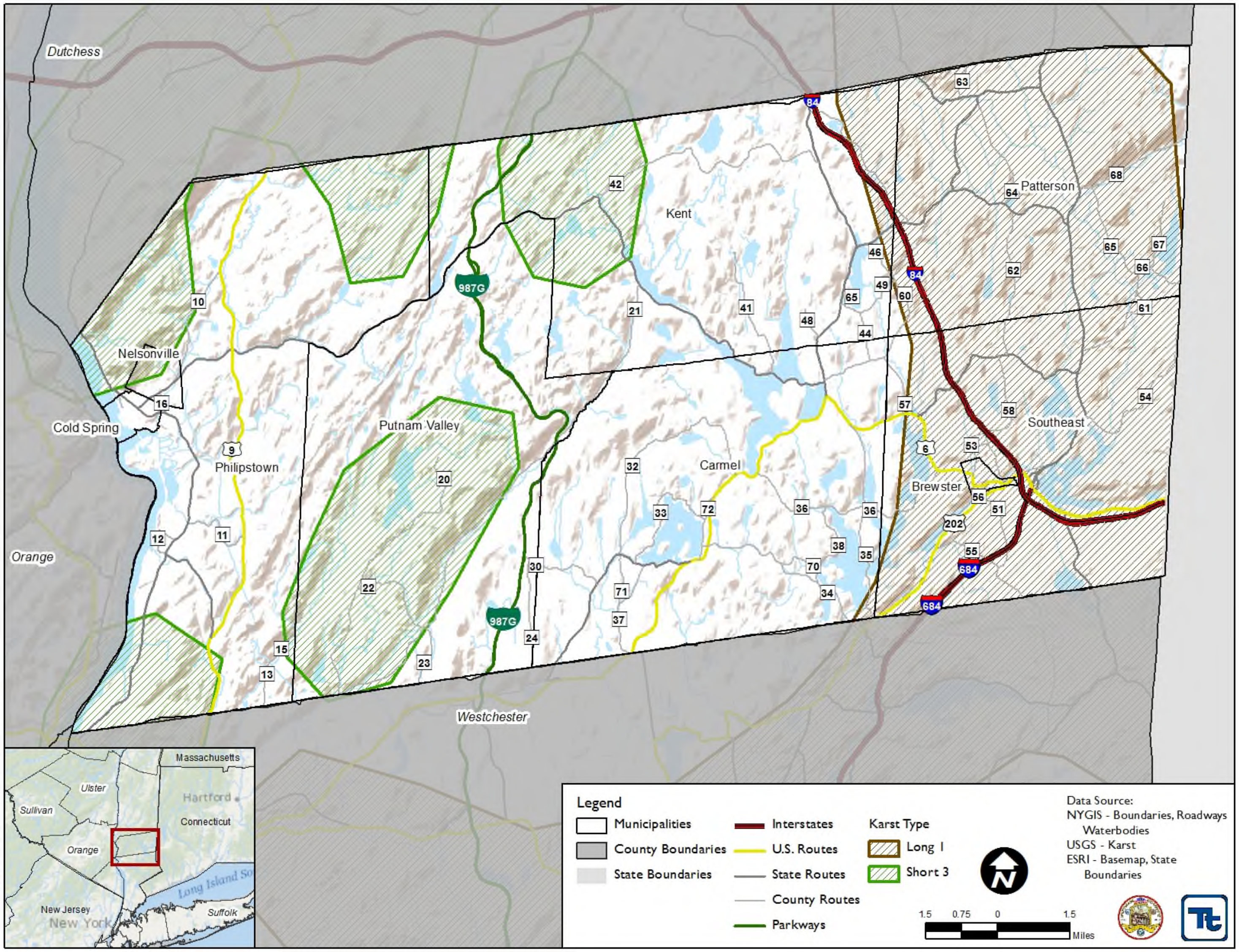
The limitations of this analysis are recognized and are only used to provide a general estimate. Over time additional data will be collected to allow better analysis for this hazard. Available information and a preliminary assessment are provided below.

Figure 5.4.4-5. Landslide Hazard Areas in Putnam County



Source: Godt, 2011 (Geology WMS Layer from the National Atlas of the United States)

Figure 5.4.4-6. Karst Areas in Putnam County



Source: Tobin and Weary, 2005

Impact on Life, Health and Safety

To estimate the population located within the land failure hazard areas, the approximate hazard area boundaries were overlaid upon the 2010 Census population data (U.S. Census, 2010). The Census blocks with their center (centroid) within the boundary of the landslide incidence hazard areas were used to calculate the estimated population considered exposed to this hazard. Table 5.4.4-3 summarizes the population within each identified area by municipality (U.S. Census 2010). Approximately 18.4% of the total County population is exposed to high landslide incidence susceptibility, and approximately 38.7% of the total County population is exposed to the karst hazard areas.

Table 5.4.4-3. Population Exposed to Landslide and Karst Areas in Putnam County

Municipality	Total Population (U.S. Census 2010)	Landslide Incidence High		Landslide Incidence Low		Karst Area	
		Pop.	% of Total	Pop.	% of Total	Pop.	% of Total
Village of Brewster	2,390	0	0%	2,390	100%	2,390	100%
Town of Carmel	34,305	0	0%	34,305	100%	186	0.5%
Village of Cold Spring	2,013	2,013	100%	0	0%	0	0%
Town of Kent	13,507	12	0.1%	13,495	99.9%	1,642	12.2%
Village of Nelsonville	628	628	100%	0	0%	165	26.3%
Town of Patterson	12,023	0	0%	12,023	100%	11,713	97.4%
Town of Philipstown	7,021	7,021	100%	0	0%	756	10.8%
Town of Putnam Valley	11,809	8,717	73.8%	3,092	26.2%	7,280	61.6%
Town of Southeast	16,014	0	0%	16,014	100%	14,469	90.4%
Putnam County	**99,710**	**18,391**	**18.4%**	**81,319**	**81.6%**	**38,601**	**38.7%**

Sources: U.S. Census 2010

Impact on General Building Stock

As discussed above, to estimate the general building stock vulnerable to this hazard, the associated building replacement values (buildings and contents) were determined for the buildings with their centroid in the hazard area. Approximately 20% of the general building stock is located in a 'high' landslide incidence area; nearly 40% of the building stock is located in a karst area. Table 5.4.4-4 lists the replacement value (structure and contents) of general building stock exposed to this hazard.

Table 5.4.4-4. General Building Stock Exposed to the Land Failure Hazard in Putnam County

Municipality	Total RCV (Structure and Contents)	Landslide Incidence		Landslide Incidence		Karst Area	
		High	% of Total	Low	% of Total	RCV	% of Total
Village of Brewster	$333,167,631	$0.00	0.0%	$333,167,631	100.0%	$332,990,819	100.0%
Town of Carmel	$6,097,638,257	$0.00	0.0%	$6,097,638,257	100.0%	$23,363,531	0.4%
Village of Cold Spring	$442,869,640	$442,869,640	100.0%	$0.00	0.0%	$0.00	0.0%
Town of Kent	$2,066,530,876	$3,120,141	0.2%	$2,063,410,735	99.8%	$291,752,644	14.1%
Village of Nelsonville	$121,130,957	$121,130,957	100.0%	$0.00	0.0%	$5,074,884	4.2%
Town of Patterson	$1,897,944,173	$0.00	0.0%	$1,897,944,173	100.0%	$1,820,971,547	95.9%
Town of Philipstown	$1,669,292,142	$1,669,292,142	100.0%	$0.00	0.0%	$230,841,667	13.8%

Table 5.4.4-4. General Building Stock Exposed to the Land Failure Hazard in Putnam County

Municipality	Total RCV (Structure and Contents)	Landslide Incidence		Landslide Incidence		Karst Area	
		High	% of Total	Low	% of Total	RCV	% of Total
Town of Putnam Valley	$2,091,379,851	$1,474,760,546	70.5%	$616,619,304	29.5%	$1,346,031,735	64.4%
Town of Southeast	$3,155,126,947	$0.00	0.0%	$3,155,126,947	100.0%	$3,022,618,516	95.8%
Putnam County	**$17,875,080,474**	**$3,711,173,426**	**20.8%**	**$14,163,907,048**	**79.2%**	**$7,073,645,344**	**39.6%**

Sources: U.S. Census 2010
Notes: RCV = Replacement Cost Value.
The total building count and total replacement values are the sum of all seven general occupancy classifications (residential, commercial, industrial, agricultural, religious, government and educational) for that jurisdiction.

Due to a lack of data regarding past losses specific to Putnam County or its municipalities, it is not possible at this time to estimate potential future losses to land failure events.

Impact on Critical Facilities

Table 5.4.4-5 lists the critical facilities identified in Section 4 (County Profile) located within the landslide hazard area.

Table 5.4.4-5. Number of Critical Facilities in the Landslide Incidence Susceptibility (High) Area in Putnam County

Municipality	Facility Types											
	Boat	Communication	Dam	Electric	Fire Station	Government	Medical	Police Station	Potable Water	Rail Facility	School	Wastewater
Village of Brewster	0	0	0	0	0	0	0	0	0	0	0	0
Town of Carmel	0	0	0	0	0	0	0	0	0	0	0	0
Village of Cold Spring	1	0	1	0	1	2	1	1	0	1	1	4
Town of Kent	0	0	0	0	0	0	0	0	0	0	0	0
Village of Nelsonville	0	0	0	0	0	1	0	1	0	0	0	0
Town of Patterson	0	0	0	0	0	0	0	0	0	0	0	0
Town of Philipstown	0	5	17	1	4	2	0	0	1	0	5	0
Town of Putnam Valley	0	0	11	1	1	5	0	0	0	0	2	0
Town of Southeast	0	0	0	0	0	0	0	0	0	0	0	0
Putnam County	**1**	**5**	**29**	**2**	**6**	**10**	**1**	**2**	**1**	**1**	**8**	**4**

Source: Radeloff et al, 2005
Note: UDF – User Defined Facility

Table 5.4.4-6. Critical Facilities Located in the Landslide and Karst Hazard Areas

Municipality	Facility Name	Facility Type	Landslide (High Incidence)	Presence of Karst
Brewster	No name	UDF	-	X
Brewster	No name	Wastewater	-	X
Brewster	No name	Wastewater	-	X

Table 5.4.4-6. Critical Facilities Located in the Landslide and Karst Hazard Areas

Municipality	Facility Name	Facility Type	Landslide (High Incidence)	Presence of Karst
Brewster	No name	Wastewater	-	X
Brewster	Apartments	Residential	-	X
Brewster	Apartments	Residential	-	X
Brewster	Apartments	Residential	-	X
Brewster	BREWSTER FD	Fire Station	-	X
Brewster	Brewster Metro North	Rail Facility	-	X
Brewster	Brewster Police	Police Station	-	X
Brewster	BREWSTER POLICE DEPT	Police Station	-	X
Brewster	BREWSTER VILLAGE HALL	Government	-	X
Brewster	CAP/ County Office Building	Government	-	X
Brewster	Carmel Ave. Bridge	Highway Bridge	-	X
Brewster	Carmel Avenue Pump Station	Wastewater	-	X
Brewster	County Record Facility	Medical	-	X
Brewster	DEP Laboratory	Wastewater	-	X
Brewster	DPW- telephone communications	Communication	-	X
Brewster	GARDEN ST SCHOOL	School	-	X
Brewster	GOVERNMENT	Government	-	X
Brewster	Highway Department	Government	-	X
Brewster	Par Street Pump Station	Wastewater	-	X
Brewster	Senior Housing	Senior	-	X
Brewster	Senior Housing	Senior	-	X
Brewster	St. Andrews	School	-	X
Brewster	St. Larence School	School	-	X
Brewster	Supermarket	Commercial	-	X
Brewster	Telephone Communications, Except Radiote	Communication	-	X
Brewster	Verizon	Commercial	-	X
Brewster	Verizon COMM	Communication	-	X
Brewster	Waste Water Head Works	Wastewater	-	X
Brewster	WWTP	Wastewater	-	X
Cold Spring	Boathouse	Boat	X	-
Cold Spring	COLD SPRING FIRE DEPT	Fire Station	X	-
Cold Spring	COLD SPRING POLICE DEPT	Police Station	X	-
Cold Spring	Cold Spring WWTP	Wastewater	X	-
Cold Spring	HALDANE JR/SR HS	School	X	-
Cold Spring	Market Street Pump Station	Wastewater	X	-
Cold Spring	Metro North - Cold Spring Station	Rail Facility	X	-
Cold Spring	PHILIPSTOWN AMBULANCE	Medical	X	-
Cold Spring	PHILIPSTOWN TOWN HALL	Government	X	-
Cold Spring	SEWAGE PUMP 3	Wastewater	X	-
Cold Spring	Village Hall	Government	X	-
Cold Spring	WEST POINT FOUNDRY DAM	Dam	X	-
Cold Spring	West Street Pump Station	Wastewater	X	-
Kent	<Null>	Communication	-	X
Kent	BROWNS POND DAM	Dam	-	X
Kent	COMMUNICAITONS TOWER	Communication	-	X
Kent	GOVERNMENT	Government	-	X
Kent	KENT FD	Fire Station	-	X
Kent	Ludington Court 1	Highway Bridge	-	X
Kent	Ludington Court 2	Highway Bridge	-	X
Kent	MERRITT RYDER LAKE DAM	Dam	-	X
Kent	Mooney Hill	Highway Bridge	-	X
Kent	RYDER LAKE DAM	Dam	-	X

Table 5.4.4-6. Critical Facilities Located in the Landslide and Karst Hazard Areas

Municipality	Facility Name	Facility Type	Landslide (High Incidence)	Presence of Karst
Kent	SAGAMORE LAKE DAM	Dam	-	X
Kent	Sagamore Road	Highway Bridge	-	X
Kent	Town of Kent Highway DEpt.	Government	-	X
Kent	TWIN BROOKS DAM	Dam	-	X
Nelsonville	NELSONVILLE VILLAGE HALL	Government	X	-
Nelsonville	Putnam COunty Sherrif Substation	Police Station	X	-
Patterson	Alpine Acres Water Treatment Plant	Potable Water	-	X
Patterson	AMOS NOACH DAM	Dam	-	X
Patterson	Bath House	Recreation	-	X
Patterson	Boat House	Boat	-	X
Patterson	Brimstone Road	Highway Bridge	-	X
Patterson	BURMAN POND DAM	Dam	-	X
Patterson	Camp Brady Dam	Dam	-	X
Patterson	CAMP HERRLICH DAM	Dam	-	X
Patterson	Camp Wilbur Herrlich	Religion	-	X
Patterson	CELL TOWER IN SILO	Communication	-	X
Patterson	Clover Lake Estates Dam	Dam	-	X
Patterson	CORNWALL HILL ESTATES DAM	Dam	-	X
Patterson	CORNWALL MEADOWS PUMP STATION	Wastewater	-	X
Patterson	Countyline Getty	Government	-	X
Patterson	Countyline Getty	Natural Gas	-	X
Patterson	Courthouse	Government	-	X
Patterson	COVINGTON GREENS PUMP STATION	Wastewater	-	X
Patterson	Dorsett Hollow Water Treatment Plant	Potable Water	-	X
Patterson	Dwelling	Residential	-	X
Patterson	Echo Road Telecommunications Tower	Communication	-	X
Patterson	Education Alliance Camp	Wastewater	-	X
Patterson	Fair St. Garage	Government	-	X
Patterson	Fox Run Condominiums	Wastewater	-	X
Patterson	FOX RUN WATER TREATMENT	Potable Water	-	X
Patterson	FRONT STREET PUMP STATION	Wastewater	-	X
Patterson	Green Chimneys School For Little People	School	-	X
Patterson	Griffin's Pond	Dam	-	X
Patterson	Group Home	Institutional	-	X
Patterson	Group Home	Institutional	-	X
Patterson	Group Home	Institutional	-	X
Patterson	Group Home	Institutional	-	X
Patterson	Highway Department	Government	-	X
Patterson	Highway Department	Government	-	X
Patterson	LAKE CHARLES DAM	Dam	-	X
Patterson	LOST LAKE DAM & DIKE	Dam	-	X
Patterson	MalDunn Telecommunications Tower	Communication	-	X
Patterson	MATTHEW PATTERSON ELEMENTARY SCHOOL	School	-	X
Patterson	Maybrook E1 Route 164	UDF	-	X
Patterson	MENDEL POND DAM	Dam	-	X
Patterson	Metro North - Patterson	Rail Facility	-	X
Patterson	Mooney Hill Bridge	Rail Bridge	-	X
Patterson	MOUNTAIN BROOK DAM	Dam	-	X
Patterson	Noletti Telecommunications Tower	Communication	-	X
Patterson	NYS Route 164	Rail Bridge	-	X
Patterson	NYS Route 164	Rail Bridge	-	X

Table 5.4.4-6. Critical Facilities Located in the Landslide and Karst Hazard Areas

Municipality	Facility Name	Facility Type	Landslide (High Incidence)	Presence of Karst
Patterson	NYS Route 164	Rail Bridge	-	X
Patterson	NYS Route 164	Rail Bridge	-	X
Patterson	NYSARC Group Home	Institutional	-	X
Patterson	NYSEG - Haviland Hollow Substation	Electric	-	X
Patterson	NYSEG - Kent Substation	Electric	-	X
Patterson	NYSEG - West Patterson Substation	Electric	-	X
Patterson	Patterson Automotive	Commercial	-	X
Patterson	Patterson Automotive	Natural Gas	-	X
Patterson	PATTERSON COMMONS PUMP STATION	Wastewater	-	X
Patterson	PATTERSON FD & AMB.	Fire Station	-	X
Patterson	PATTERSON FIRE DEPT. STATION 2	Fire Station	-	X
Patterson	PATTERSON HAMLET WWTP	Wastewater	-	X
Patterson	Patterson Highway Garage	Government	-	X
Patterson	Patterson Highway Salt Shed	Government	-	X
Patterson	Patterson Library	Government	-	X
Patterson	Patterson Mobil	Natural Gas	-	X
Patterson	PATTERSON TOWN HALL	Government	-	X
Patterson	PATTERSON VILLAGE PUMP STATION	Wastewater	-	X
Patterson	Pump House	Wastewater	-	X
Patterson	Putnam County Bus Garage	Bus	-	X
Patterson	PUTNAM LAKE DAM	Dam	-	X
Patterson	PUTNAM LAKE FIRE DEPT	Fire Station	-	X
Patterson	PVMP Pavilion	Government	-	X
Patterson	Rec Building	Recreation	-	X
Patterson	Recycling Center	Government	-	X
Patterson	Recycling Center	Government	-	X
Patterson	RIHM & KITTEL DAM	Dam	-	X
Patterson	Route 22 Bridge	Highway Bridge	-	X
Patterson	Route 311 Bridge	Highway Bridge	-	X
Patterson	SOUTH STREET PUMP STATION	Wastewater	-	X
Patterson	Stateline Food & Beverage	Natural Gas	-	X
Patterson	Stateline Food & Beverage (Citgo)	Commercial	-	X
Patterson	Storage	Government	-	X
Patterson	The Plaza at Clover Lake	Senior	-	X
Patterson	Thunder Ridge Ski Area	Wastewater	-	X
Patterson	Verizon	Communication	-	X
Patterson	Veterans of Foreign Wars	Government	-	X
Patterson	Watchtower Dam	Dam	-	X
Patterson	Watchtower Education Center	Wastewater	-	X
Patterson	Waterfield Farms Dam	Dam	-	X
Patterson	WONDER LAKE DAM	Dam	-	X
Philipstown	BREAKNECK BROOK DAM	Dam	X	X
Philipstown	CAMP WICCOPEE DAM	Dam	X	X
Philipstown	CARGILL RESERVOIR DAM	Dam	X	X
Philipstown	CELL TOWER	Communication	X	-
Philipstown	CELL TOWER	Communication	X	X
Philipstown	CENHUD - Indian Brook Road	Electric	X	-
Philipstown	COLD SPRING DAM (LOWER)	Dam	X	X
Philipstown	COLD SPRING DAM (UPPER)	Dam	X	X
Philipstown	COLD SPRING RESERVOIR DAM	Dam	X	-
Philipstown	COLT ESTATE DAM	Dam	X	X
Philipstown	COMMUNICATIONS TOWER	Communication	X	-

Table 5.4.4-6. Critical Facilities Located in the Landslide and Karst Hazard Areas

Municipality	Facility Name	Facility Type	Landslide (High Incidence)	Presence of Karst
Philipstown	COMMUNICATIONS TOWER	Communication	X	-
Philipstown	CONTINENTAL VILLAGE FD	Fire Station	X	-
Philipstown	CROWN ATLANTIC TOWER	Communication	X	-
Philipstown	DAVID ULMAR POND DAM	Dam	X	-
Philipstown	DIAMOND POND DAM	Dam	X	X
Philipstown	EAST MOUNTAIN LAKE DAM	Dam	X	X
Philipstown	EVELINA PERKINS POND DAM	Dam	X	-
Philipstown	GARRISON ELEMENTARY/MIDDLE SCHOOL	School	X	-
Philipstown	GARRISON SCHOOL DIST	School	X	-
Philipstown	GARRISON SCHOOL DIST.	School	X	-
Philipstown	Garrison Union Free School Distric	School	X	-
Philipstown	Garrison VFD - Station #1	Fire Station	X	-
Philipstown	GARRISON VFD - STATION 2	Fire Station	X	-
Philipstown	GOVERNMENT	Government	X	-
Philipstown	GOVERNMENT	Government	X	-
Philipstown	LAKE SURPRISE DAM	Dam	X	X
Philipstown	LAKE VALHALLA DAM	Dam	X	-
Philipstown	LOCH LYALL DAM	Dam	X	-
Philipstown	LOWER PUMP HOUSE	Potable Water	X	-
Philipstown	North Highlands FD	Fire Station	X	-
Philipstown	PERKINS ESTATE POND DAM	Dam	X	-
Philipstown	SCHOOL	School	X	-
Philipstown	SLOAN DAM	Dam	X	-
Philipstown	WEISE POND DAM	Dam	X	-
Putnam Valley	(213-0477)	Dam	X	X
Putnam Valley	DUCK POND DAM A & B	Dam	X	-
Putnam Valley	FLORADAN ESTATES DAM	Dam	X	X
Putnam Valley	FRANK & COOPER POND DAM	Dam	X	-
Putnam Valley	G L LLOYD POND DAM	Dam	X	X
Putnam Valley	GOVERNMENT	Government	X	-
Putnam Valley	GOVERNMENT	Government	X	-
Putnam Valley	GOVERNMENT	Government	X	X
Putnam Valley	GOVERNMENT	Government	X	X
Putnam Valley	HIDDEN LAKE DAM	Dam	X	-
Putnam Valley	HOLLOW BROOK DAM	Dam	X	X
Putnam Valley	INDIAN LAKE DAM	Dam	X	X
Putnam Valley	JOHN ALLEN POND DAM	Dam	X	-
Putnam Valley	L BERMAN POND DAM	Dam	X	X
Putnam Valley	LOWER (SOUTH) WICCOPEE DAM	Dam	-	X
Putnam Valley	NYSEG - Adams Corners	Electric	X	-
Putnam Valley	OSCAWANA LAKE DAM	Dam	X	X
Putnam Valley	PUTNAM VALLEY HS	School	X	X
Putnam Valley	PUTNAM VALLEY MS	School	X	-
Putnam Valley	PUTNAM VALLEY TOWN HALL	Government	X	X
Putnam Valley	PUTNAM VALLEY VFD	Fire Station	X	X
Southeast	Algonquin - Tulip Road	Natural Gas	-	X
Southeast	BOG BROOK DAM #1	Dam	-	X
Southeast	BOG BROOK DAM #2	Dam	-	X
Southeast	BOG BROOK WATER CONTROL DAM	Dam	-	X
Southeast	BREWSTER FD - STATION 2	Fire Station	-	X
Southeast	BREWSTER HIGH SCHOOL	School	-	X

Table 5.4.4-6. Critical Facilities Located in the Landslide and Karst Hazard Areas

Municipality	Facility Name	Facility Type	Landslide (High Incidence)	Presence of Karst
Southeast	BREWSTER SCHOOL ADMIN BLDG	School	-	X
Southeast	BREWSTER SCHOOL BUS GARAGE	School	-	X
Southeast	CELL TOWER	Communication	-	X
Southeast	CELL TOWER WAY BACK IN DRIVEWAY	Communication	-	X
Southeast	CV STARR SCHOOL	School	-	X
Southeast	DIVERTING RESERVOIR DAM	Dam	-	X
Southeast	GOVERNMENT- Post Office	Government	-	X
Southeast	HH WELLS MIDDLE SCHOOL	School	-	X
Southeast	Hudson Valley UniteD Cerebral Palsey	Medical	-	X
Southeast	JFK ELEMENTARY SCHOOL	School	-	X
Southeast	JUENGST DAM	Dam	-	X
Southeast	LAKE TONETTA DAM	Dam	-	X
Southeast	Local and Suburban Transit	Transportation	-	X
Southeast	LOUNSBURY WILDLIFE POND #1 DAM	Dam	-	X
Southeast	LOUNSBURY WILDLIFE POND #2 DAM	Dam	-	X
Southeast	MIDDLE BRANCH DAM	Dam	-	X
Southeast	MILLTOWN ESTATES DAM	Dam	-	X
Southeast	MT EBO CORPORATE CENTER DAM	Dam	-	X
Southeast	MTA Brewster Yard	Rail Facility	-	X
Southeast	NY STATE POLICE	Police Station	-	X
Southeast	NYSEG - Brewster City Gate	Natural Gas	-	X
Southeast	NYSEG - Dingle Ridge	Electric	-	X
Southeast	NYSEG - Putnam Lake	Electric	-	X
Southeast	NYSEG - Tilly Foster	Electric	-	X
Southeast	PUTNAM RIDGE NURSING HOME	Senior	-	X
Southeast	SE SCHOOLHOUSE	School	-	X
Southeast	Sewage Lift Station	Wastewater	-	X
Southeast	Sewage Lift Station	Wastewater	-	X
Southeast	Sewage Lift Station	Wastewater	-	X
Southeast	Sewage Lift Station	Wastewater	-	X
Southeast	Sewage Lift Station	Wastewater	-	X
Southeast	Sewage Lift Station	Wastewater	-	X
Southeast	Sewerage Systems	Wastewater	-	X
Southeast	SODOM DAM	Dam	-	X
Southeast	Southeast station	Rail Facility	-	X
Southeast	Tilly Foster Farm	Agriculture	-	X
Southeast	Vacant Dwelling	Vacant	-	X
Southeast	WASTWATER TREATMENT PLAN	Wastewater	-	X
Southeast	Water Supply- Pump House	Potable Water	-	X
Southeast	Water Supply- Well Field	Potable Water	-	X
Southeast	Water Tank	Potable Water	-	X
Southeast	WATER TANK, PUMPHOUSE	Potable Water	-	X
Southeast	WATER TREATMENT	Potable Water	-	X
Southeast	WELL AND CLUBHOUSE	Potable Water	-	X
Southeast	WELL SITE	Potable Water	-	X
Southeast	WW TREATMENT PLANT	Wastewater	-	X

Source: Planning Committee
Notes: Does not include facilities located in 'low' Landslide Incidence Susceptibility areas.
'X' indicates the critical facility is located in the area identified. '-' indicates the critical facility is not located in the area identified.

Impact on the Economy

Land failure's impact on the economy and estimated dollar losses are difficult to measure. As stated earlier, landslides and other land failure 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, land failure threatens transportation corridors, fuel and energy conduits and communication lines (USGS, 2003). Estimated potential damages to general building stock can be quantified as discussed above. For the purposes of this analysis, general building stock damages are discussed further.

Direct building losses are the estimated costs to repair or replace the damage caused to the building. The estimated replacement value of general building stock located in 'high' landslide susceptible areas is $3.7 billion. The estimated replacement value of general building stock located in karst areas is $7 billion. These dollar value losses to the County's total building inventory replacement value would impact Putnam's tax base and the local economy.

Future Growth and Development

As discussed in Section 4 and Volume II, Section 9, areas targeted for future growth and development have been identified across the County. It is anticipated that new development within the high landslide incidence areas identified by USGS and/or on karst environments will be exposed to land failure risks.

Additional Data and Next Steps

Obtaining historic damages to buildings and infrastructure incurred due to ground failure will help with loss estimates and future modeling efforts, given a margin of uncertainty. More detailed landslide susceptibility zones can be generated so that communities can more specifically identify high hazard areas. A pilot study was conducted for Schenectady County, New York as described in the 2011 New York State Hazard Mitigation Plan to develop higher resolution landslide susceptibility zones. The methodology included using the Natural Resource Conservation Services (NRCS) Digital Soil Survey soil units and their associated properties including the American of State Highway Transportation Officials (AASHTO) rating, liquid limit, hydrologic group, percentage of silt and clay, erosion potential and slope derived from high resolution digital elevation models. Further, research on rainfall thresholds for forecasting landslide potential may also be an option for Putnam County.