



Landslide Risk Assessment in the Mountain State of West Virginia: Broad-Scale Geologic and Physiographic Influences on Landslide Susceptibility and Slope Failure Types

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West Virginia GIS Technical Center (WV GIS TC)

West Virginia University Department of Geology & Geography

Not a Geological Survey

[Session 207 T42: Landslide Hazards: Inventories, Hazard Maps, Risk Analysis, and Warning Systems](#)

Paper 9: <https://gsa.confex.com/gsa/2021AM/meetingapp.cgi/Paper/370833>

10:30-10:45 - AM, Wednesday, 13 October 2021

Oregon Convention Center - Portland Ballroom 254

***2018-2022 Effort Funded by FEMA Hazard Mitigation Grant Program &
WV Division of Homeland Security and Emergency Preparedness***

* Presenter Contact: jkite@wvu.edu

** Matt Bell is now affiliated with Meiser & Earl Hydrogeologists

1.15 km

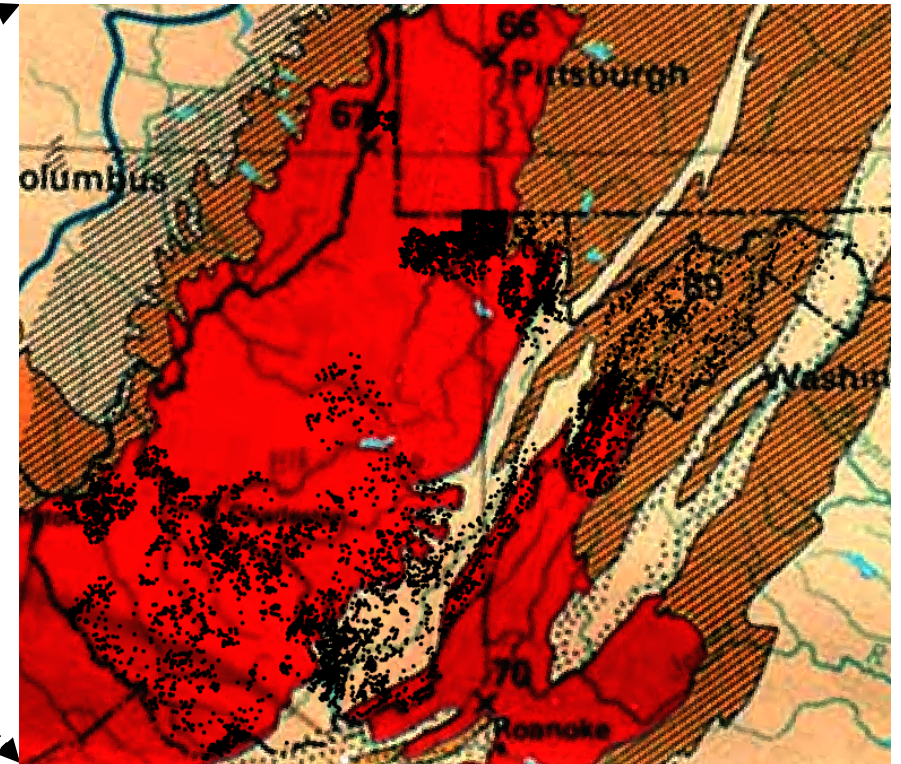
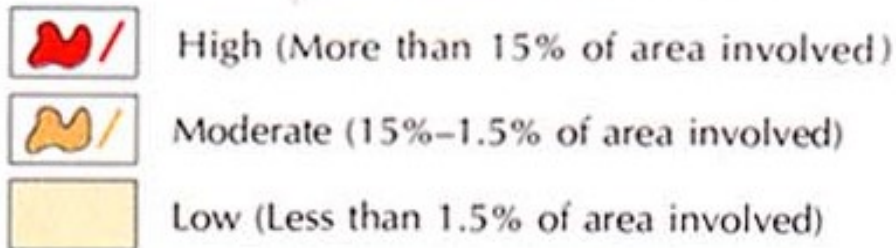
Why Assess West Virginia Landslide Risk?

- Landslides = #2 West Virginia Hazard (FEMA).
- West Virginia = #1 in *Per Capita* Landslide \$ in 48 states (USGS OF 84-486).
- ~70% of West Virginia = “**High Landslide Incidence**” (USGS PP 1183).
 - *No Other State >25%*

Coterminous
U.S. Landslide
Overview Map
USGS PP 1183



LANDSLIDE INCIDENCE



Existing Physiographic Maps Not Adequate for WV Landslide Project

MLRA Boundaries Better

Provinces & Subdivisions

Appalachian Plateaus

- Kanawha Section
- Logan Plateau #
- Allegheny Mountains
 - Southern vs Northern

Valley & Ridge

- Ridge & Valley
 - Southern vs.
 - Northern
- Great Valley

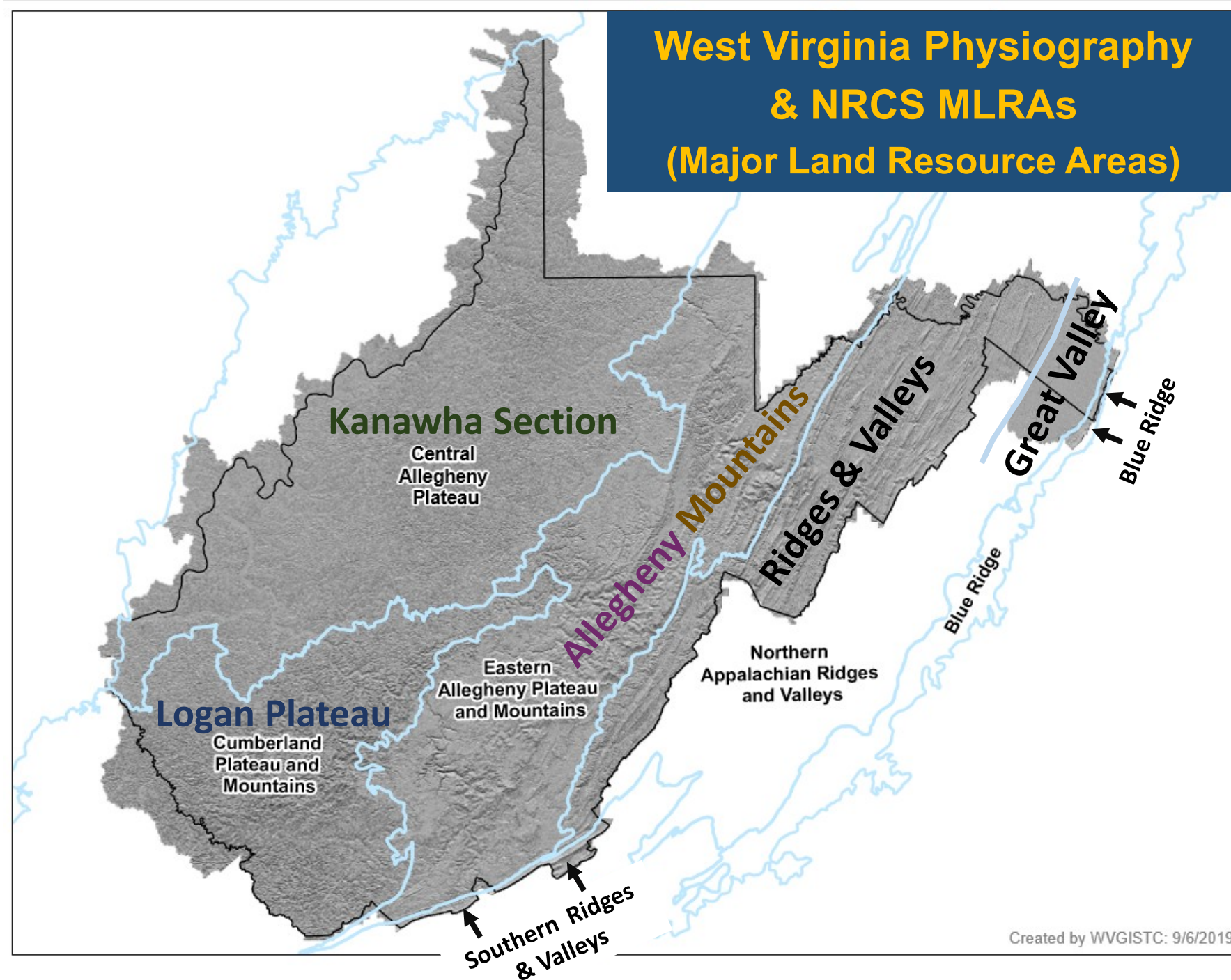
Blue Ridge

Combined
into
**Ridges &
Valleys**
for this talk

See Outerbridge, W.F., 1987
USGS Bulletin 1620

<https://pubs.usgs.gov/bul/1620/report.pdf>

West Virginia Physiography & NRCS MLRAs (Major Land Resource Areas)



WV Landslide Areas Based on NRCS MLRA (Major Land Resource Areas)

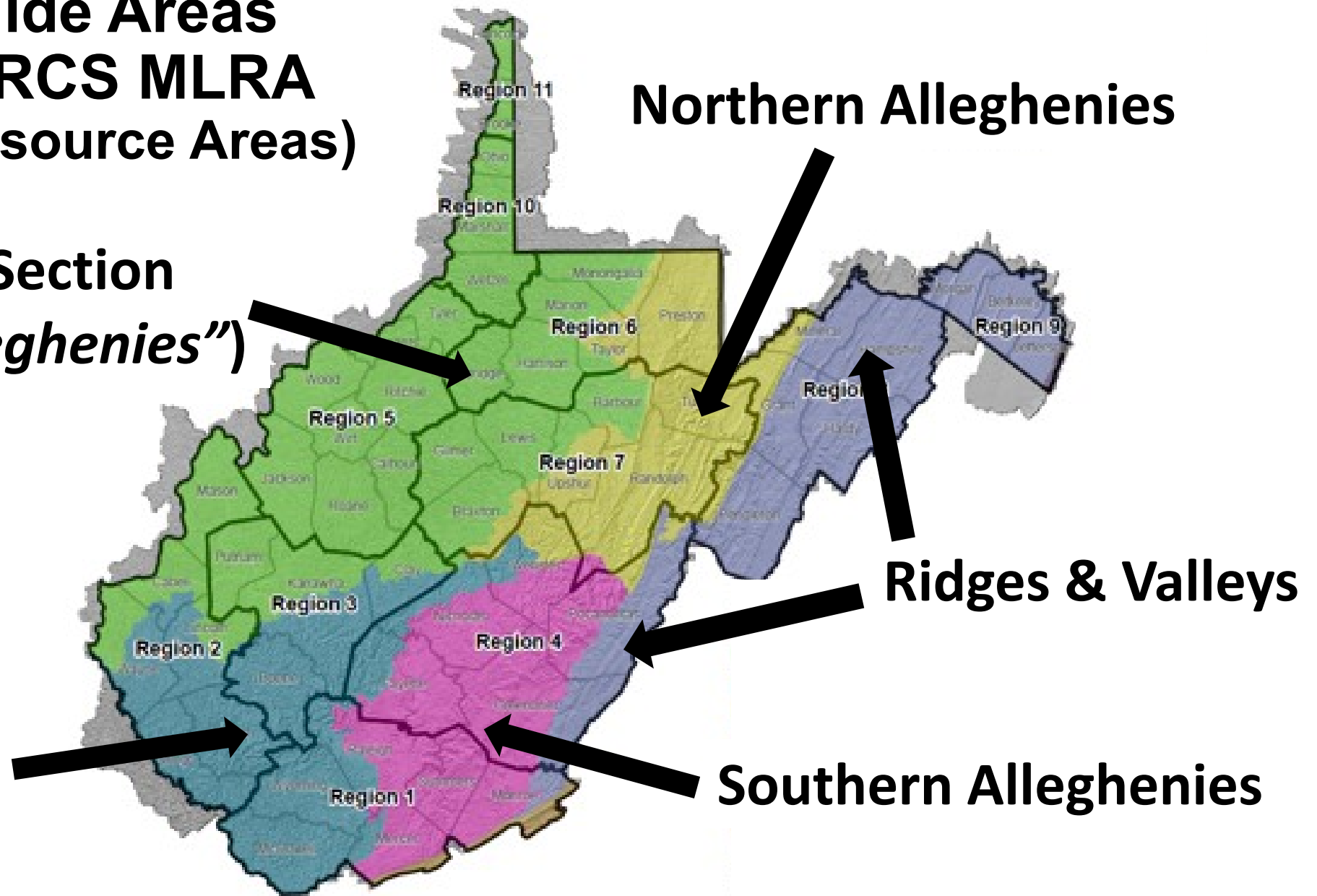
**Kanawha Section
(Central “Alleghenies”)**

Northern Alleghenies

Ridges & Valleys

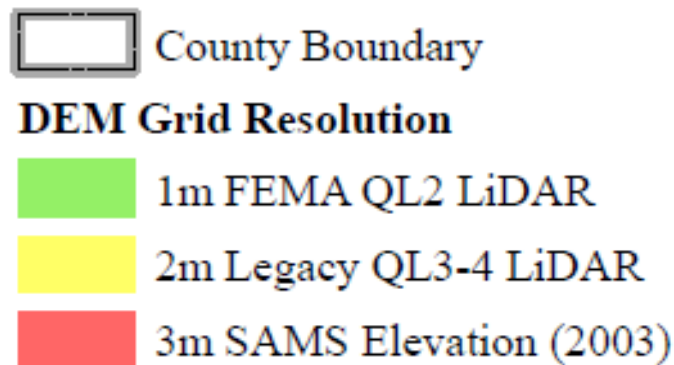
**Logan
(Cumberland)
Plateau**

Southern Alleghenies



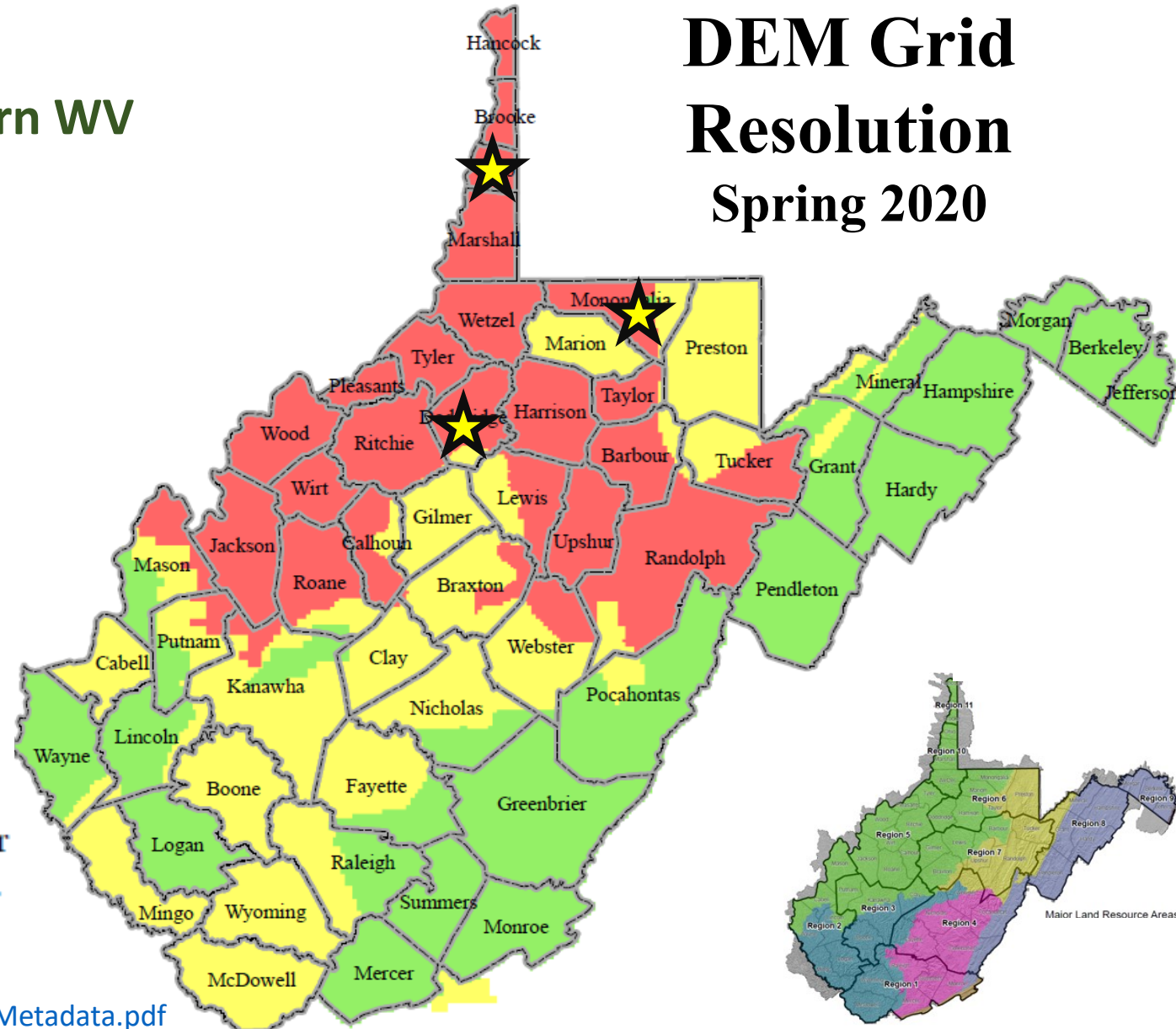
West Virginia Landslide Mapping

- QL2 & QL3-4 LiDAR 1 m or 2m DEMs
- **Good Coverage in Eastern & Southern WV**
- **3 m DEMs = Useless in Mapping**
- Used Best Available Hill-Shade
- >10 m Minimum Width
- Very Conservative in Landslide ID



★ Non-public, 2-foot resolution DEMs exist for Doddridge, Monongalia, and Ohio Counties.

**DEM Grid
Resolution
Spring 2020**



- **Best-Available WV Elevation Sources:**
www.mapwv.gov/floodtest/docs/WV_FloodTool_ElevationSource_Metadata.pdf

West Virginia Landslide Mapping Progress

October 2021

WV Landslide Tool

<http://wvu.maps.arcgis.com/apps/webappviewer/index.html?id=cb01c47cfa884309b4f38dcd7542f805/>

>65,000

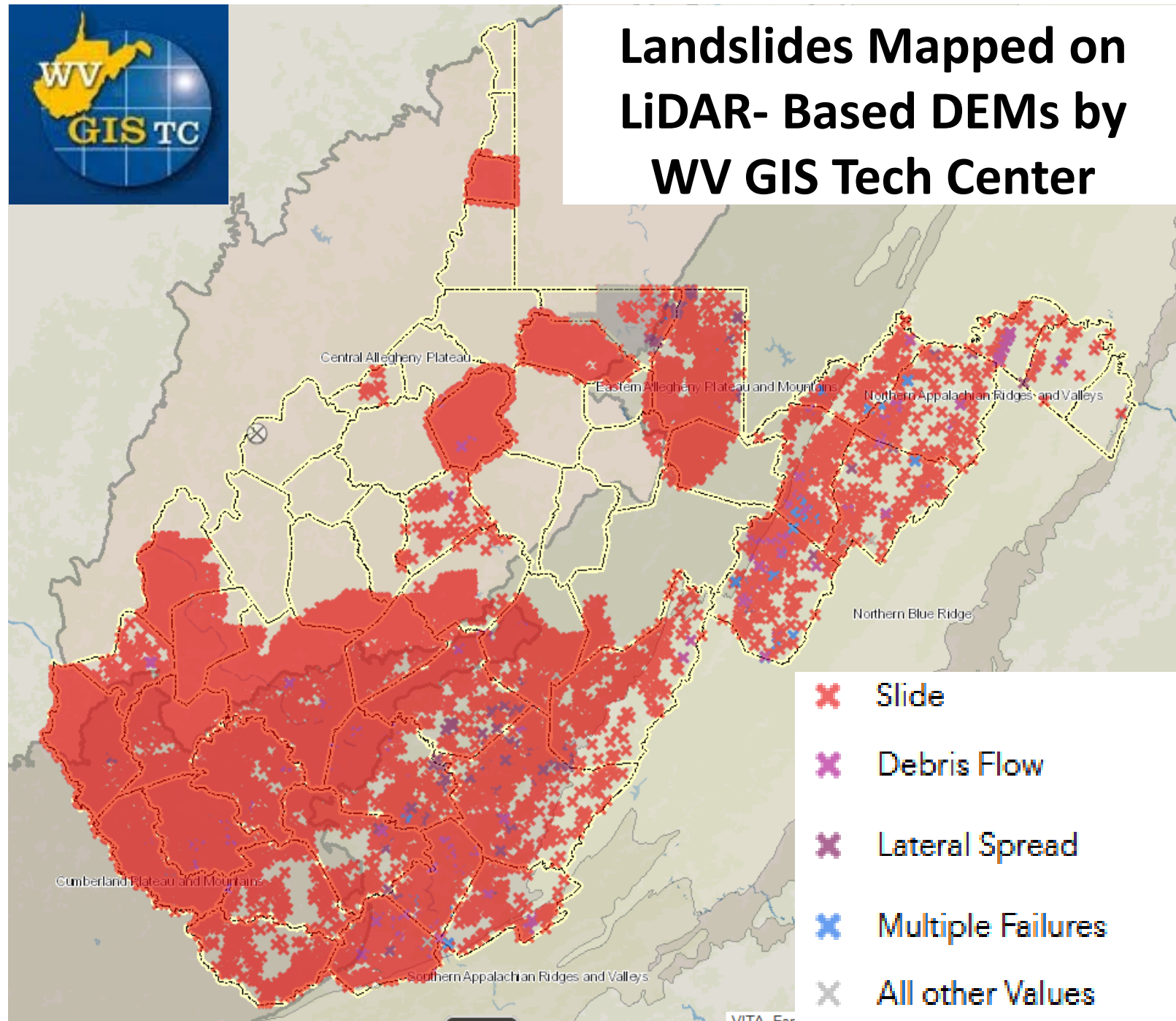
Landslide Initiation Points

Mapped by Shannon Maynard, Matthew Bell,
& Rachel Yesenchak

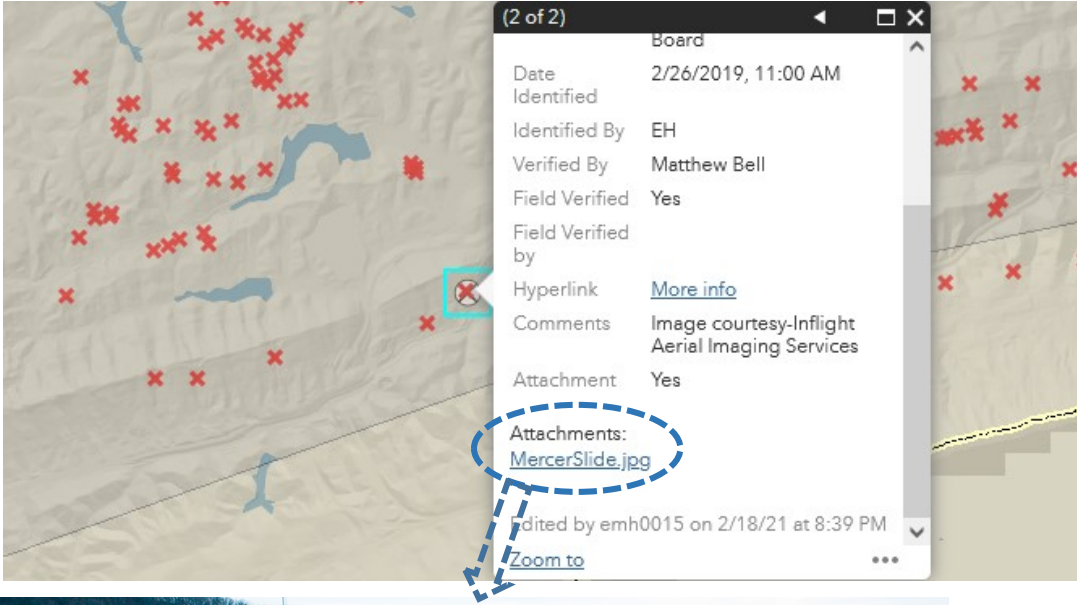
Slope, Geology, & Soil
Attributes of
41,730 Landslides
compared to
>463,000 Random
Non-Landslide Points
in the same areas



Landslides Mapped on LiDAR- Based DEMs by WV GIS Tech Center



“WV Landslide Tool”



(2 of 2)

Board

Date2/26/2019, 11:00 AM

Identified

Identified ByEH

Verified ByMatthew Bell

Field VerifiedYes

Field Verified by

Hyperlink[More info](#)

CommentsImage courtesy-Inflight Aerial Imaging Services

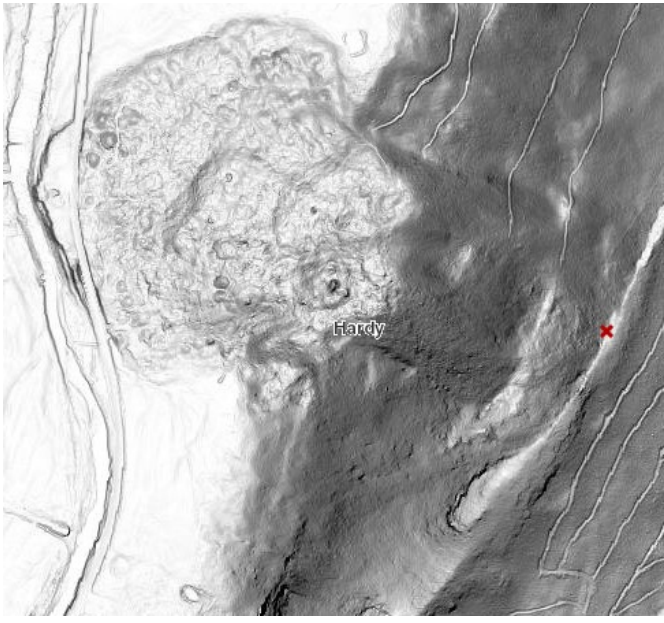
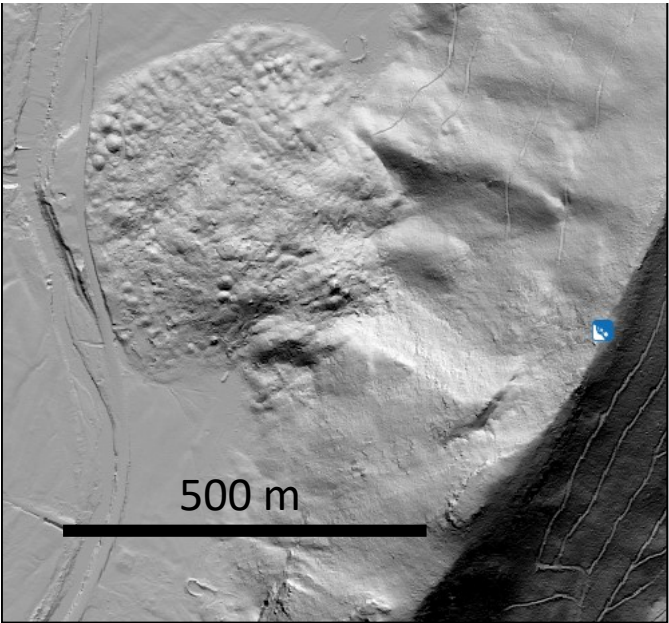
AttachmentYes

Attachments:
[MercerSlide.jpg](#)

edited by emh0015 on 2/18/21 at 8:39 PM

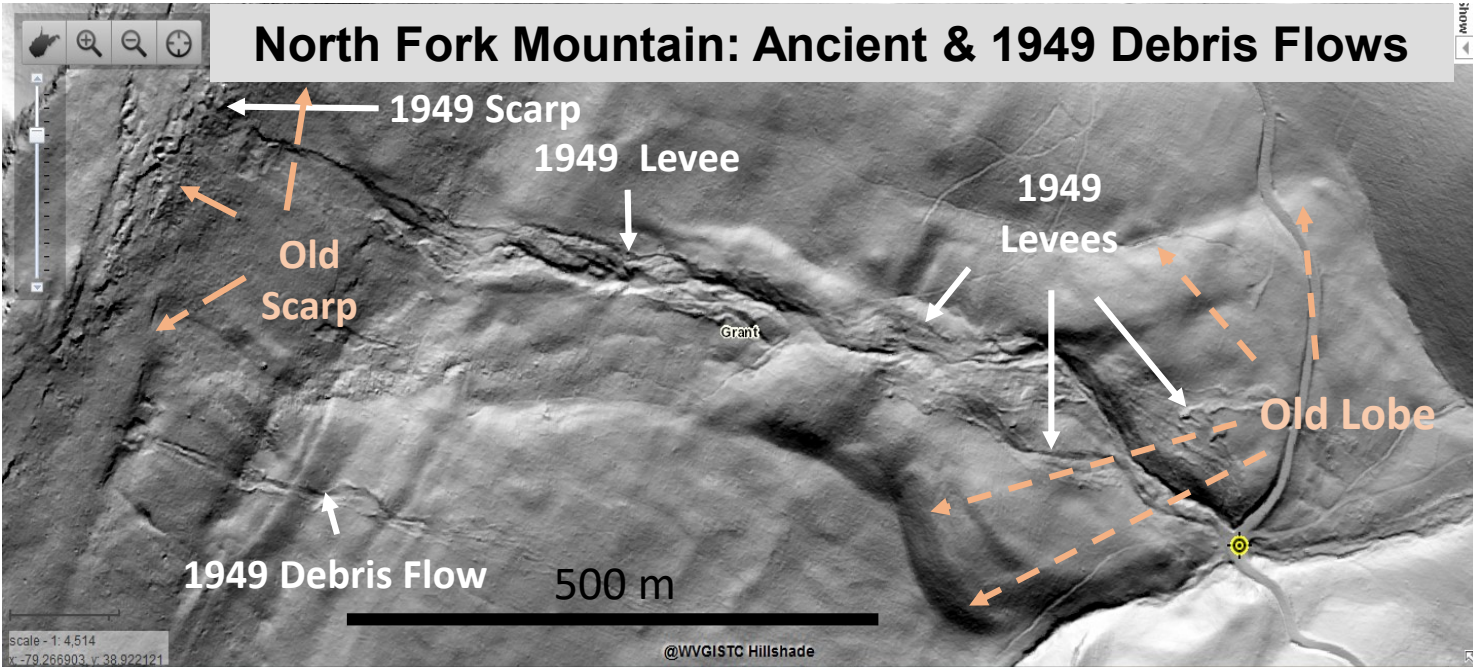
[Zoom to](#)

Hillshade **Lost River Rock Slide** Slope Shade



2020-21
Mercer
County
Debris
Flow

Inflight
Aerial
Imaging
Services
Image



North Fork Mountain: Ancient & 1949 Debris Flows

1949 Scarp

1949 Levee

Old
Scarp

1949
Levees

Old Lobe

1949 Debris Flow

500 m

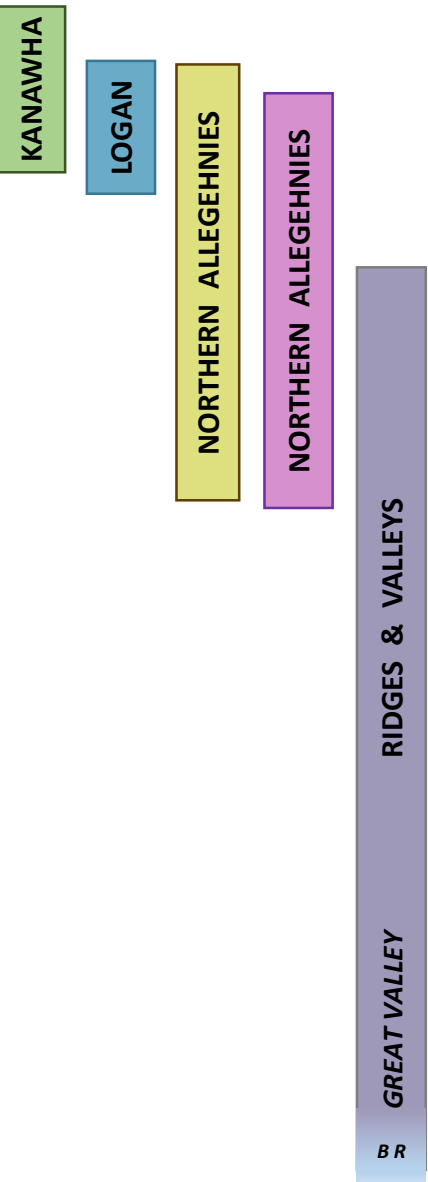
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@WVGISTC Hillshade

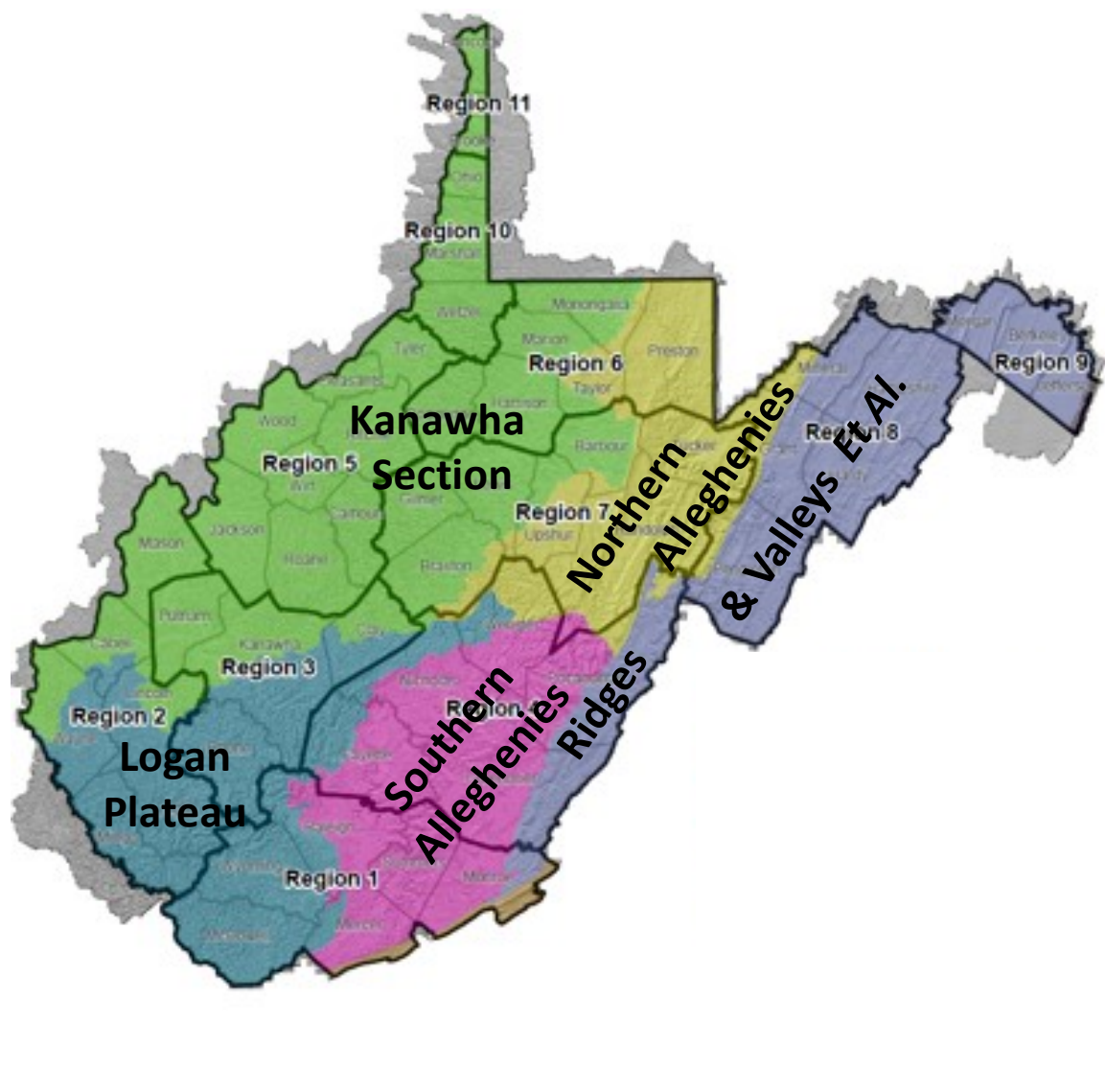
WVGES Bedrock Stratigraphy

Era		System	Series/Stage	Western WV		Eastern WV			
CENOZOIC		Paleogene	Eocene			Igneous Intrusives			
MESOZOIC		Jurassic							
PHANEROZOIC		PERMIAN							
		CARBONIFEROUS	PENNSYLVANIAN (Subsystem)	Upper	Dunkard Group		Coal Bearing		
					Monongahela Fm.				
				Middle	Conemaugh Group				
					Allegheny Fm.				
			Lower	Kanawha Fm. New River Fm. Pooahontas Fm.		Pottsville Group			
		MISSISSIPPIAN (Subsystem)	Upper	Bluestone Fm. Princeton Ss. Hinton Fm. Bluefield Fm.		Mauch Chunk Group			
			Middle	Greenbrier Group					
			Lower	Maccrady Fm. (south)					
		DEVONIAN		Upper	Sunbury Sh. Berea Ss.	Price Fm.			
					Ohio Sh. — Cleveland Sh. Chapin Sh. Huron Sh. Java Fm. — Hanover Sh. Pope Creek Sh. West Falls Fm. — Angola Sh. Rhinestreet Sh. Soyea Fm. — Cashaqua Sh. Middlesex Sh. Genesee Fm. — West River Sh. Genesee Sh./Burket Sh.	Hampshire Group Greenland Gap Group — Forks Knobs Fm. Scherer Fm.			
					Brallier Fm.				
				Middle	Hamilton Group — Tully Ls. Mahantango Fm. Marcellus Sh.	Millboro Sh.			
	Onondaga Ls. — Toga ash beds			Huntersville Chert — Needmore Sh.					
Lower	Oriskany Ss.								
SILURIAN		Upper	Bass Islands Fm.		Big Mountain Sh. — Clifton Forge Ss.	Keyser Fm.			
			Salina Fm.	Lower Keyser Mbr.					
				Tonoloway Fm.					
			Lockport Dol.	Wills Creek Fm. Williamsport Fm. McKenzie Fm.	Bloomsburg Fm.				
				Rochester Sh.					
			Lower	Keefer Fm.					
		Rose Hill Fm.							
		ORDOVICIAN		Upper	Juniata Fm.		Juniata Fm.	Oswego Fm.	
"Martinsburg" Fm.					Reedsville Fm.	Martinsburg Fm.			
"Trenton" Ls.					Trenton Group — Dolly Ridge Fm.	Nealmont Ls.			
Black River Group									
Middle	Wells Creek Fm.				St. Peter Ss.	St. Paul Group — Lincolnshire Fm. New Market Ls. Row Park Ls.			
Lower	Knox Group				Beekmantown Dol.	Beekmantown Dol.	Pineburg Station Dol. Rockdale Run Fm. Stonhenge Ls. Stoufferstown Mbr.		
	CAMBRIAN			Upper	Copper Ridge Dol.		Conococheague Fm.		
Middle				Conasauga Group		Elbrook Fm.			
Lower				Rome Group		Waynesboro Fm.			
				Tomstown Dol.					
PRECAMBRIAN		"Chilhowee Group"/basal ss.		Antietam Fm. Harpers Fm. Weverton Fm.					
				Catoctin Fm.					
				Swift Run Fm.					
Igneous/Metamorphic		Coal-bearing interval	Organic shale	Fm. Formation	Ss. Sandstone	Dol. Dolomite	Sh. Shale	Mbr. Member	unconformity facies

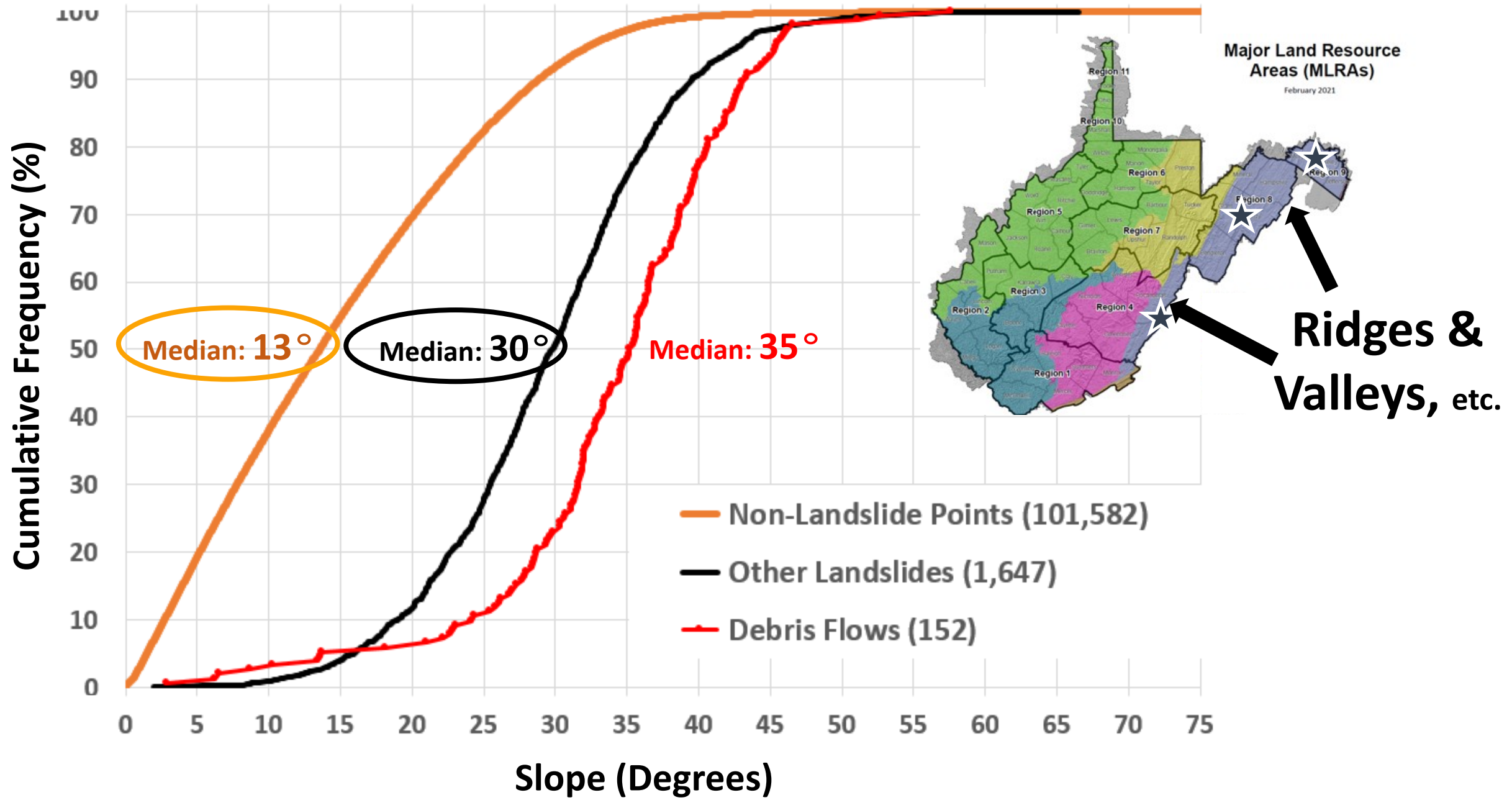
Section within MLRA

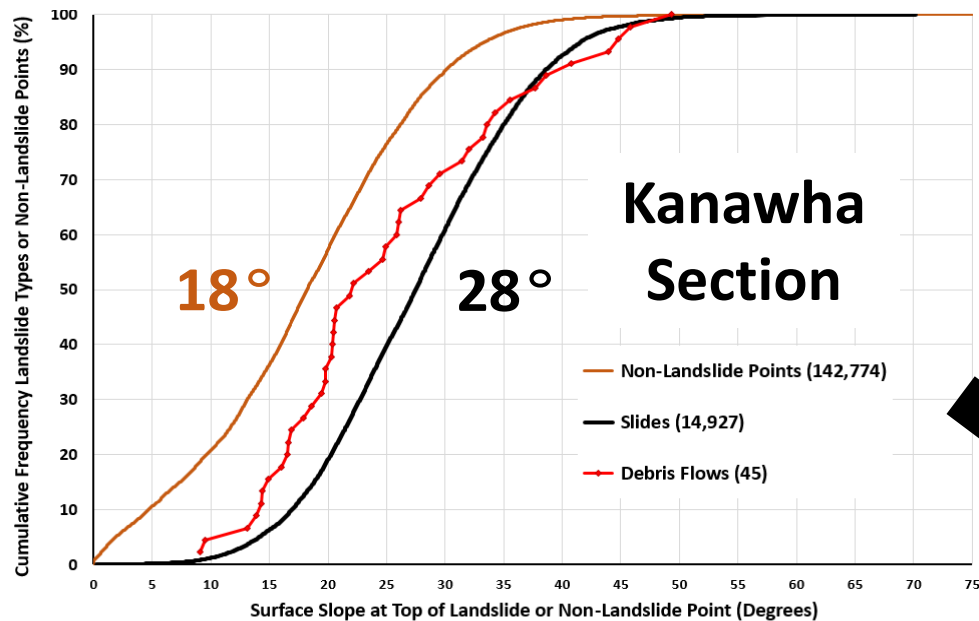


West Virginia Landslide Areas Based on NRCS MLRA



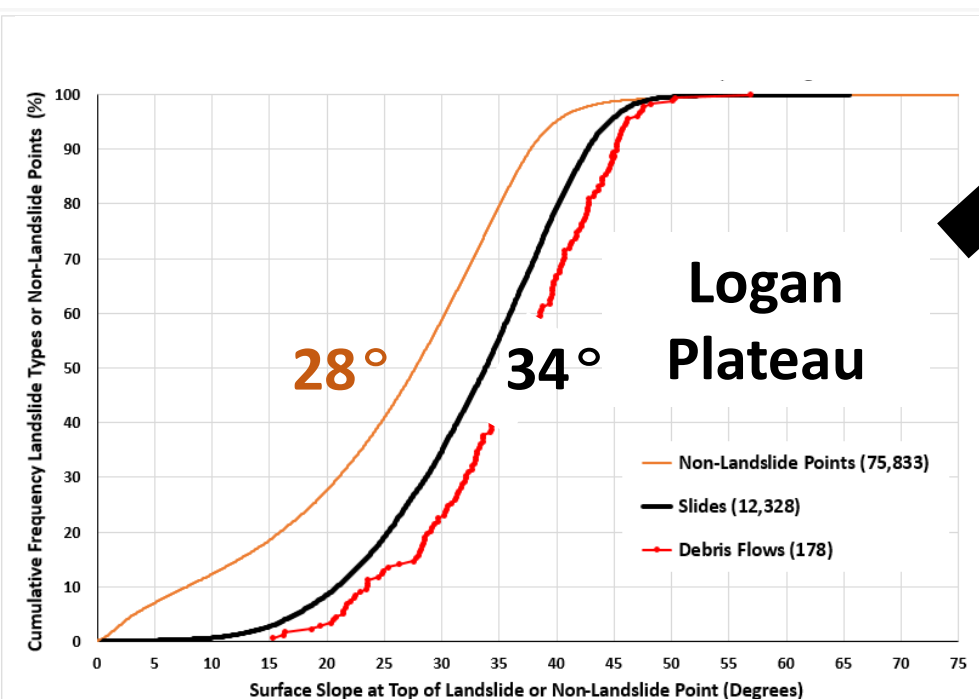
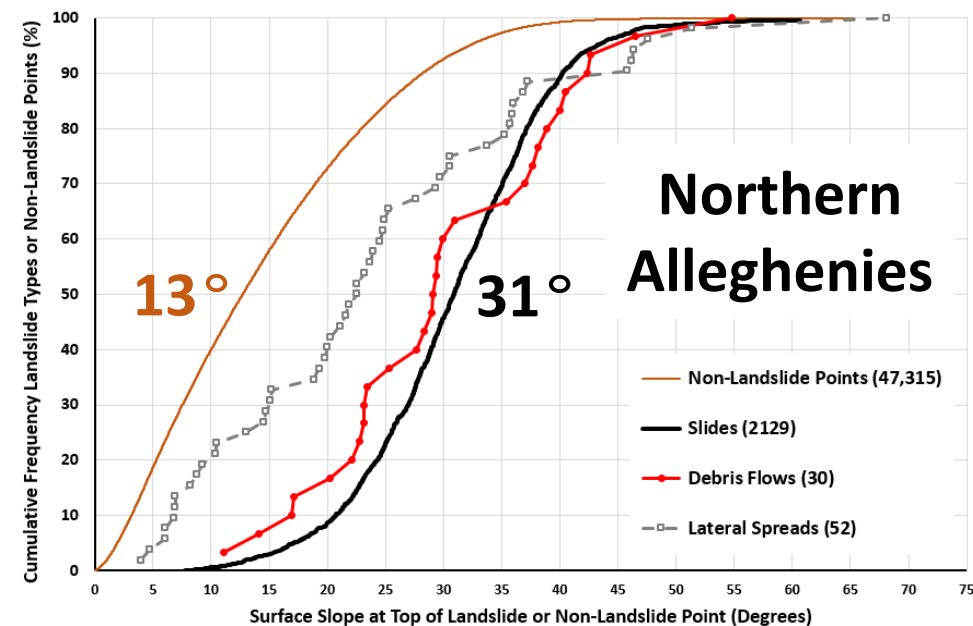
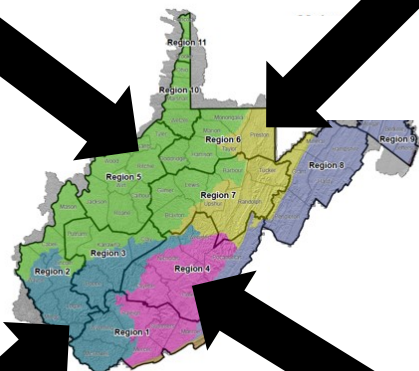
Slope at **Debris Flow** & Other Landslide Initiation Points vs. **Random Points**





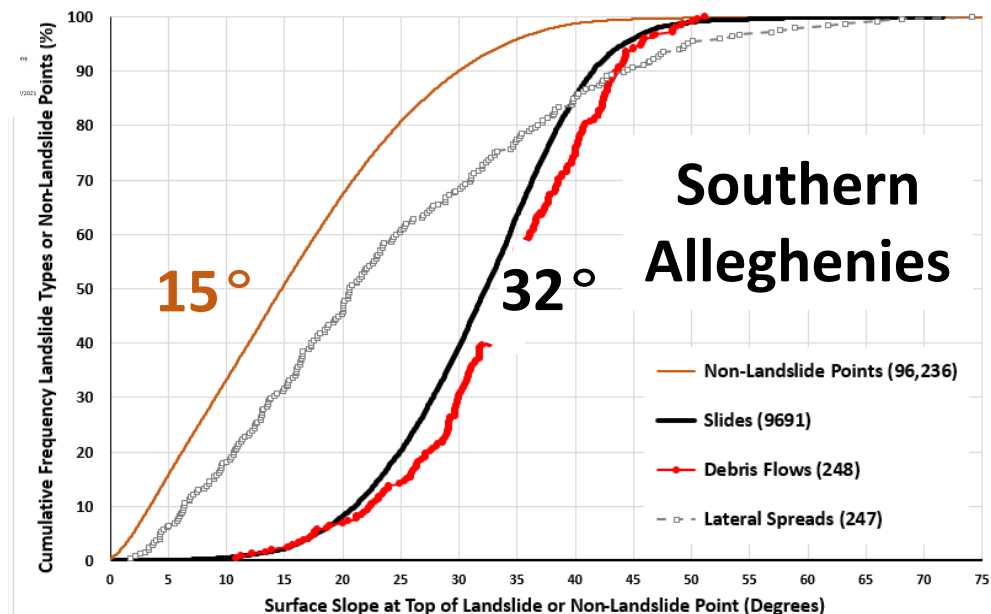
Cumulative Frequency of Slope (Degrees)

Initiation Points vs.
Random Points in Other
4 MLRAs

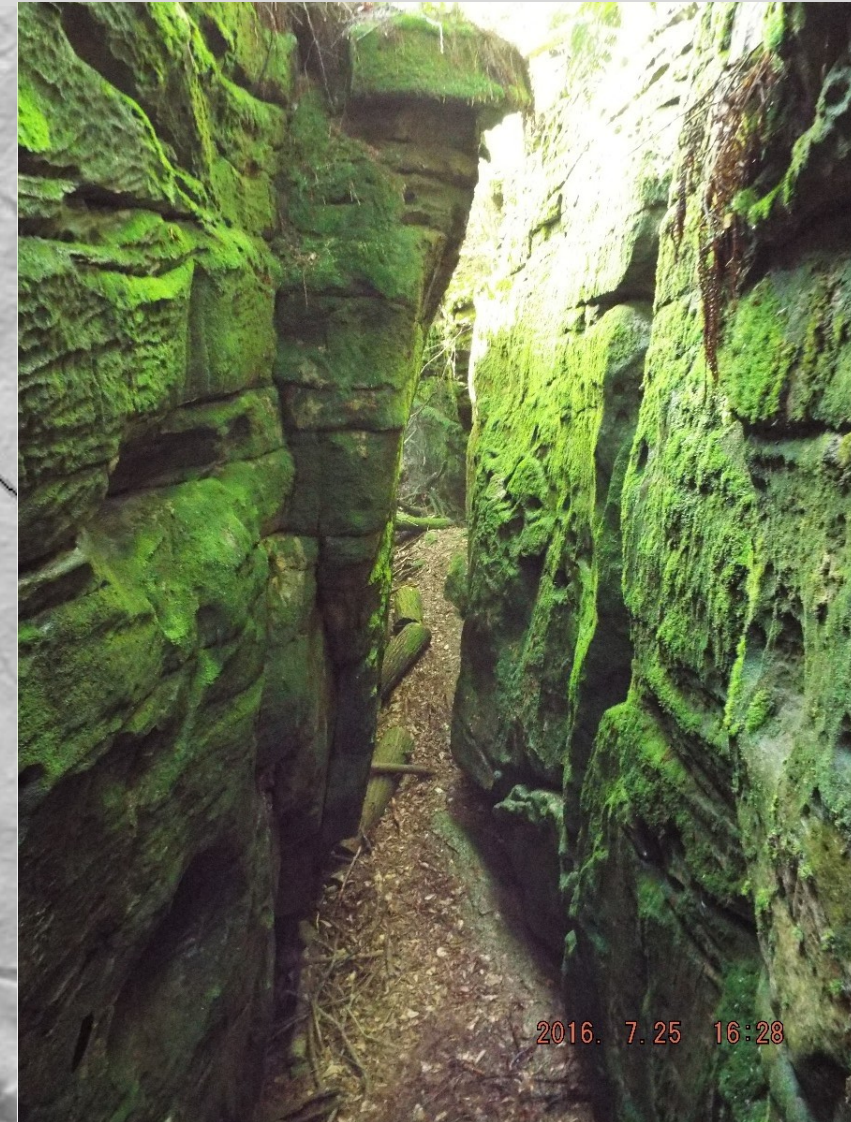
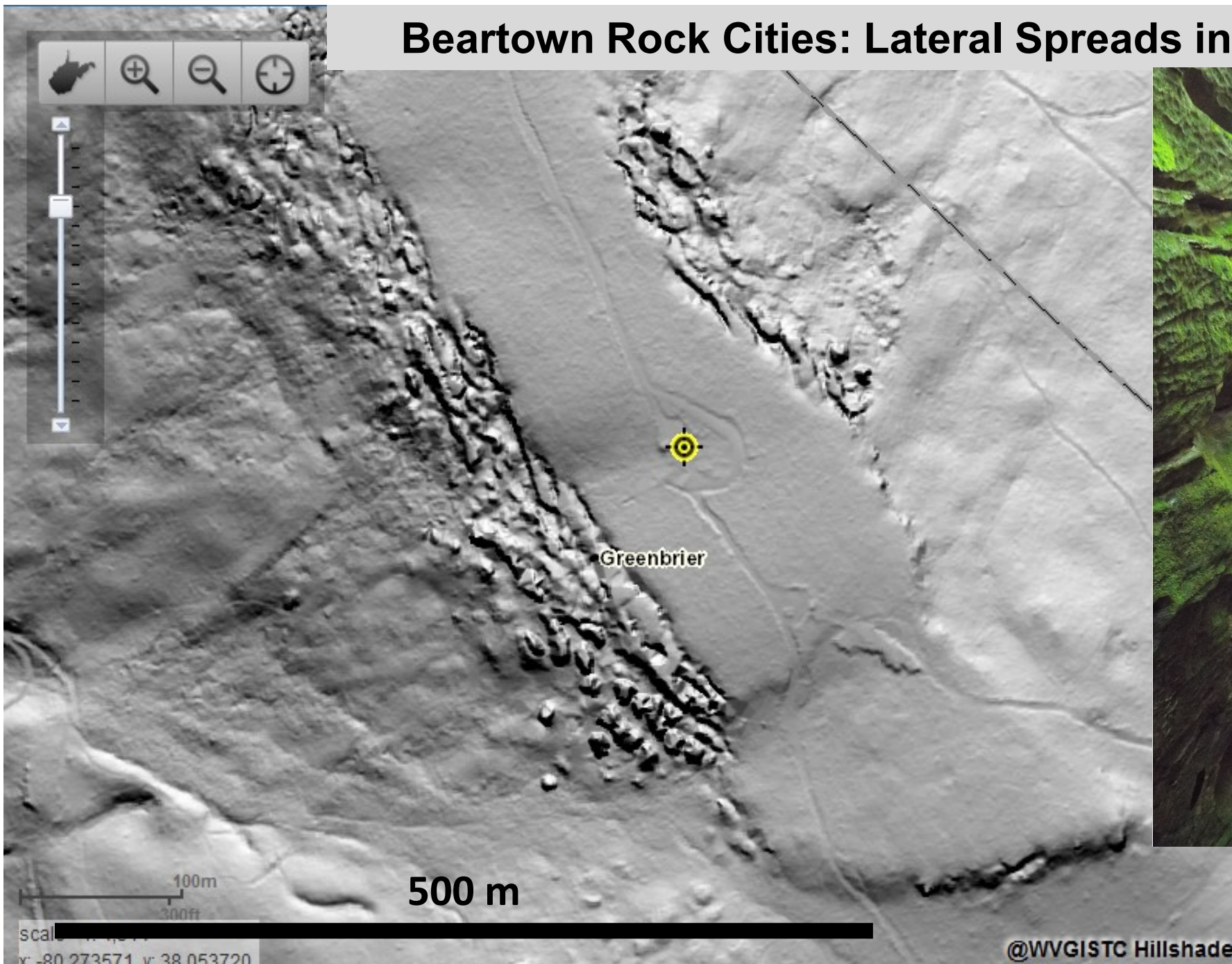


**Non-Landslide Point
Median Slope**
*Logan Plateau Slopes
= 10-15 ° Steeper*

**Landslide Initiation
Point Median Slope
*Varies by Only 6°***



Beartown Rock Cities: Lateral Spreads in Mauch Chunk Group



Beartown State Park

<https://www.naturallyamazing.com/americasparks/19454.jpg>

314 Mapped Lateral Spreads

(*>100 Fold MLRA Variation*)

Pottsville Group: 65 %

Mauch Chunk Group: 28 %

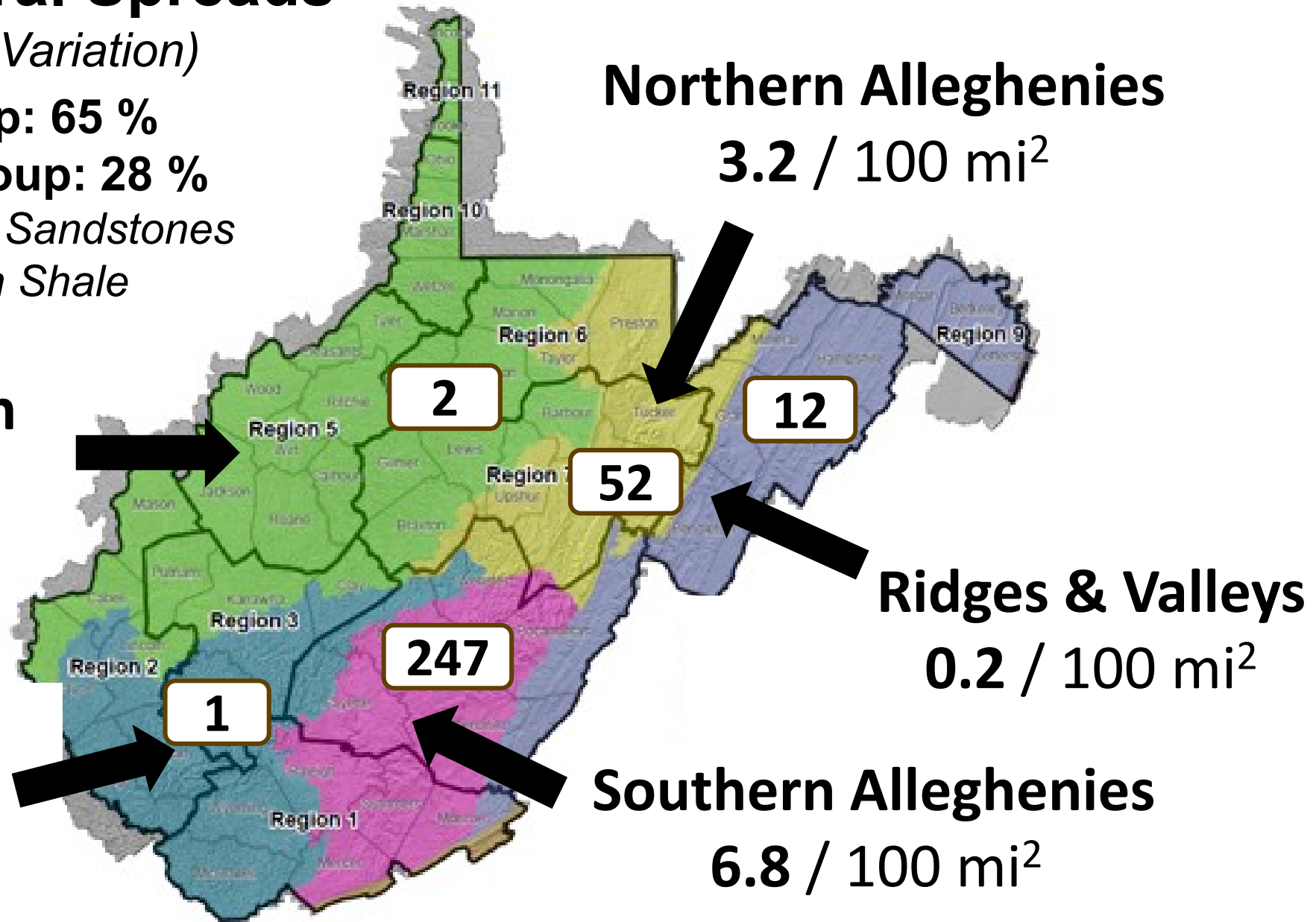
*Gently Dipping, Thick Sandstones
Interbedded with Shale*

Kanawha Section

0.06 / 100 mi²

Logan Plateau

0.02 / 100 mi²



Caution: Mapped Slope Failures / Area Values Are for Comparison Only, Not Exact Estimations of Susceptibility

Debris Flow Susceptibility

(5 Fold MLRA Variation)

*Data Reflect Debris Flow Counts
NOT Extent or Risk*

SE-NW Decreasing Trend

Kanawha Section

1.3 / 100 mi²

Logan Plateau

4.0 / 100 mi²

Northern Alleghenies

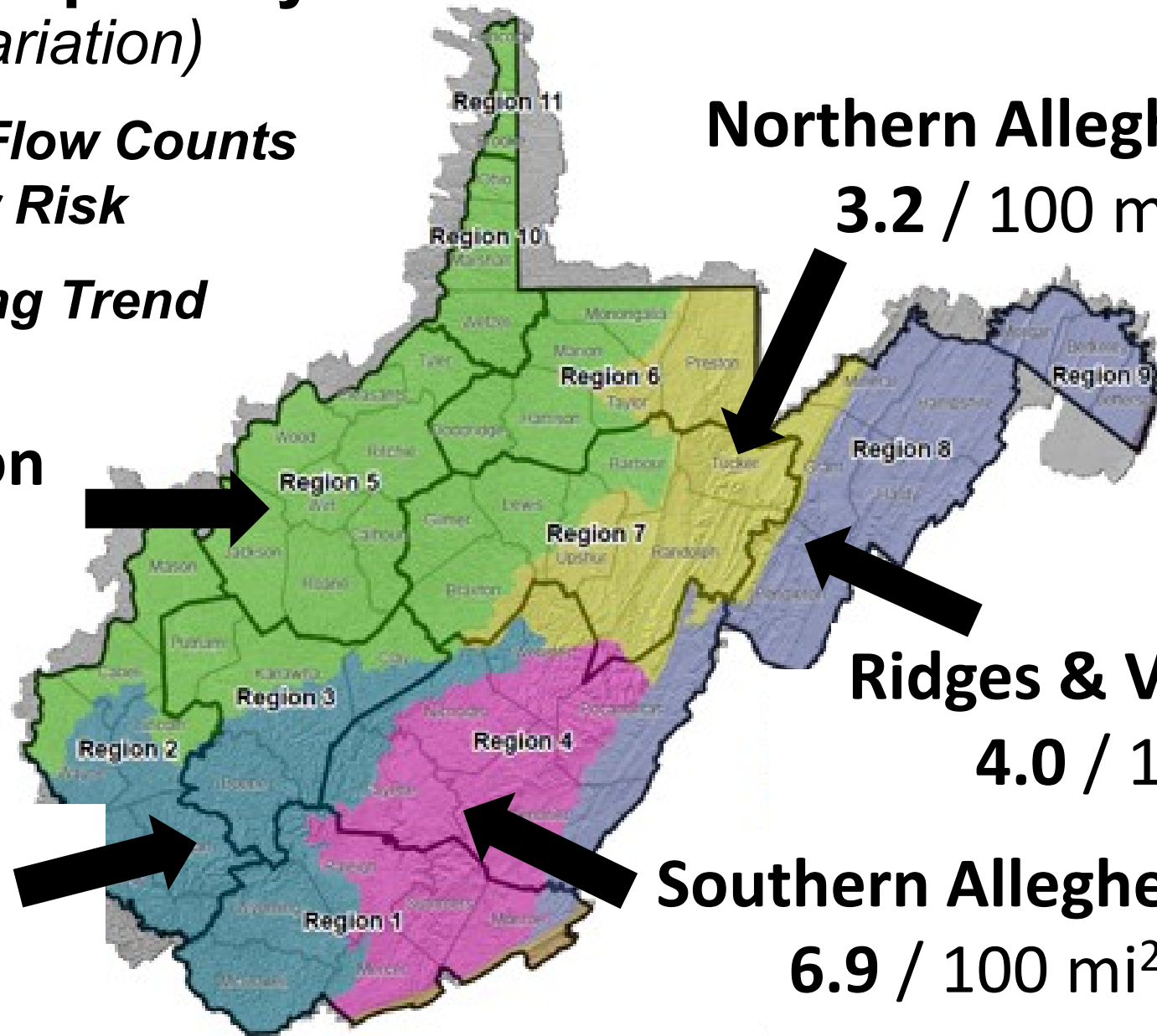
3.2 / 100 mi²

Ridges & Valleys et al.

4.0 / 100 mi²

Southern Alleghenies

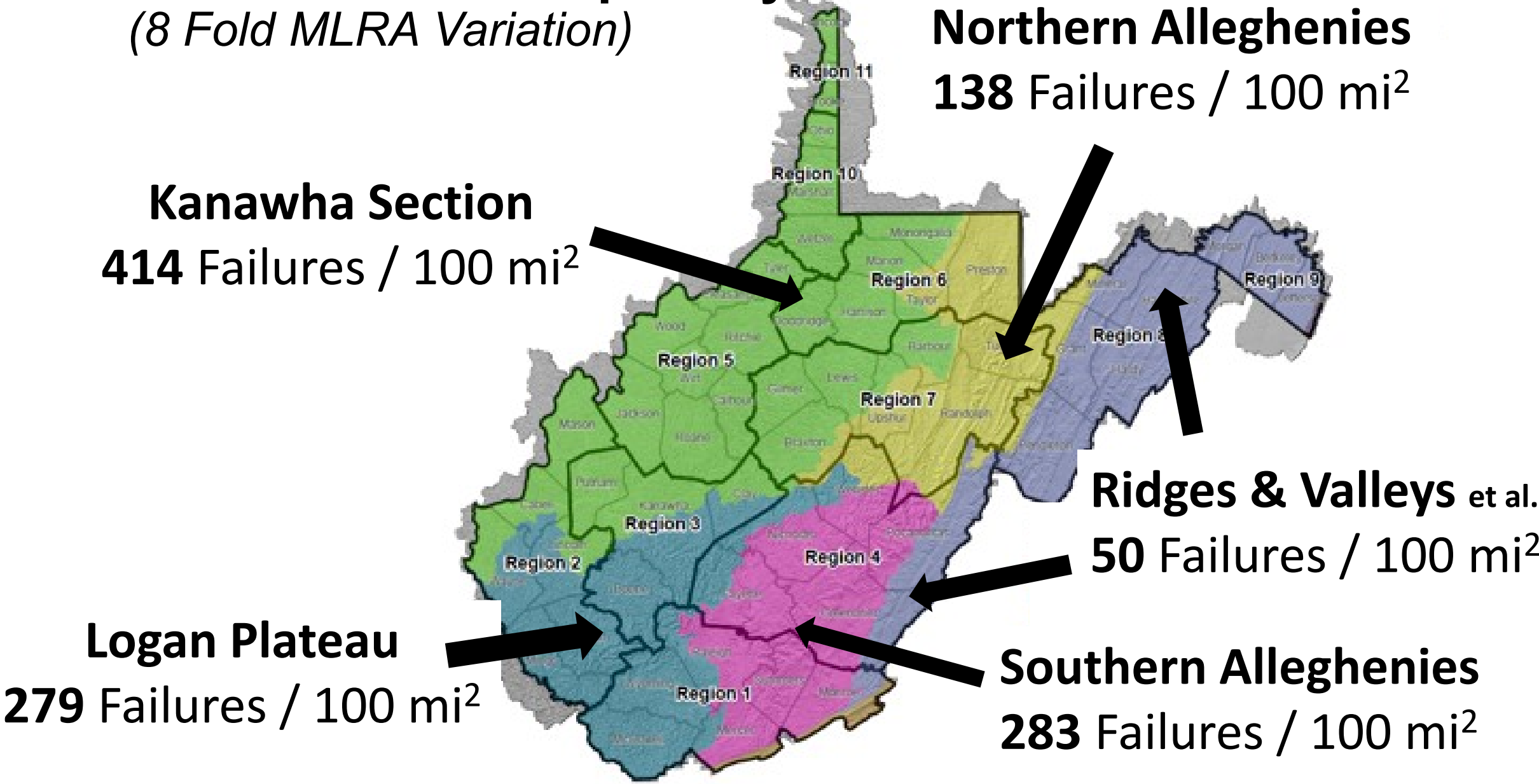
6.9 / 100 mi²



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Overall Landslide Susceptibility

(8 Fold MLRA Variation)

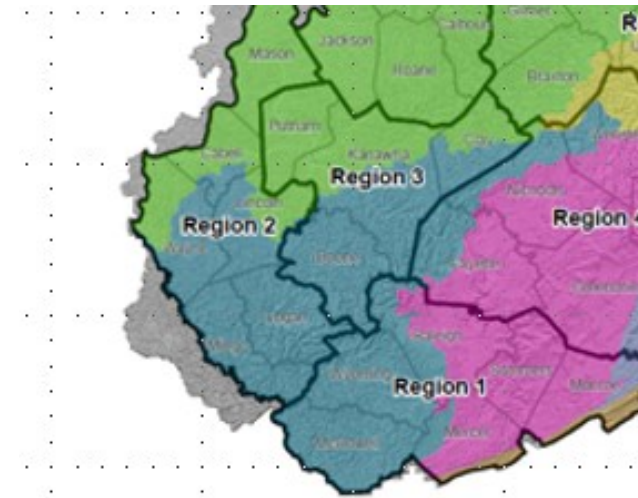


Caution: Mapped Slope Failures / Area Values Are for Comparison Only, Not Exact Estimations of Susceptibility

Logan Plateau Landslide Geology Data

WVGES Geologic Map Unit	Period	Mapped Landslide Count	% of All Landslides	Unit Area mi²	Mapped Landslides /100 mi²
Alluvium	Q	0	0.0	15.9	0
Monongahela Group	Penn	0	0.0	23.2	0
Conemaugh Group	Penn	198	1.6	406.9	49
Allegheny Formation	Penn	993	7.9	654.3	152
Kanawha Formation	Penn	10,146	81.0	2382.3	426
New River Formation	Penn	642	5.1	776.3	83
Pocahontas Formation	Penn	509	4.1	200.2	254
Bluestone & Princeton Formations	Miss	38	0.3	33.1	115
Hinton Formation *	Miss	0	0.0	0.1	*
Overall MLRA 125		12,526	100.0	4492.3	279

Geologic map units, in stratigraphic order. Data include all landslides, including debris flows. * Hinton Formation extent is too small for calculation of failures/100 mi².



Why is the Kanawha a “Bad Actor” in the Logan Plateau?

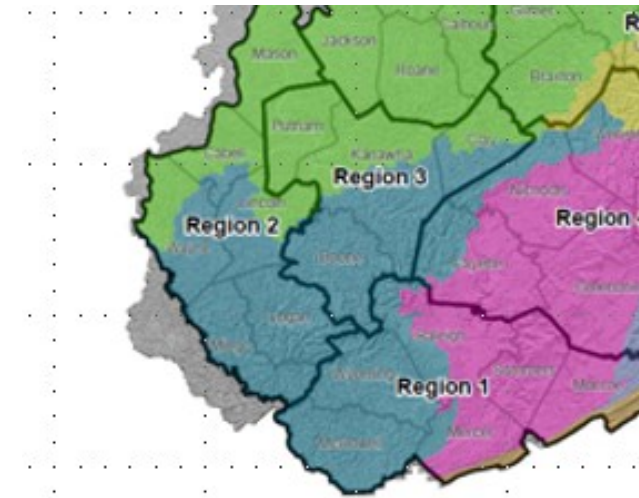
Caution: Mapped Slope Failures / Area Values Are for Comparison Only, Not Exact Estimations of Susceptibility

Logan Plateau Landslide **Soil Parent Material** Data

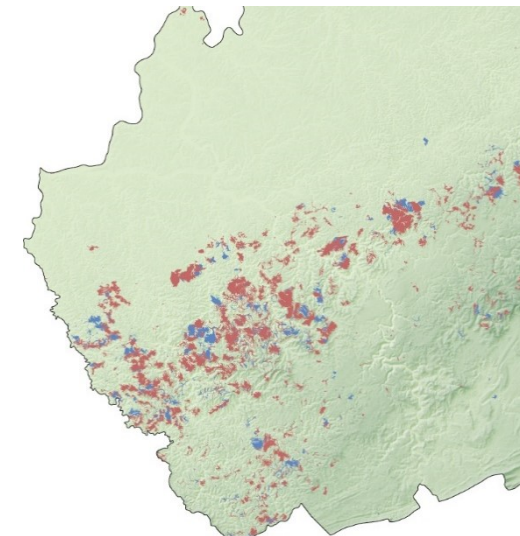
NRCS Soil Parent Material	Mapped Landslide Count	% of All Failures	Unit Area mi ² (Approx.)	Mapped Failures /100 mi ²
Colluvium	7598	60.66	3089.0	246
Mining Regolith	3047	24.33	403.5	755
Residuum, Acid Clastic	1458	11.64	729.8	200
Disturbed Areas	406	3.24	99.7	407
Recent Alluvium	13	0.10	114.2	11
Residuum, Calcareous Clastic	2	0.02	0.4	482
Old Terrace Alluvium	1	0.01	35.7	3
Water	1	0.01	20.1	5
Overall MLRA Total	12,526	100.00	4492.3	279

Dominant soil parent material for all landslides mapped in the Logan Plateau, listed in decreasing order by number of landslides of all types.

Caution: Mapped Slope Failures / Area Values Are for Comparison Only, Not Exact Estimations of Susceptibility



Why is the Kanawha a “Bad Actor” in the Logan Plateau?



Mining Permits (NASA)

<https://visibleearth.nasa.gov/images/8344/mining-permits-across-west-virginia>

Most Susceptible Geologic Units in Each Area

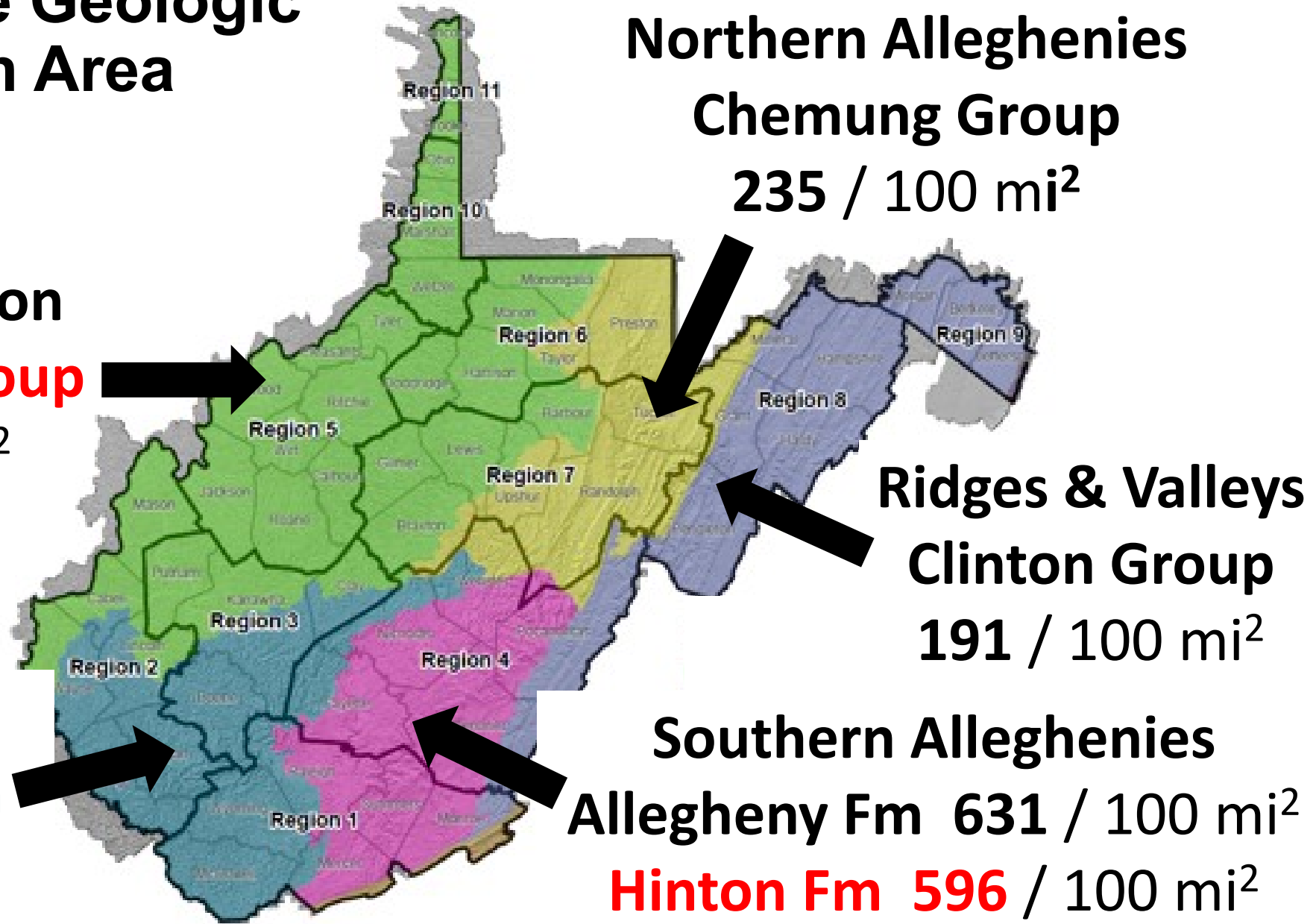
Logan Plateau
Kanawha Formation
426 / 100 mi²

Kanawha Section
Conemaugh Group
731 / 100 mi²

Southern Alleghenies
Allegheny Fm 631 / 100 mi²
Hinton Fm 596 / 100 mi²

Ridges & Valleys
Clinton Group
191 / 100 mi²

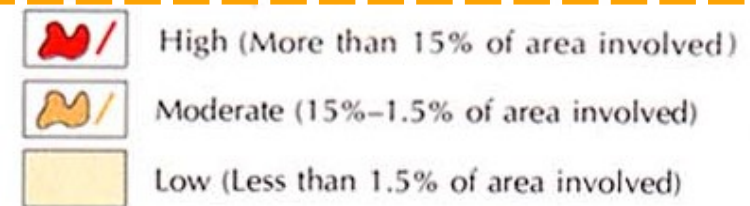
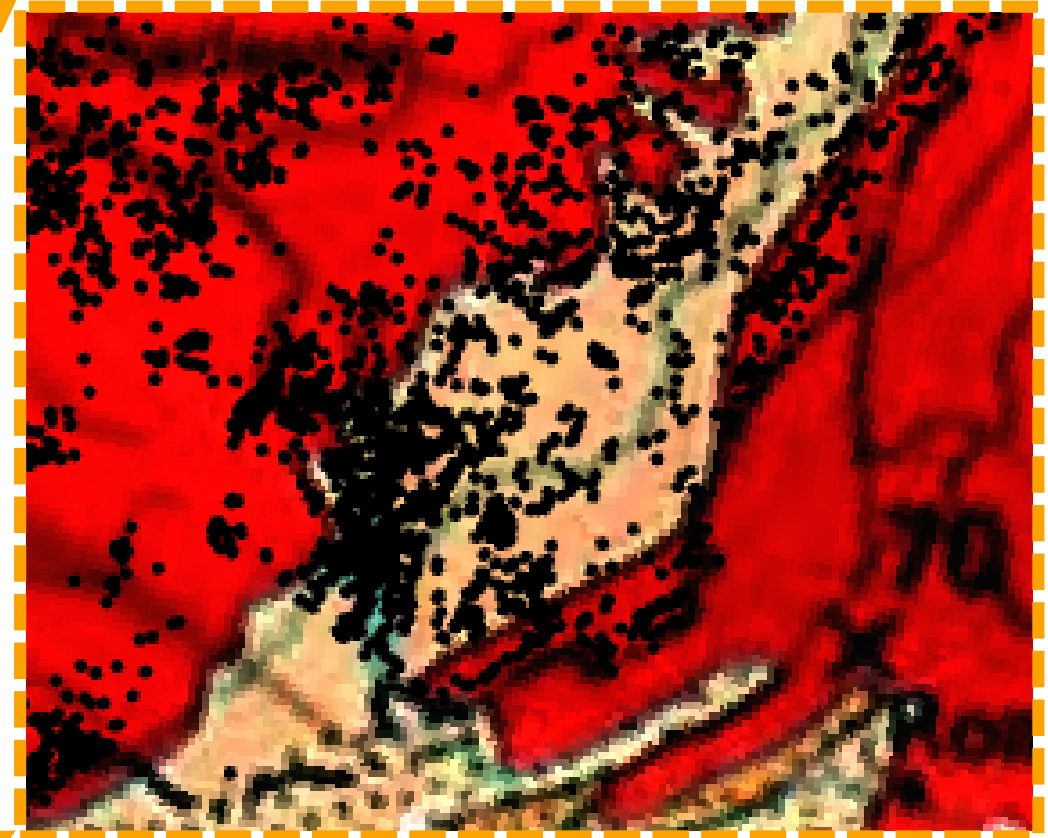
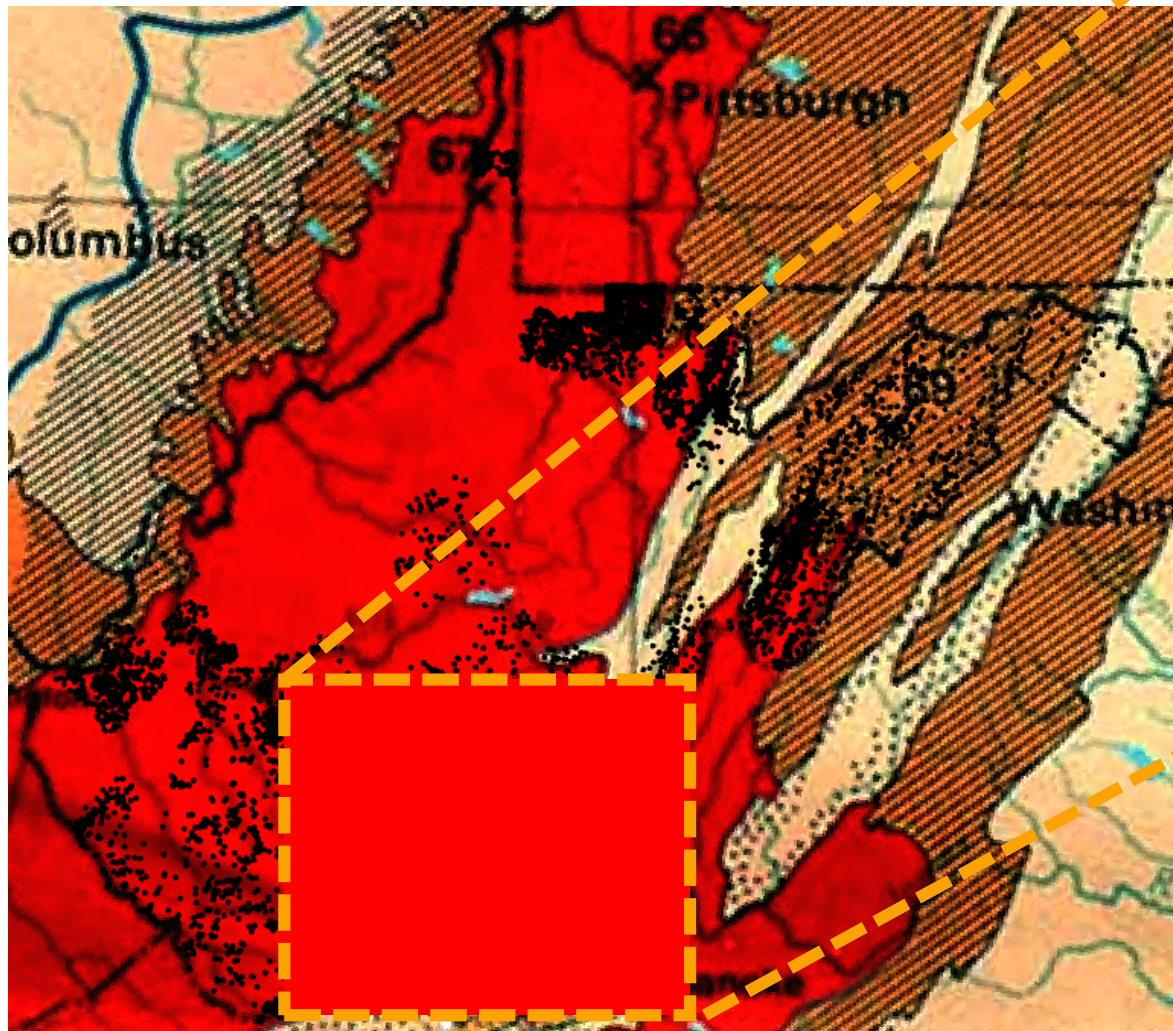
Northern Alleghenies
Chemung Group
235 / 100 mi²



Caution: Mapped Slope Failures / Area Values Are for Comparison Only, Not Exact Estimations of Susceptibility

Landslide Mapping Shows USGS Landslide Overview Map Understates Landslide Susceptibility in the Hinton Formation

Newly Mapped Landslides on LiDAR-Based DEMs
Plotted vs. USGS PP 1183 Landslide Overview Map



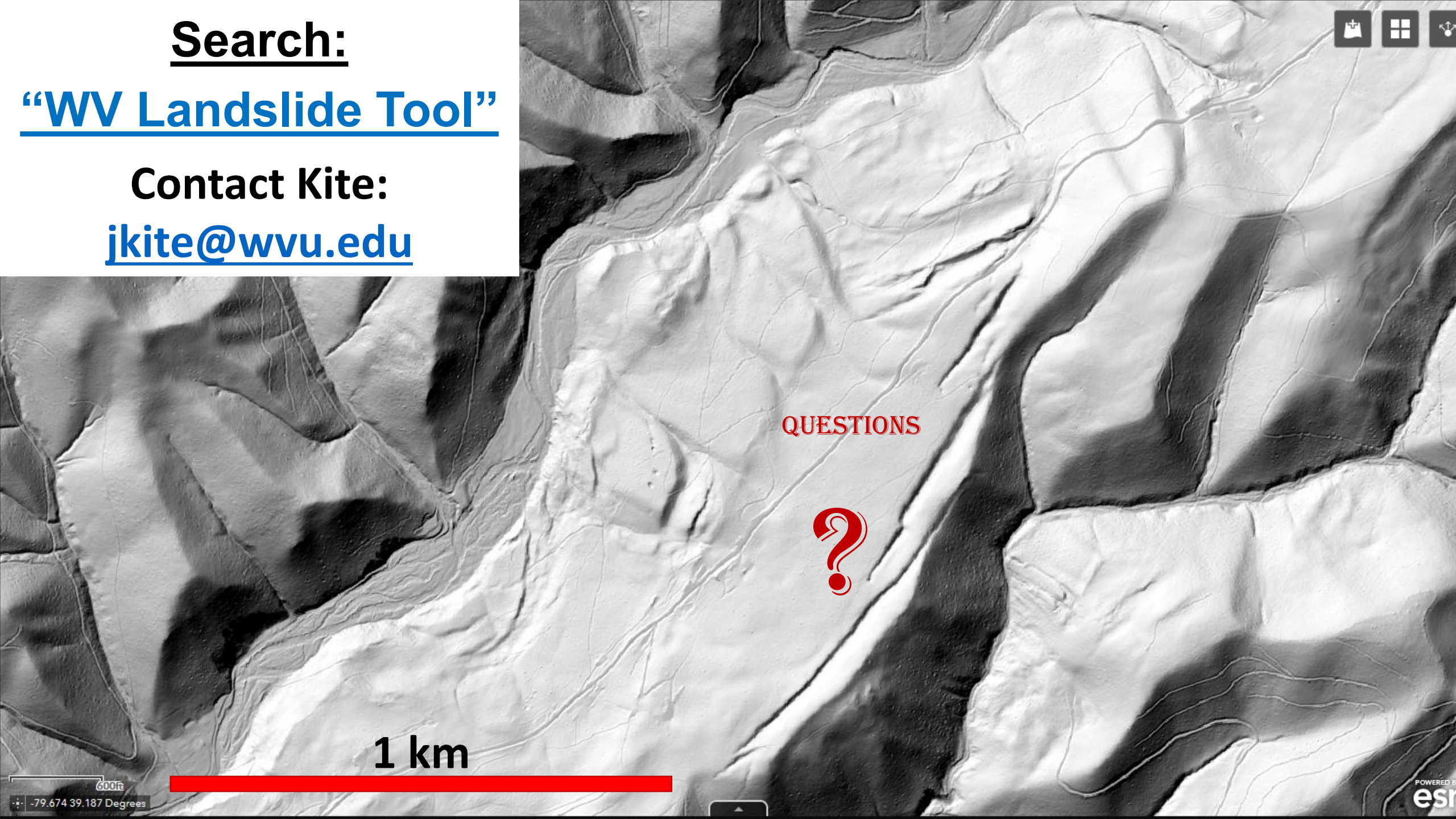
~ 70 75% of WV = "High Landslide Incidence"
An Example of Why We Map Landslides!

Search:

“WV Landslide Tool”

Contact Kite:

jkite@wvu.edu



QUESTIONS



1 km

600ft

-79.674 39.187 Degrees

POWERED BY
esri