A Landslide Risk Assessment Project for the Mountain State of West Virginia

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West Virginia University DEPARTMENT OF GEOLOGY AND GEOGRAPHY

Session # 41 "T25. Geologic Hazards: Hazard Maps, Risk Analysis and Reduction, and Long-term Landscape Evolution

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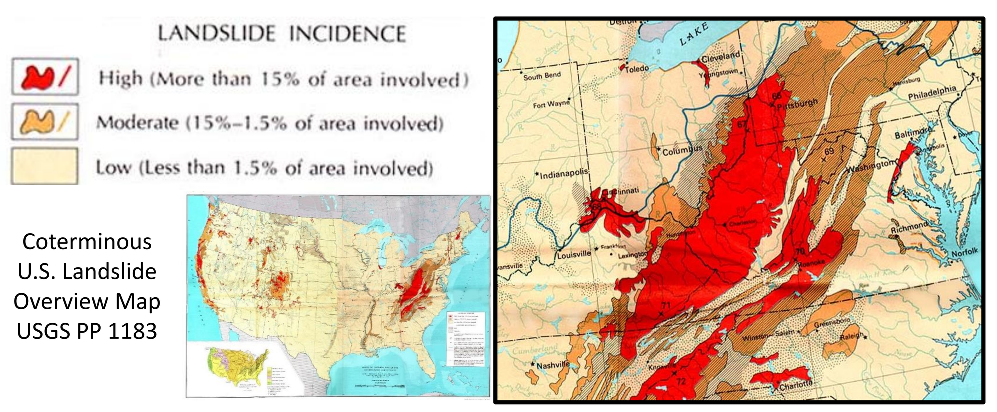
Why West Virginia Landslides?

- **Landslides = #2 West Virginia Hazard** (FEMA).
- **West Virginia = 11.2% of 1973-1983 Landslide Damage in 48 States** (Brabb, 1984, USGS OF 84-486).
- **West Virginia = #1 in *Per Capita* Landslide Damage.**
- **~75% of West Virginia Has "High Landslide Incidence" -** *No Other State Has >25%* (USGS PP 1183).



Project Highlights

West Virginia GIS Technical Center Began FEMA-supported Statewide Landslide Risk Assessment in Summer 2018.

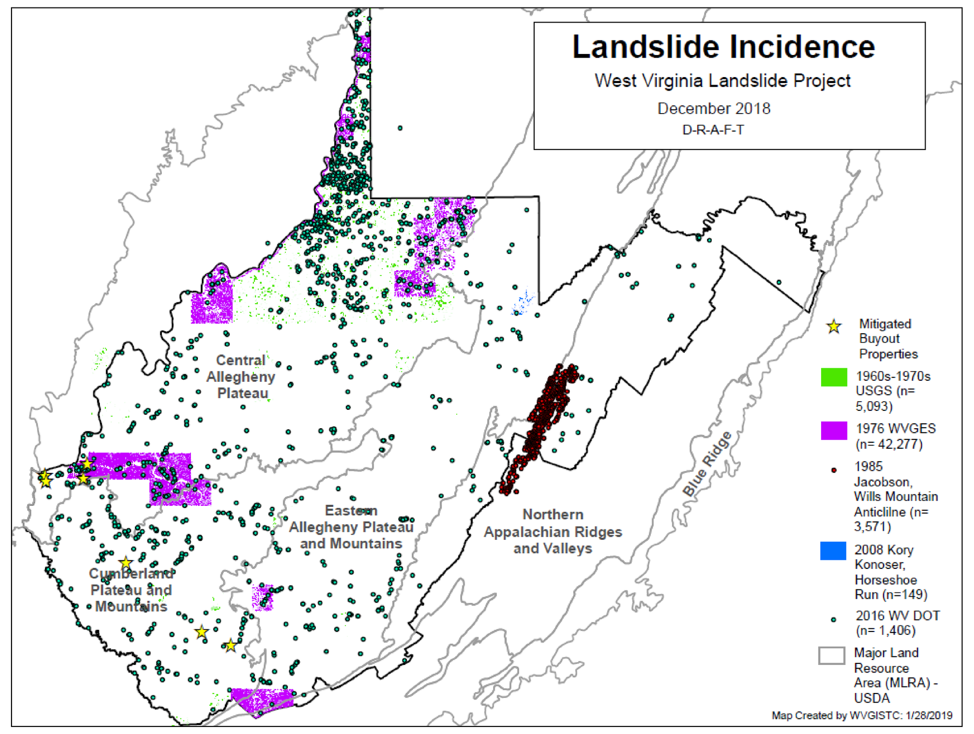
Long-Term Goals:
- Comprehensive Ongoing Statewide **Landslide Inventory**.
- **Interactive Web-based App** for Graphically Displaying & Collecting Landslide Information.
- **Landslide Models** for Specific WV Regions.
- County-Level Landslide **Susceptibility Maps**.
- Local **Landslide Risk Reports** to Inform Emergency Preparedness & Hazard Mitigation Planning.
- Public & Stakeholder **Outreach**.
- **Update** State **Hazard Mitigation Plan**.

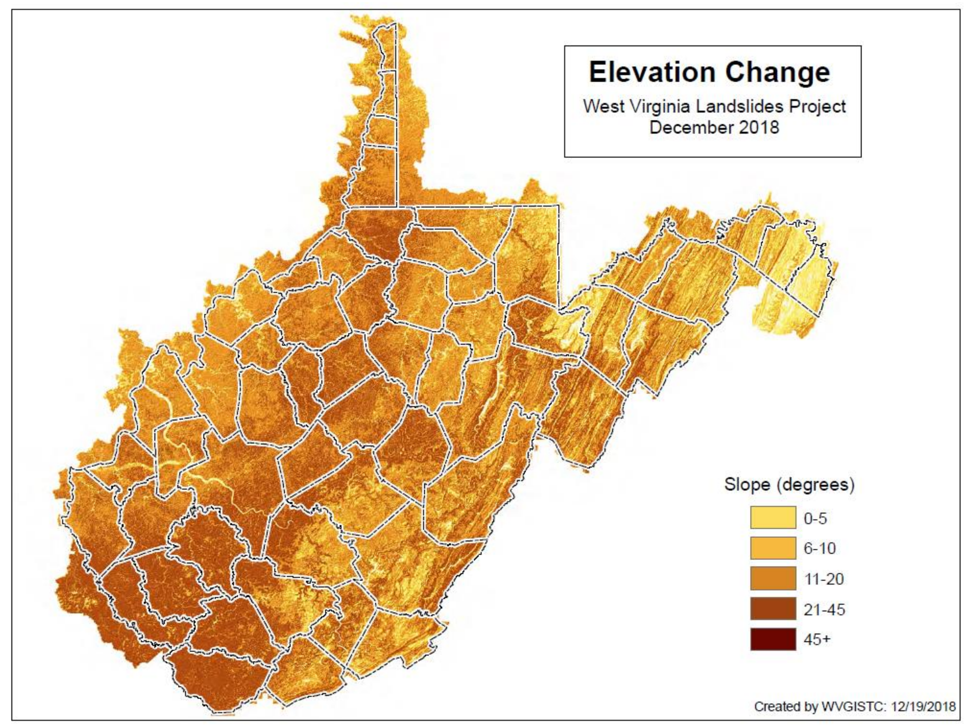
Initial Steps:
- Launched Statewide **Landslide Inventory**.
  - >75,000 Previously Identified Landslides.
  - > 10 Disparate Sources: Disparate Data.
- Landslide **Mapping Protocol** for QL2 LiDAR DEMs
  - >3,000 Newly Mapped Landslides.
  - Updates as West Virginia QL2 LiDAR DEMs Arrive.
- **Digital Topography**, Hill-Shade, & Slope-Shade Layers.
- Lithology & Soil Parent **Material Maps**.
- West Virginia Landslide **Bibliography**.
- **ESRI Story Maps** on Case Studies & General Hazard.

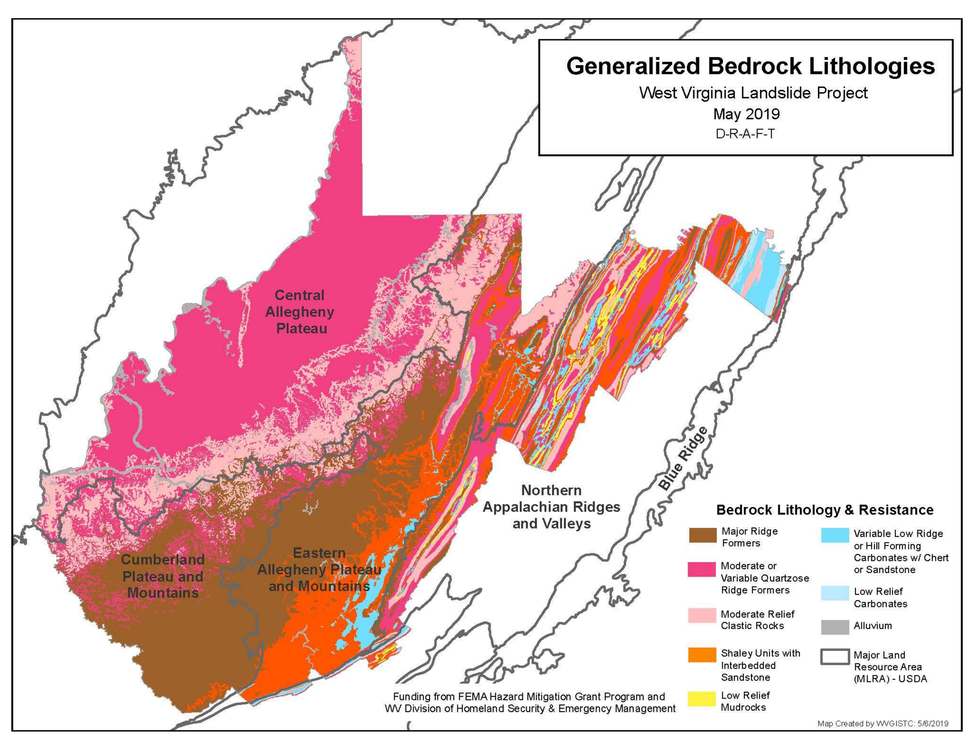
Landslide Incidence Modelling Inputs:
- **Geology** (Stratigraphic Units & General Lithologies).
- **Soils** (Parent Material & Drainage Class).
- **Topography**.
- **Transportation** Infrastructure.
- Flow-Accumulation Generated **Stream Networks**.

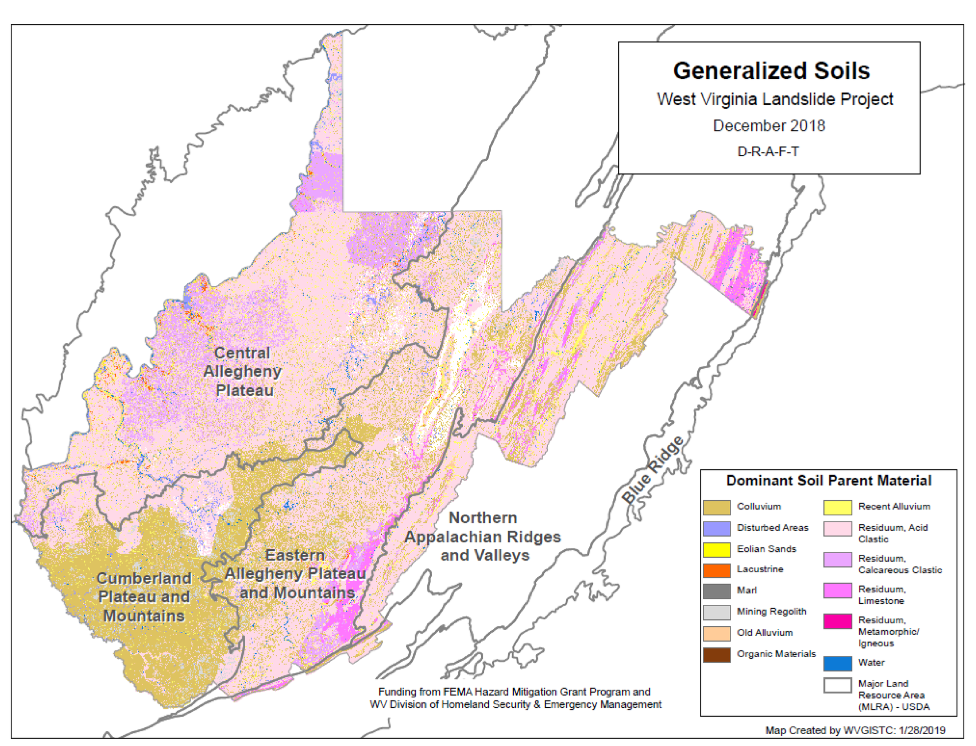
Key Factors in Regional Slope Instability:
- **Anthropogenic** Activities.
- Quaternary **River Rerouting** & Valley **Incision**.
- Pleistocene **Periglacial** Instability.
- Bedrock **Dip *vs.* Slope** Orientation.

Landslide Risk:
- Address in **Years 2-3** (after Incidence & Susceptibility).



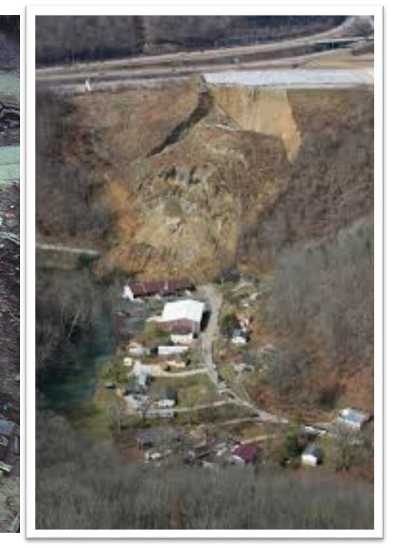






Infamous WV Landslides

1973 Kanawha City Debris Flow 3 Deaths (R. Smosna Photo)



2015 Yeager Airport $18 Million (AP Photo)

Landslide Classification for Mapping WV

Arm-Chair Thoughts - ***J.S. Kite Draft Version 0.1, Feb 2019***

Failure Motion		Material before Failure (Engineering Criteria)		
		Bedrock	Soil	
General Motion	Type of Motion	Rock	Debris (>20% larger than sand)	Earth (<20% larger than sand)
Falling	**Fall**	**Rock Fall**	Debris Fall	Earth Fall
	Topple (Falling Over)	**Rock Topple**	Debris Topple	Earth Topple
	Collapse * *(Roof Failure into Large Void Space)*	***Rock Collapse***	*Debris Collapse*	*Earth Collapse*
Sliding	**Slide (**Translational Sliding along Planar Surface)	**Rock Slide**	**Debris Slide**	Earth Block Slide
	Slump (Rotational Sliding along Concave Surface)	Rock Slump	**Debris Slump**	**Earth Slump**
Flowing	**Lateral Spread**	**Rock Lateral Spread**	Debris Lateral Spread	Earth Lateral Spread
	Creep * *(Slow Downslope Creep)*	***Rock Creep***	***Debris Creep***	***Earth Creep***
	Flow (Viscous Channel Flow)	Rock Flow	**Debris Flow**	**Earth Flow**
	Avalanche *(Very Rapid Flow over Compressed Air)*	*Rock Avalanche*	*Debris Avalanche*	*Earth Avalanche*
Complex	*Common W. Va. Examples*	**Rock Spread-Slide**	**Debris Slide-Flow**	**Earth Slump-Flow**

Modified from Campbell, RH, Varnes, DJ, Fleming, RW, Hampton, MA, Prior, DB, Sangrey, DA, Nichols, DR, & Brabb, EE, 1985, Landslide classification for identification of mud flows and other landslides: **USGS Open-File Report 85-276**, p A1-A24.

- Asterisk *** Denotes Landslide Type Not in USGS Open-File Report 85-276**.
- ***Italicized* Landslides Not Mapped** Because Types Are Difficult to Recognize, Rare Statewide, or Outside Project Scope.
- Some Debris Flows Have Been Labelled Debris Avalanches, But Central **Appalachian Debris Avalanches Are Very Rare**.

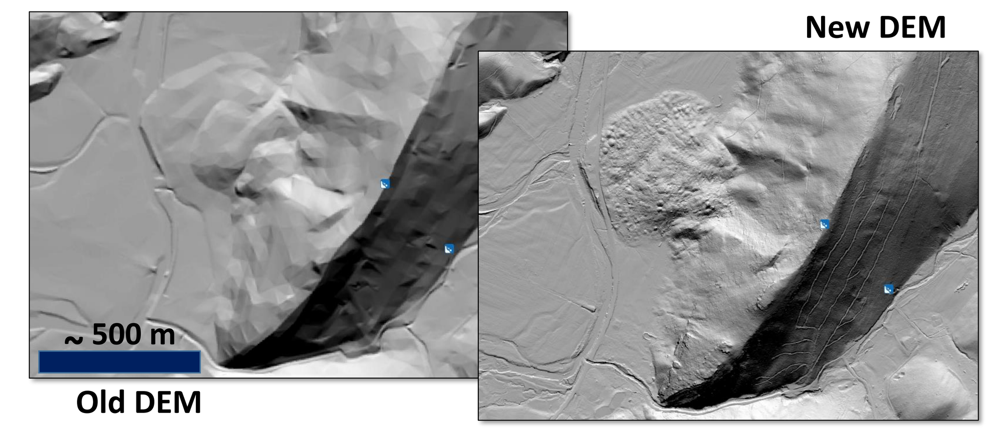
Reality Check After Mapping Trials –
Draft Version 0.2, March 2019, Revised 4 June 2019

Failure Motion		Material before Failure (Engineering Criteria)	
		Bedrock	Soil
General Motion	Type of Motion	Rock	Debris = Default Material in WV
Falling	**Fall**	**Rock Fall**	*Rare & Difficult to Discern*
	Topple (Falling Over)		
	Collapse * *(Roof Failure into Large Void Space)*	*Karst & Mine Subsidence Outside Project Scope*	
Sliding	**Slide (**Translational Sliding along Planar Surface)	**Slide**	
	Slump (Rotational Sliding along Concave Surface)		
Flowing	**Lateral Spread**	**Lateral Spread**	*Rare & Difficult to Discern*
	Creep * *(Slow Downslope Creep with No Slip Surface)*	*Creep Not Discernable from Stable Slope*	
	Flow (Rapid Viscous Channel Flow)	*Very Rare*	**Debris Flow**
	Avalanche *(Very Rapid Flow over Compressed Air)*	*True Avalanches Are Very Rare in Central Appalachians*	
Complex	**Multiple Motion Types -** e.g. Multiple Small Failures	**Multiple Failures**	
Undifferentiated	**Failure Process Unclear** from Available Data	**Undifferentiated Slope Failure**	

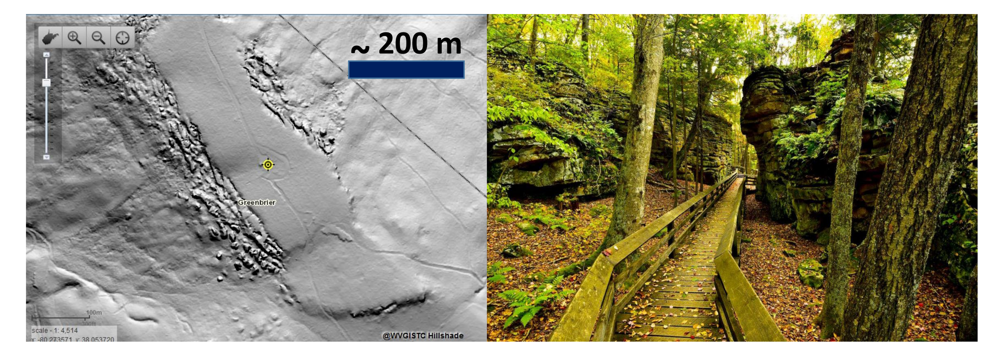
Modified from Version 0.1 Based On Multiple Operator Mapping Efforts..
- Landslide Identification Biased to Head Scarp Morphology.
- LiDAR-based Dems Will Not Allow Debris *vs.* Earth Differentiation, & May Not Allow Soil-Rock Differentiation.
- Consistent Translational Slide vs. Rotational Slump Differentiation Is Unlikely.

70 Ton Boulder, Morgantown, 1994 (S. Kite Photo)

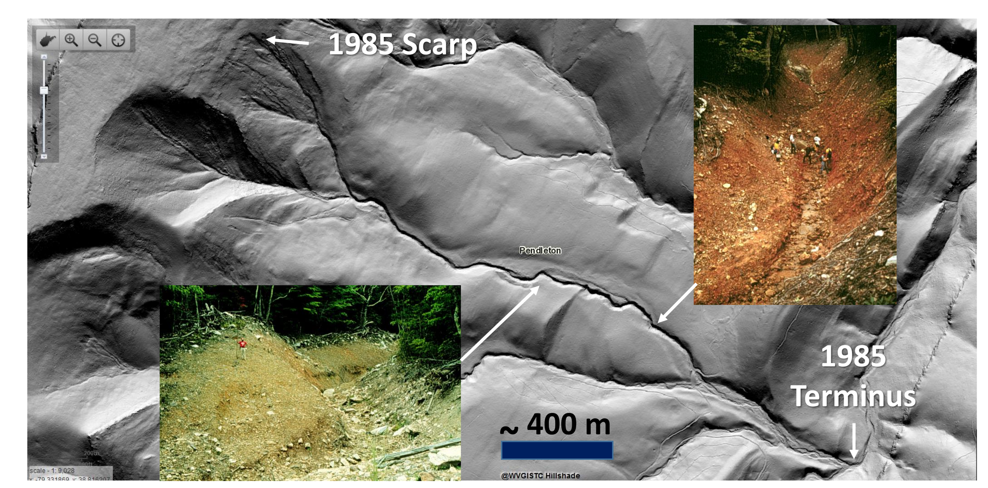
Landslides on QL2 LiDAR DEMs



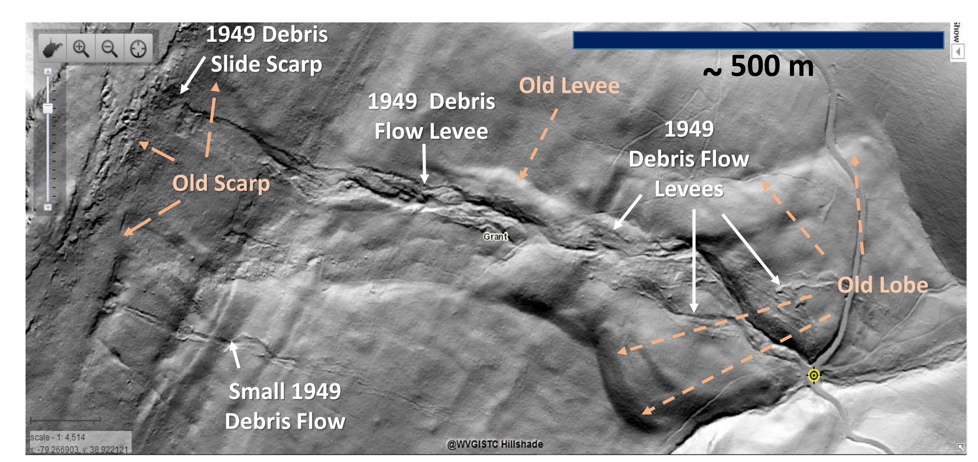
10 Foot Photo-Based DEM *vs.* 1 Meter LiDAR DEM
(Vertical Accuracy: 305 cm *vs.* 6.7 cm)



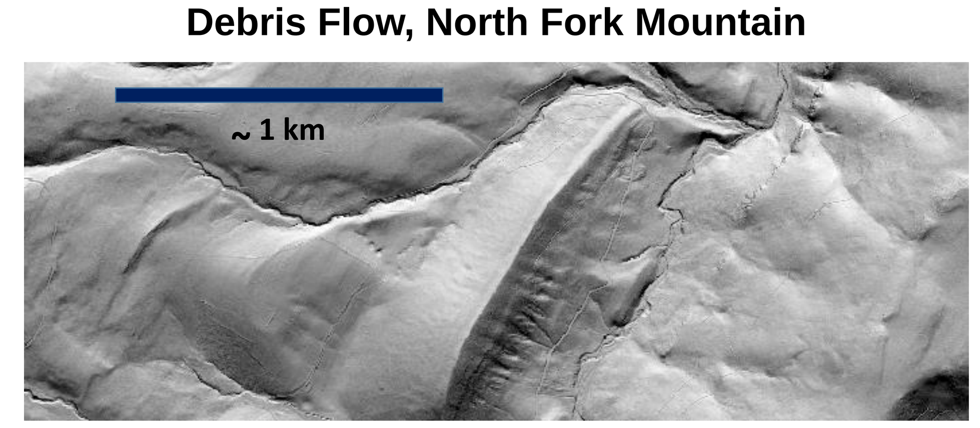
Rock Lateral Spreads - Beartown Rock Cities



1985 Twin Run Debris Flow: 2.8 km, 21,000 m³

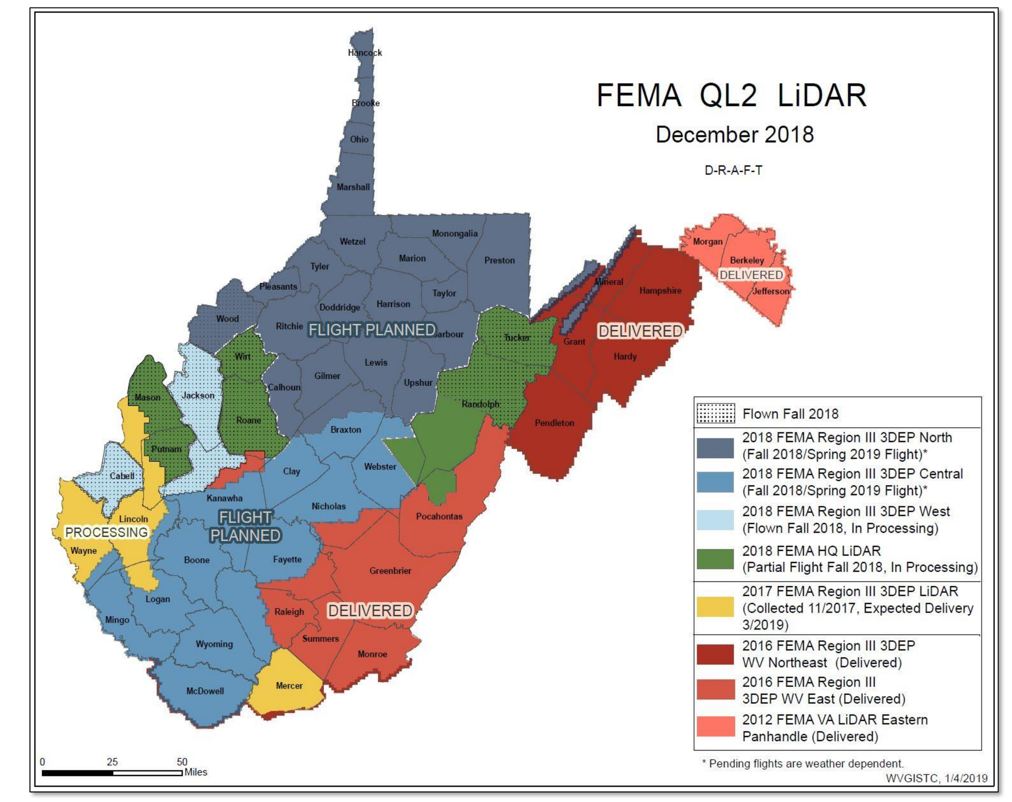


Huge Prehistoric Failure Over-Ridden by 1949 Debris Flow, North Fork Mountain



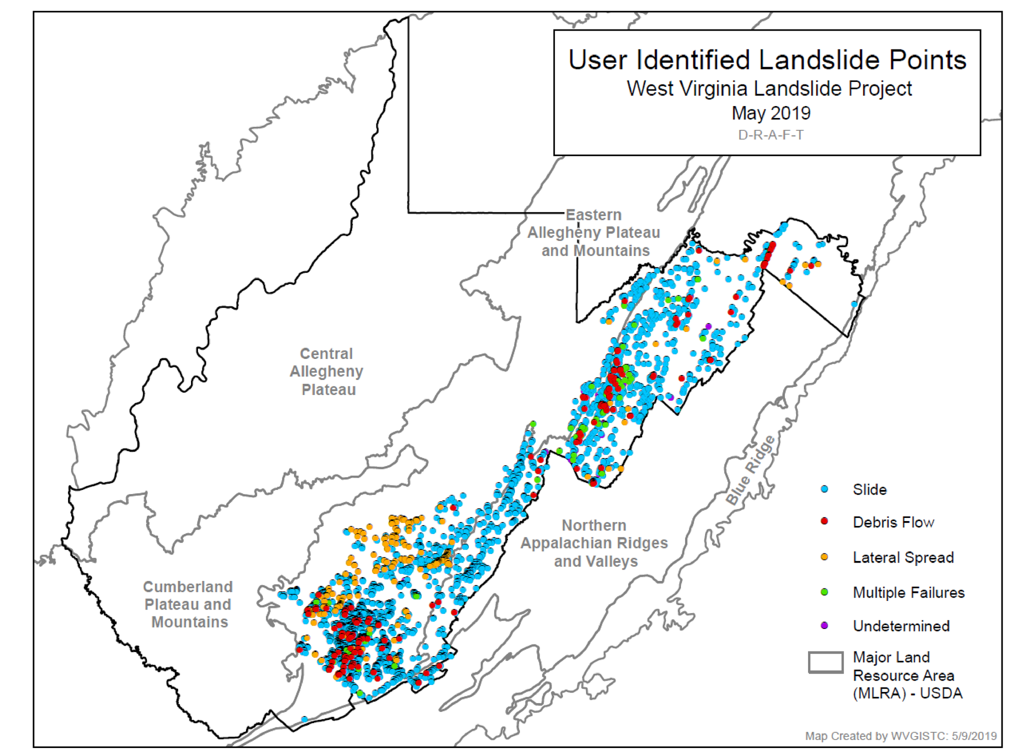
Complex Multiple Small 1985 Debris Flows, Slides, & Blow Outs, Big Mountain

QL2 LiDAR DEM Status



Find Best-Available Elevation Sources for West Virginia at
www.mapwv.gov/floodtest/docs/WV_FloodTool_ElevationSource_Metadata.pdf

Results to Date



From WVGISTC Landslide App https://www.mapwv.gov/landslide

Failure Movement	Number of Mapped Slides	% of Mapped Slides
Slide	2,624	84.8
Fall	0	0.0
Debris Flow	177	5.7
Lateral Spread	201	6.5
Multiple Failures	74	2.4
Undetermined	20	0.6
Total	3,096	100.0

Salient Points:
- West Virginia **Landslide Incidence** Is **Nearly Ubiquitous**.
- **NRCS** Major Land Resource Areas (**MLRAs**) & **LiDAR DEMs** Show **Need for Updating Physiographic Maps**.
- **Regional Variations** Exist in Slope Failure Types:
  - **Appalachian Plateaus (Nearly Flat-lying Bedrock):** **Debris Slumps, Debris Slides, Rock Falls, Short-Runout Debris Flows, & Rock Lateral Spreads.**
  - **Ridges & Valleys: (Folded Bedrock)**: **Debris Slumps, Debris Slides, Rock Falls, Long-Runout Debris Flows, & Huge Planar Rock Slides.**
- **(1) Human Activity, (2) Late Cenozoic Geologic History, & (3) Bedrock Geology Influence Spatial Distribution of Landslides** (*Debatably in This Order*).