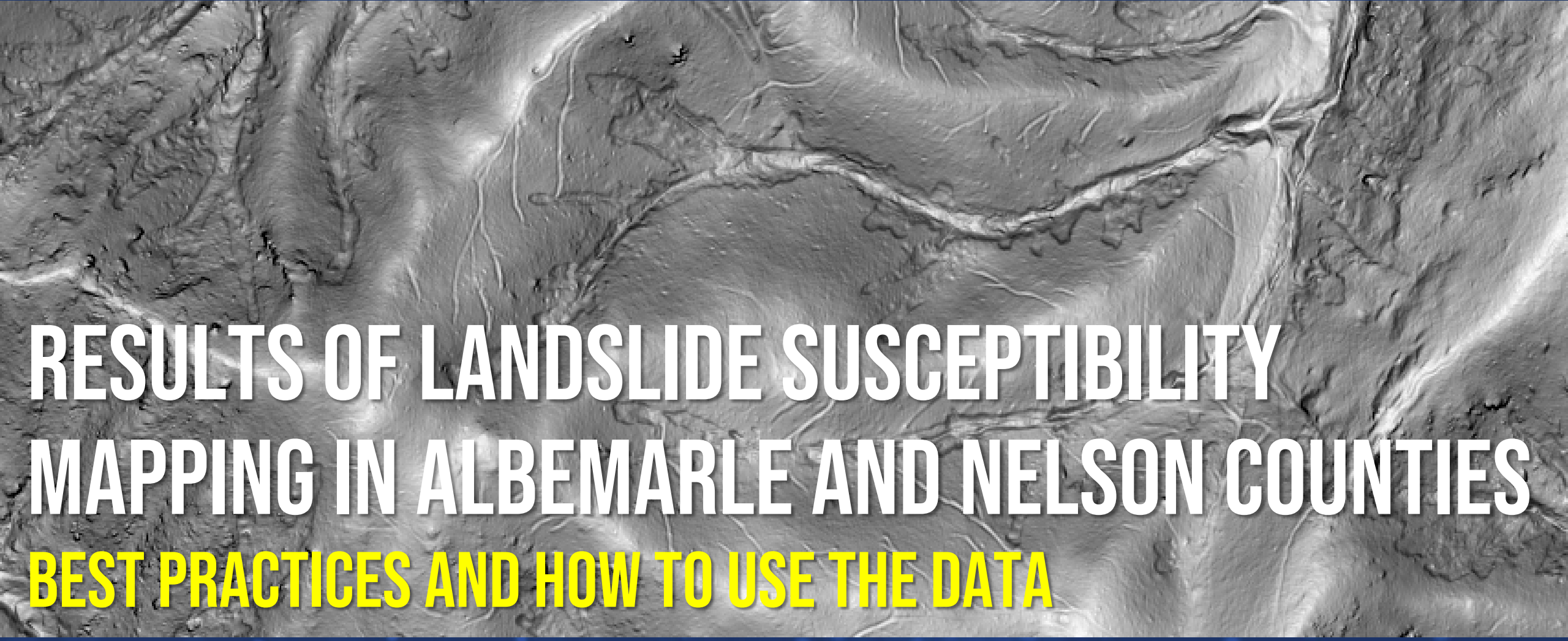


RESULTS OF LANDSLIDE SUSCEPTIBILITY MAPPING IN ALBEMARLE AND NELSON COUNTIES

BEST PRACTICES AND HOW TO USE THE DATA

Anne C. Witt and Wendy S. Kelly
Geology and Mineral Resources Program
anne.witt@energy.virginia.gov

VIRGINIA Energy

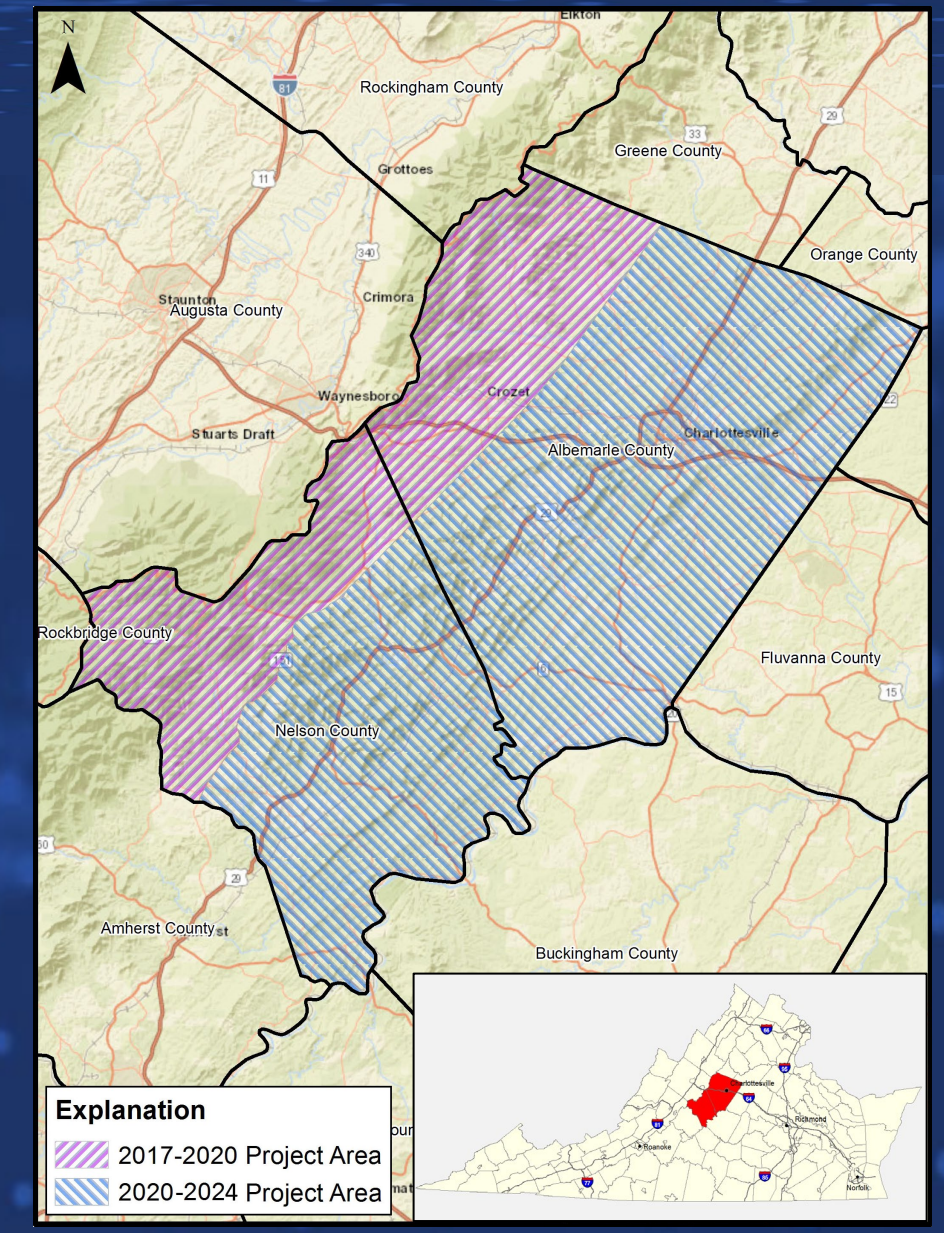
VIRGINIA DEPARTMENT OF EMERGENCY MANAGEMENT

FEDERAL EMERGENCY MANAGEMENT AGENCY

VDEM-FEMA PRE-DISASTER MITIGATION GRANT PROJECTS IN NELSON & ALBEMARLE COUNTIES:

Western Landslide Risk Assessment (2017-2020)
Eastern Landslide Risk Assessment (2020-2024)

- GMRP received funding to support 1 full-time grant funded geologist for 3 years
- Goal: Complete a landslide hazard map for Nelson and Albemarle Counties to identify at-risk properties and infrastructure
- First in Commonwealth to use high-resolution LIDAR
- Western Study area delivered March 2022
- Final Maps delivered September 2024



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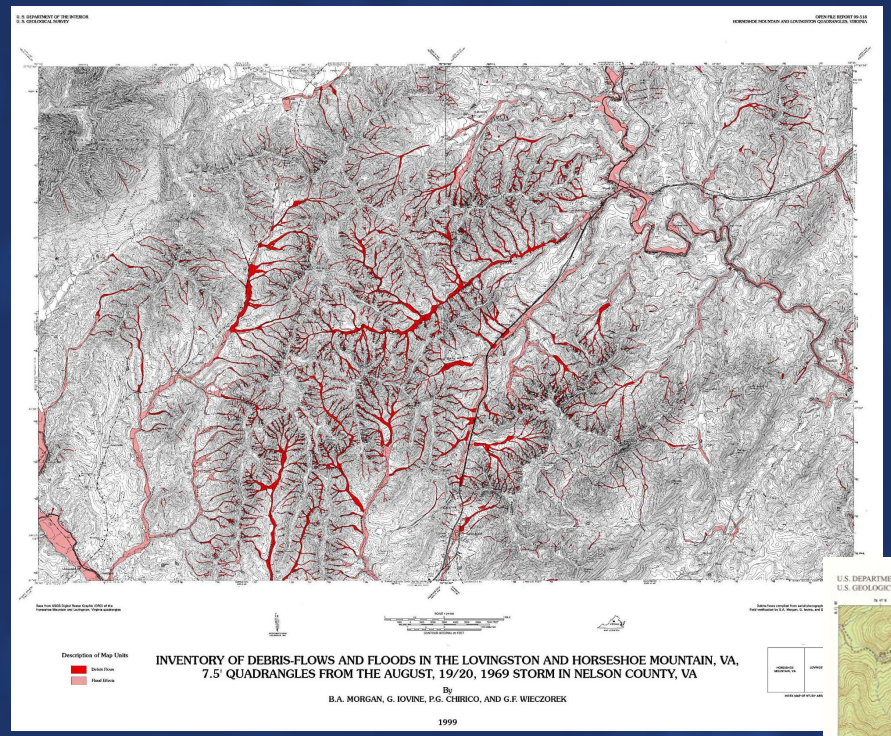
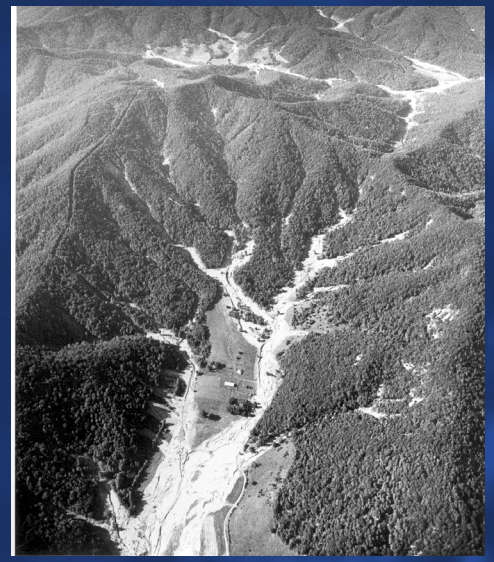
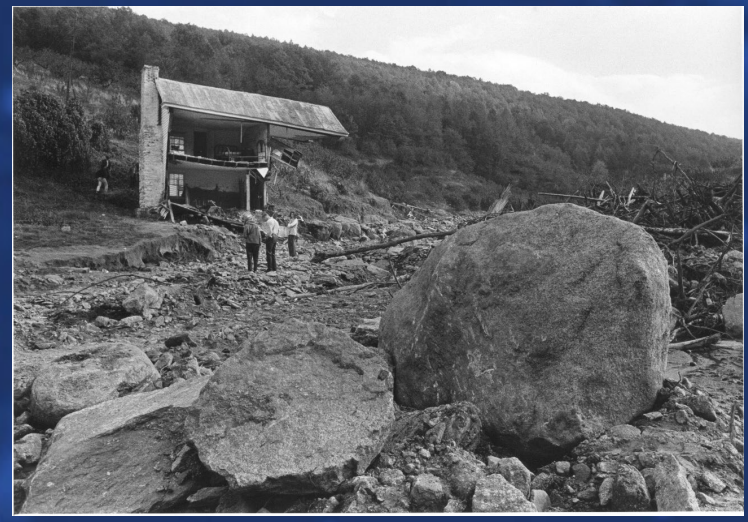
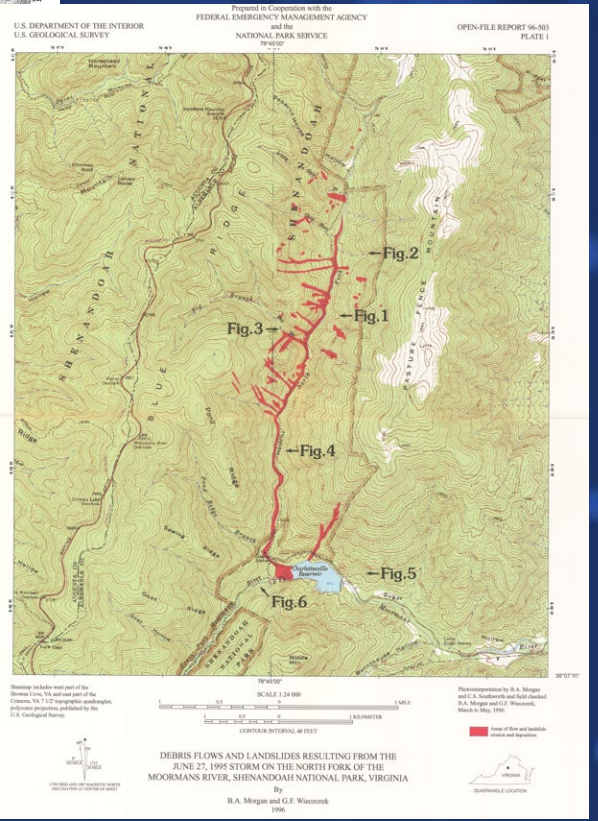
BACKGROUND

- Nelson and Albemarle were affected by two major rainfall events which generated 100s to 1000s of landslides
  - Hurricane Camille (1969) – Nelson County
  - Severe Thunderstorm (1995) – Western Albemarle County
- USGS produced inventory maps of part of the study area (1996, 1999)









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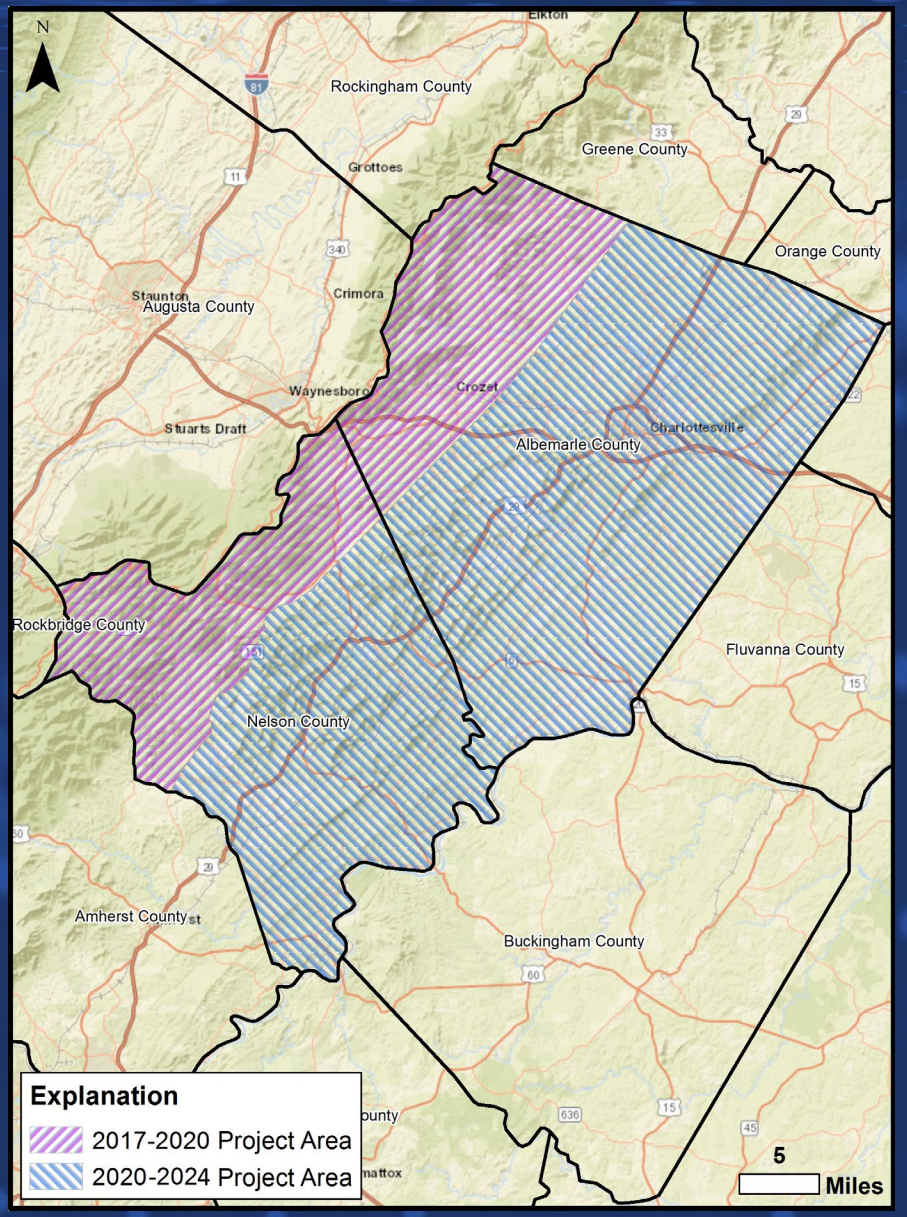
VDEM-FEMA PRE-DISASTER MITIGATION GRANT PROJECTS IN NELSON & ALBEMARLE COUNTIES:

Western Landslide Risk Assessment (2017-2020)
Eastern Landslide Risk Assessment (2020-2024)

This project was completed in four phases:

1. Remote sensing of modern and prehistoric landslides in the study area using LIDAR
2. Geologic field mapping of landslide prone areas
3. Landslide susceptibility mapping and modeling
4. Presentation of data products and results to the planning community and the public.



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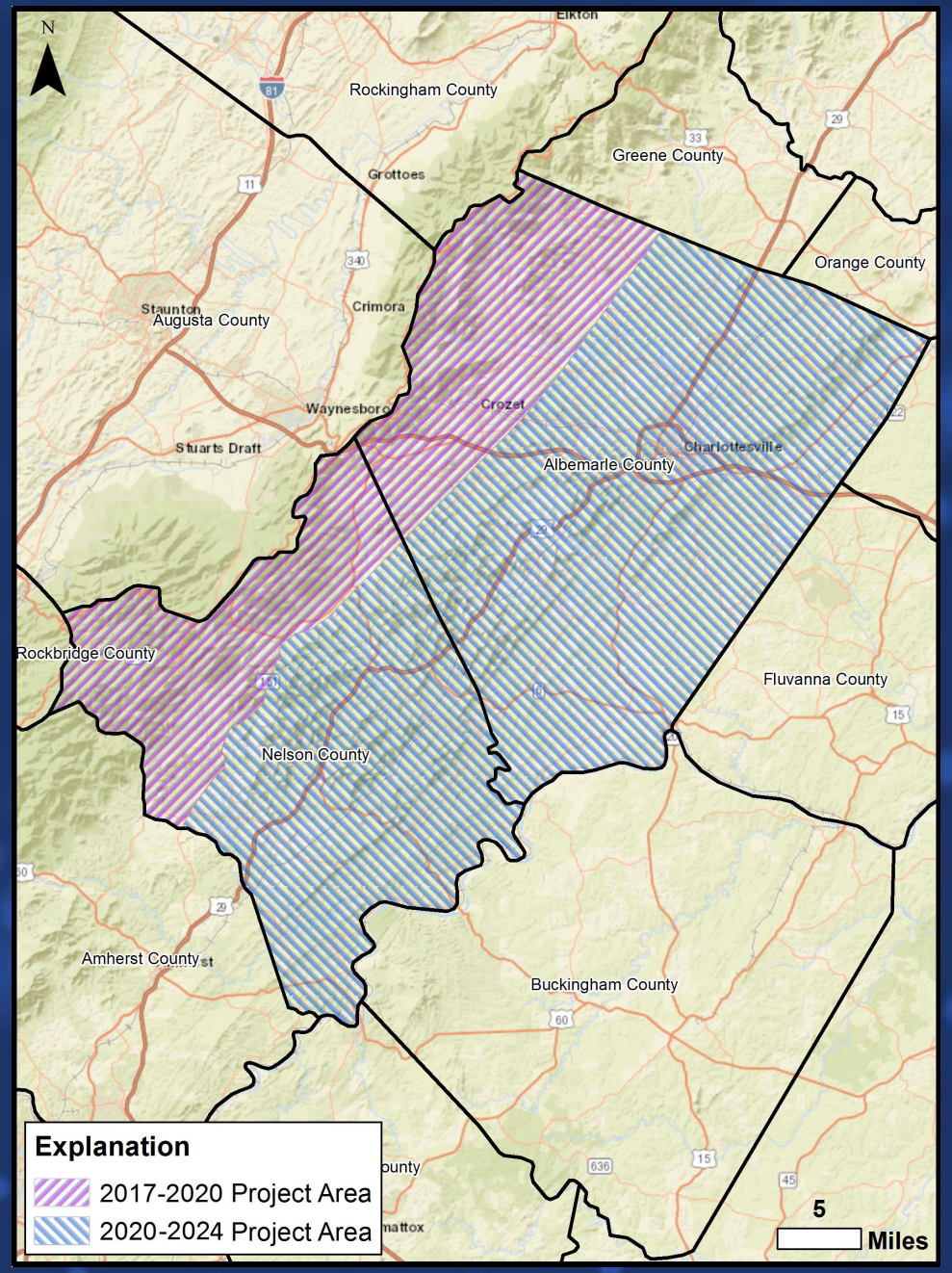
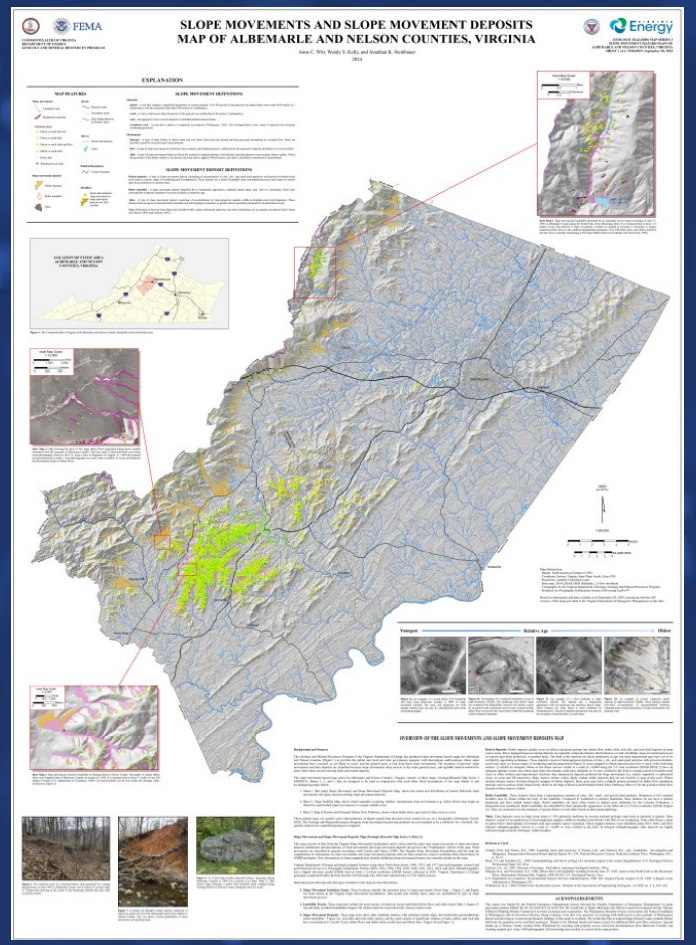
SEPTEMBER 2024 FEMA/VDEM DELIVERABLES

1. PDF Maps
2. GIS Data and Metadata
3. Users Guide and Presentations
4. Project web page and GIS web map

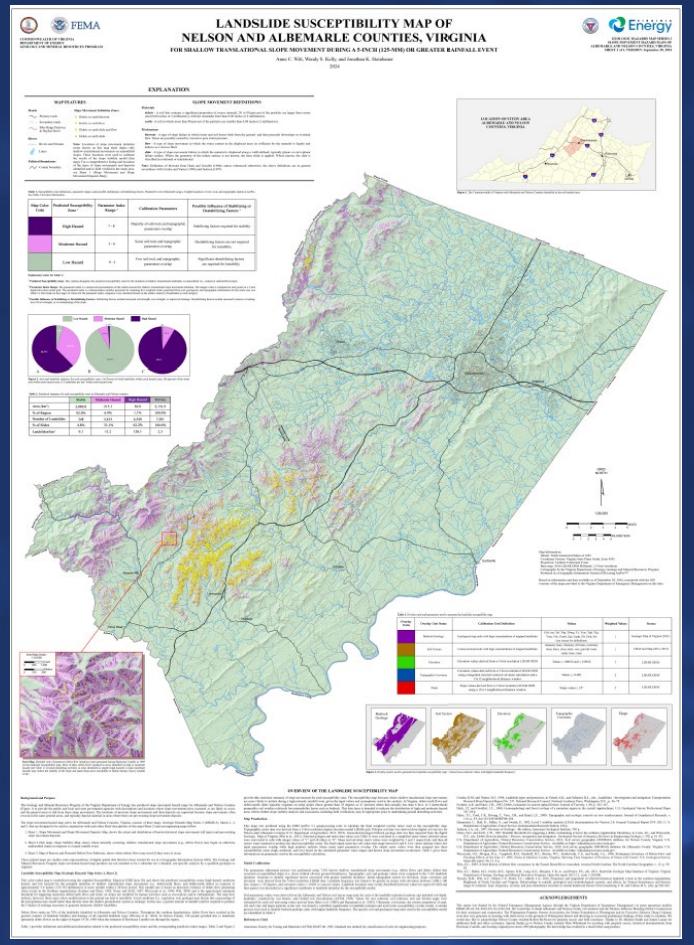


*This report was funded by the Federal Emergency Management Agency through the Virginia Department of Emergency Management via grant agreement number PDMC-PL-03-VA-2017-009 for $114,198 and PDMC-PL-03-VA-2019-013 for $182,764.

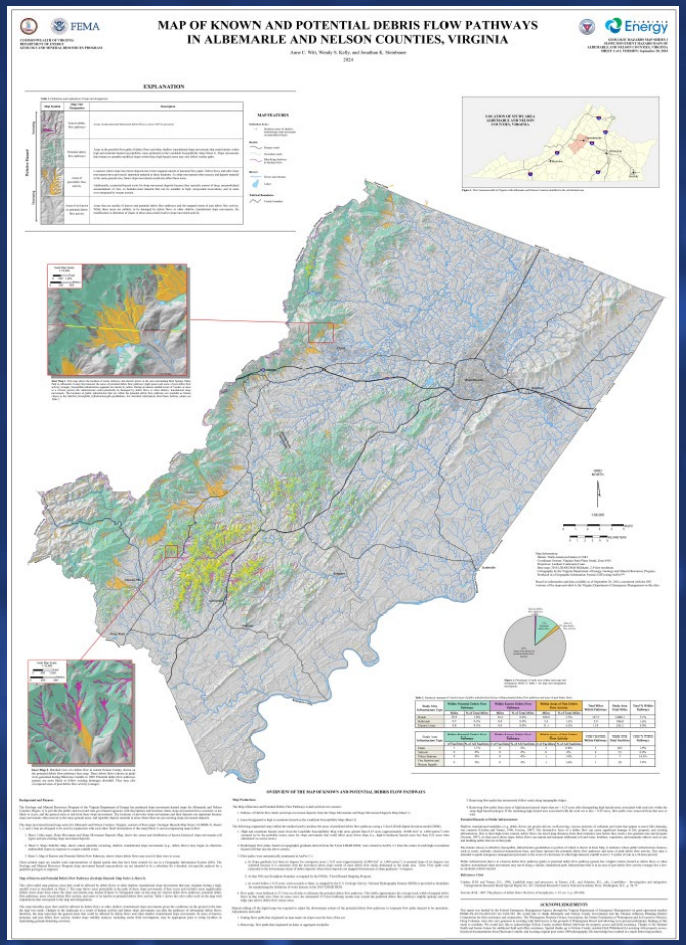
SEPTEMBER 2024 FEMA/VDEM DELIVERABLES: PDF MAPS



1 Landslide Inventory Map



2 Landslide Susceptibility Map



3 Landslide Pathway Map

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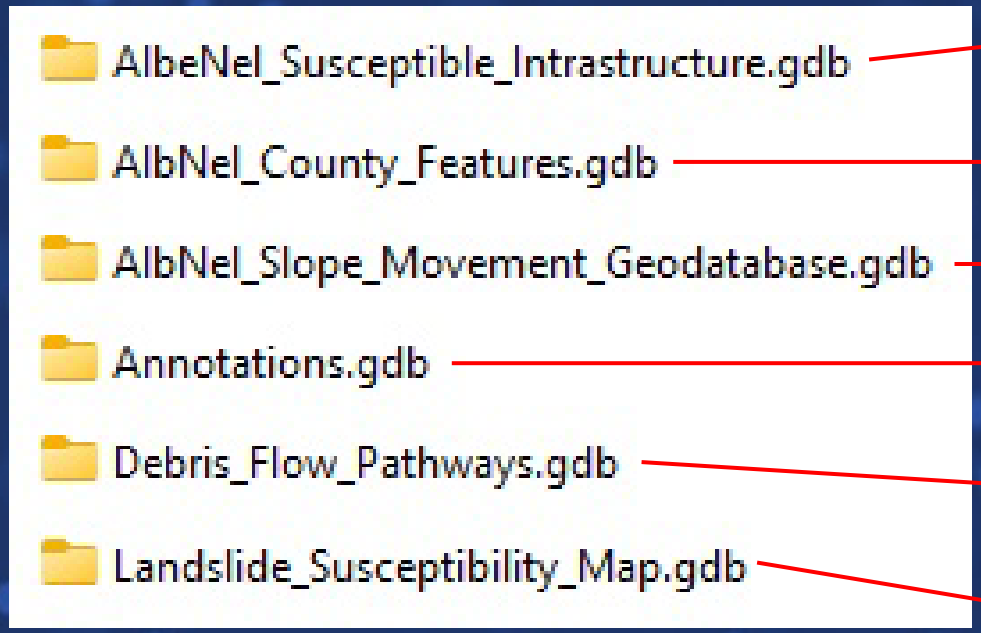
*Three maps are designed to be used together

SEPTEMBER 2024 FEMA/VDEM DELIVERABLES: GIS DATA

The GIS data was compiled in Esri ArcPro 3.1 as file geodatabases (.gdb extension). These can only be viewed in ArcGIS/ArcPro or another GIS viewer.



Roads, critical facilities, etc. that could be impacted by potential landsides.

Roads, streams, etc. used as part of the base map.

Landslide inventory data.

Text and labels used as part of the base map.

Polygons that represent potential inundation areas during a heavy rainfall event.

Rasters that indicate where a potential landslide might start during a heavy rainfall event.

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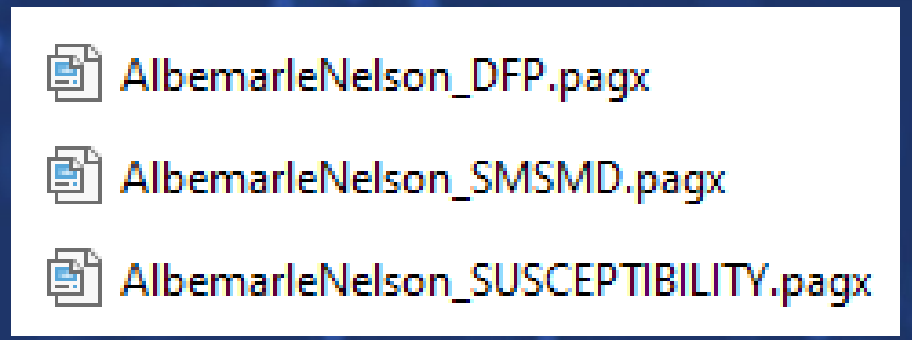
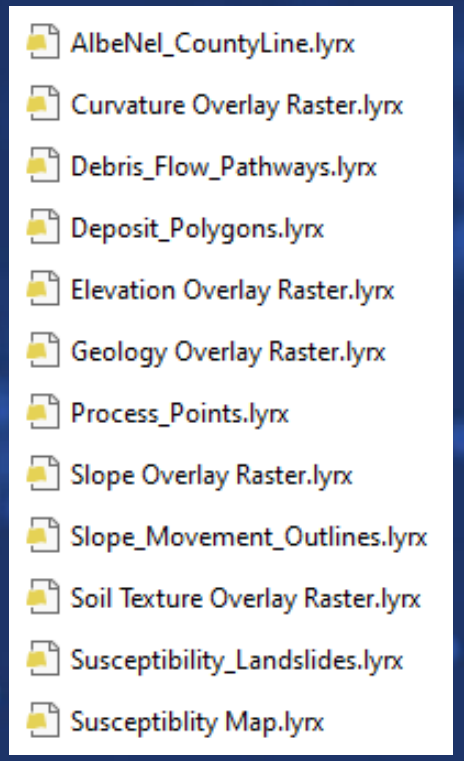
SEPTEMBER 2024 FEMA/VDEM DELIVERABLES: GIS DATA

To view the GIS version of the maps, it is recommended that the user open the layout document file for each map (.pagx extension).



If the feature classes are loaded into an empty ArcPro/ArcGIS map document, it is recommended that the user load the layer files (.lyrx extension) so that each feature class will be symbolized correctly.



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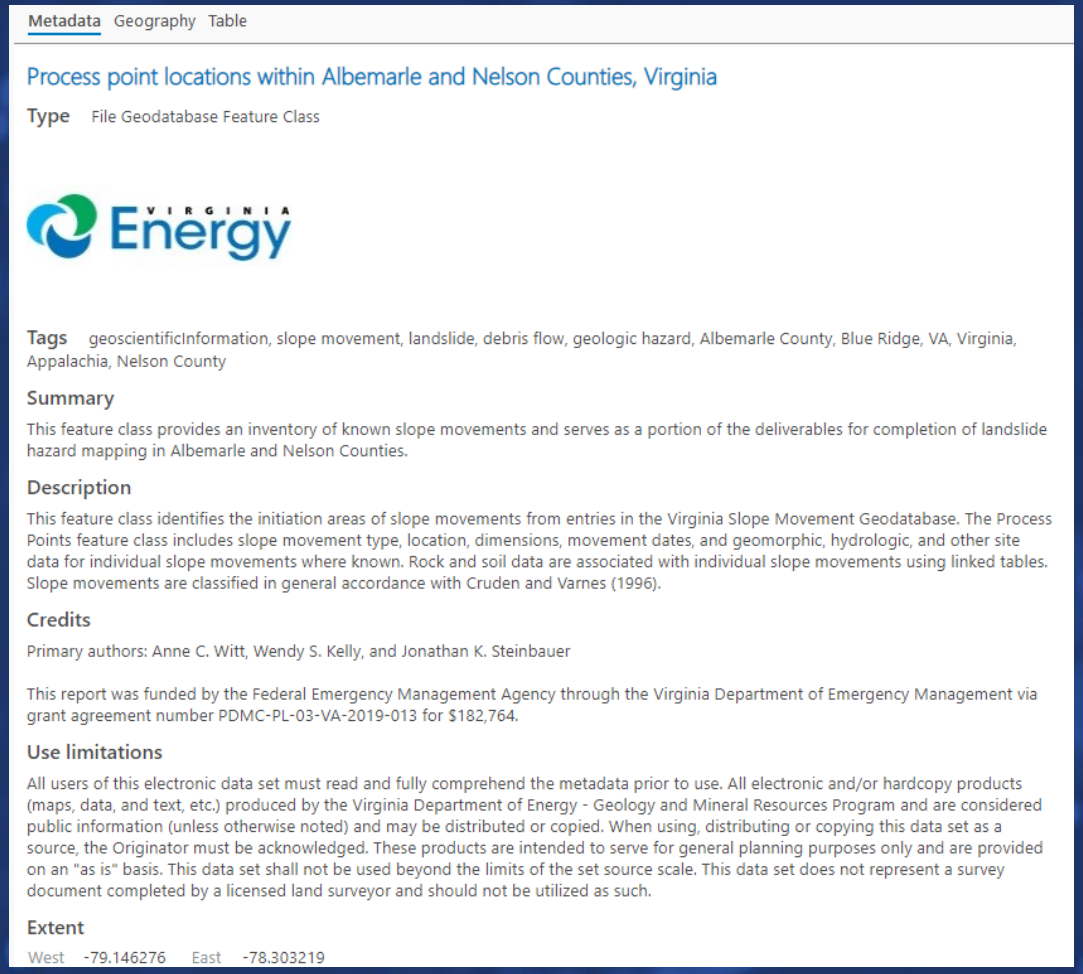
SEPTEMBER 2024 FEMA/VDEM DELIVERABLES: GIS DATA

Metadata is provided for each feature class as an XML file and can also be viewed in ArcGIS/ArcPro.



Metadata Geography Table

Process point locations within Albemarle and Nelson Counties, Virginia

Type File Geodatabase Feature Class

Tags geoscientificInformation, slope movement, landslide, debris flow, geologic hazard, Albemarle County, Blue Ridge, VA, Virginia, Appalachia, Nelson County

Summary

This feature class provides an inventory of known slope movements and serves as a portion of the deliverables for completion of landslide hazard mapping in Albemarle and Nelson Counties.

Description

This feature class identifies the initiation areas of slope movements from entries in the Virginia Slope Movement Geodatabase. The Process Points feature class includes slope movement type, location, dimensions, movement dates, and geomorphic, hydrologic, and other site data for individual slope movements where known. Rock and soil data are associated with individual slope movements using linked tables. Slope movements are classified in general accordance with Cruden and Varnes (1996).

Credits

Primary authors: Anne C. Witt, Wendy S. Kelly, and Jonathan K. Steinbauer

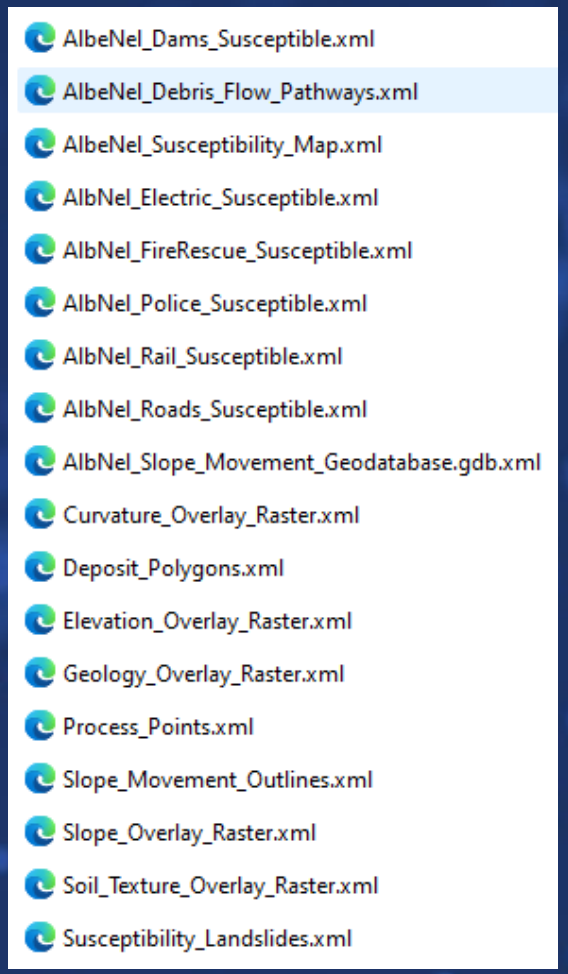
This report was funded by the Federal Emergency Management Agency through the Virginia Department of Emergency Management via grant agreement number PDMC-PL-03-VA-2019-013 for $182,764.

Use limitations

All users of this electronic data set must read and fully comprehend the metadata prior to use. All electronic and/or hardcopy products (maps, data, and text, etc.) produced by the Virginia Department of Energy - Geology and Mineral Resources Program and are considered public information (unless otherwise noted) and may be distributed or copied. When using, distributing or copying this data set as a source, the Originator must be acknowledged. These products are intended to serve for general planning purposes only and are provided on an "as is" basis. This data set shall not be used beyond the limits of the set source scale. This data set does not represent a survey document completed by a licensed land surveyor and should not be utilized as such.

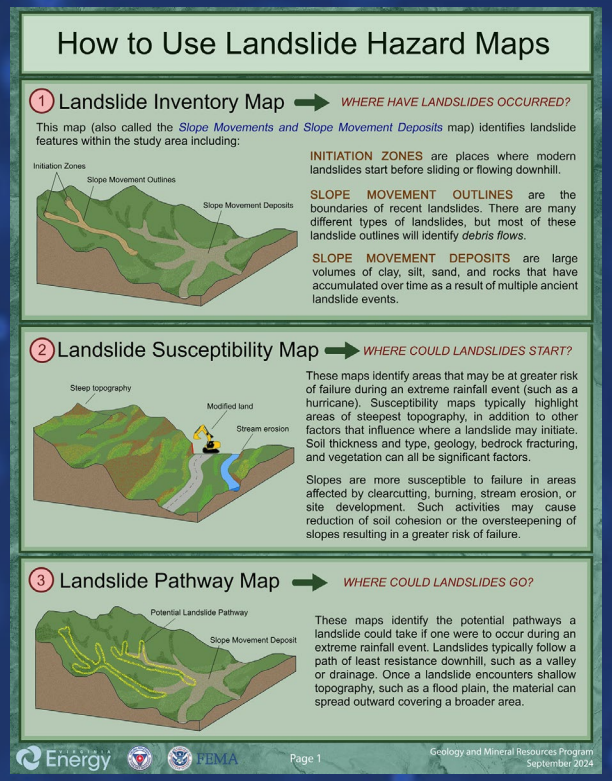
Extent

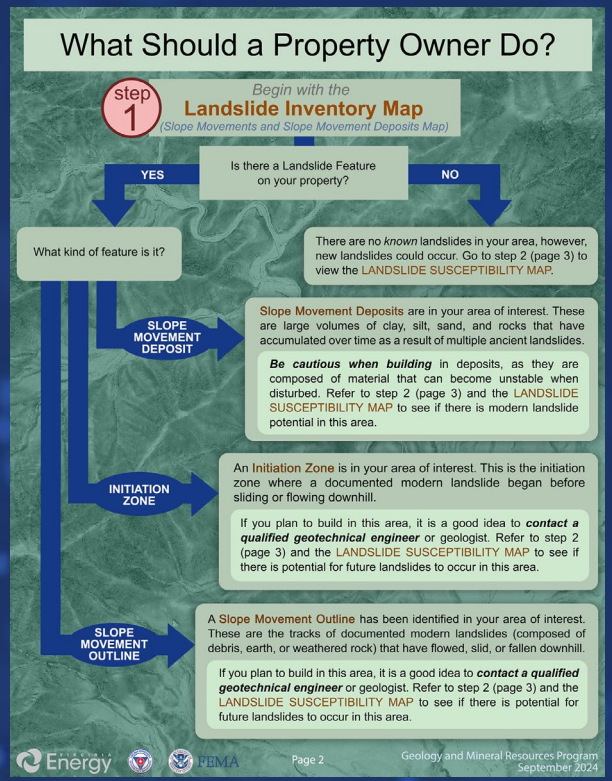
West -79.146276 East -78.303219

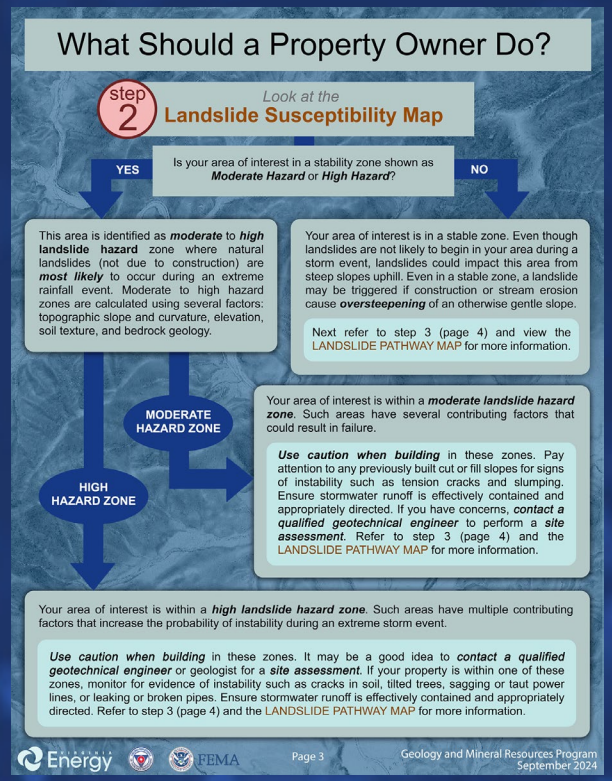


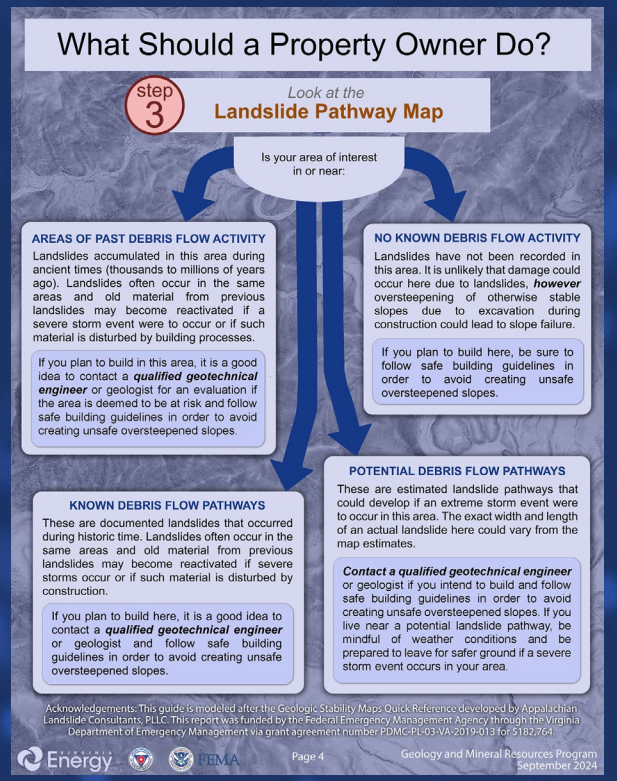
AlbeNel_Dams_Susceptible.xml
AlbeNel_Debris_Flow_Pathways.xml
AlbeNel_Susceptibility_Map.xml
AlbNel_Electric_Susceptible.xml
AlbNel_FireRescue_Susceptible.xml
AlbNel_Police_Susceptible.xml
AlbNel_Rail_Susceptible.xml
AlbNel_Roads_Susceptible.xml
AlbNel_Slope_Movement_Geodatabase.gdb.xml
Curvature_Overlay_Raster.xml
Deposit_Polygons.xml
Elevation_Overlay_Raster.xml
Geology_Overlay_Raster.xml
Process_Points.xml
Slope_Movement_Outlines.xml
Slope_Overlay_Raster.xml
Soil_Texture_Overlay_Raster.xml
Susceptibility_Landslides.xml

SEPTEMBER 2024 FEMA/VDEM DELIVERABLES: USER GUIDE









This 4-page guide walks users through each of the three maps and what to do if they are in or near an area identified as a landslide hazard zone.

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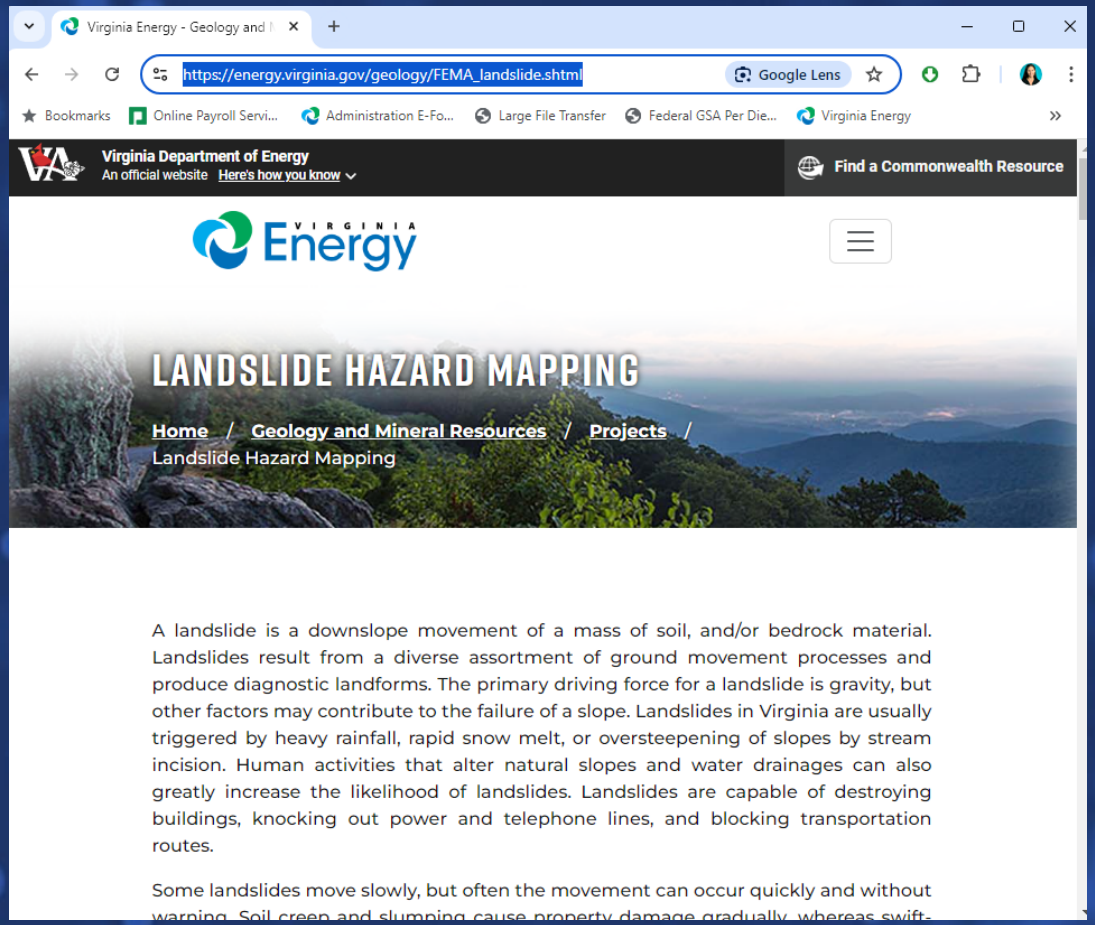
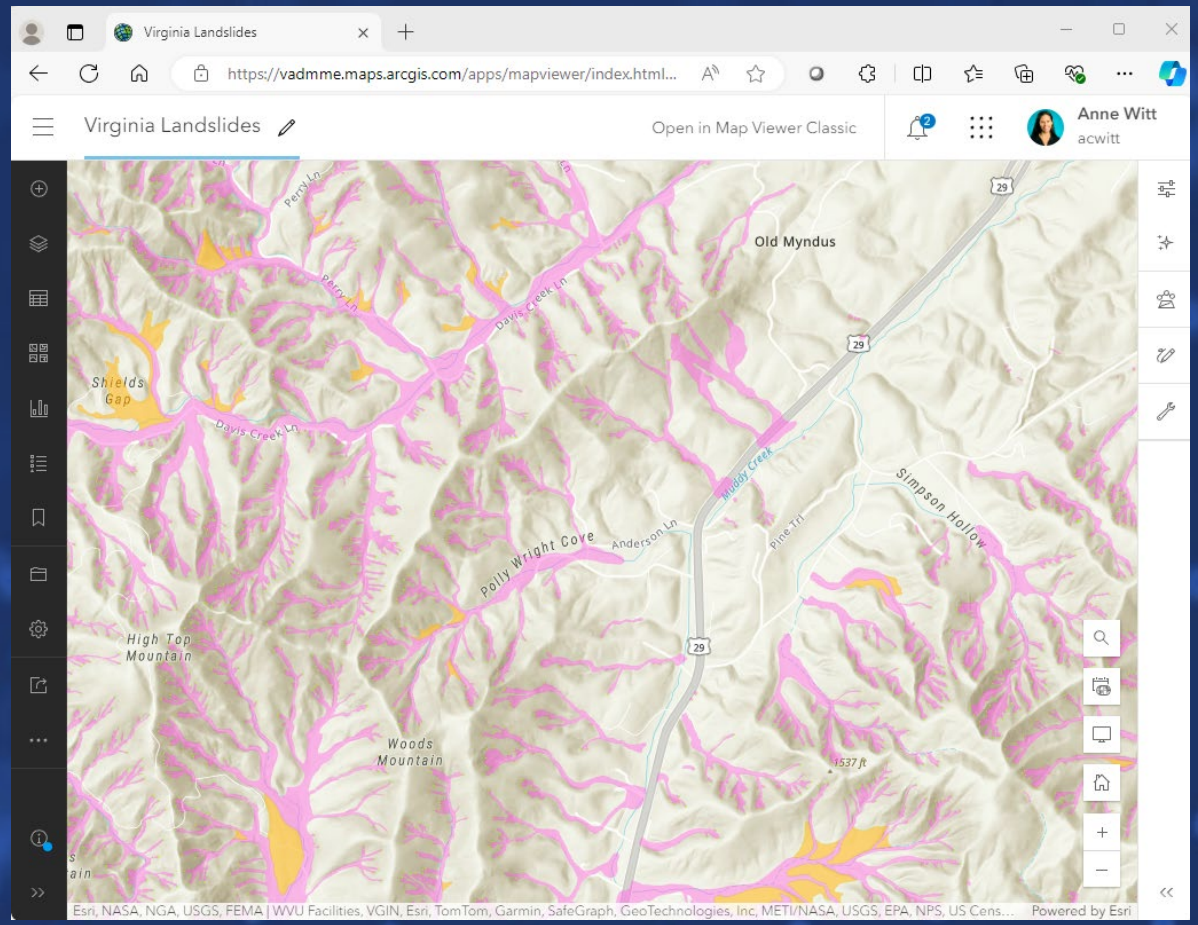
SEPTEMBER 2024 FEMA/VDEM DELIVERABLES: PROJECT WEBPAGE

https://energy.virginia.gov/geology/FEMA_landslide.shtml





HOW DO I GET THIS DATA?

- Download the data as ZIP files from our project website: https://energy.virginia.gov/geology/FEMA_landslide.shtml
- View the data in our GIS web map viewer:

  REST SERVICE: https://www.energy.virginia.gov/gis/rest/services/DGMR/Landslides/MapServer
- Contact us:

  The Virginia Department of Energy – Geology and Mineral Resources Program

  Phone: 434-951-6340

  Email: DGMRInfo@energy.virginia.gov

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ALBEMARLE AND NELSON COUNTY PROJECT RESULTS

SEPTEMBER 2024

1 Landslide Inventory Map

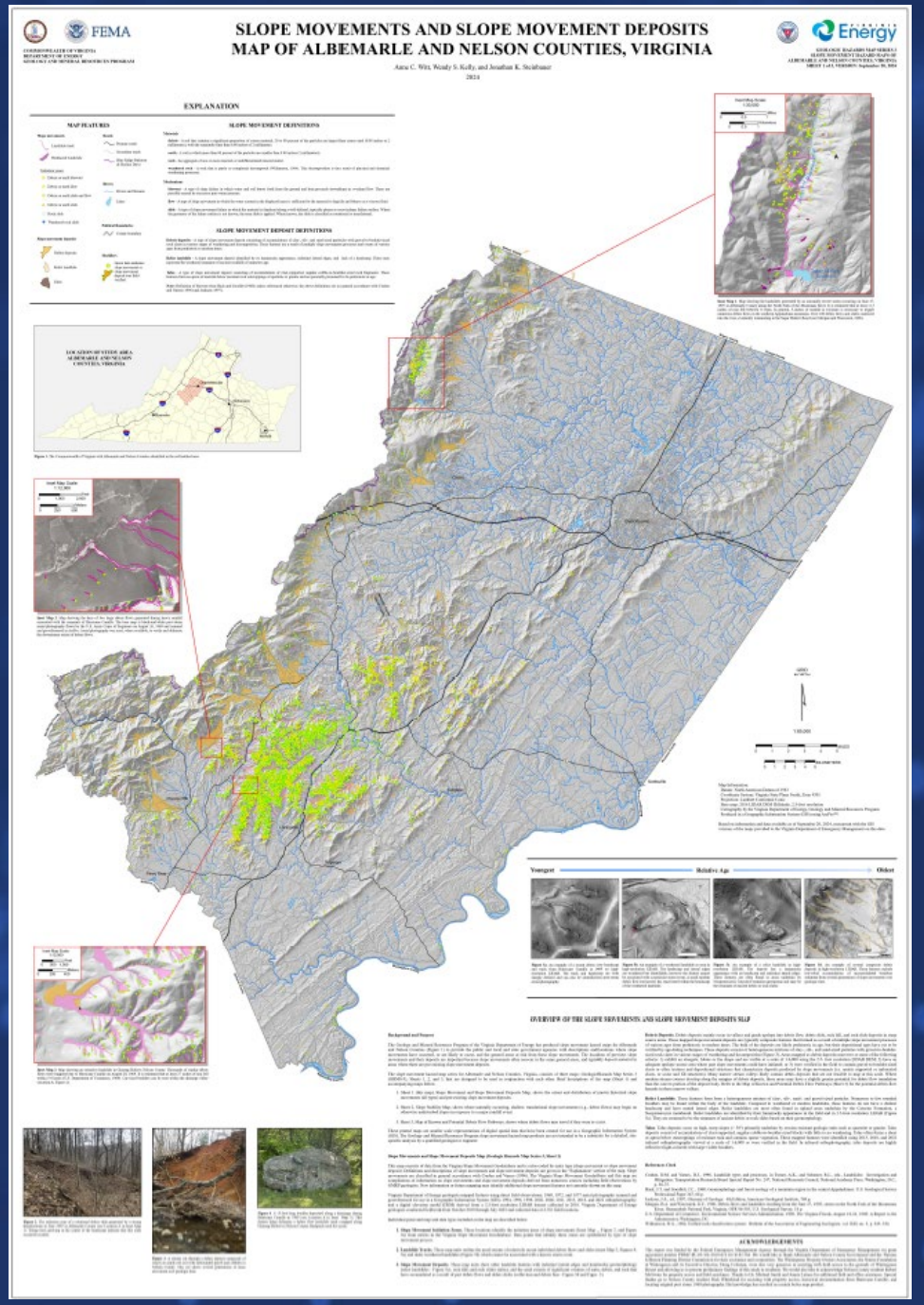
To open the map, go to either:

- AlbemarleNelson_SMSMD_150dpi.pdf
- AlbemarleNelson_SMSMD.pagx (GIS map)

Landslide inventory GIS data located in the AlbeNel_Slope_Movement_Geodatabase.gdb

GIS layers within the geodatabase:

- Process_Points
- Slope_Movement_Outlines
- Deposit_Polygons



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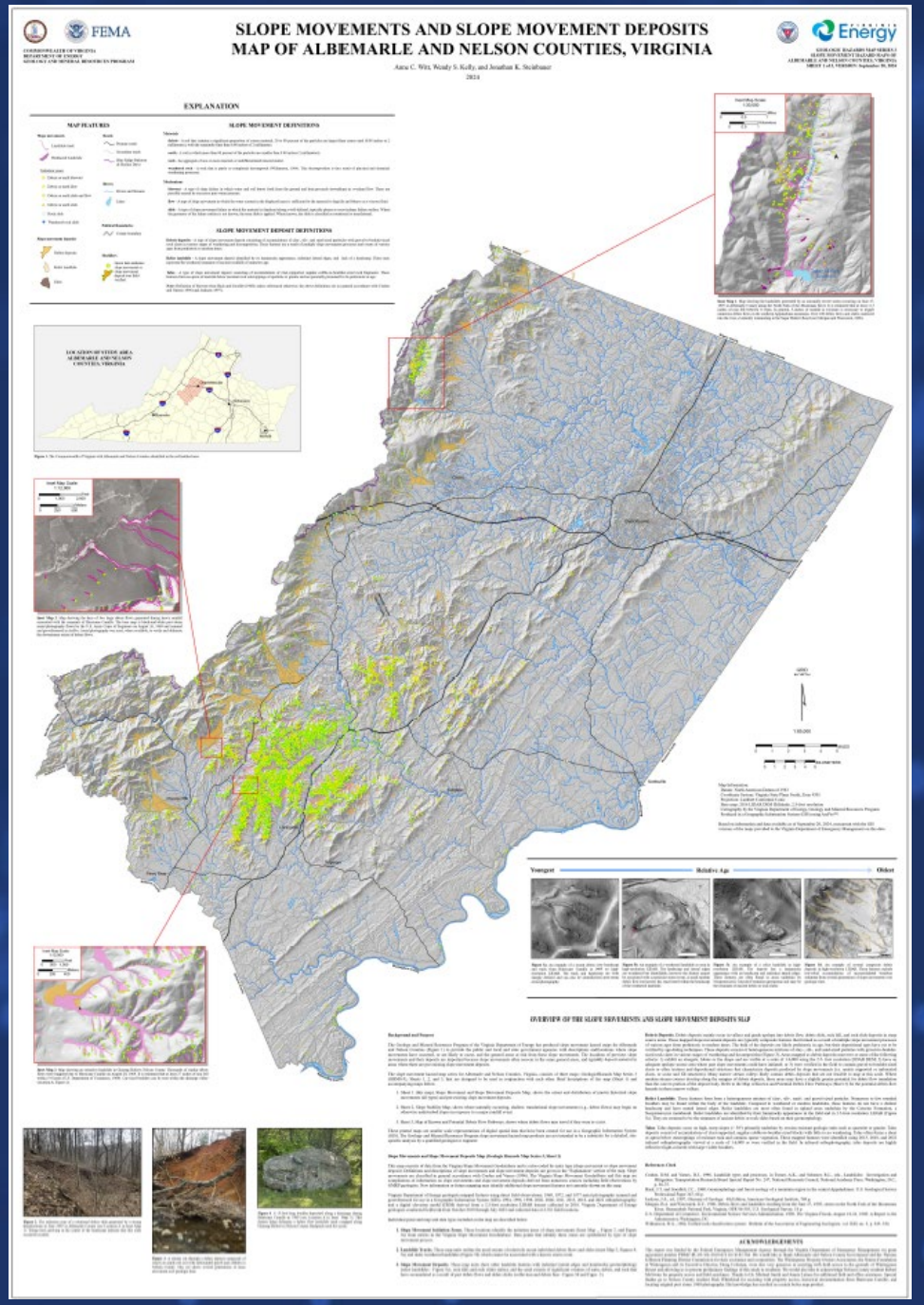
1 Landslide Inventory Map

- Process_Points (landslide initiation): 7,809
  - Includes various types of landslides
  - Hurricane Camille 1969: 7,241 (93%)
  - June 27, 1995 Storm: 189 (2%)
  - Landslides field verified by a Virginia Energy geologist: 415 (5%)
- Slope_Movement_Outlines (tracks): 1,753
  - 72 Weathered & 144 Relict Landslides
- Deposit_Polygons (ancient landslide deposits): 1,583



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1 Landslide Inventory Map

Slope movements

- Landslide track
- Weathered Landslide

Initiation zones

- Debris or earth blowout 7
- Debris or earth flow 6,082
- Debris or earth slide and flow 5
- Debris or earth slide 1,696
- Rock slide 5
- Weathered rock slide 1

Slope movement deposits

- Relict landslide
- Debris deposits
- Talus

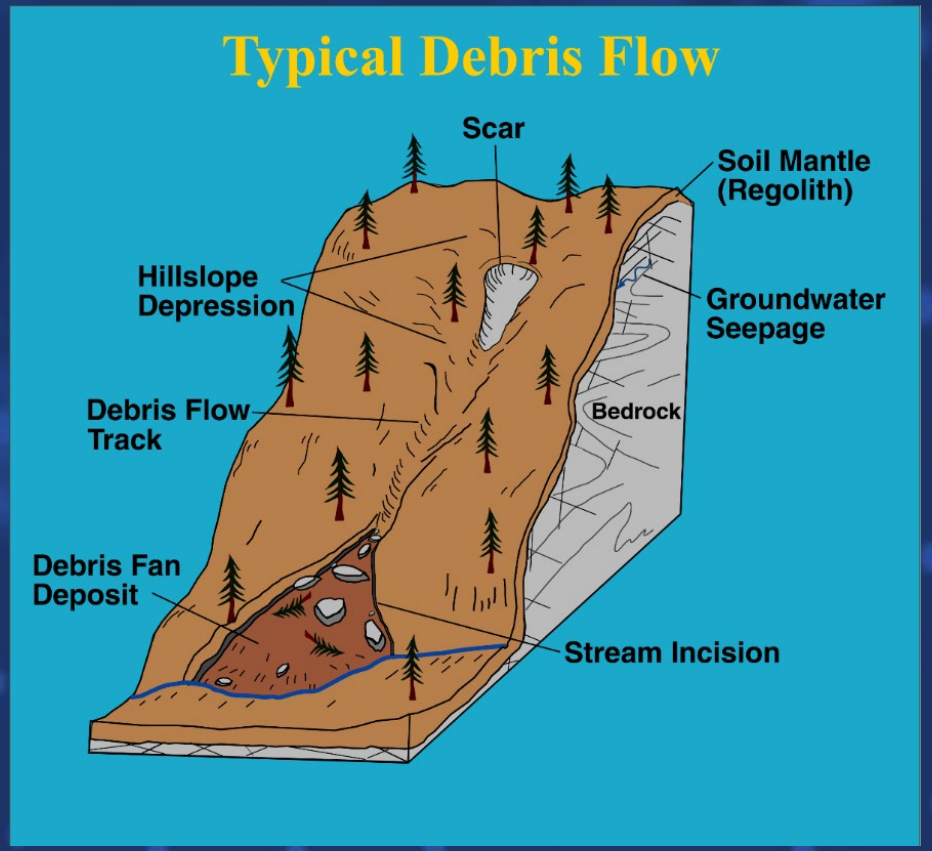
Modifiers

- Green halo indicates slope movement or slope movement deposit was field verified

	Type of Movement	Slide (Translational / Rotational)	Flow	Topple	Fall	Composite
MATERIAL	Earth (>80% <2mm)					
	Debris (>20% >2mm)		X			
	Weathered Rock (PDS-CDS)					
	Rock (STS-VFS)					

The most common type of landslide found in the study area is a debris flow.

Debris flows are swift moving landslides composed of water, sediment, and rock with the consistency of wet concrete. They can move downslope quickly and often strike without warning. Debris flows are usually triggered by high-intensity, heavy rainfall events like hurricanes.



1 Landslide Inventory Map

Slope movements

- Landslide track
- Weathered Landslide

Initiation zones

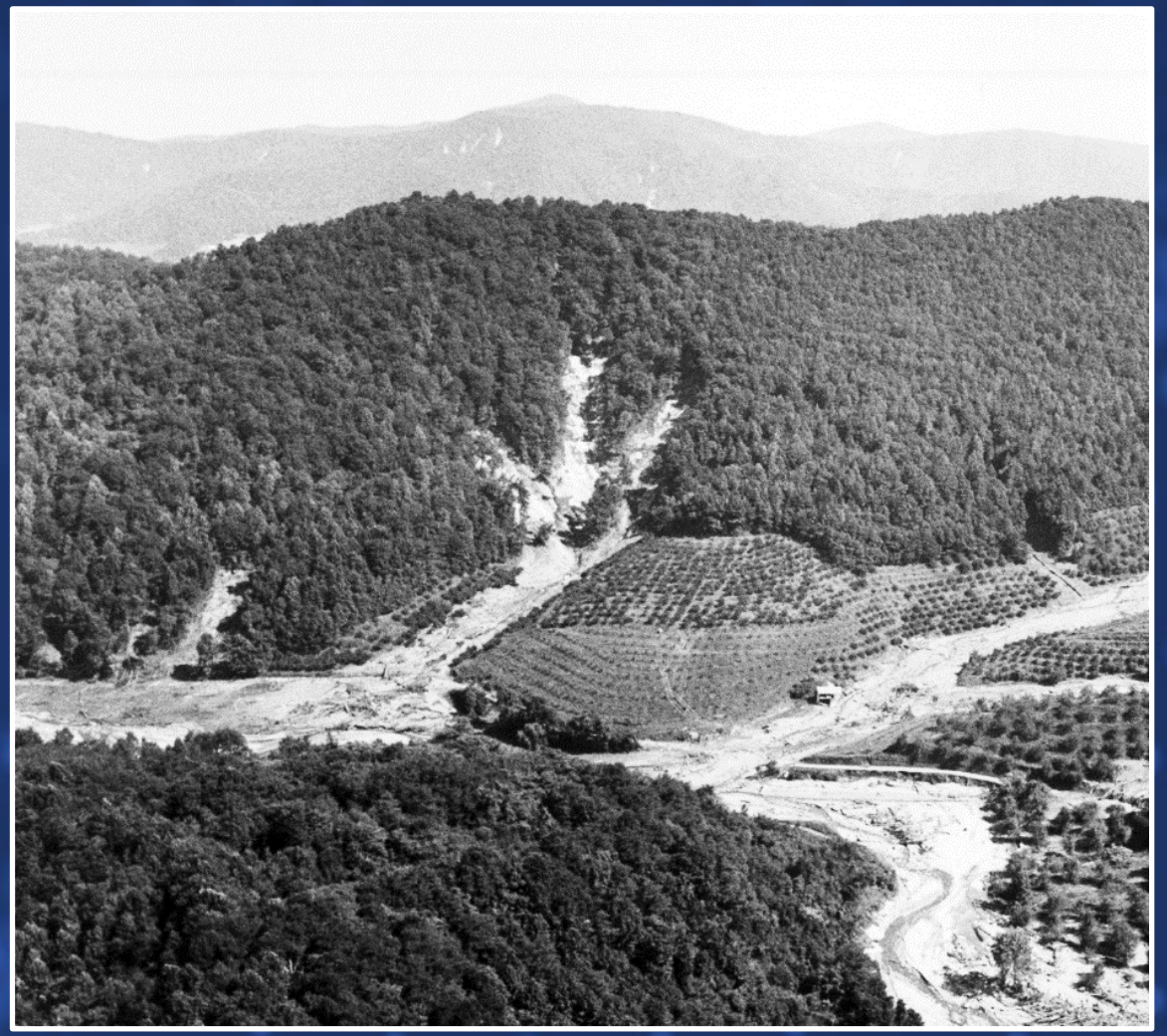
- Debris or earth blowout 7
- Debris or earth flow 6,082
- Debris or earth slide and flow 5
- Debris or earth slide 1,696
- Rock slide 5
- Weathered rock slide 1

Slope movement deposits

- Relict landslide
- Debris deposits
- Talus

Modifiers

Green halo indicates slope movement or slope movement deposit was field verified



Debris flows initiated during Hurricane Camille (1969) in Nelson County

1 Landslide Inventory Map

Slope movements

- Landslide track
- Weathered Landslide

Initiation zones

- Debris or earth blowout 7
- Debris or earth flow 6,082
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- Debris or earth slide 1,696
- Rock slide 5
- Weathered rock slide 1

Slope movement deposits

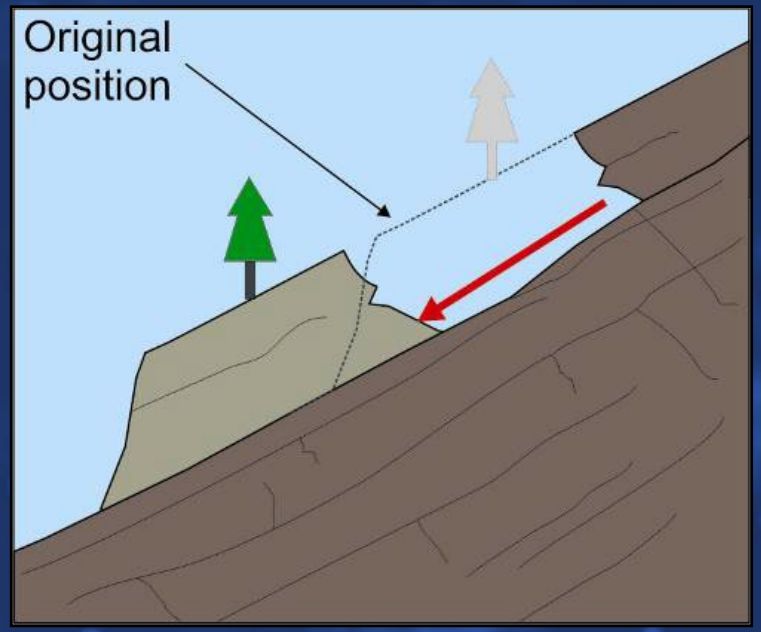
- Relict landslide
- Debris deposits
- Talus

Modifiers

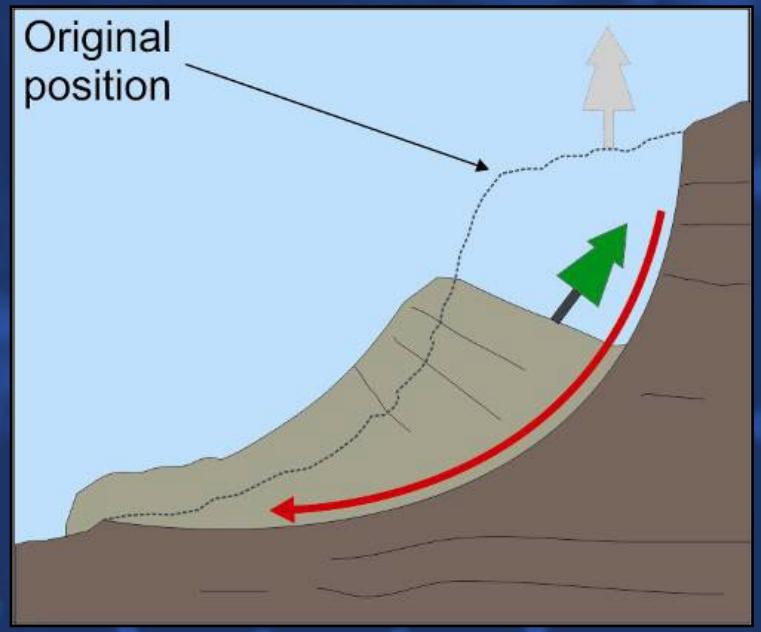
Green halo indicates slope movement or slope movement deposit was field verified

	Type of Movement	Slide (Translational / Rotational)	Flow	Topple	Fall	Composite
MATERIAL	Earth (>80% <2mm)					
	Debris (>20% >2mm)	X				
	Weathered Rock (PDS-CDS)					
	Rock (STS-VFS)					

Debris slides are the second most common type of landslide feature in the study area.



Translational slide



Rotational slide

1 Landslide Inventory Map

Slope movements

- Landslide track
- Weathered Landslide

Initiation zones

- Debris or earth blowout 7
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- Debris or earth slide 1,696
- Rock slide 5
- Weathered rock slide 1

Slope movement deposits

- Relict landslide
- Debris deposits
- Talus

Modifiers

- Green halo indicates slope movement or slope movement deposit was field verified

Debris Slide:
Albemarle County (1995)

Rock Slide:
US 250 Albemarle County (2021)

1 Landslide Inventory Map

Slope movements

- Landslide track
- Weathered Landslide

Initiation zones

- Debris or earth blowout 7
- Debris or earth flow 6,082
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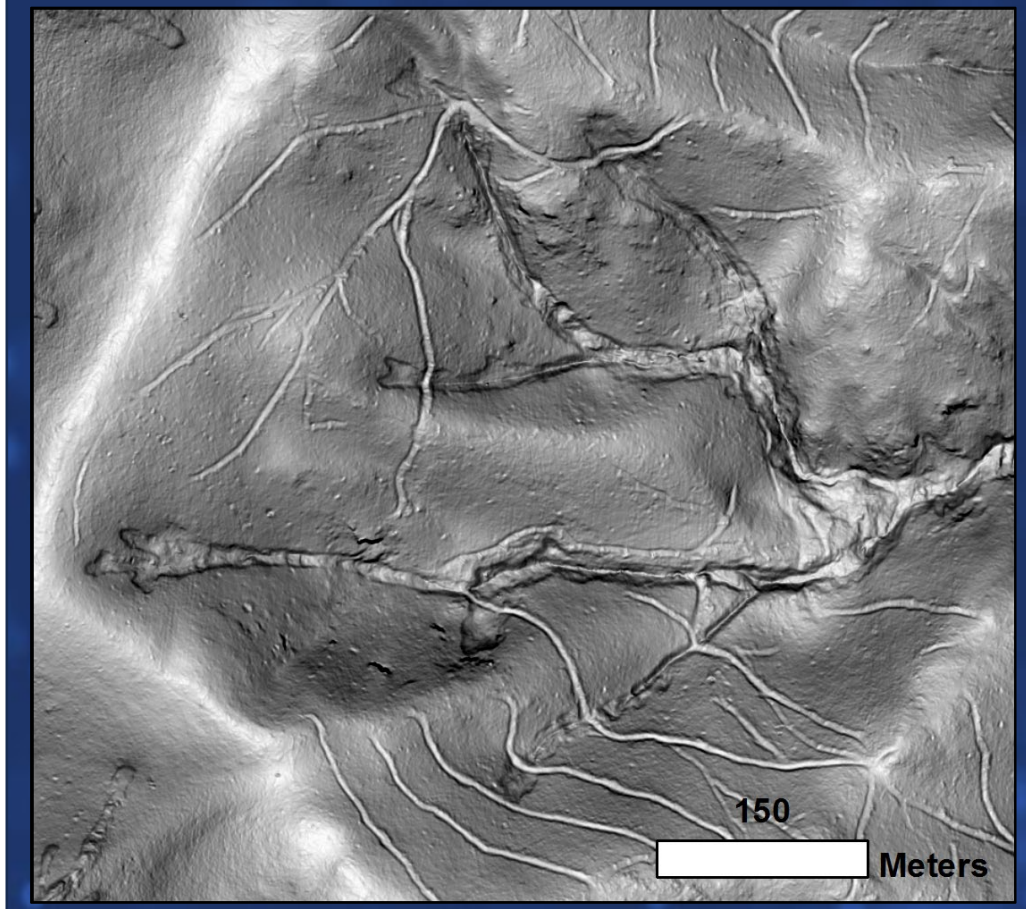
Slope movement deposits

- Relict landslide
- Debris deposits
- Talus

Modifiers

- Green halo indicates slope movement or slope movement deposit was field verified



Landslide Track: The areal extent of a modern landslide. The track and headscarp are sharply defined in LIDAR and can be identified on post-storm aerial photography.

Aerial Photograph: Post-storm 1969 photograph of the Davis Creek area of Nelson County. The tracks of modern landslides are highly reflective.

1 Landslide Inventory Map

Slope movements

- Landslide track
- Weathered Landslide

Initiation zones

- Debris or earth blowout 7
- Debris or earth flow 6,082
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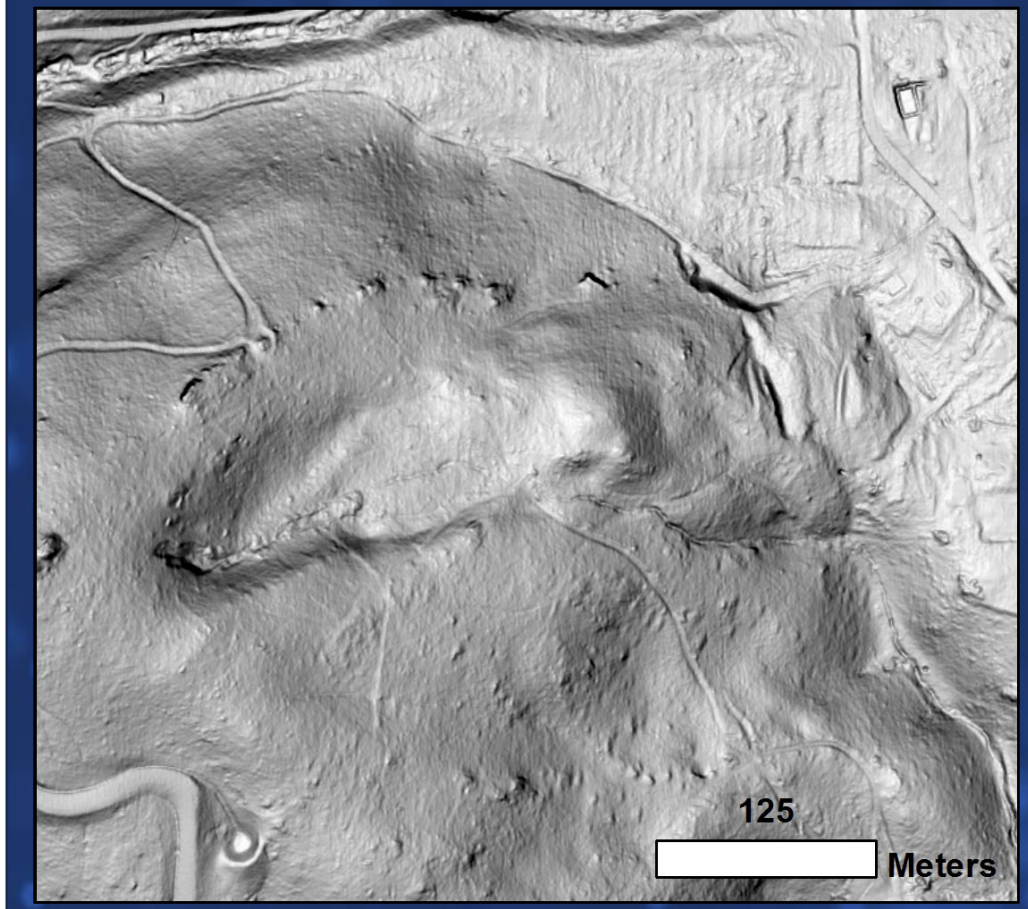
Slope movement deposits

- Relict landslide
- Debris deposits
- Talus

Modifiers

Green halo indicates slope movement or slope movement deposit was field verified



Weathered Landslide: headscarp and lateral edges weathered but identifiable in LIDAR; cannot be associated with a storm event.

Photograph: weathered concave headscarp with piles of subangular-to-angular bouldery debris. These features are often found within colluvial hollows or along linear tracks.

1 Landslide Inventory Map

Slope movements

- Landslide track
- Weathered Landslide

Initiation zones

- Debris or earth blowout 7
- Debris or earth flow 6,082
- Debris or earth slide and flow 5
- Debris or earth slide 1,696
- Rock slide 5
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Slope movement deposits

- Relict landslide
- Debris deposits
- Talus

Modifiers

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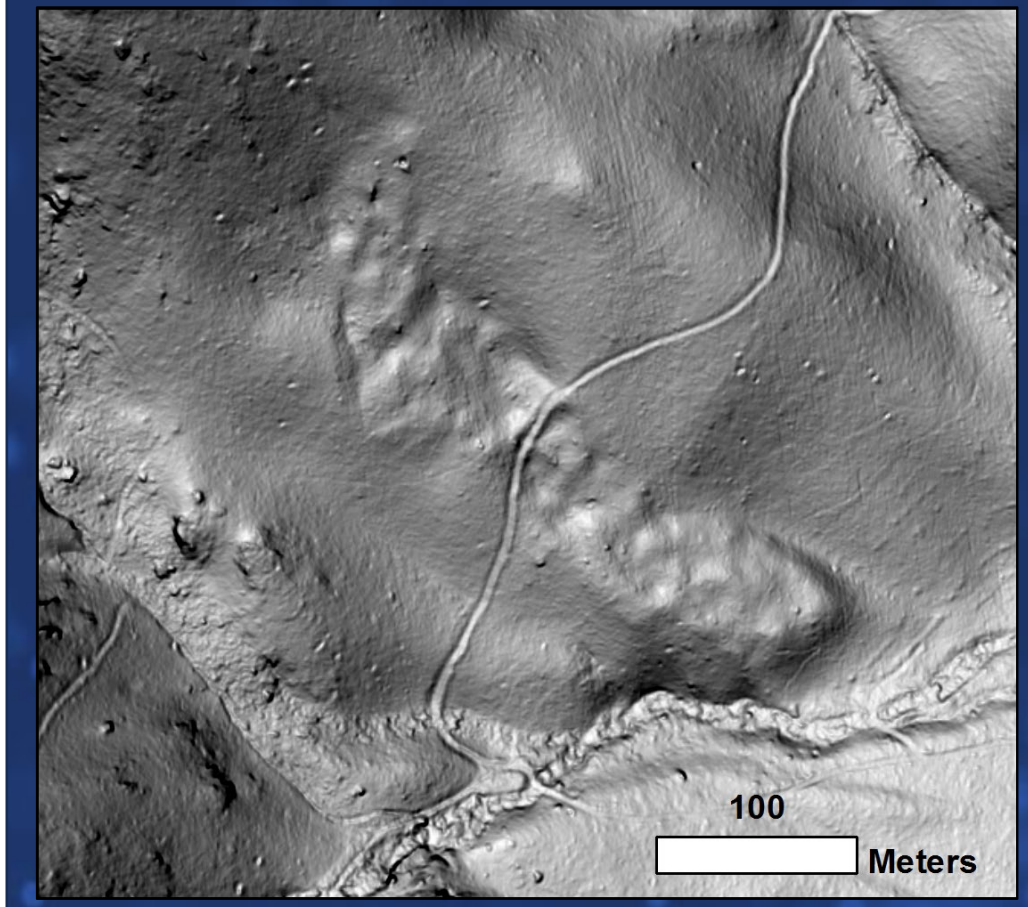

Relict Landslide: hummocky appearance in LIDAR, indistinct lateral edges and no headscarp.

Photograph: Piles of subangular to subrounded boulder- to cobble-size debris scattered across a hummocky slope. May represent weathered rockfall when found downslope from outcrop ledges.

1 Landslide Inventory Map

Slope movements

- Landslide track
- Weathered Landslide

Initiation zones

- Debris or earth blowout 7
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- Debris or earth slide and flow 5
- Debris or earth slide 1,696
- Rock slide 5
- Weathered rock slide 1

Slope movement deposits

- Relict landslide
- Debris deposits
- Talus

Modifiers

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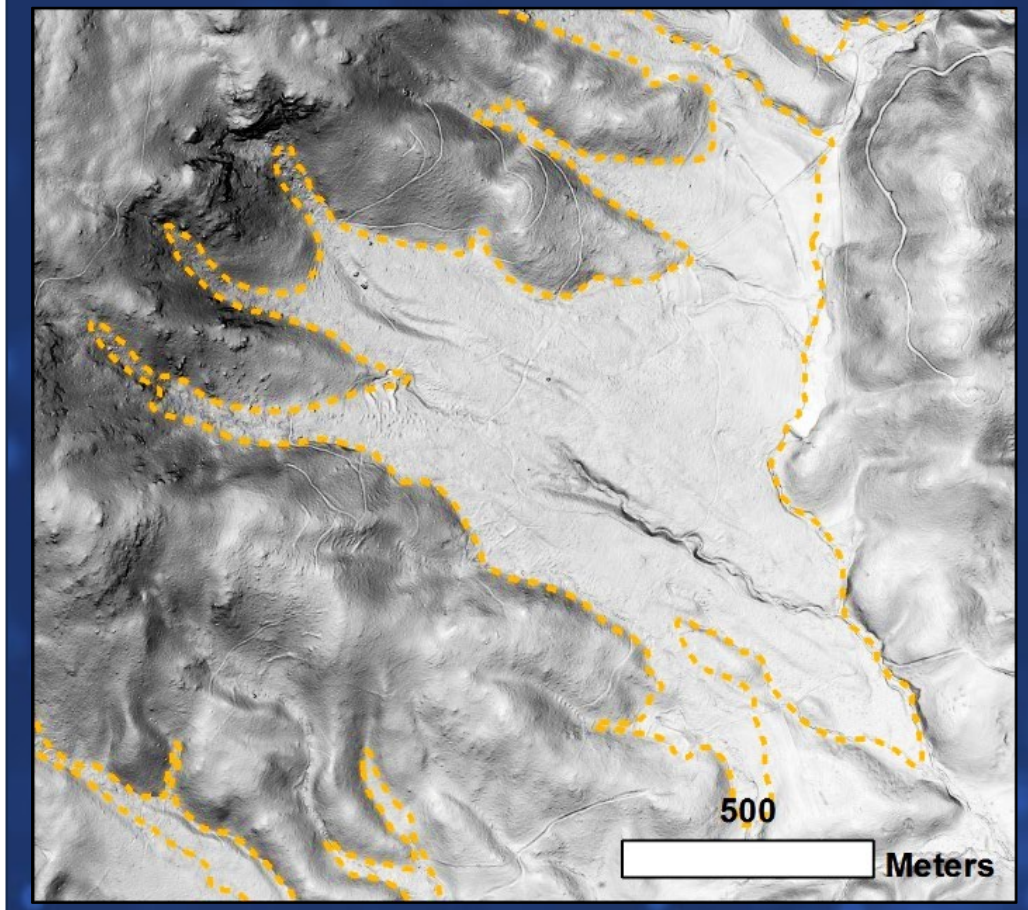
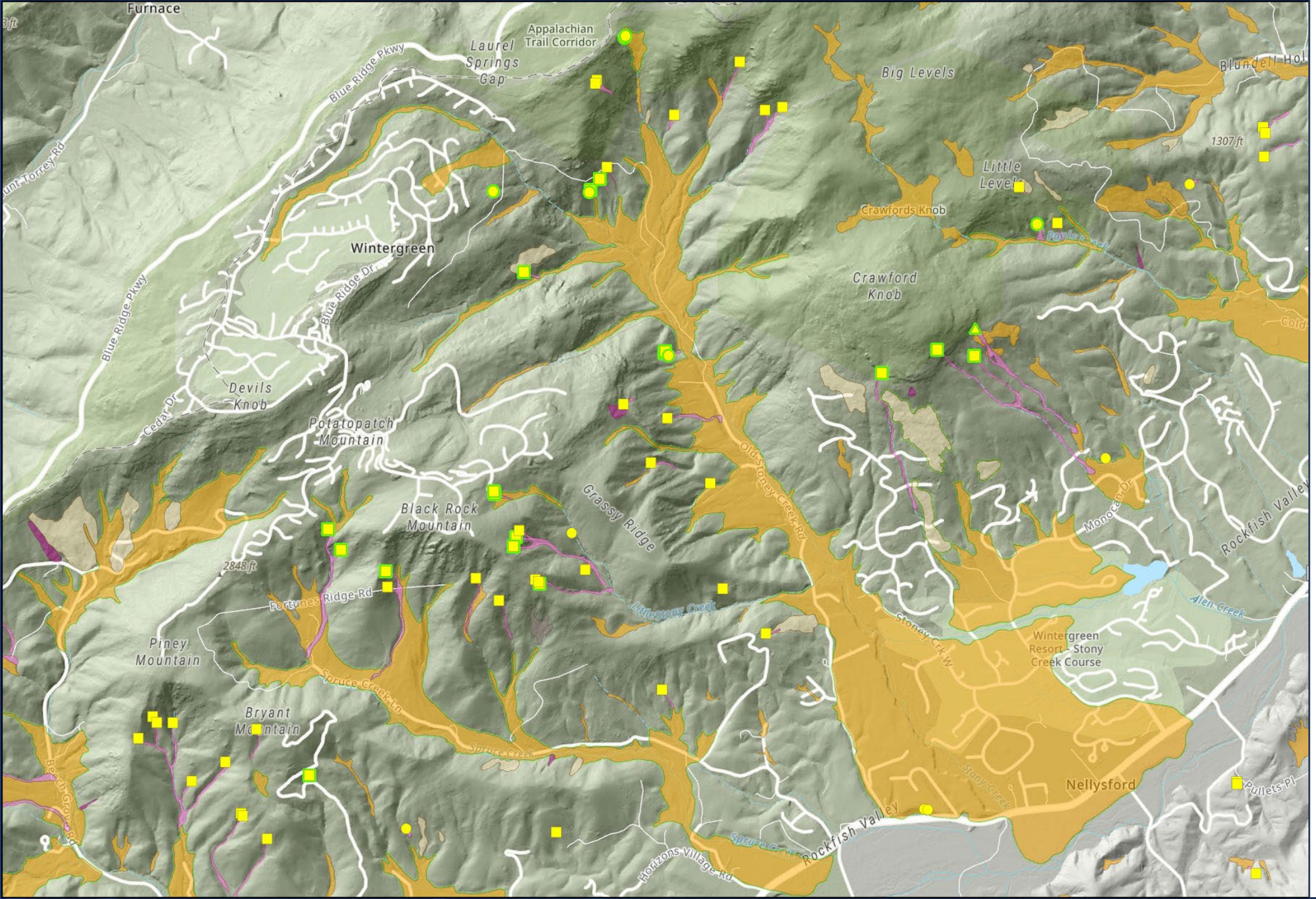


Debris Deposits: low-relief accumulations of unconsolidated bouldery sediment. They are easily identified on 1-meter LIDAR

Photograph: Boulder levee within larger accumulation of subrounded gravel- to boulder-sized debris. Boulder streams and levees transition to broad flat surfaces downslope with few boulders. First-order streams often occur along the margins or within debris deposits.



Slope movements

- Landslide track
- Weathered Landslide

Initiation zones

- Debris or earth blowout
- Debris or earth flow
- Debris or earth slide and flow
- Debris or earth slide
- Rock slide
- Weathered rock slide

Slope movement deposits

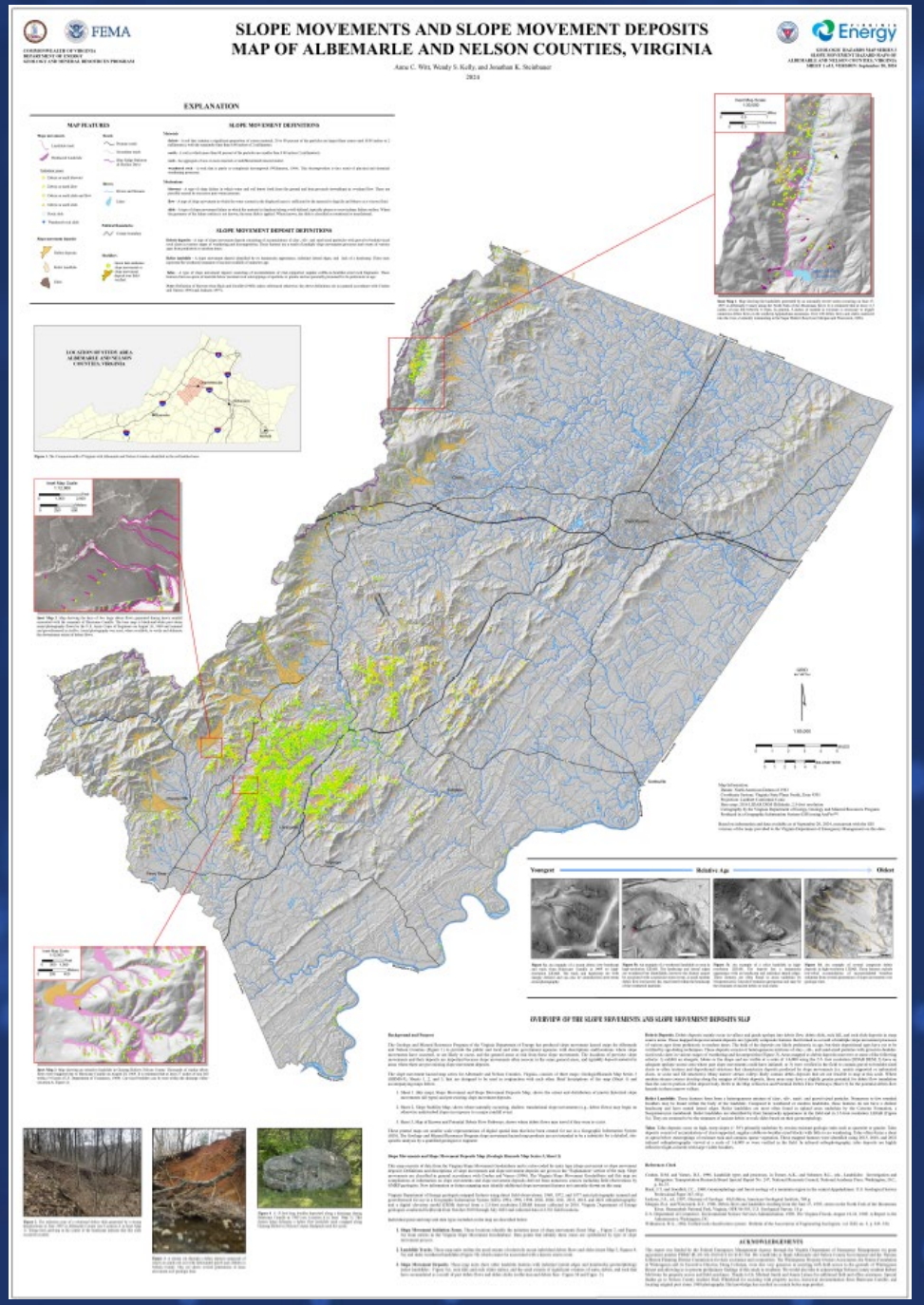
- Debris deposits
- Relict landslide
- Talus

Modifiers

Green halo indicates slope movement or slope movement deposit was field verified

1 Landslide Inventory Map

- A robust inventory allows Virginia Department of Energy geologists to perform spatial statistics with pre-existing digital datasets (slope, aspect, elevation, geology, soil, etc.)
- The inventory also helps to constrain data used for susceptibility modeling
- Provides useful information to planners and emergency management about past landslide activity in an area



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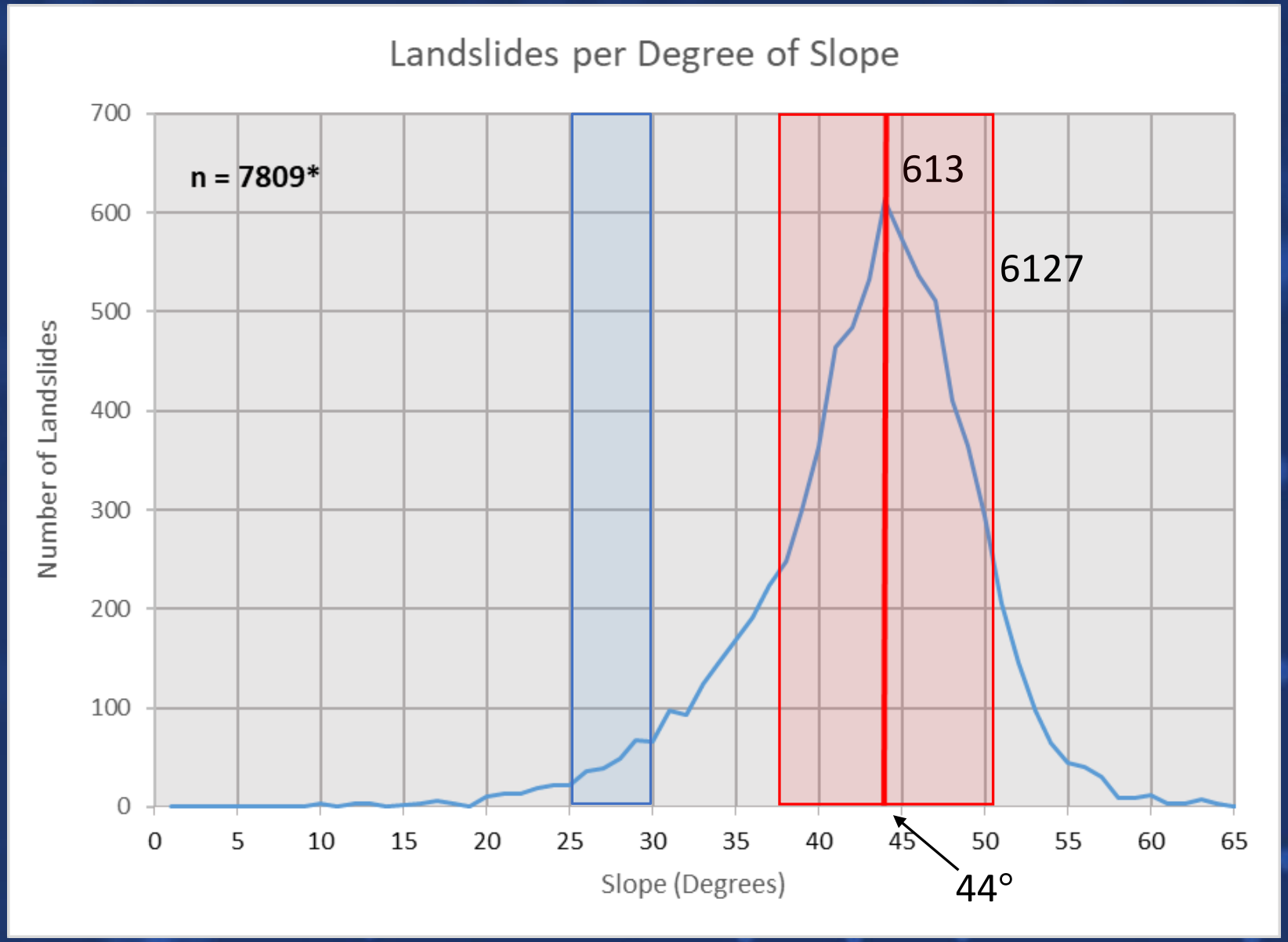
LANDSLIDE STATISTICS: SLOPE

Most landslides in the study area tend to start on slopes that are greater than 25 degrees.

However, most landslides occur on slopes that are between 37 and 51 degrees.



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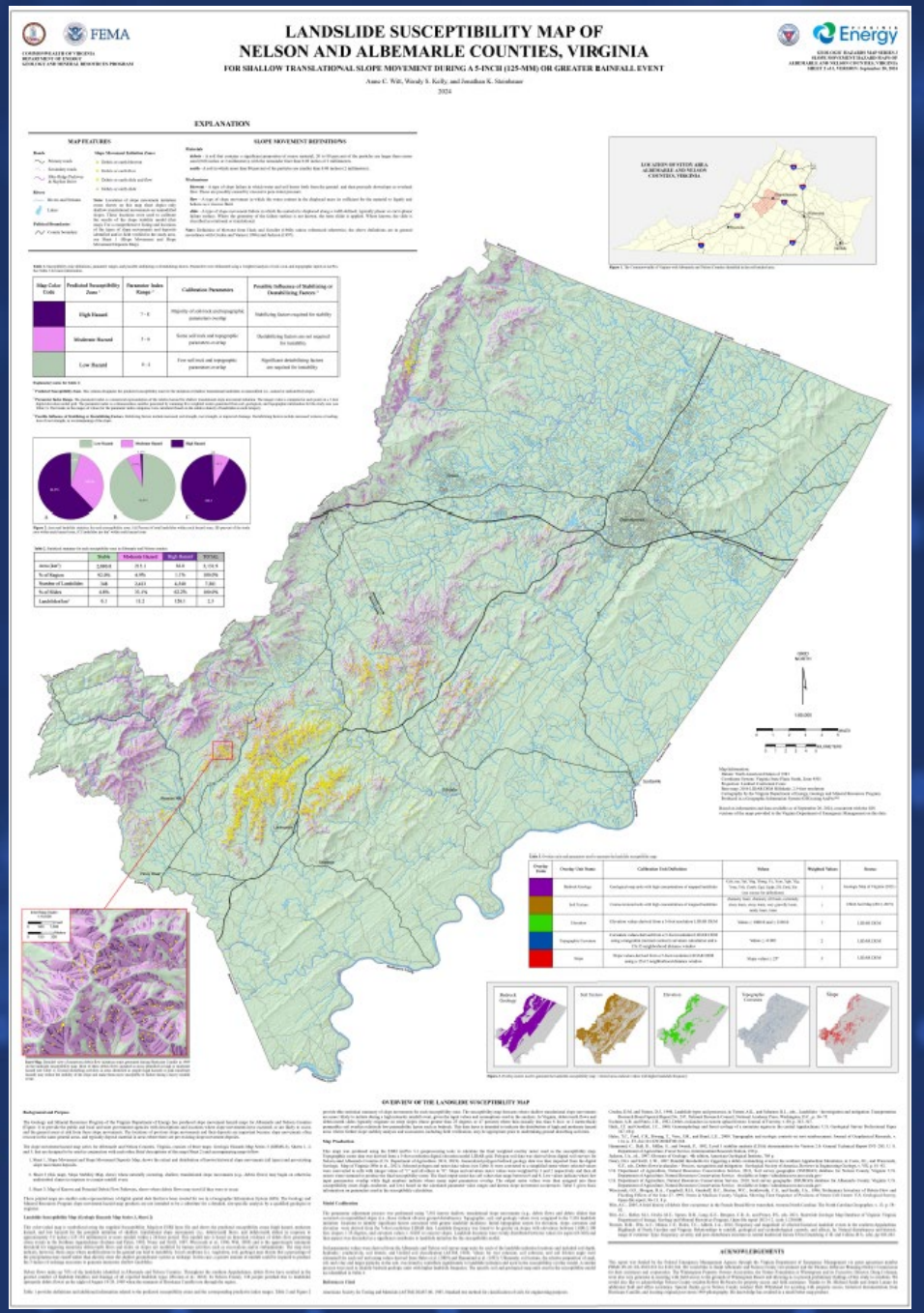
2 Landslide Susceptibility Map

To open the map, go to either:

- AlbemarleNelson_SUSCEPTIBILITY_150dpi.pdf
- AlbemarleNelson_SUSCEPTIBILITY.pagx (GIS map)

The susceptibility map is a raster and is in the Landslide_Susceptibility_Map.gdb

It is highly recommended that users either use the .pagx file or the Susceptibility Map.lyrx file to properly display the map in GIS.



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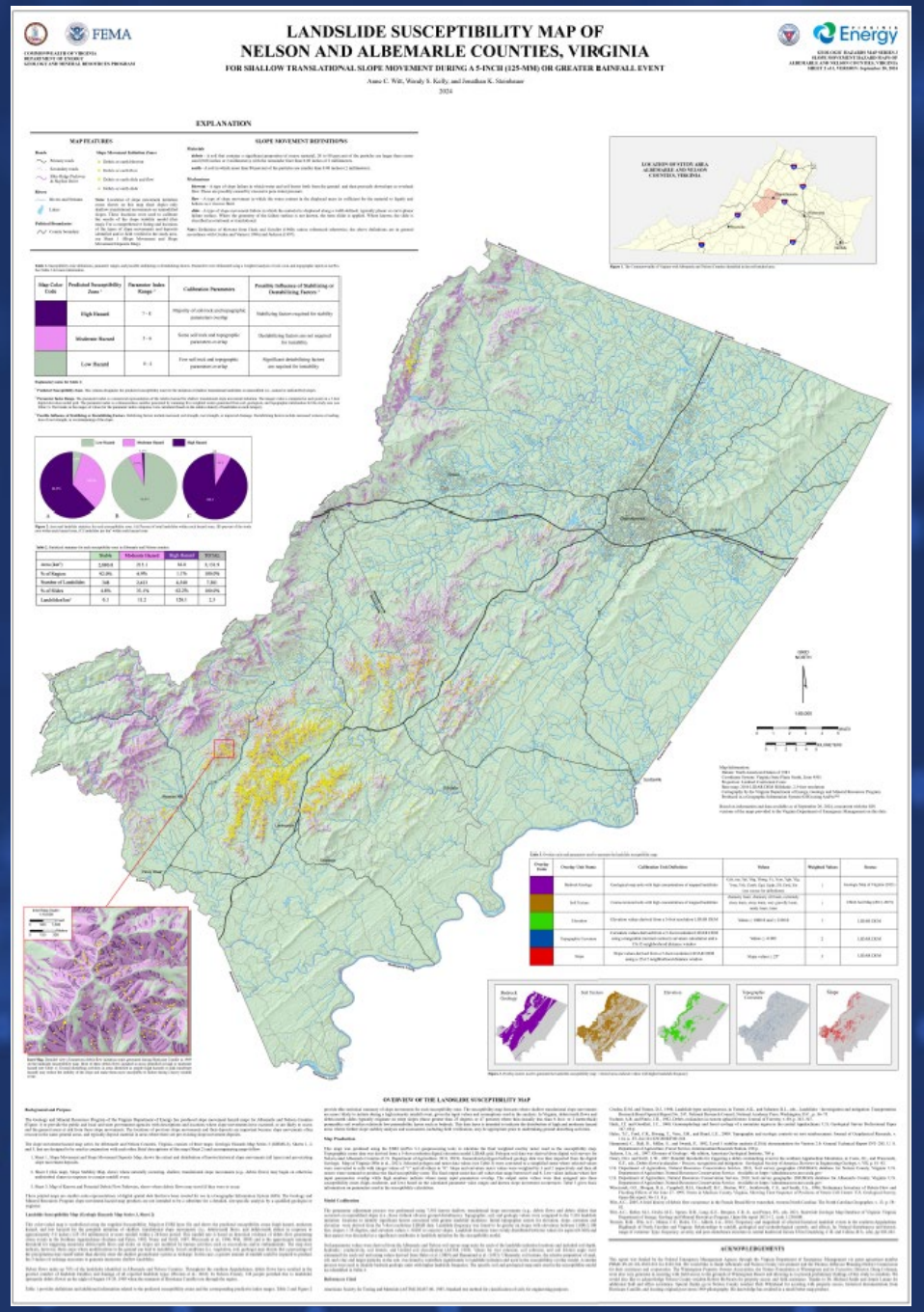
2 Landslide Susceptibility Map

To open the map, go to either:

- AlbemarleNelson_SUSCEPTIBILITY_150dpi.pdf
- AlbemarleNelson_SUSCEPTIBILITY.pagx (GIS map)

GIS data within the geodatabase:

- AlbeNel_Susceptibilty_Map (Raster)
- Several overlay rasters - used in the susceptibility analysis
- Susceptibility_Landslides (landslide point locations used in the susceptibility analysis)



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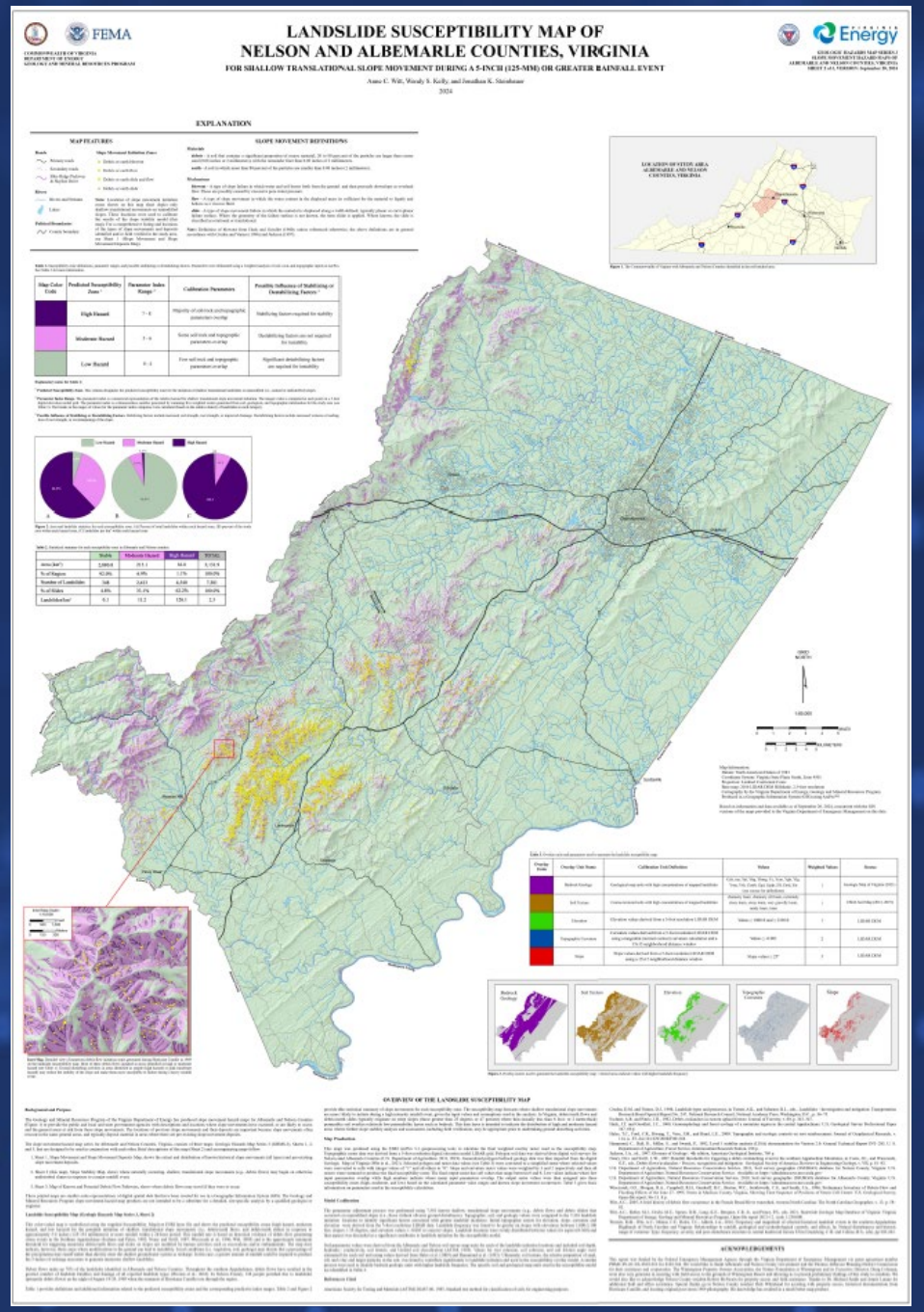
2 Landslide Susceptibility Map

- This map shows were shallow landslides like debris flows and slides might start on natural slopes (not modified by people) during a heavy rainfall event.
- The landslide inventory from Map 1 was used to identify topographic, geologic, and soil material factors that influenced landslide initiation.
- Dark purple and pink colors indicate a high or moderate landslide hazard. Green colors indicate the area is stable or less likely to produce landslides.



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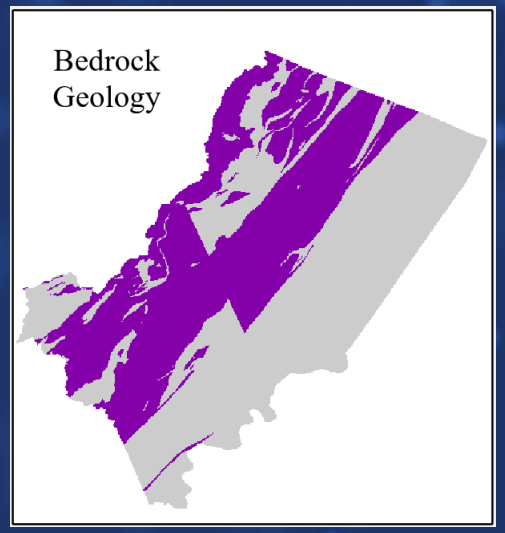
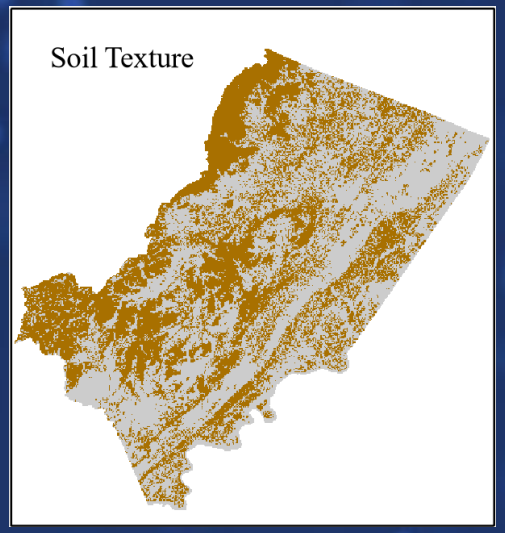
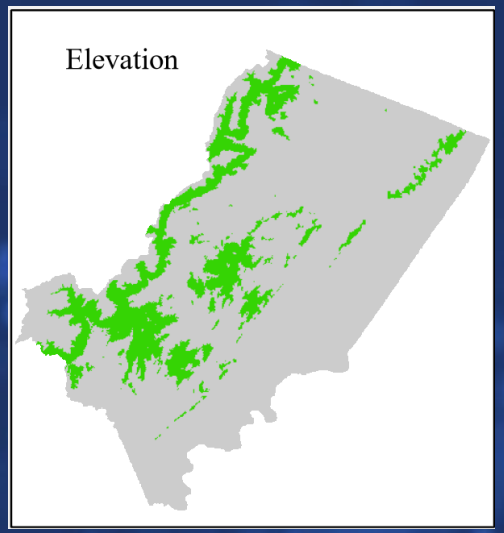
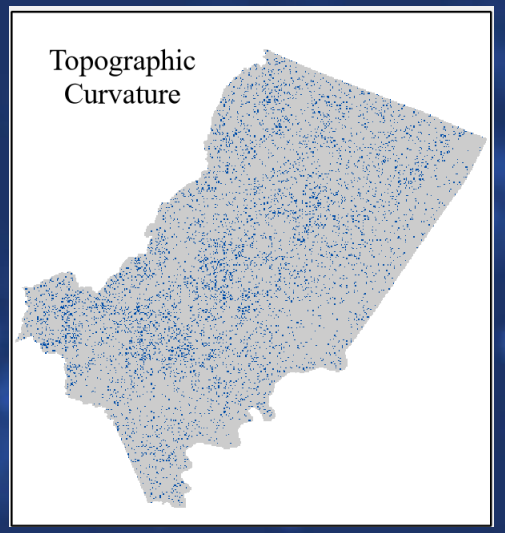
2 Landslide Susceptibility Map: Methodology

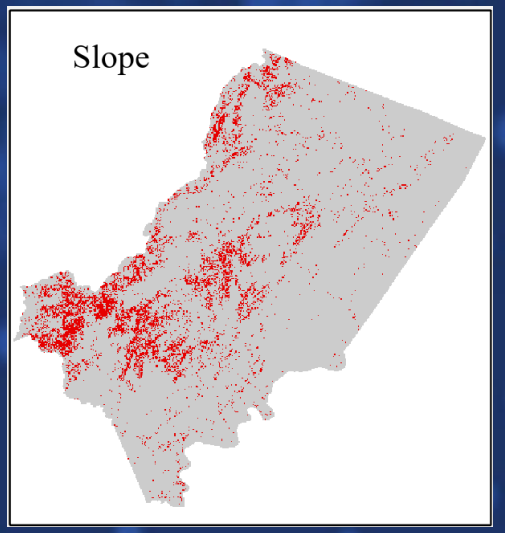
Topographic slope and curvature, elevation, bedrock geology, and soil texture were found to be most important for landslide initiation. Each digital dataset was converted to an integer raster and all were summed.











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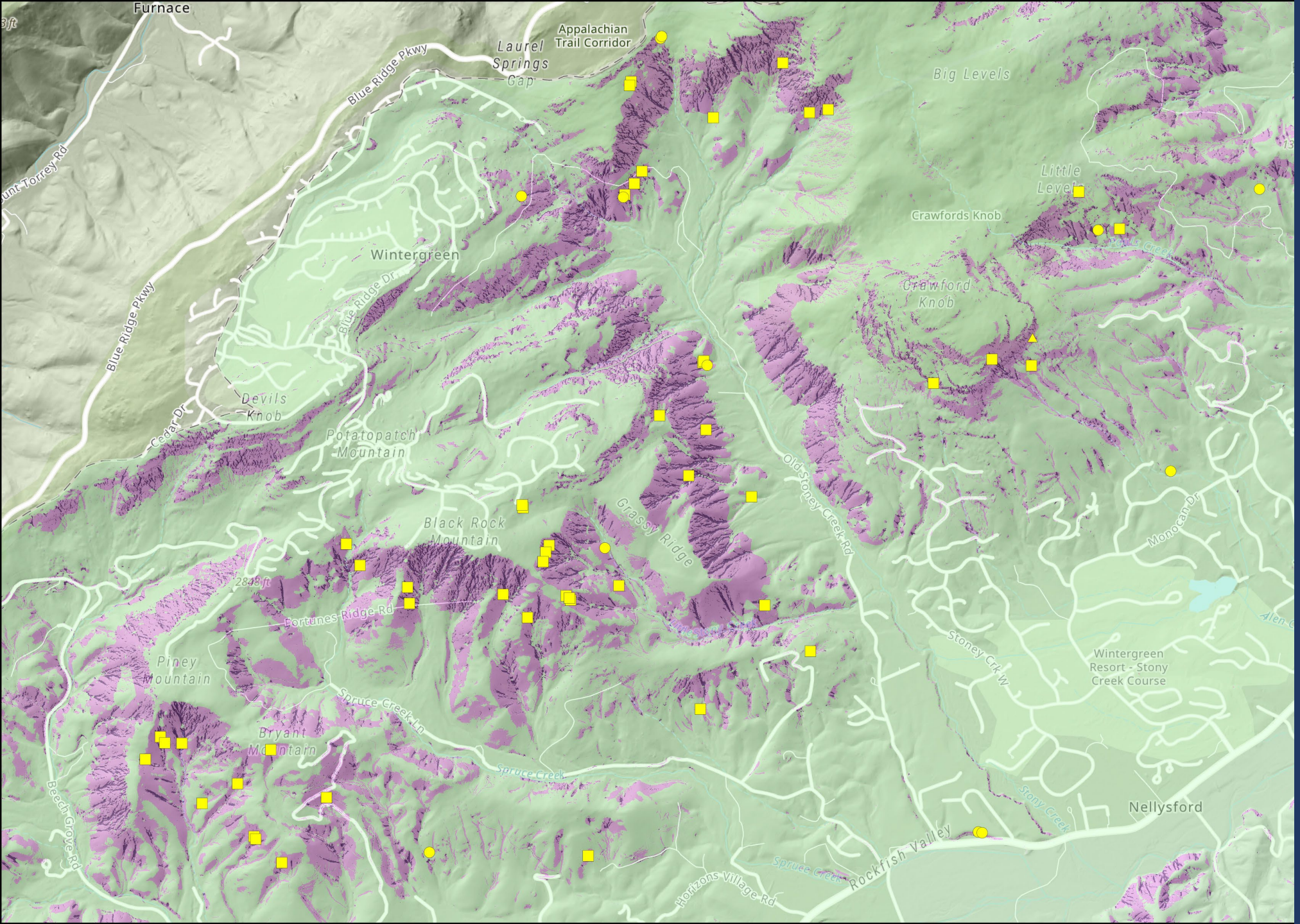
2 Landslide Susceptibility Map: Methodology

Parameters used for each overlay raster can be found in Table 3.

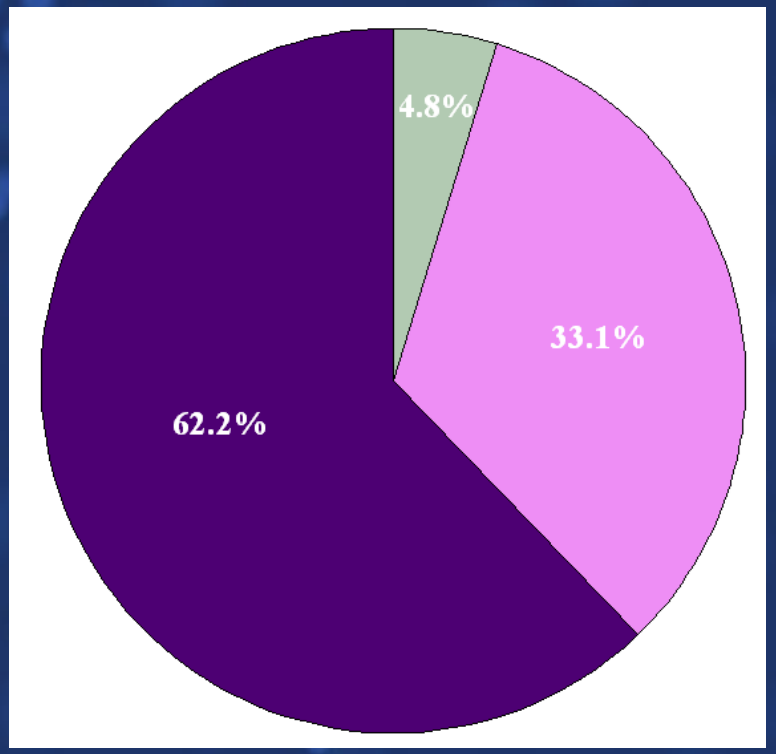
Overlay Units	Overlay Unit Name	Calibration Unit Definition	Values	Weighted Values	Source
	Bedrock Geology	Geological map units with high concentrations of mapped landslides	Ꞓch, my, Yal, Ybg, Ybmg, Yc, Ycm, Ygb, Ylg, Yma, Ysh, Zcmb, Zgd, Zgdp, Zll, Zmd, Zsr (see source for definitions)	1	Geologic Map of Virginia (2021)
	Soil Texture	Coarse-textured soils with high concentrations of mapped landslides	channery loam, channery silt loam, extremely stony loam, stony loam, very gravelly loam, sandy loam, loam	1	USDA Soil Map (2013, 2019)
	Elevation	Elevation values derived from a 5-foot resolution LIDAR DEM	Values ≥ 1000 ft and ≤ 2100 ft	1	LIDAR DEM
	Topographic Curvature	Curvature values derived from a 5-foot resolution LIDAR DEM using a tangential (normal contour) curvature calculation and a 15x15 neighborhood distance window	Values ≤ -0.003	2	LIDAR DEM
	Slope	Slope values derived from a 5-foot resolution LIDAR DEM using a 15x15 neighborhood distance window	Slope values ≥ 25°	3	LIDAR DEM



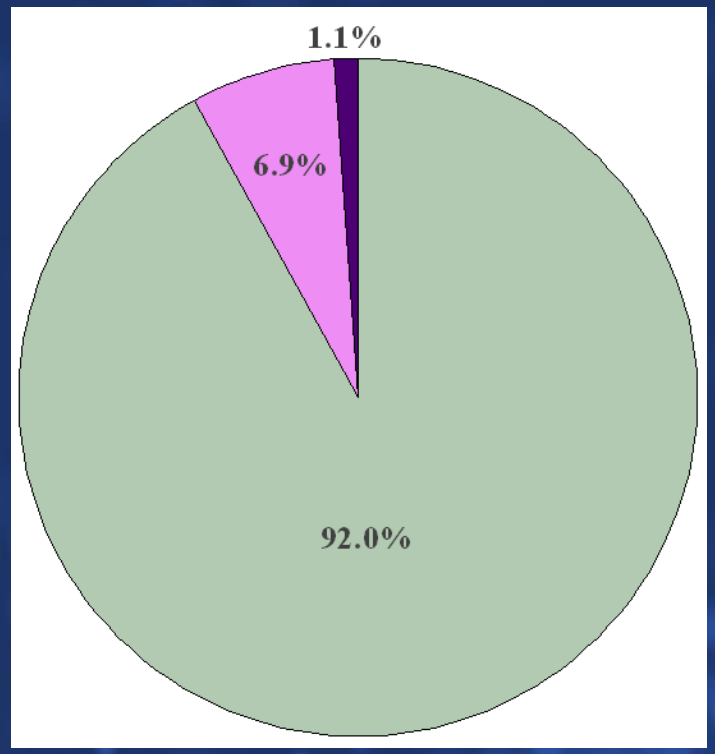
The final susceptibility raster has values between 0 and 8. Higher numbers indicate greater overlap between the parameter rasters and a greater likelihood of landslide initiation (hazard).

Map Color Code	Predicted Susceptibility Zone [1]
	High Hazard
	Moderate Hazard
	Low Hazard

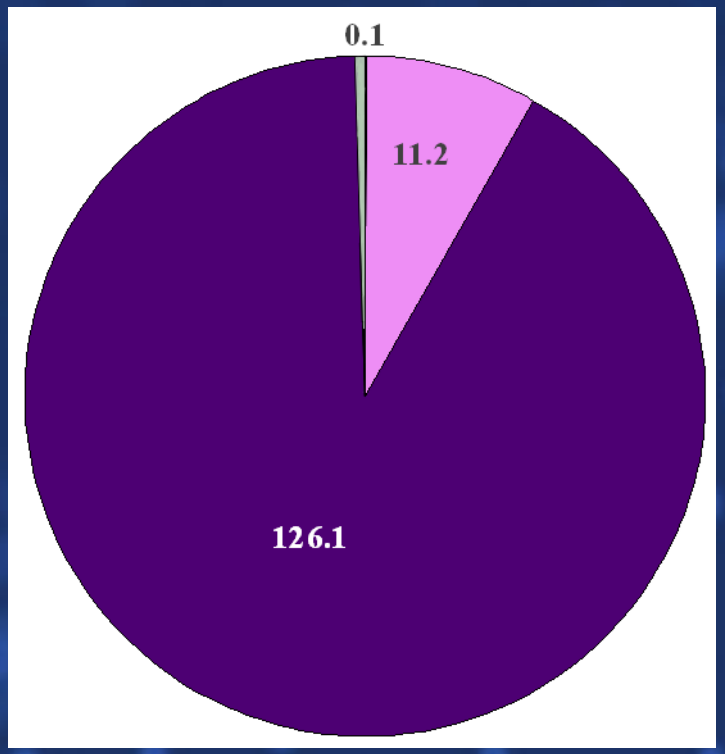
2 Landslide Susceptibility Map: Results



Percent of total landslides within each hazard zone. This graph indicates that most of the landslides were captured in high and moderate hazard zones.



Percent of the study area within each hazard zone. This graph indicates that most of the study area is captured in the stable hazard zone.



The number of landslides per km^2 within each hazard zone. This graph indicates that most of the landslides were captured in a small percentage of the study area high and moderate hazard zones.

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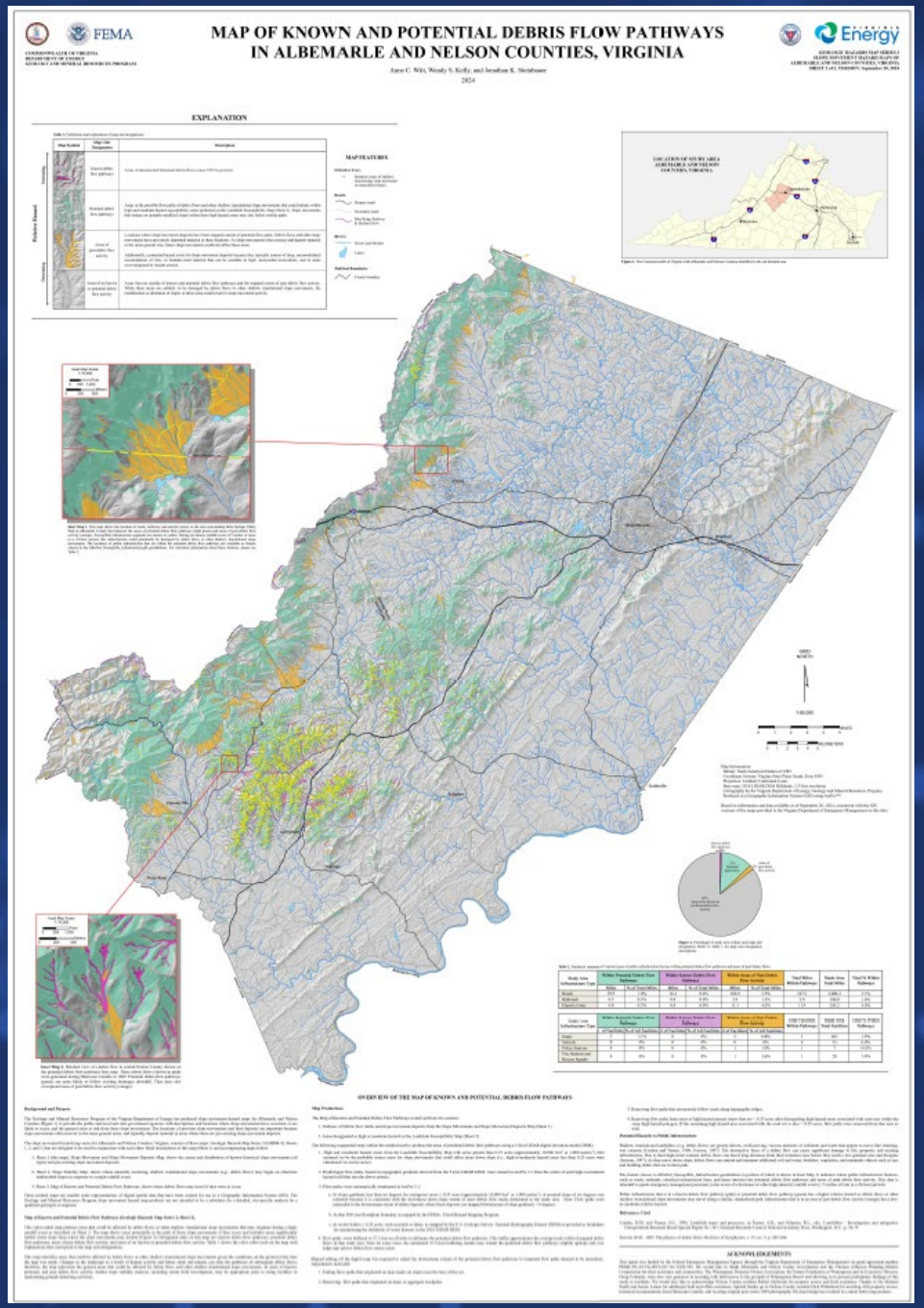
3 Landslide Pathways Map

To open the map, go to either:

- AlbemarleNelson_DFP_150dpi.pdf
- AlbemarleNelson_DFP.pagx (GIS map)

Data located in the Debris_Flow_Pathways.gdb

It is highly recommended that users either use the .pagx file or the Debris Flow Pathways.lyrx file to properly display the map.



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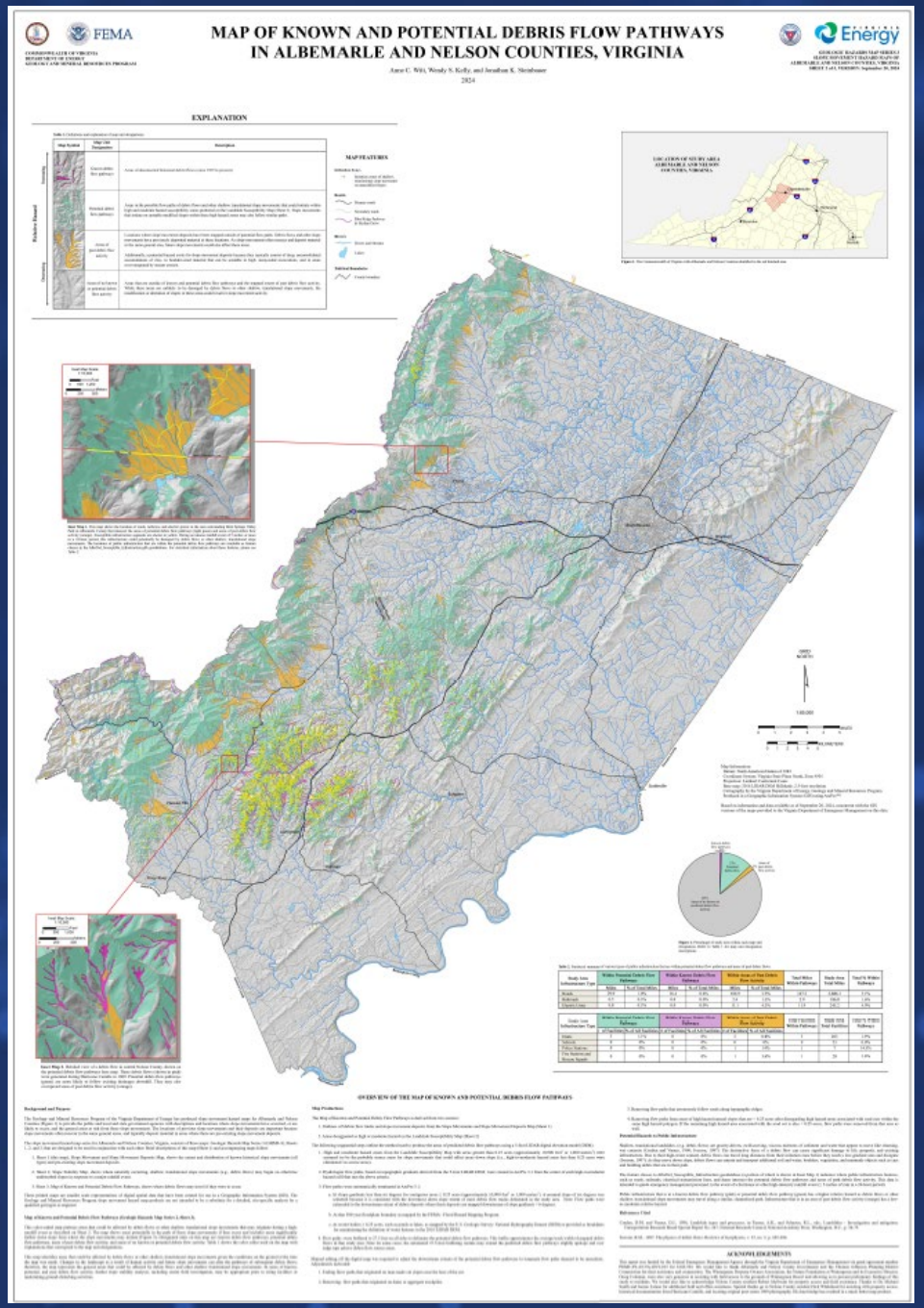
3 Landslide Pathways Map

Infrastructure that intersects these pathways is in AlbeNel_Susceptible_Infrastructure.gdb and includes the following layers:

- AlbNel_Dams_Susceptible (points)
- AlbNel_Electric_Susceptible (lines)
- AlbNel_FireRescue_Susceptible (points)
- AlbeNel_Police_Susceptible (points)
- AlbNel_Rail_Susceptible (lines)
- AlbNel_Roads_Susceptible (lines)



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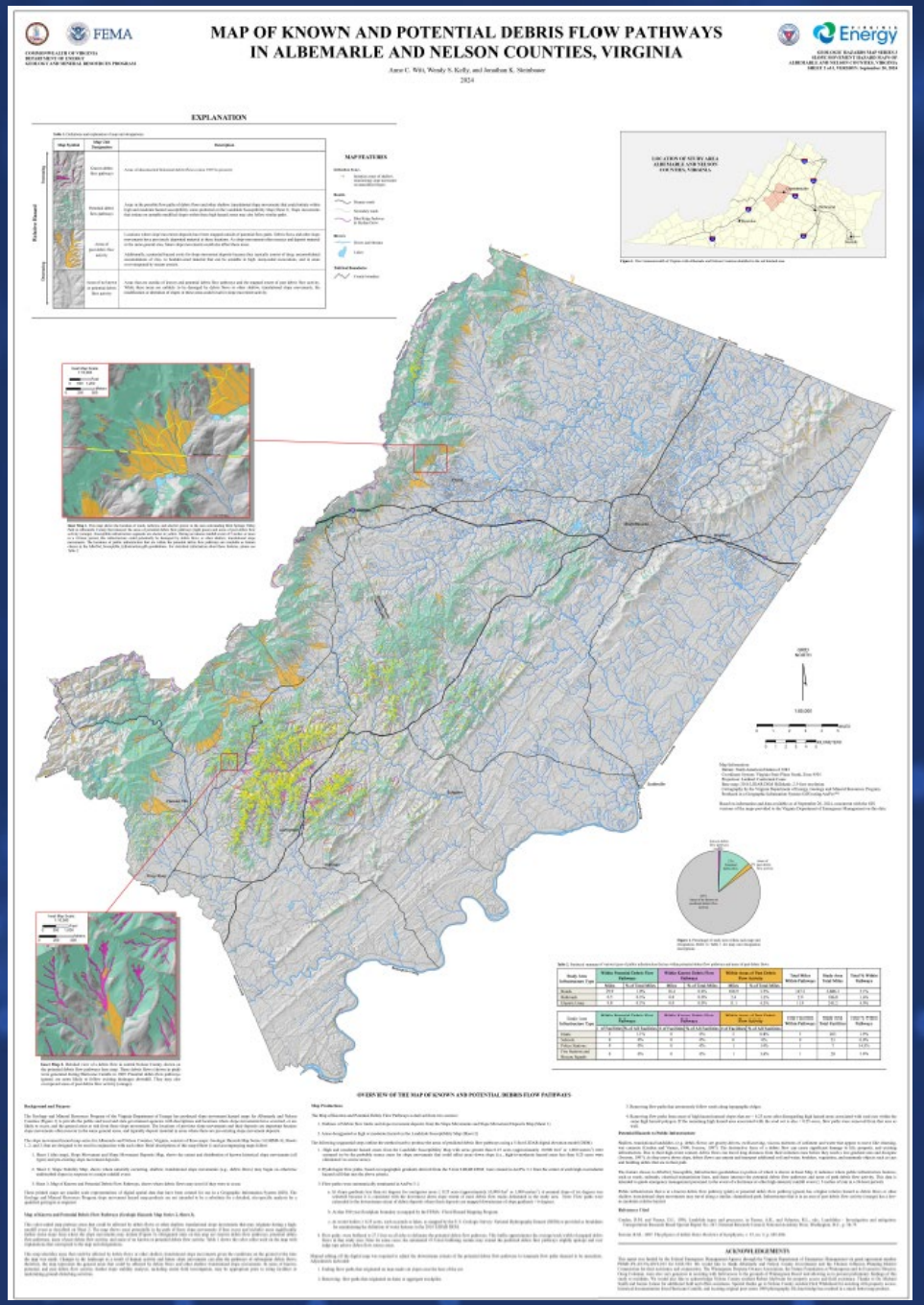
3 Landslide Pathways Map

The landslide pathways map shows where landslides may travel if they initiate from high and moderate hazard areas identified on Map 2.

Due to their high-water content, some landslides, like debris flows, can travel long distances, destroying objects in their path. Because of this inherent danger, feature classes for public infrastructure and critical facilities were compared to the landslide pathways.



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3 Landslide Pathways Map: Methodology

1. Hydrologic flow paths were generated in ArcPro 3.1 from high and moderate hazard zones on Map 2 using the LIDAR DEM.
2. Flow paths were terminated:
   - At slopes of 6 degrees – this was the slope value consistent with lowermost down slope extent of landslides in the study area.
   - When they encountered the 500-year floodplain
   - When they encountered a mapped lake or pond
   - At the base of cut slopes
3. Flow paths were buffered to 27.5 feet (55 feet total) on all sides to delineate the landslide pathway. This is the average track width of mapped debris flows in the study area.

3 Landslide Pathways Map: Methodology

4. After the pathways were complete, GIS data layers of critical facilities and public infrastructure information were compared to pathways.

Study Area Infrastructure Type	Within Potential Debris Flow Pathways		Within Known Debris Flow Pathways		Within Areas of Past Debris Flow Activity		Total Miles Within Pathways	Study Area Total Miles	Total % Within Pathways
	Miles	% of Total Miles	Miles	% of Total Miles	Miles	% of Total Miles			
Roads	29.9	1.0%	16.4	0.6%	100.9	3.5%	147.2	2,886.3	5.1%
Railroads	0.5	0.3%	0.0	0.0%	2.4	1.3%	2.9	186.8	1.6%
Electric Lines	0.8	0.3%	0.0	0.0%	11.1	4.5%	11.9	245.2	4.9%

Study Area Infrastructure Type	Within Potential Debris Flow Pathways		Within Known Debris Flow Pathways		Within Areas of Past Debris Flow Activity		Total Facilities Within Pathways	Study Area Total Facilities	Total % Within Pathways
	# of Facilities	% of All Facilities	# of Facilities	% of All Facilities	# of Facilities	% of All Facilities			
Dams	3	1.1%	0	0%	2	0.8%	5	263	1.9%
Schools	0	0%	0	0%	0	0%	0	53	0.0%
Police Stations	0	0%	0	0%	1	14%	1	7	14.3%
Fire Stations and Rescue Squads	0	0%	0	0%	1	3.6%	1	28	3.6%

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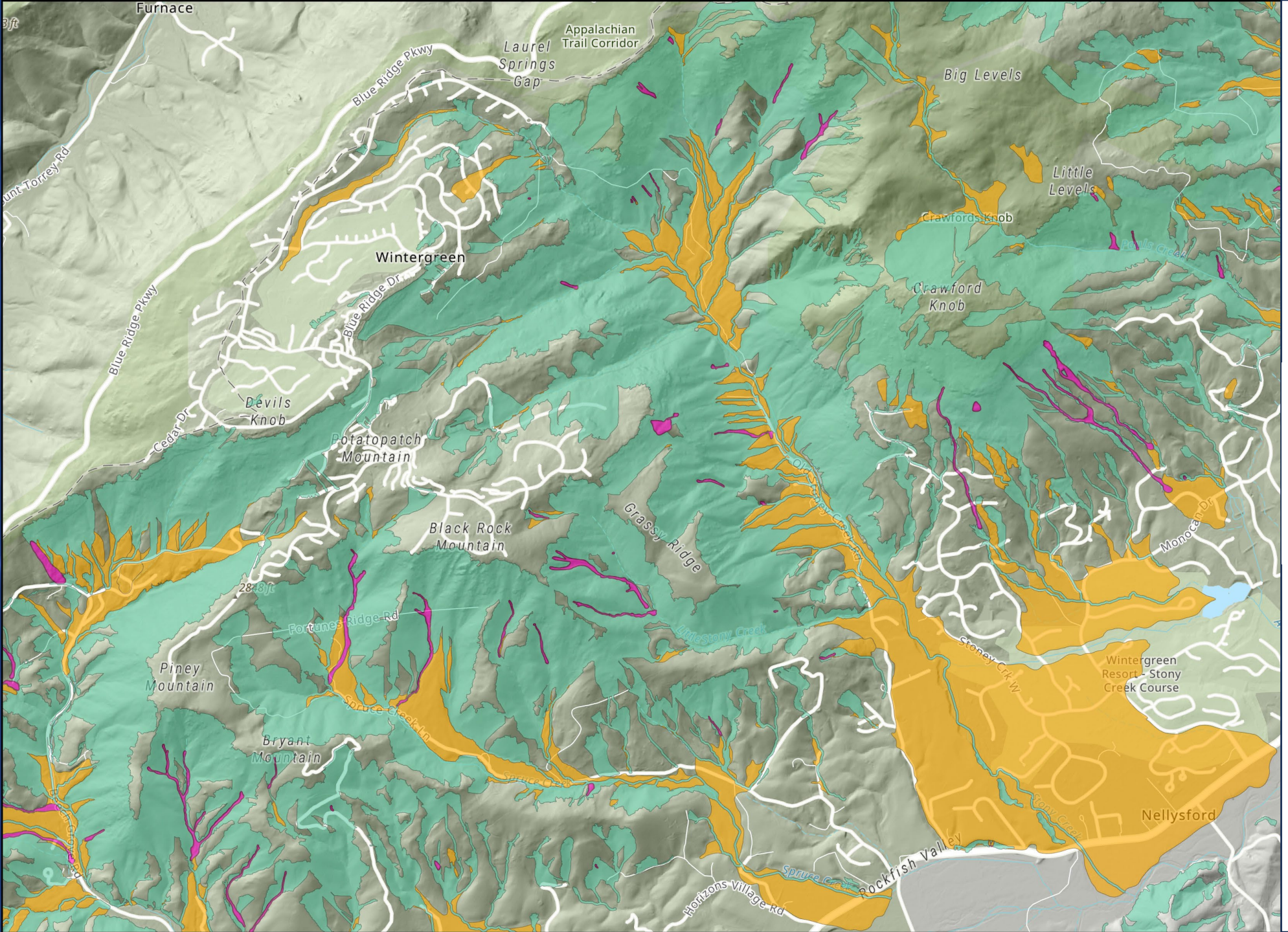
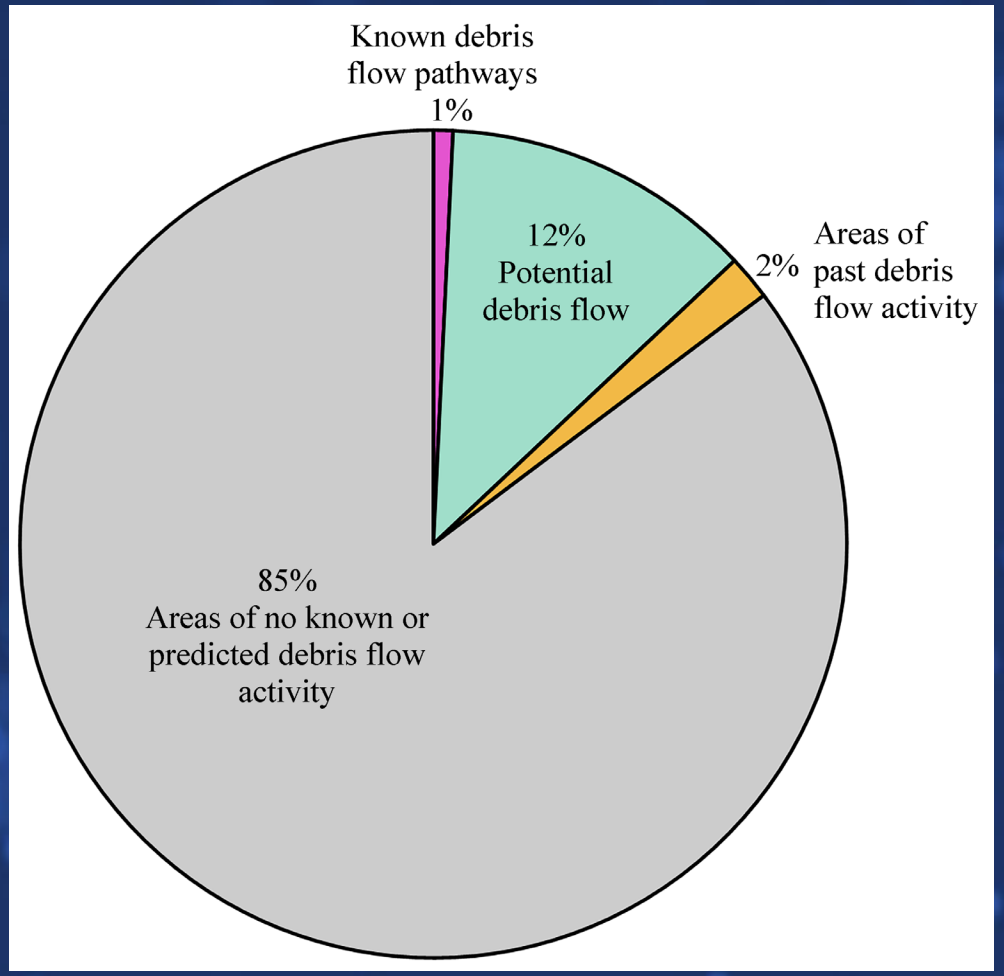


Map Symbol	Map Unit Designation
	Known debris flow pathways
	Potential debris flow pathways
	Areas of past debris flow activity
	Areas of no known or potential debris flow activity

Relative Hazard: Increasing ↑ Decreasing

3 Landslide Pathways Map: Results

- 15% of the study area is within a landslide pathway (known, potential or past activity)
- Many of these pathways follow small drainages and streams
- Luckily, few critical facilities (schools, police, fire and rescue squads) are within a landslide pathway
- However, over 100 miles of road in the study area intersect a landslide pathway.
- This data is intended to guide emergency management in identifying areas for further investigation in the event of a high rainfall event.



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RECOMMENDED USES FOR THE MAPS AND DATA

- These maps do not substitute for a site-specific investigation by a qualified geologist or engineer but should be regarded as starting place for additional investigation.
- The data and information provided as part of this study should be included in future revisions to the local/state hazard mitigation plans and reviewed as part of regional planning efforts.
- Citizens should review the maps to understand landslide hazards in their area and be aware potential risks during a heavy rainfall event.
- The landslide inventory is important as landslides tend to occur in places where they have happened before.
- Landslides tend to be triggered on steep slopes (greater than 25 degrees) during heavy rainfall events like hurricanes.

RECOMMENDED ACTIONS FOR HOMEOWNERS

Be aware of changes to your property:

- Cracks in the soil
- Tilted or bent trees
- Increasing spring activity or newly wet ground
- Hummocky or uneven terrain
- Sagging or taut utility lines
- Sunken or broken road beds

Be aware of changes to your home:

- Movement of soil away from foundations
- Leaking or broken water lines
- Separation of chimneys from walls
- Doors/windows that are hard to shut

Large tension crack in soil.
This indicates the ground is shifting.

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RECOMMENDED ACTIONS FOR HOMEOWNERS

- Consider a set back. When citing a new structure, include a set back of 10-20 feet away from streams and drainages. New landslides tend to inundate streams.
- Live trees strengthen slopes. After trees are cut down, roots will begin to slowly loose strength. Deep root systems strengthen slopes.
- Reduce water on slopes. Direct downspouts and surface water well away from slopes and foundations. Water reduces the strength of soils.
- Consult with a professional before significantly altering a steep slope uphill or downslope of your home.
- When moving soil avoid excavating at the base of a steep slope or placing fill soil on or near steep slopes.

VIRGINIA Energy

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Jonathan Steinbauer: Contract Geologist

https://energy.virginia.gov/geology/FEMA_landslide.shtml