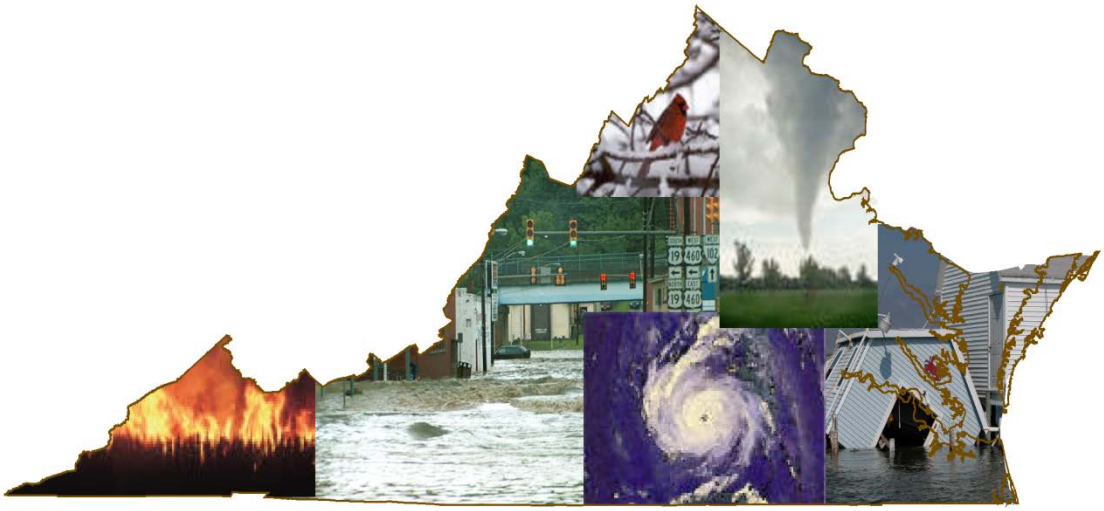
COMMONWEALTH OF VIRGINIA

Hazard Mitigation Plan



Chapter 3
Hazard Identification and Risk Assessment (HIRA)

Section 3.12 - Landslides

SECTION 3.12

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Section 3.12: Landslides

Description

A landslide is the downhill movement of soil, rock, or other earth materials, in response to gravity. Landslides may include rock falls and topples, debris flows and debris avalanches, earthflows, mudflows and mudslides, creep, and lateral spread of rock or soil. Frequently landslides occur in areas where the soil is saturated from heavy rains or snowmelt. They can also be started by earthquakes, changes in groundwater, disturbance or change of a slope by man-made construction activities, or any combination of these factors. A landslide occurs when the force that is pulling the slope downward (gravity) exceeds the strength of the earth materials that compose the slope.[1]

June 27, 1995 Flooding and Landslides
Madison County, Virginia
Source: USGS Open File Report 97-438

Some landslides move slowly and cause damage gradually, whereas others move so rapidly that they can destroy property and take lives suddenly and unexpectedly. Debris flows (also referred to as mudslides, mudflows, or debris avalanches) are a common type of fast-moving landslide that generally occurs during intense rainfall on water-saturated soil. They usually start on steep hillsides as soil slumps or slides that liquefy and accelerate to speeds as great as 35 miles per hour or more. They continue flowing down hills and into channels, depositing sand, mud, boulders, and organic material onto more gently sloping ground. The flow consistency ranges from watery mud to thick, rocky mud (like wet cement), which is dense enough to carry boulders, trees, and cars. Debris flows from different sources can combine in channels, where their destructive power may be greatly increased.[2]

Landslides are a major geologic hazard because they are widespread, occurring in all 50 states and U.S. territories, causing $1-2 billion in damages, and leading to more than 25 fatalities on average each year[1]. Casualties in the United States are primarily caused by rockfalls, rock slides, and debris flows. Expansion of urban and recreational developments into hillside areas exposes more people to landslide-prone conditions each year.

[1] National Atlas Articles Geology: http://www.nationalatlas.gov/articles/geology/a_geohazards.html
[2] USGS Fact Sheet: FS-159-96: Debris-Flow Hazards in the Blue Ridge of Virginia http://landslides.usgs.gov/docs/faq/fs159-96.pdf

Historic Occurrence

The greatest landslide hazards are present in western and southwestern Virginia. Similar to karst, there is no comprehensive database documenting all landslide occurrences within the state.

One federally-declared disaster has been recorded for Buchanan County; two other declared disasters in Nelson and Madison Counties have experienced landslides as a result of flooding or hurricane related events. The USGS has an informative publication titled "Debris-Flow Hazards in the Blue Ridge of Virginia" that highlights past events, specifically the June 27, 1995 event in Madison County.

In the 2010 Hazard Mitigation Plan, scientists from the USGS determined that most of the debris-flow events between 1844 and 1985 have occurred in the Blue Ridge area. Studies of stream channels found evidence of prehistoric debris flows in Madison County. Radiocarbon dating from these debris-flow deposits indicates that landslide events have repeatedly occurred there over the last 34,000 years[3].

The National Climatic Data Center (NCDC) Storm Events database has landslide records for Buchanan County, King George County, Pulaski County, Giles County, Alleghany County, and Tazewell County. Additional sources, including local plans, were used to collect information on historical occurrences that have been included in Table 3.12-1 below.

Table 3.12-1: Historical Landslide Occurrences

Year	Location of Landslide	Description
1969	Nelson County	Hurricane Camille stalled over the Blue Ridge Mountains, dropping more than 30 inches of rain in less than eight hours. Flooding and numerous landslides and debris flows led to the deaths of more than 150 people, 100 injuries, destruction of more than 100 bridges, and more than $150 million in property damage. This event resulted in the most recorded deaths by a natural hazard in the Commonwealth.
1985	Potomac and Cheat River Watersheds	Affecting both Virginia and West Virginia, 72 hours of storms produced record floods and extensive landslide and debris flow activity, causing 70 deaths and a total of $1.3 billion in damage to homes, businesses, roads, and farmlands.
1987	Alleghany County	Heavy rains caused landslides along Smith Creek in the Town of Clifton Forge.
1994	Pulaski County	Landslides were observed in June when six inches of rain fell in a three hour period. The landslides knocked one home from its foundation and blocked five miles of roads.

[3] USGS Fact Sheet: FS-159-96: Debris-Flow Hazards in the Blue Ridge of Virginia http://landslides.usgs.gov/docs/faq/fs159-96.pdf

Year	Location of Landslide	Description
1995	Buchanan County	Previous rains and a saturated ground caused an abandoned/sealed underground mine to burst. Water, rocks, and dirt cascaded into a home along Laurel Creek, about three miles south of Whitewood. A 26-year-old woman was buried in the basement by debris and property damage was estimated at $15,000.
1995	Madison County	During 16 hours approximately 30 inches of rain fell in small area of Madison County. Eight people were killed in June when hundreds of landslides combined with widespread flooding. As many as 2,000 homes were affected and 35,000 acres of crops were damaged. Total property damages were estimated at $112 million.
1996	King George County	A rockslide caused a portion of local route 627 to slide down a cliff. At least 1/2 the width of the road was removed. The rockslide was partly due to repeated heavy rains, very moist soil, and minor flooding along the river during the winter of 1997/98. Major river and flash flood events in 1996 likely set the stage, over the long term, for the slide. Property damage was estimated at $150,000.
2000	City of Staunton	Sixteen landslides were experienced along Staunton district roads.
2004	City of Richmond	The remnants of Tropical Depression Gaston caused severe landslides throughout the Church Hill and Riverside Drive sections of Richmond in August following 14" of rain in eight hours.
2006	Tazewell County	A severe storm with very intense rain. Intense enough to help produce a landslide near a pipeline construction project near the town of Tannersville, VA. The landslide blocked sections of Freestone Valley Road with mud up to 3 inches deep.
2008	Giles County	Showers and thunderstorms produced enough rain to cause a mudslide that blocked Highway 42. Property damage was estimated at $10,000
2008	Alleghany County	Due to a series of thunderstorms and rainfall, a rock slide occurred on Route 220 just north of the City of Covington. No property damage estimates were reported.

Probability

Landslide probability is highly site-specific, and cannot be accurately characterized on a statewide basis, except in the most general sense. Relative risk ranking is intended only for general comparison to the other hazards that impact Virginia.

The magnitude of landslides is dependent on the amount of liquid and landmass in motion and the amount of development in the area. Often a landslide will be more severe in areas with higher slopes with poorly drained soils. Some areas that are generally prone to landslides include old landslide sites, base of slopes, base of minor drainage hollows, base or top of old fill slope, base or top of a steep cut slope, and developed hillsides where leach field septic systems are used. [4]

[4] USGS Fact Sheet: FS-0071-00: Landslide Hazards

A hazard map was developed by the USGS based on the 1995 Madison County event. This report states the mapping procedures applicability to other parts of the Blue Ridge. Recurrence for a debris-flow event, in a small area, can be one event every 3,000 to 4,000 years (0.03 – 0.025% annual chance) for Nelson County[5]. These intervals will decrease when considering larger areas.

Impact and Vulnerability

Landslides can cause serious damage to highways, buildings, homes and other structures that support a wide range of economies and activities. Landslides commonly coincide with other natural disasters. Expansion of urban development contributes to greater risk of damage by landslides.

The USGS recognizes six major impacts caused by landslides:[6]

1. Causes damage in all 50 States, Puerto Rico, and the U.S. Virgin Islands
2. Costs $3.5 billion per year, in 2005 dollars, in damage repair
3. Causes between 25 and 50 deaths in the United States annually
4. Reduces real estate values and tourist revenue
5. Leads to lost human, industrial, agricultural, and forest productivity
6. Causes damage to the natural environment

Risk

Because the data are highly generalized, owing to the small scale and the scarcity of precise landslide information for much of the country, it is unsuitable for local planning or actual site selection. Without well-established occurrence probabilities true risk and annualized dollar losses cannot be estimated. However, a rough estimate of financial impact can be developed based on the NCDC Storm Events database, although such an estimate is subject to the biases and inconsistencies present in that data. In the 19 years from 1993 through 2011, NCDC reports an annual average of about $12,609 per year. As noted in section 3.3 there are many inaccuracies in reporting what hazard type an event falls within and the NCDC reporting of geological hazards. For example, Madison County was reported to experience $112 million in damages during the severe storms and flooding in 1995. This event is represented in the flooding section of this report but should also be represented here and in the ranking.

The best available landslide data is the USGS Landslide Overview Map of the Coterminous United States. This dataset shows areas in the United States where large numbers of landslides have occurred and areas which are susceptible to landslides.

[5] USGS Morgan, BA, Wieczorek, GF, Campbell, RH, Gori, PL. Debris-Flow Hazards in Areas affected by the June 27, 1995 storm in Madison County, Virginia. Open File Report 97-438. 1997
[6] USGS Fact Sheet: FS-2005-3156: Landslide Hazards—A National Threat

This dataset is a digital representation of USGS Open-File Report 97-289, which is a PDF version of the 1997 USGS Digital Representation of Landslide Overview Map (scale 1:4,000,000).The report classifies the major physical subdivision of the United States and assesses the vulnerability based on subdivision characteristics. Figure 3.12-1 shows the areas that may be susceptible to landslides.

This assessment focuses on areas that may be susceptible to landsliding and are likely to occur based on past incidence. The assigning of any area to the lowest incidence or susceptibility category should not be construed to mean that no landslides exist or that no areas are susceptible to landsliding. Even areas in the lowest category may contain landslides unknown to the compilers or have an incidence of less than 1.5 percent. In general, the possibility is great that a lot more landslides than indicated exist in any given map area (except for the highest category), owing to the overall scarcity of landslide information for many parts of the country. Moreover, many published special-purpose geologic maps do not show landslides, even where they are known to exist[7].

The USGS divides landslide risk into six categories. These six categories were grouped into three, broader categories to be used for the risk analysis and ranking; geographic extent is based off of these groupings. These categories include:

High Risk

1. High susceptibility to landsliding and moderate incidence.
2. High susceptibility to landsliding and low incidence.
3. High landslide incidence (more than 15% of the area is involved in landsliding).

Moderate Risk

4. Moderate susceptibility to landsliding and low incidence.
5. Moderate landslide incidence (1.5 - 15% of the area is involved in landsliding).

Low Risk

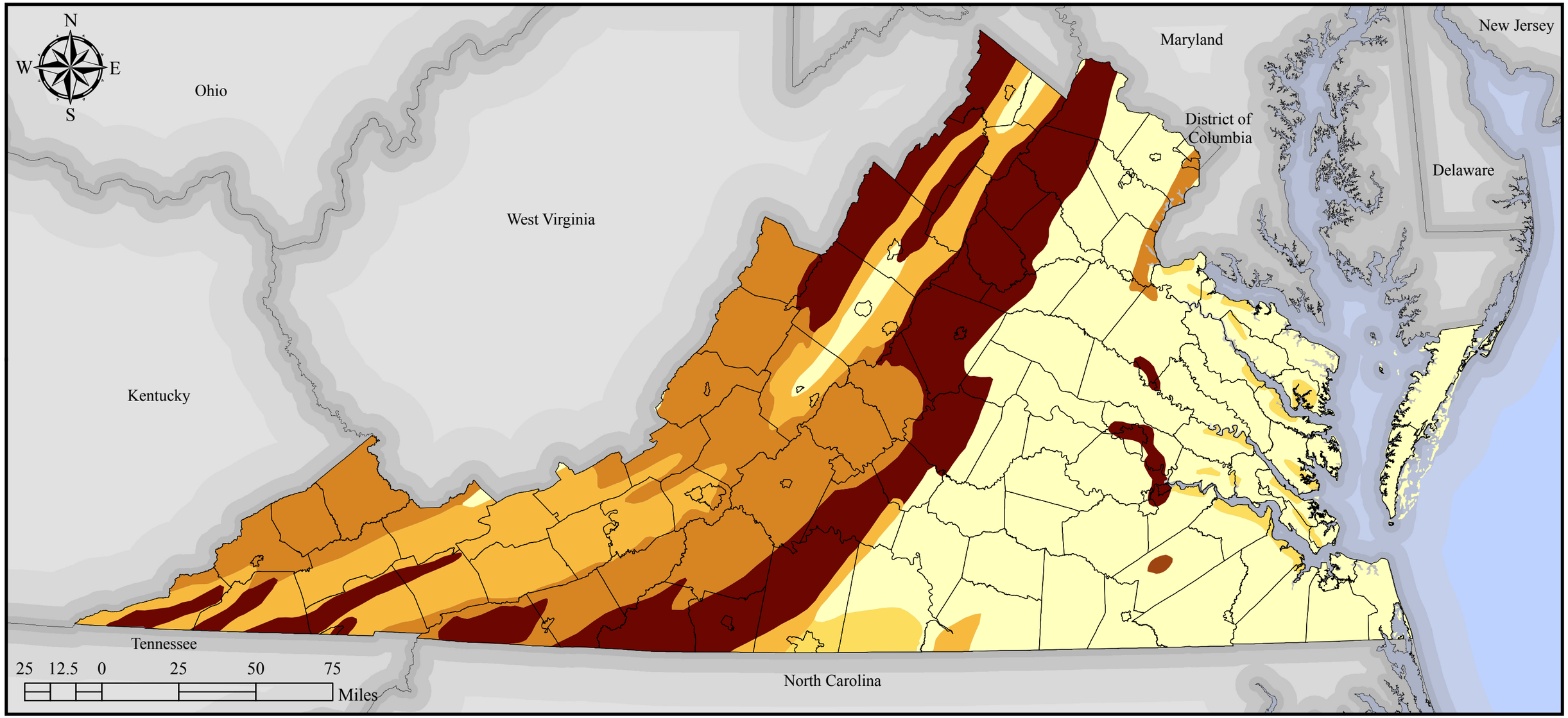
6. Low landslide incidence (less than 1.5 % of the area is involved in landsliding).

The six categories were grouped into High (categories 1-3), Medium (categories 4 – 5), and Low (category 6) to assess the risk to state faculties, critical facilities and jurisdictions.

The Virginia Department of Mines and Minerals (DMME) has also reviewed Virginia's susceptibility to landslides and provided their own assessment based on the USGS Landslide Overview Map (Figure 3.12-1). Their assessment is shown in Figure 3.12-2. However, DMME notes that a detailed landslide risk study for the state of Virginia is still needed.

[7] Radbruch-Hall, et al. Landslide Overview Map of the Conterminous United States, 1982. USGS Professional Paper 1183. http://pubs.usgs.gov/pp/p1183/pp1183.html

Figure 3.12-1: Landslide Incidence and Susceptibility



DATA SOURCES:

USGS NLHP
VGIN Jurisdictional Boundaries
ESRI State Boundaries

PROJECTION: *VA Lambert Conformal Conic*
North American Datum 1983

LEGEND:

Landslide Categories

- High Susceptibility & Moderate Incidence
- High Susceptibility & Low Incidence
- High Incidence
- Moderate Susceptibility & Low Incidence
- Moderate Incidence
- Low Incidence

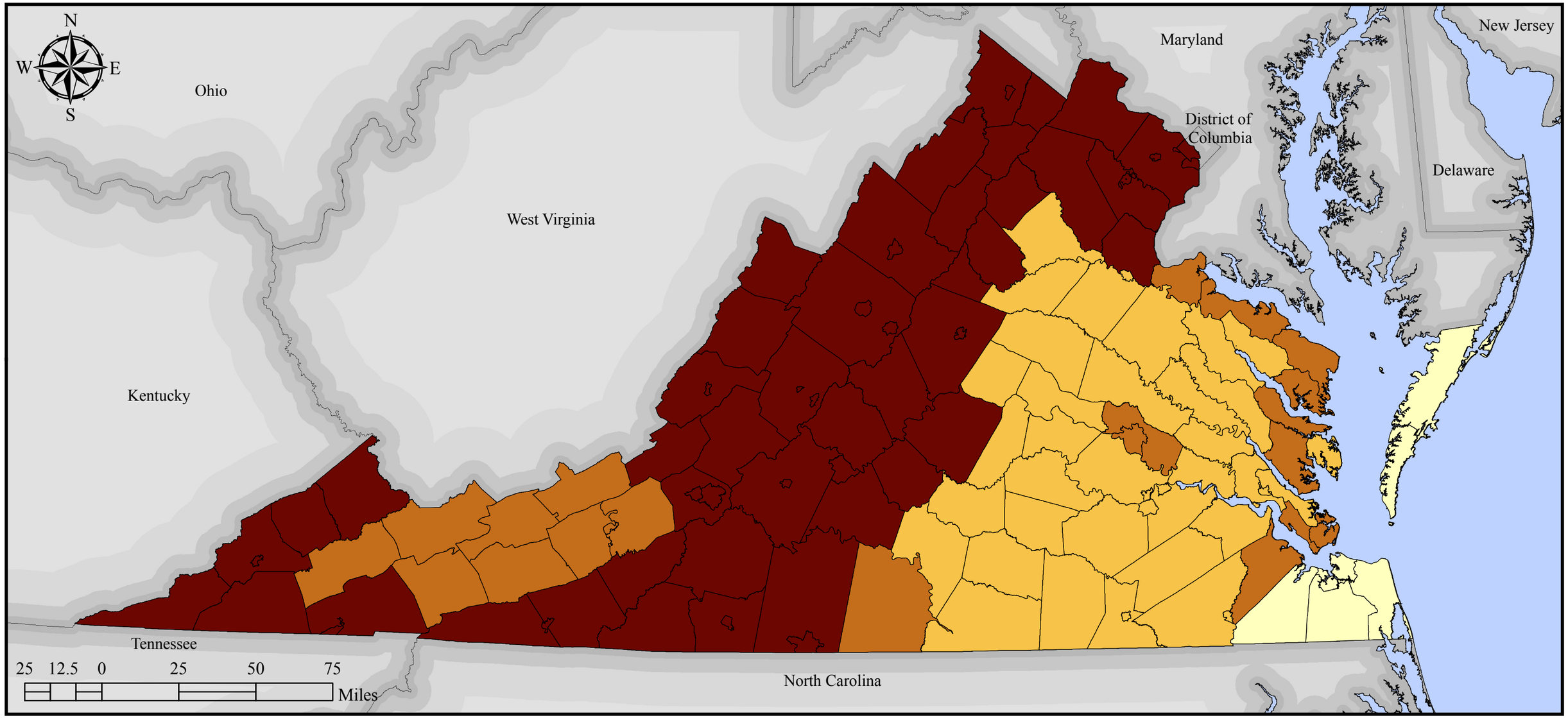
HAZARD IDENTIFICATION:

The Landslide Incidence and Susceptibility map layer shows areas of landslides and areas susceptible to future landsliding. Areas where large numbers of landslides have occurred and areas which are susceptible to landsliding have been delineated in this layer.

Landslides are defined to include most types of gravitational mass movement such as rockfalls, debris flows, and the failure of engineered soil materials.

DISCLAIMER: Majority of available hazard data is intended to be used at national or regional scales. The purpose of the data sets are to give general indication of areas that may be susceptible to hazards. In order to identify potential risk in the Commonwealth available data has been used beyond the original intent.

Figure 3.12-2: Landslide Potential as Assessed by Virginia DMME



DATA SOURCES:

Virginia DMME
VGIN Jurisdictional Boundaries
ESRI State Boundaries

LEGEND:

Landslide Potential by Jurisdiction

- Low
- Moderate to Low
- Moderate
- High

DATA IDENTIFICATION:

This map shows landslide potential according to the Virginia Department of Mines and Minerals (DMME), adapted from the USGS Landslide Overview Map of the Coterminous United States.

PROJECTION: *VA Lambert Conformal Conic*
North American Datum 1983

DISCLAIMER: Majority of available hazard data is intended to be used at national or regional scales. The purpose of the data sets are to give general indication of areas that may be susceptible to hazards. In order to identify potential risk in the Commonwealth available data has been used beyond the original intent.

State Facility Risk

In order to determine which facilities were at risk for landslide, the state facilities were intersected with the USGS Landslide Incidence and Susceptibility layer, and the dominant risk category was then assigned to the facilities. The results of this analysis indicate 3,978 buildings are in regions with relatively high landslide risk. Table 3.12-2 shows the distribution of risk and building value at risk for state facilities. Annualized loss estimates were not calculated for state facilities due to the scale of available landslide mapping and lack of probabilities of future occurrences.

Table 3.12-2: Number of state facilities located in each landslide risk zone

Category	Risk Zone	Landslide Type	Number of State Facilities	Building Value at Risk
1	High	High Susceptibility	2,493	$6,717,165,387
		Moderate Incidence		
2	High	High Susceptibility	8	$171,973
		Low Incidence		
3	High	High Incidence	1,477	$1,327,963,042
4	Moderate	Moderate	2,097	$3,053,572,560
		Low Incidence		
5	Moderate	Moderate Incidence	363	$192,576,159
6	Low	Low Incidence	6,420	$11,217,081,478
		Total	**12,858**	**$22,508,530,599**

Those 3,978 buildings can be divided between 123 different state agencies in Virginia. The top five of those state agencies have been listed in Table 3.12-3, by building value. The agencies listed represent 24% of the buildings and 75% of total building value in high landslide risk zones.

Table 3.12-3: The top five state agencies in a high landslide risk zone

Agency	Number of Buildings in High Risk Zone	Building Value in High Risk Zone
University of Virginia-Academic Division	613	$3,087,266,690
Virginia Commonwealth Uni-Academic Division	191	$1,635,873,670
Department of General Services	58	$655,534,487
Central Virginia Training Center	89	$307,157,907
Virginia Museum of Fine Arts	7	$259,792,404
Total	**958**	**$5,945,625,158**

Critical Facility Risk

Risk for critical facilities was calculated in the same fashion as for state facilities. Almost all critical facilities are in regions with some level of landslide hazard, with 28% in areas of high risk. Table 3.12-4 shows the distribution of risk, by landslide type, for critical facilities. Annualized loss estimates were not calculated for critical facilities due to the scale of available landslide mapping, limited information on mapped critical facilities, and the lack of probabilities of future occurrences.

Table 3.12-4: Number of critical facilities located in each landslide risk zone.

Risk Zone	Landslide Type	Law Enforcement	Transportation	Public Health	Emergency Response	Education	Total
High	High Susceptibility Moderate Incidence	99	4	149	455	396	**1,103**
High	High Susceptibility Low Incidence	0	0	0	0	0	**0**
High	High Incidence	95	6	122	453	370	**1,046**
Moderate	Moderate Susceptibility Low Incidence	116	10	177	394	381	**1,078**
Moderate	Moderate Incidence	16	3	50	89	83	**241**
Low	Low Incidence	329	32	573	1,445	1,805	**4,184**
None	Not analyzed	-	-	-	-	-	**21**
	Total	**655**	**55**	**1,071**	**2,836**	**3,035**	**7,673**

Landslide Risk to Energy Pipelines

Soil movement associated with landslides can destabilize the structural supports of pipelines, possibly leading to pipeline ruptures. In Virginia, landslides can be expected to occur in conjunction with other hazard events such as flooding or earthquake, which also pose independent risks to pipelines (see section 3.7 and 3.13).

Jurisdictional Risk

The hazard ranking for landslide is based on events reported in the NCDC Storm Events database and a generalized geographic extent rating developed from the USGS landslide susceptibility and incidence. Ranking inputs for landslide were very limited as a result of having only five historical landslide events available from the NCDC database. To be able to include landslide in the risk assessment some general assumptions were made; geographical extent was the primary basis for establishing risk and was calculated as a percent of the jurisdictional area in high risk. In lieu of probability of future occurrence, areas with higher landslide risk were assumed to be at greater risk. These parameters are illustrated in Figure 3.12-2, along with the total ranking. The majority of the Commonwealth is in the lower risk categories. The Coastal Plain and Piedmont areas of Virginia are not very susceptible to landslides or debris flows of any major significance, with the exception of shorelines or riverbanks where wave action and erosion by streams tend to cause some localized undercutting and slumping.

Currently the NCDC database is the most standardized and comprehensive database for all of the hazards discussed in this plan. This database is limited in the amount of data that is available for geological hazards. The limitations are evident in the ranking and when compared to the known historical events; Hurricane Camille in 1969 resulted in landslides that killed 150 people but this event is not within the period of record of the NCDC database. The classification of events also led to the exclusion of the 1995 Madison County landslide which is currently included in the flooding events. See section 3.5 for more information on the methodology used for ranking hazards.

Figure 3.12-2 shows the relative ranking results for landslide. The following communities are located in high and medium-high risk zones:

- City of Charlottesville
- City of Alexandria
- City of Hopewell
- City of Lynchburg
- Buchanan County
- Albemarle County
- Loudoun County
- Greene County
- Franklin County
- Amherst County
- Bedford County
- Campbell County
- City of Richmond
- Carroll County
- Wise County
- Henry County
- City of Norton
- City of Bedford
- City of Galax
- City of Martinsville
- City of Covington

With future growth, various non-structural methods, such as zoning and grading ordinances, as well as structural methods, would have to be analyzed in terms of being cost-effective alternatives. Zoning and grading ordinances to avoid building in areas of potential hazard or to regulate construction to minimize potential for landsliding is one non-structural method to reduce the likely consequences of debris flows. For example, Loudoun County, Virginia, has adopted a zoning ordinance preventing the development of building sites with steep slopes along the Blue Ridge (defined in the ordinance as exceeding a 15 percent grade, equivalent to an 8 degree slope) which substantially reduces the hazards of landslides and debris flows within that area[8].

Local Plan Risk Assessment

Local plans were reviewed for spatial data sources used, historical occurrences, hazard probabilities, vulnerability, loss estimations, and land use and development trends. When available, this information supplements the text and figures of each of the sections in this revision.

None of the twenty-five local plans provided loss estimates for this hazard. Of the plans that provided a general description of landslides, some of them referred to the USGS landslide susceptibility and incidence mapping. The overall consensus in the local plan is that there is no definitive way to estimate potential damages due to landslides.

Comparison with Local Ranking

Lenowisco PDC and Cumberland Plateau PDC both ranked landslide as a medium-high hazard. Some of these jurisdictions have also been ranked as high or medium-high in the statewide analysis.

The Northern Virginia regional plan ranked landslide as a medium hazard.

One plan ranked landslide as a medium-low hazard, fourteen additional plans ranked landslide as a low hazard, and seven plans did not provide a rank for this hazard, resulting in a local plan average of low for landslide. Furthermore, six of the regional and local plans didn't assign the landslide hazard a ranking. The 2013 statewide analysis has ranked landslide as medium-low risk. Section 3.6 (Table 3.6-2) includes the complete ranking of all the local plans.

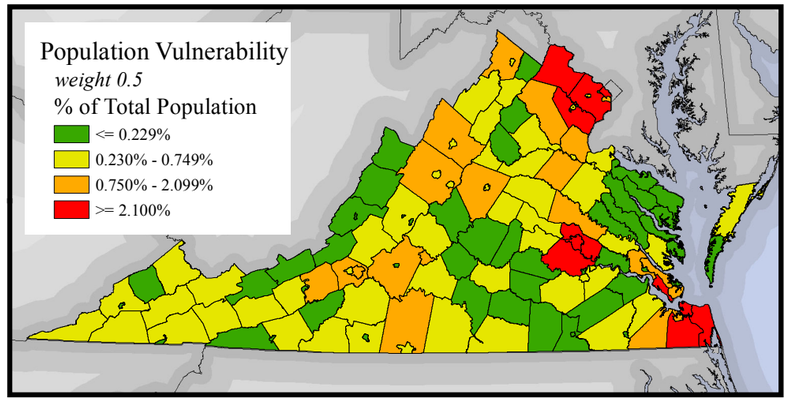
Changes in Development

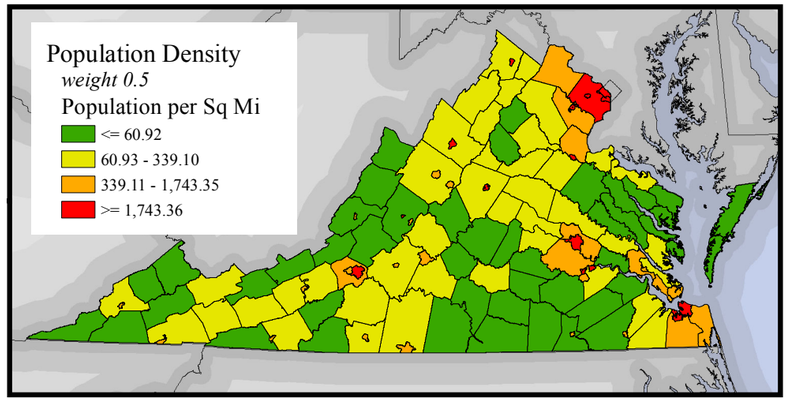
The majority of local plans did not specifically address changes in development for each hazard or the effects of changes in development on loss estimates. In most cases overall development patterns were discussed in general. Sixteen of the twenty-five local plans cite their comprehensive plans for current and future land use changes (section 3.2).

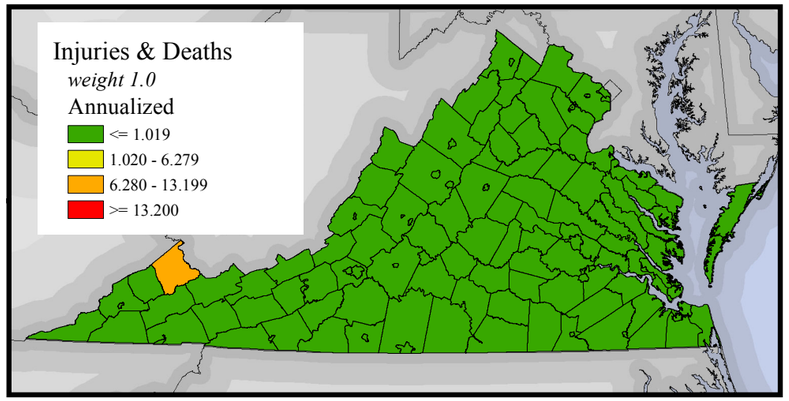
[8] USGS Fact Sheet: FS-159-96: Debris-Flow Hazards in the Blue Ridge of Virginia http://landslides.usgs.gov/docs/faq/fs159-96.pdf

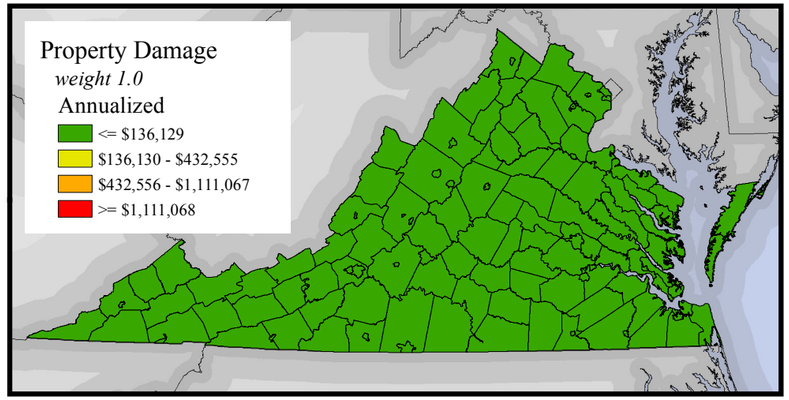
Lenowisco PDC and Cumberland Plateau PDC mentioned that the densely populated areas in the PDC are in areas with a more gradual slope and therefore the widespread damages due to landslides would be limited in the those developed areas. Changes in development would most likely have an impact on loss estimates if there was an established method for calculating loss due to land sliding.

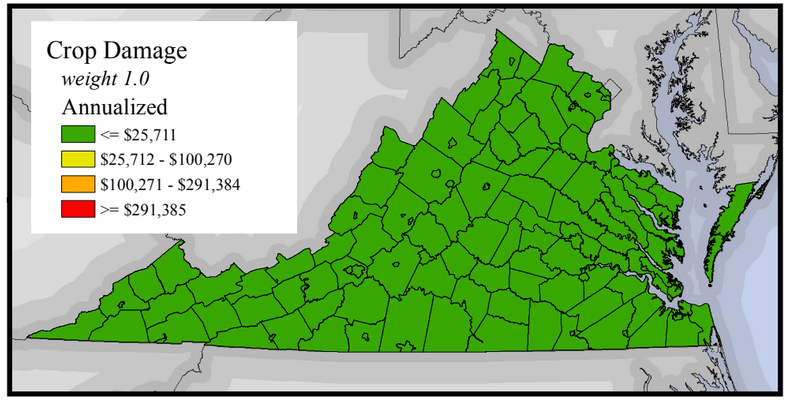
Figure 3.12-3: Landslide Hazard Ranking Parameters and Risk Map

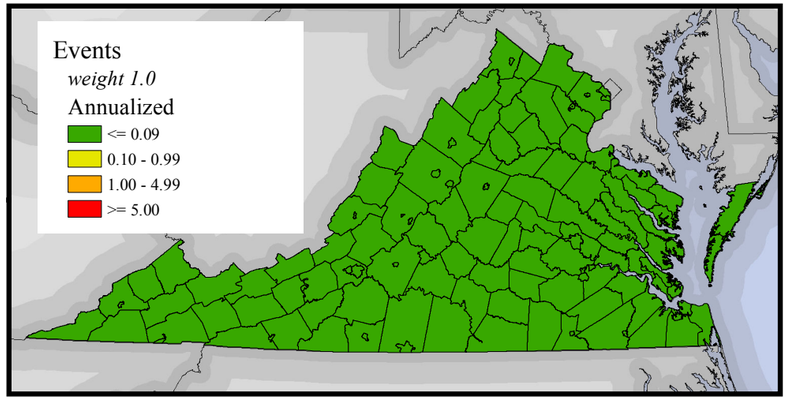


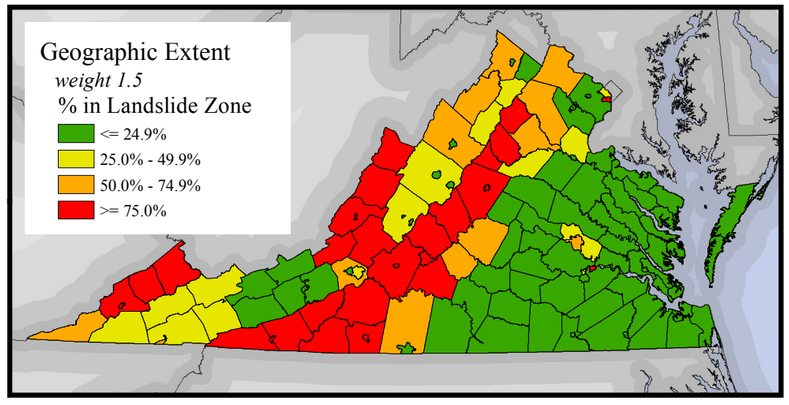


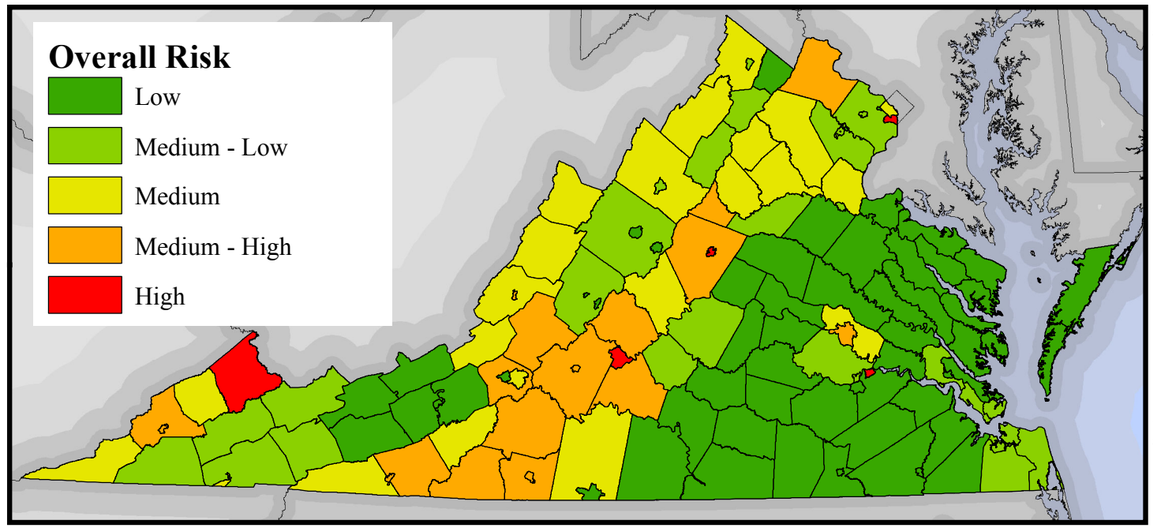












HAZARD RANKING:

A number of factors have been considered in this risk assessment to be able to compare between jurisdictions and hazards. The factors have been added together to come up with the overall total ranking for each hazard.
Some factors were weighted based on imput from the HIRA sub-committee.
Section 3.5 explains each of the factors in detail.

Factors & Weighting Include:
- Population Vulnerability & Density 0.5 weighting
- Injuries & Deaths 1.0 weighting
- Crop & Property Damage 1.0 weighting
- Annualized Events 1.0 weighting
- Geographic Extent 1.5 weighting

DATA SOURCES:

CGIT Ranking Methodology
VGIN Jurisdictional Boundaries
ESRI State Boundaries

PROJECTION: *VA Lambert Conformal Conic*
North American Datum 1983

DISCLAIMER: Majority of available hazard data is intended to be used at national or regional scales. The purpose of the data sets are to give general indication of areas that may be susceptible to hazards. In order to identify potential risk in the Commonwealth available data has been used beyond the original intent.

Table 3.12-5: EMAP Analysis

Subject	Detrimental Impacts
Health and Safety of Public	Localized impacts are expected to be moderate to catastrophic for the impacted area, the worst disaster the Commonwealth has experienced is the landslides associated with Tropical Storm Camille in 1969, 150 deaths.
Health and Safety of Response Personnel	Localized impacts could be serious as local responders are working within the impacted area, if they live within the impacted area then they may be displaced or isolated for an extended period of time.
Continuity of Operations	Damage to facilities/personnel in the area of the event may require temporary relocation of some operations.
Property, Facilities, and Infrastructure	Depending on the magnitude of the event, localized impact to facilities, residential properties, and infrastructure in the area of the event could be severe.
Delivery of Services	Localized disruption of roads, facilities, communications and/or utilities caused by the event may postpone the delivery of some services.
The Environment	Localized impacts expected to be severe for the impacted areas. With a high potential for debris, HAZMAT may be an issue.
Economic and Financial Condition	Local economic and financial conditions may be impacted for a long period of time depending on duration and geographical area of the event, as well as the size and capabilities of the local jurisdiction.
Public Confidence in the Jurisdiction's Governance	Ability to respond and recover may be questioned and challenged if planning, response, and recovery time is not sufficient. Local and state land development policies may be in question.

Table was modeled from the Missouri State Hazard Mitigation Plan