# 5.4.5 Landslide

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

## 5.4.5.1 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), 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 that include:

- erosion by rivers, glaciers, or ocean waves create oversteepened slopes
- rock and soil slopes are weakened through saturation by snowmelt or heavy rains
- earthquakes create stresses that make weak slopes fail
- earthquakes of magnitude 4.0 and greater have been known to trigger landslides
- volcanic eruptions produce loose ash deposits, heavy rain, and debris flows
- excess weight from accumulation of rain or snow, stockpiling of rock or ore, from waste piles, or from man-made structures may stress weak slopes to failure and other structures (USGS 2016)

Landslides may be triggered by both natural and human-caused changes in the environment, including heavy rain, rapid snow melt, steepening of slopes caused by construction or erosion, earthquakes, and changes in groundwater levels. Areas generally prone to landslide hazards include previous landslide areas, bases of steep slopes, bases of drainage channels, developed hillsides, and areas recently burned by forest and brush fires (NYS DHSES 2014). Human activities that contribute to slope failure include altering the natural slope gradient, increasing soil water content, and removing vegetation cover. Warning signs for landslide activity include:

- Springs, seeps, or saturated ground in areas that have not typically been wet before
- New cracks or unusual bulges in the ground, street pavement, or sidewalk
- Soil moving away from foundations
- Ancillary structures, such as decks and patios, tilting and moving relative to the main house
- Tilting or cracking of concrete floors and foundations
- Broken water lines and other underground utilities
- Leaning telephone poles, trees, retaining walls, or fences
- Offset fence lines
- Sunken or down-dropped road beds
- Rapid increase in creek water levels, possibly accompanied by increased turbidity
- Sudden increase in creek water levels while rain is still falling or just recently ended
- Sticking doors and windows, and visible open spaces indicating jambs and frames out of plumb
- A faint rumbling sound that increases in volume as the landslide nears
- Unusual sounds, such as trees cracking or boulders knocking together (U.S. Geological Survey [USGS] 2013).

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 DHSES 2014).

## Extent

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:

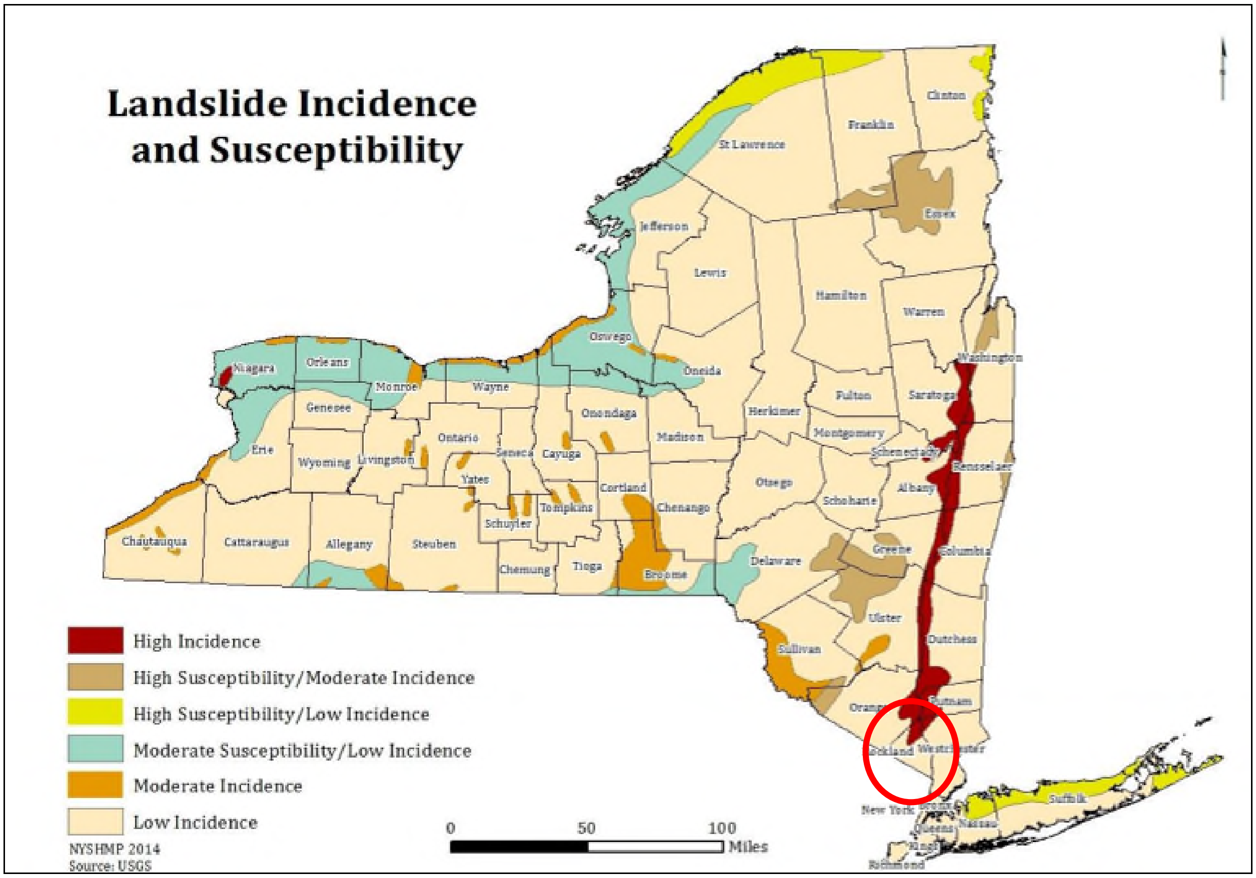
- Landslide incidence is the number of landslides that have occurred in a given geographic area. High incidence means greater than 15-percent of a given area has been involved in landsliding; medium incidence means that 1.5 to 15-percent of an area has been involved; and low incidence means that less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

## Location

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 DHSES 2014).

According to the NYS HMP Update, over 30,000 people in Rockland County live in a high incidence of landslide area, while over 281,000 live in a low incidence area.

**Figure 5.4.5-1. Landslide Susceptibility in New York State**




*Source:* *NYS DHSES 2014*

*Note:* *The circle indicates the approximate location of Rockland County. According to this figure, the northern portion of the county is located within the high incidence area for landslide susceptibility while the remainder of the county has a low incidence.*

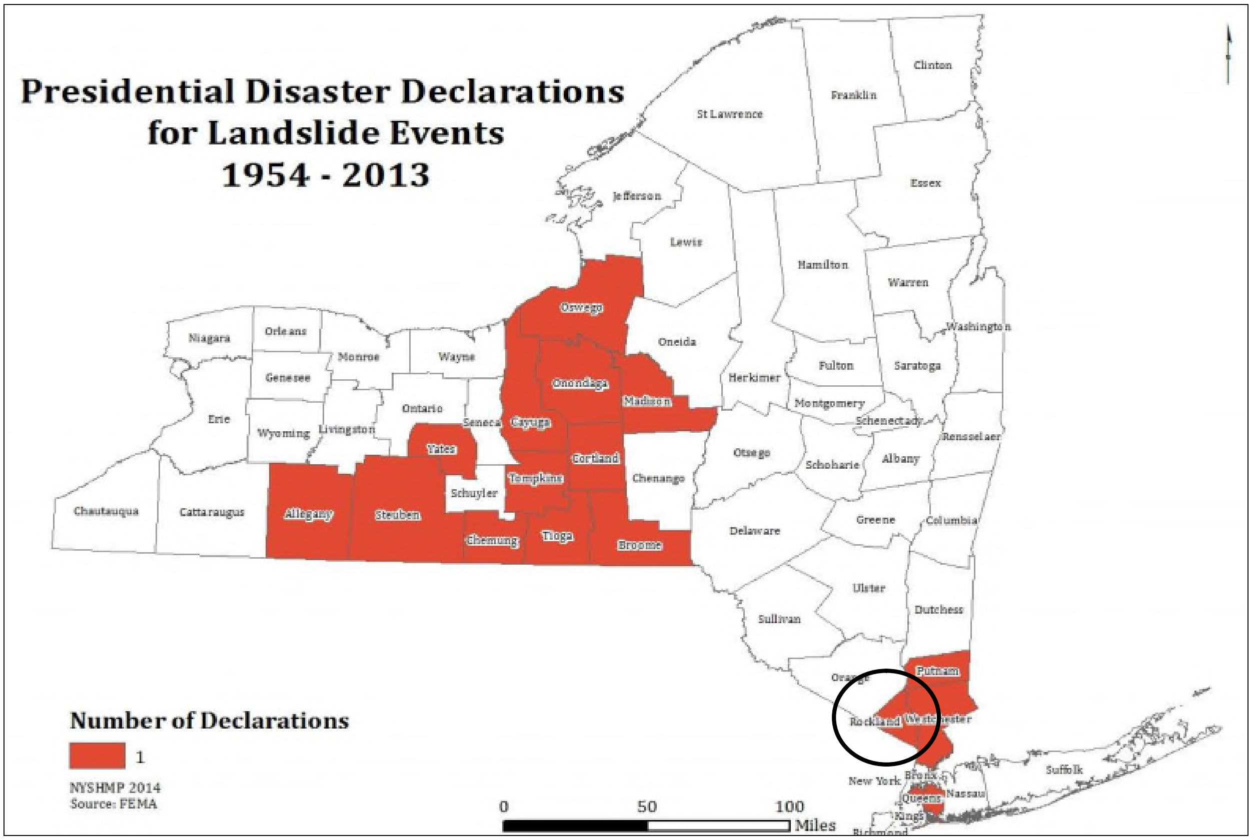
As illustrated in Figure 5.4.5-1 above, the northern section of Rockland County has a high incidence of landslide. This area within the County is classified as such because of its steep slopes, resulting in bed rock topples and soil slides (also known as debris slides). The remainder of the County has a low landslide incidence. According to the 2010 Rockland County HMP, the Village of South Nyack and Upper Nyack have identified concerns about landslides due to development on steeply sloped areas (Rockland County HMP 2010). In the Town of Ramapo, there are areas of steep slopes along Route 202. In the Town of Stony Point, there are steeply sloped areas along Route 9W heading north (Rockland County Comprehensive Plan 2011).

## Previous Occurrences and Losses

Between 1953 and 2016, 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. NYS HMP and other sources indicate that Rockland County was declared as a disaster or emergency area as part of that landslide declaration (FEMA 2016).

Figure 5.4.5-2 shows the FEMA disaster declaration (DR) (and does not indicate emergency (EM) declarations) for the landslide event in New York State, from 1954 to 2013. This figure indicates that Rockland County was included in one disaster declaration which is in agreement with FEMA data.

**Figure 5.4.5-2. Presidential Disaster Declarations for Landslide Events, 1954 to 2013**




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

For this Plan update, landslide events that occurred in the county between 2009 and 2016 were researched. However, specific information regarding any landslide events was not identified. For events prior to 2009, refer to the 2010 Rockland County Multi-Jurisdictional Hazard Mitigation Plan.

## Probability of Future Events

As indicated in the NYS HMP, and given the history of landslides in NYS, future landslides certainly will occur, but severity of these landslides cannot be determined. Therefore, probability of future landslides in NYS is considered high; however, because documentation on landslides in Rockland County is sparse, predicting the extent of future landslides in the County is difficult.

According to the New York State Geological Survey (NYSGS) Landslide Inventory Study to estimate probability of future landslides (based on documented historical occurrences), NYS can expect on average approximately two major landslides each year; a greater number of smaller but still significant slides, slumps, or flows each year; and at least one landslide causing a fatality once every 12 years.

In Section 5.3, identified hazards of concern for Rockland County were ranked according to various parameters. Probability of occurrence, or likelihood of the event, is one parameter used for hazard rankings. Based on historical records and input from the Planning Partnership, probability of occurrence of landslides in Rockland County is considered “occasional” (hazard event likely to occur within 100 years).

### Climate Change Impacts

Projecting future climate change within a specific region is challenging. Shorter-term projections are more closely tied to existing trends, rendering longer-term projections even more challenging. The further into the future a prediction extends, the more it is subject to change.

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.

## 5.4.5.2 VULNERABILITY ASSESSMENT

To understand risk, a community must evaluate what assets are exposed or vulnerable to the identified hazard. For this analysis, the hazard area is defined as the high incidence landslide zones. The analysis of potential impacts of the landslide hazard on Rockland County includes the following:

- 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
- Effect of climate change on vulnerability
- Change of vulnerability as compared to that presented in the 2010 Rockland County Hazard Mitigation Plan
- Further data collections that will assist understanding of this hazard over time

### 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).

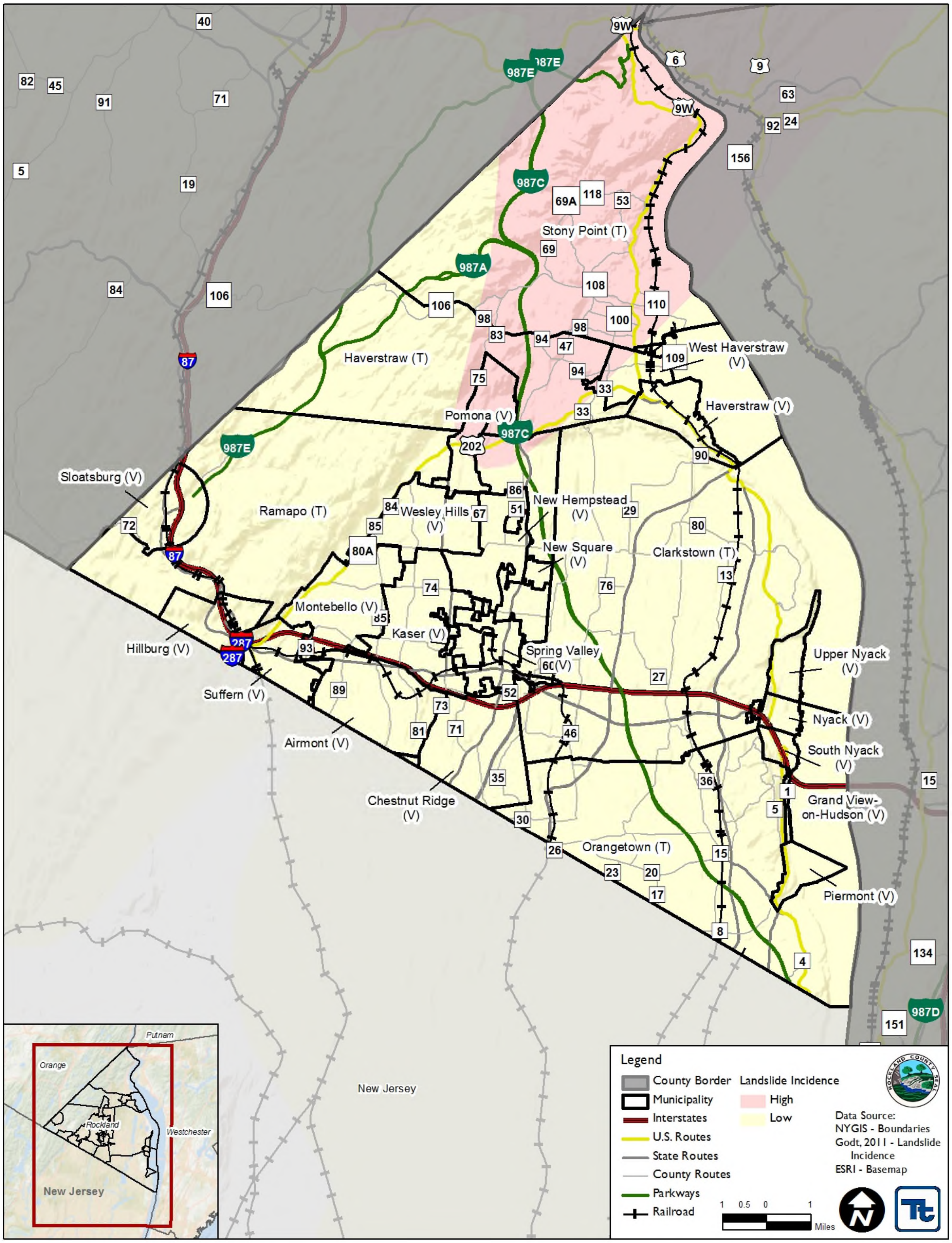
### Data and Methodology

In an attempt to estimate Rockland 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 Rockland County municipalities, 2010 Census population data, custom building inventory and Rockland 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).

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 5.4.5-3. Landslide Hazard Areas in Rockland County**




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

## Impact on Life, Health and Safety

Table 5.4.5-1 estimates the population within each hazard ranked area by municipality. To estimate populations within landslide hazard areas, approximate hazard area boundaries were overlaid on 2010 U.S. Census population data (U.S. Census 2010). Census blocks with centers (centroids) within boundaries of landslide incidence hazard areas were used to calculate estimated populations considered exposed to this hazard. In total, 30,351 (9.7%) of the County's population is within the high incidence hazard area.

**Table 5.4.5-1. Estimated Populations Exposed to Landslides in Rockland County**

| Municipality | Total Population (U.S. Census 2010) | Landslide Incidence | |
|---|---|---|---|
| | | High | % of Total |
| Airmont, Village of | 8,628 | 0 | 0.0% |
| Chestnut Ridge, Village of | 7,916 | 0 | 0.0% |
| Clarkstown, Town of | 78,867 | 0 | 0.0% |
| Grand View on Hudson, Village of | 285 | 0 | 0.0% |
| Haverstraw, Town of | 12,808 | 11,552 | 90.2% |
| Haverstraw, Village of | 11,910 | 0 | 0.0% |
| Hillburn, Village of | 951 | 0 | 0.0% |
| Kaser, Village of | 4,724 | 0 | 0.0% |
| Montebello, Village of | 4,526 | 0 | 0.0% |
| New Hempstead, Village of | 5,132 | 0 | 0.0% |
| New Square, Village of | 6,944 | 0 | 0.0% |
| Nyack, Village of | 6,765 | 0 | 0.0% |
| Orangetown, Town of | 36,832 | 0 | 0.0% |
| Piermont, Village of | 2,510 | 0 | 0.0% |
| Pomona, Village of | 3,103 | 2,007 | 64.7% |
| Ramapo, Town of | 38,252 | 263 | <1% |
| Sloatsburg, Village of | 3,039 | 0 | 0.0% |
| South Nyack, Village of | 3,510 | 0 | 0.0% |
| Spring Valley, Village of | 31,347 | 0 | 0.0% |
| Stony Point, Town of | 15,059 | 14,942 | 99.2% |
| Suffern, Village of | 10,723 | 0 | 0.0% |
| Upper Nyack, Village of | 2,063 | 0 | 0.0% |
| Wesley Hills, Village of | 5,628 | 0 | 0.0% |
| West Haverstraw, Village of | 10,165 | 1,587 | 15.6% |
| **Rockland County** | **311,687** | **30,351** | **9.7%** |

Sources: Godt 2001, U.S. Census 2010

## Impact on General Building Stock

In general, the building environment within the high susceptibility zones, as well as population, structures, and infrastructure downslope, are vulnerable to this hazard. Custom building inventory and landslide incidence hazard areas were used to calculate estimated building stock exposed to this hazard. Table 5.4.5-2 lists building replacement cost values and numbers of buildings within defined hazard areas, respectively.

**Table 5.4.5-2. Estimated Number of Buildings and Replacement Cost Values in the Landslide Hazard Area**

| Municipality | Total Number of Buildings | Total GBS RCV | Number of Buildings | | Replacement Cost Value | |
|---|---|---|---|---|---|---|
| | | | High | % of Total | High | % of Total |
| Airmont, Village of | 2,769 | $1,918,825,000 | 0 | 0.0% | $0 | 0.0% |
| Chestnut Ridge, Village of | 2,966 | $2,012,432,000 | 0 | 0.0% | $0 | 0.0% |
| Clarkstown, Town of | 26,894 | $17,738,436,000 | 0 | 0.0% | $0 | 0.0% |
| Grand View on Hudson, Village of | 146 | $90,160,000 | 0 | 0.0% | $0 | 0.0% |
| Haverstraw, Town of | 3,978 | $2,105,505,000 | 3,506 | 88.1% | $1,839,969,000 | 87.4% |
| Haverstraw, Village of | 2,304 | $1,383,509,000 | 0 | 0.0% | $0 | 0.0% |
| Hillburn, Village of | 343 | $274,003,000 | 0 | 0.0% | $0 | 0.0% |
| Kaser, Village of | 605 | $905,538,000 | 0 | 0.0% | $0 | 0.0% |
| Montebello, Village of | 1,432 | $1,087,531,000 | 0 | 0.0% | $0 | 0.0% |
| New Hempstead, Village of | 1,402 | $761,317,000 | 0 | 0.0% | $0 | 0.0% |
| New Square, Village of | 503 | $469,065,000 | 0 | 0.0% | $0 | 0.0% |
| Nyack, Village of | 1,854 | $2,151,804,000 | 0 | 0.0% | $0 | 0.0% |
| Orangetown, Town of | 12,622 | $9,753,484,000 | 0 | 0.0% | $0 | 0.0% |
| Piermont, Village of | 902 | $607,070,000 | 0 | 0.0% | $0 | 0.0% |
| Pomona, Village of | 1,177 | $751,081,000 | 781 | 66.4% | $495,240,000 | 65.9% |
| Ramapo, Town of | 8,174 | $4,907,209,000 | 98 | 1.2% | $39,023,000 | <1% |
| Sloatsburg, Village of | 1,147 | $560,532,000 | 0 | 0.0% | $0 | 0.0% |
| South Nyack, Village of | 962 | $909,458,000 | 0 | 0.0% | $0 | 0.0% |
| Spring Valley, Village of | 4,397 | $3,250,707,000 | 0 | 0.0% | $0 | 0.0% |
| Stony Point, Town of | 5,612 | $3,203,457,000 | 5,557 | 99.0% | $3,147,734,000 | 98.3% |
| Suffern, Village of | 3,159 | $2,003,083,000 | 0 | 0.0% | $0 | 0.0% |
| Upper Nyack, Village of | 814 | $420,682,000 | 0 | 0.0% | $0 | 0.0% |
| Wesley Hills, Village of | 1,734 | $1,046,454,000 | 0 | 0.0% | $0 | 0.0% |
| West Haverstraw, Village of | 2,688 | $1,607,273,000 | 487 | 18.1% | $291,552,000 | 18.1% |
| **Rockland County** | **88,584** | **$59,918,615,000** | **10,429** | **11.8%** | **$5,813,518,000** | **9.7%** |

Source: Godt 2001, HAZUS-MH 3.2

## Impact on Critical Facilities

Table 5.4.5-4 lists the critical facilities identified in Section 4 (County Profile) located within the landslide hazard area.

**Table 5.4.5-3. Number of Critical Facilities in the Landslide Incidence Susceptibility Area**

| Municipality | Facility Types | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Communication | Day Care | DPW | EMS | Fire Station | Hazmat | Medical | Municipal Hall | Police Station | Post Office | School | Senior | Water Tower | Well | Wastewater Pump | Wastewater Treatment |
| Haverstraw, Town of | 0 | 9 | 1 | 0 | 3 | 2 | 0 | 1 | 1 | 1 | 4 | 0 | 1 | 23 | 0 | 0 |
| Pomona, Village of | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ramapo, Town of | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 2 | 0 |
| Stony Point, Town of | 1 | 8 | 1 | 1 | 2 | 5 | 0 | 1 | 2 | 2 | 3 | 2 | 0 | 24 | 0 | 1 |
| West Haverstraw, Village of | 0 | 2 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| **Rockland County** | **2** | **19** | **2** | **2** | **5** | **8** | **1** | **3** | **3** | **4** | **7** | **2** | **2** | **48** | **2** | **1** |

Source: Godt 2001, Rockland County

## Impact on the Economy

The impact of a landslide on the economy and estimated dollar losses are difficult to measure. As stated earlier, landslides can exert direct and indirect effects on society. Direct costs include 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, landslides threaten transportation corridors, fuel and energy conduits, and communication lines (USGS 2003). Estimated potential damage to general building stock can be quantified as discussed above. For the purposes of this analysis, damage to general building stock is discussed below.

Direct building losses are estimated costs to repair or replace damaged buildings. Approximately $5.8 billion in replacement cost value or 9.7% of Rockland County's total building inventory is within the estimated landslide high incidence area. Losses to Rockland County's building inventory would impact Allegany County's tax base and the local economy.

US Highways 9W and 202, as well as the Palisades Interstate Parkway traverse the high incidence landslide hazard areas. Multiple county roads also traverse the hazard area. Refer to Figure 5.4.5-3 for locations of major roadways in the County within hazard areas.

## Effect of Climate Change on Vulnerability

Climate is defined not simply as average temperature and precipitation but also by the type, frequency and intensity of weather events. Both globally and at the local scale, climate change has the potential to alter the prevalence and severity of extremes such as flood events. While predicting changes of flood events under a changing climate is difficult, understanding vulnerabilities to potential changes is a critical part of estimating future climate change impacts on human health, society and the environment (U.S. Environmental Protection Agency [EPA], 2006).

## Change of Vulnerability

The 2010 HMP did not include a quantitative assessment of the landslide hazard area. For the 2016 HMP update, risks to the County's population, building stock, and critical facilities were assessed. Overall, the County remains potentially vulnerable to the landslide hazard.

## 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 Rockland County.