4.3.7 Landslide

This section provides a profile and vulnerability assessment of the landslide hazard in Fulton County. 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 (USGS 2016). Landslides are classified by type of material involved and the type of movement. In addition, they are classified at the rate of movement and the water content of the material. Movement rates range from inches over many years to many feet per second (DCNR 2001).

Landslides may be triggered by both natural and human-caused changes in the environment, including heavy rain, rapid snow melt, steepening of slopes through construction or erosion, earthquakes, and changes in groundwater levels. Areas that are generally prone to landslide hazards include previous landslide areas, the bases of steep slopes, the bases of drainage channels, developed hillsides, and areas recently burned by forest and brush fires (Delano and Wilshusen 2001). Human activities that contribute to slope failure include altering the natural slope gradient, increasing soil water content, and removing vegetation cover.

4.3.7.1 Location and Extent

The entire U.S. experiences landslides, with 36 states having moderate to highly severe landslide hazards. Expansion of urban and recreational developments into hillside areas exposes more people to the threat of landslides each year. According to the USGS, Fulton County has high landslide potential.

Rockfalls and other slope failures occur in areas of Pennsylvania with moderate to steep slopes; however, most of Pennsylvania has areas susceptible to landslides. The southwestern area of Pennsylvania has the highest concentration of landslides (PEMA, 2018; DCNR 2001). According to DCNR, most major and minor highways have sections cut in rock or soil that can lead to slope failure. Steep mountain slopes across Pennsylvania have experienced debris avalanches associated with extreme rainfall or rain-on-snow events. Additionally, urban and rural land development is increasing the number of landslide occurrences. Major highway construction with large excavations and fills creates potential for landslides (DCNR 2001). Figure 4.3.7-1 shows the landslide susceptible areas across the Commonwealth. Fulton County is noted as having moderate incidence and high susceptibility to landslides throughout the entire county.

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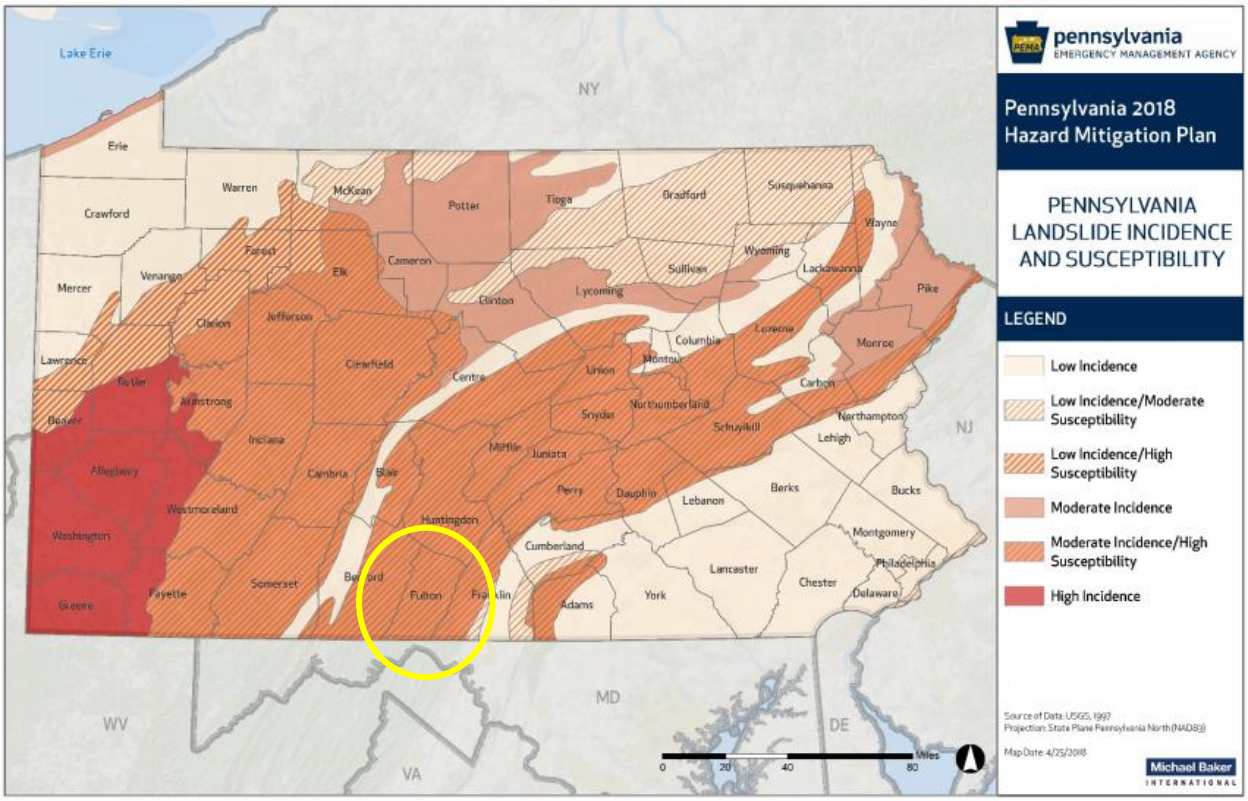
Figure 4.3.7-1. Areas of Pennsylvania Susceptible to Landslides



Source: *PEMA, 2018*

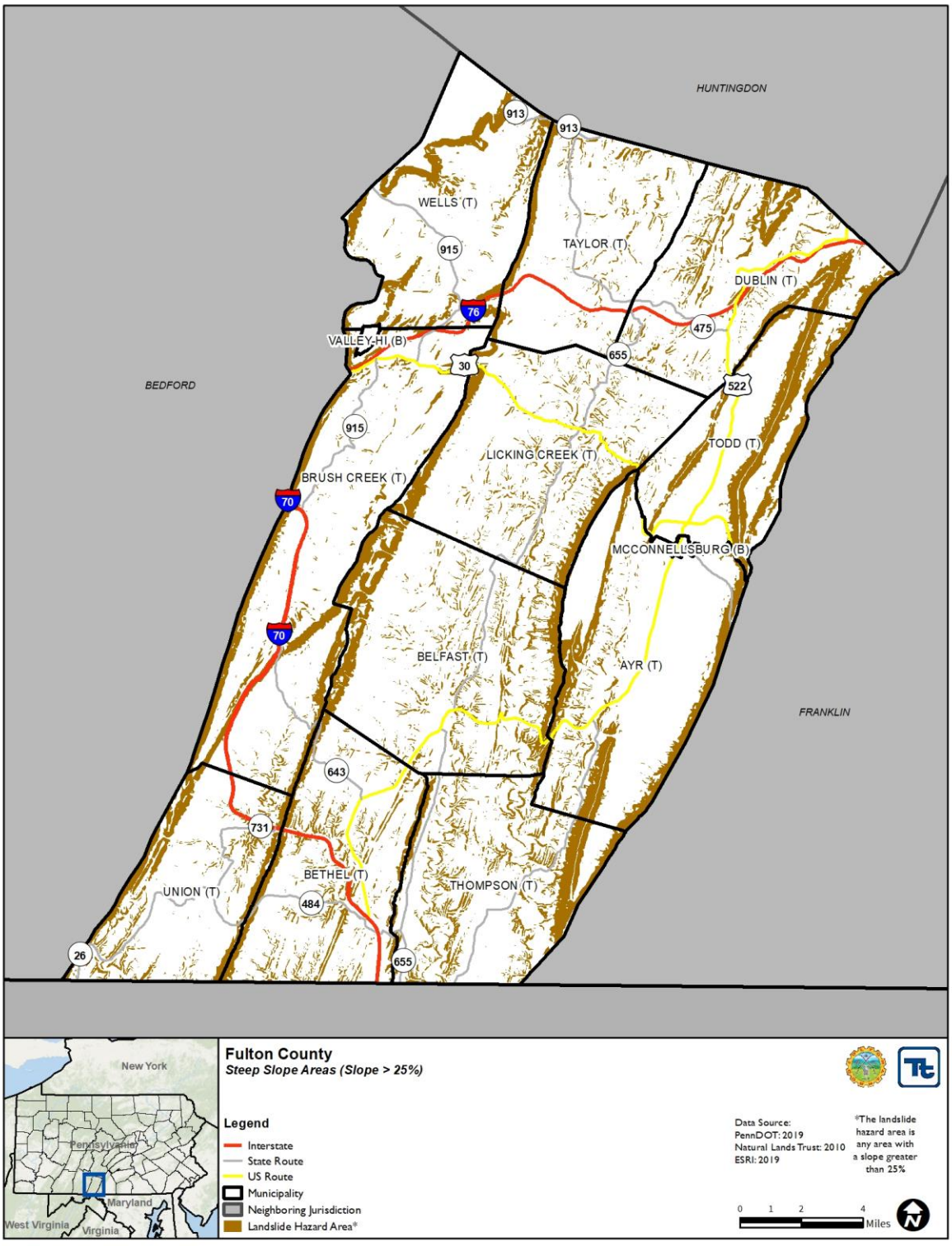
Note: *The yellow circle indicates the approximate location of Fulton County. Fulton County is shown as having a moderate incidence and high susceptibility to landslide throughout the entire county.*

To determine the extent of a landslide hazard, the affected areas need to be identified, and the probability of the landslide occurring within some time period needs to be assessed. Natural variables that contribute to the overall extent of potential landslide activity in any particular area include soil properties, topographic position and slope, and historical incidence. Predicting a landslide is difficult, even under ideal conditions and with reliable information. As a result, the landslide hazard is often represented by landslide incidence and/or susceptibility, as defined below:

- Landslide incidence is the number of landslides that have occurred in a given geographic area. High incidence means greater than 15% of a given area has been involved in landsliding; medium incidence means that 1.5 to 15% of an area has been involved; and low incidence means that less than 1.5% of an area has been involved (Radbruch-Hall 1982).
- 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 (Radbruch-Hall 1982).

According to the Steep Slopes GIS layer from the Natural Lands Trust as shown in Figure 4.3.7-2, Fulton County has a considerable amount of steep slope area distributed throughout Fulton County. For the purposes of this planning effort, any area with a slope greater than 25 percent is considered the hazard area.

Figure 4.3.7-2. Landslide Hazard Area in Fulton County



4.3.7.2 Range of Magnitude

Landslides have the potential to damage transportation routes, utilities, and buildings. They can also create travel delays and other side effects. Fortunately, deaths and injuries caused by landslides are rare in Pennsylvania, and most landslides in the Commonwealth are moderate to slow moving, damaging things rather than people. Almost all of the known deaths caused by landslides have occurred when rockfalls or other slides along highways have involved vehicles. Storm-induced debris flows are the only other type of landslide likely to cause death and injuries. As residential and recreational development increases on and near steep mountain slopes, the hazards from these events will also increase (PEMA 2018).

According to DCNR, the Pennsylvania Department of Transportation and large municipalities incur substantial costs due to landslide damage and to extra construction costs for new roads in known landslide-prone areas. One PennDOT estimate in 1991 showed an average of $10 million per year in landslide repair contracts across the Commonwealth and a similar amount in mitigation costs for grading projects (DCNR 2001).

The impact of landslides on the environment depends on the size and specific location of the event. In general, impacts include:

- Changes to topography
- Damage or destruction of vegetation
- Potential diversion or blockage of water in the vicinity of streams, rivers, etc.
- Increased sediment runoff both during and after event (PEMA 2018).

Fulton County's worst-case scenario would be an event similar to one in Beaver County in 1942 (PEMA 2018). In that event, 150 cubic yards of rock fell from a highway cut onto a bus. Twenty-two people were killed, and four others were injured.

4.3.7.3 Past Occurrence

Outside of impacts to important transportation routes, landslide history is not documented as completely (if at all) as other hazards, primarily because landslides are not always seen, and therefore historical landslide occurrences in Fulton County are not well known.

The National Center for Environmental Information (NCEI) does not have any records of landslides in the county (NCEI 2019). Between 1954 and 2019, FEMA issued a disaster (DR) or emergency (EM) declaration for Pennsylvania for one geological hazard-related event, classified as severe storms, flooding, and mudslide. This declaration did not include Fulton County (FEMA 2019).

4.3.7.4 Future Occurrence

Based upon risk factors and past occurrences, it is likely that landslides will continue to occur in Fulton County in the future. However, severity of the landslides can vary depending on type and location of event. Landslide probabilities are largely a function of surface geology but are also influenced by both weather and human activities. Mismanaged, intense development in steeply sloped areas could increase the frequency of landslide occurrence. Periods of intense rain or snowmelt can also increase the risk of landslides.

Mismanaged, intense development in steeply sloped areas could increase the frequency of landslides in Fulton County. Building and road construction are contributing development factors to landslides, as they can often undermine or steepen otherwise stable soil. Any events that do occur would take place in steeply sloped areas that do not feature extensive land development or many structures. Increased deforestation and soil disturbances caused by development on sloped areas further increases these risks. As timbering and

development of sloped land continue, the risk of significant landslides increases. The probability of future occurrence of landslides in Fulton County cannot be calculated due to the lack of reported landslide events within the County. This does not indicate that landslides do not occur, but that they are not commonly reported in the County.

Based on available historical data, the future occurrence of landslides can be considered *unlikely* as defined by the Risk Factor Methodology probability criteria (refer to Section 4.4).

4.3.7.5 Vulnerability Assessment

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

- Overview of vulnerability
- Data and methodology used for the evaluation
- Impact on (1) life; (2) health and safety; (3) general building stock; (4) critical facilities, economy; and (5) future growth and development
- Effect of climate change on vulnerability
- Additional data and next steps.

Vulnerability to ground failure hazards is a function of location, soil type, geology, type of human activity, use, and frequency of events. Effects of landslides on people and structures can be reduced by total avoidance of hazard areas or by restricting, prohibiting, or imposing conditions on hazard-zone activity. Local governments can reduce effects of landslides through land use policies and regulations. Individuals can reduce their exposure to hazards by educating themselves on the past hazard history of the site and by making inquiries to planning and engineering departments of local governments (National Atlas 2018).

Overall, 17.5 percent (or 76.9 square miles) of Fulton County is located within the landslide hazard area. Landslide hazard areas are present throughout Fulton County. For the purposes of this assessment, steep slope areas with a slope angle greater than 25 percent are considered the hazard zone. Refer to Figure 4.3.7-2 earlier in this section. Further information regarding these hazard areas is presented below.

Impact on Life, Health, and Safety

As discussed above, 17.5 percent of Fulton County is located in the landslide hazard area. Therefore, the County's population (U.S. Census 2010 population of 14,845) within this area is considered exposed to this hazard; however, based on the historic record, landslide events tend to be localized events. Landslide events can cause both direct and indirect (impact on buildings) damage to the County's population.

To estimate populations within the hazard area, the hazard area boundary (shown in Figure 4.3.7-2) was overlaid upon the 2010 U.S. Census population data (U.S. Census 2010). Census blocks with their centers (centroids) within the boundary of the landslide hazard area were used to calculate the estimated population considered exposed to this hazard. The U.S. Census blocks do not align exactly with the hazard area, and thus these estimates should be considered for planning purposes only. Additionally, the hazard area boundary is only available at the municipal level and more detailed breakdowns are not available; this presents another reason to only use these estimates for planning purposes. In addition to being available at the census block level, the 2010 U.S. Census data is the default demographic data in HAZUS-MH v4.2. The census block level provides a higher resolution of population distribution than American Community Survey spatial data, which

is only available at the census tract level. The 2010 U.S. Census data is also used to maintain consistency in data throughout vulnerability assessments throughout this Hazard Mitigation Plan (HMP).

Table 4.3.7-1 lists populations exposed by municipality (U.S. Census 2010). The population downslope of the landslide hazard areas is particularly vulnerable to this hazard. Due to the nature of U.S. Census block data, it is difficult to determine demographics of populations vulnerable to mass movements of geological material. Using this approach, 176 people (1.2 percent of the population) are located in the landslide hazard area. Please note while reviewing the table that exposure rates do not equate to actual potential impacts. Although an entire jurisdiction may be located in a high-susceptibility area, as noted, most landslide events are localized. Therefore, while a large number of residents may have a high exposure risk to landslide events, few residents will actually be significantly impacted.

Table 4.3.7-1. Estimated Fulton County Population Vulnerable to the Landslide Hazard Area

Municipality	U.S. Census 2010 Population	Estimated Population Exposed	
		Estimated Population Exposed	% of Total
Ayr Township	1,942	47	2.4%
Belfast Township	1,448	26	1.8%
Bethel Township	1,508	30	2.0%
Brush Creek Township	819	5	0.7%
Dublin Township	1,264	9	0.7%
Licking Creek Township	1,703	25	1.5%
McConnellsburg Borough	1,220	0	0.0%
Taylor Township	1,118	1	0.1%
Thompson Township	1,098	16	1.5%
Todd Township	1,527	14	0.9%
Union Township	706	2	0.3%
Valley-Hi Borough*	15	0	0.0%
Wells Township	477	0	0.0%
Fulton County	**14,845**	**176**	**1.2%**

Sources: United States Census 2010, National Lands Trust 2010

Impact on General Building Stock

For this analysis, the HAZUS-MH v4.2 dasymetric census blocks were used (refer to Section 4.1 for more information). In general, the built environment within the landslide hazard area and the population, structures, and infrastructure downslope are vulnerable to this hazard. Using the default general building stock, the replacement cost values of the U.S. Census blocks with their centroids in the hazard area were totaled to provide the exposed replacement cost value. Building footprints provided by Fulton County were used to estimate the number of structures within the landslide hazard area. Approximately $34.9 million in replacement cost is located in the landslide hazard area (1.5 percent) or an estimated 110 structures. Table 4.3.7-2 lists building stock exposure per municipality.

Table 4.3.7-2. Estimated General Building Stock Exposure to the Landslide Hazard Area

Municipality	Number of Buildings	Total Replacement Cost Value (RCV)	Estimated Building Stock Exposed			
			Number of Buildings	% of Total	RCV	% of Total
Ayr Township	1,139	$328,056,000	31	2.7%	$25,878,000	7.9%
Belfast Township	740	$181,485,000	14	1.9%	$3,945,000	2.2%
Bethel Township	853	$243,010,000	18	2.1%	$2,492,000	1.0%
Brush Creek Township	519	$110,481,000	4	0.8%	$1,015,000	0.9%
Dublin Township	697	$153,284,000	5	0.7%	$0	0.0%
Licking Creek Township	881	$203,625,000	16	1.8%	$1,042,000	0.5%
McConnellsburg Borough	538	$276,419,000	0	0.0%	$0	0.0%
Taylor Township	697	$141,644,000	1	0.1%	$0	0.0%
Thompson Township	572	$155,461,000	12	2.1%	$0	0.0%
Todd Township	858	$298,975,000	7	0.8%	$0	0.0%
Union Township	421	$106,265,000	2	0.5%	$0	0.0%
Valley-Hi Borough*	29	$5,827,000	0	0.0%	$0	0.0%
Wells Township	292	$58,946,000	0	0.0%	$544,000	0.9%
Fulton County	**8,236**	**$2,263,478,000**	110	1.3%	$34,916,000	1.5%

Source: HAZUS-MH v4.2; Fulton County 2019; USGS 2010
Notes:
% Percent
RCV Replacement cost value (structure and contents)

Critical Facilities and the Economy

To estimate exposure, the approximate hazard area was overlaid upon the essential and municipal facilities. In addition to critical facilities, a significant amount of infrastructure can be exposed to mass movements of geological material:

- *Roads* – Access to major roads is crucial to life-safety after a disaster event and to response and recovery operations. Landslides can block egress and ingress on roads, isolating neighborhoods, posing traffic problems, and causing delays of public and private transportation. This can result in economic losses for businesses.
- *Bridges* – Landslides can significantly impact road bridges. Mass movements can knock out bridge abutments or significantly weaken the soil supporting them, rendering them hazardous for use.
- *Power Lines* – Power lines are generally elevated above steep slopes but the towers supporting them can be subject to landslides. A landslide could trigger failure of the soil underneath a tower, causing it to collapse and ripping down the lines. Power and communication failures due to landslides can create problems for vulnerable populations and businesses.

Several other types of infrastructure may also be exposed to landslides, including water and sewer infrastructure. At this time, all critical facilities, infrastructure, and transportation corridors within the hazard areas are considered vulnerable until more information becomes available. There is a single communications facility in Bethel Township as the only critical facility in Fulton County within the landslide hazard area.

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

A landslide event alters the landscape. In addition to changes in topography, vegetation and wildlife habitats may be damaged or destroyed, and soil and sediment runoff will accumulate downslope, potentially blocking waterways and roadways and impacting quality of streams and other water bodies. Additional environmental impacts include loss of forest productivity. Considering both landslide hazard areas, the entire building stock is potentially exposed to a landslide event. These dollar value losses to Fulton County's total building inventory would impact Fulton County's tax base and the local economy.

All major roadways and transportation routes located in, and downslope of, the landslide hazard area may be vulnerable to a landslide event.

Impact on the Environment

The impact of landslides on the environment depends on the size and specific location of the event. Impacts include:

- Changes to topography
- Damage or destruction of vegetation
- Potential diversion or blockage of water in the vicinity of streams, rivers, etc.
- Increased sediment runoff both during and after event (PEMA 2018)

Future Growth and Development

Areas targeted for potential future growth and development within the next five years have been identified across Fulton County. Refer to Section 2.4 of this HMP for further details. New development within the landslide hazard areas are considered exposed to these risks.

Effect of Climate Change on Vulnerability

Climate is defined not just as average temperature and precipitation but also by type, frequency, and intensity of weather events. Both globally and at the local scale, climate change could alter prevalence and severity of extremes such as severe storms, including those that may bring intense or prolonged precipitation (U.S. Environmental Protection Agency [EPA] 2006). An increase in rainfall intensity and duration will saturate the soil, potentially erode the local landscape, and impair slope stability, leading to an increase of landslide events in Fulton County.

While predicting changes in these types of 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 (EPA 2006). Potential effects of climate change on Fulton County's vulnerability to landslide events must be considered as understanding of impacts of regional climate change increases.

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Additional Data and Next Steps

More detailed landslide susceptibility zones can be generated so that communities can more accurately identify high hazard areas. A pilot study conducted for Schenectady County, New York, (described in the 2011 Draft New York State HMP) developed higher-resolution landslide susceptibility zones. The methodology included use of the Natural Resource Conservation Services (NRCS) Digital Soil Survey soil units and their associated properties, including the American Association of State Highway and Transportation Officials (AASHTO) rating, liquid limit, hydrologic group, percentage of silt and clay, erosion potential, and slope, derived from high-resolution digital elevation models. Identifying historical damages to buildings and infrastructure incurred from landslides will also help with loss estimates and future modeling efforts, given a margin of uncertainty. Furthermore, research on rainfall thresholds for forecasting landslide potential may also be an option for Fulton County.

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