REQUEST FOR BOARD ACTION

HENDERSON COUNTY
PLANNING BOARD

MEETING DATE: June 16, 2011

SUBJECT: State Landslide Hazard Mapping for Henderson County

PRESENTER: Senior Geologist Rick Wooten, NC Geological Survey Agency

ATTACHMENTS: 1. Summary Sheet
2. PowerPoint Presentation

SUMMARY OF REQUEST:

The NC Geological Survey (NCGS), an agency within the NC Department of Environment & Natural Resources (DENR), began the development of a series of county maps that identify higher risk areas for landslides and their debris flow locations. As a result of state legislation, the NCGS completed mapping for four counties in Western North Carolina with Henderson County being the most recent.

NCGS staff plans to provide a brief overview of the mapping results. Mr. Rick Wooten, P.G., is a Senior Geologist for Geohazards and Engineering Geology with the NCGS and has led the Landslide Hazard Mapping Program for the last several years. The NCGS is a non-regulatory agency within DENR and the landslide hazard mapping creates no regulations. The attachments provided give key points about the mapping results.

It appears that the proposed budget (beginning July 1, 2011) for DENR will eliminate funding for all staffing but one position for this program. As a result this may be the final opportunity for the Board to hear directly from the individuals responsible for the maps' preparation.

PLANNING BOARD ACTION REQUESTED:

No action is required by the Board.

Suggested Motion: None provided.

North Carolina Geological Survey

Henderson County Landslide Hazard Mapping Program

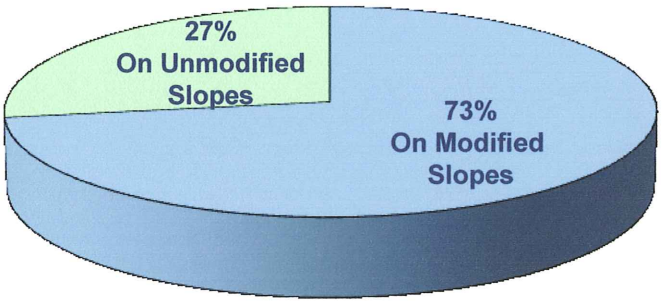
Data and Mapping Products

- Where landslides occurred – Slope Movements/Deposits
- Where landslides might start – Stability Index Map
- Where landslides might go – Potential Debris Flow Pathways

Landslide Facts For Henderson County

- 88 modern landslides in the last 94 years
- 3 homes destroyed, 6 deaths attributed to landslides
- 6% of county is high hazard based on Stability Index Map
- 14% of county within Potential Debris Flow Pathways
- 96% of landslides starting on unmodified ground are on slopes of 28° (53%) or steeper
- Slope failures on modified ground have occurred on pre-modified ground slopes as low as 22° (40%)

Where landslides have started in Henderson County



More landslides have occurred on modified slopes

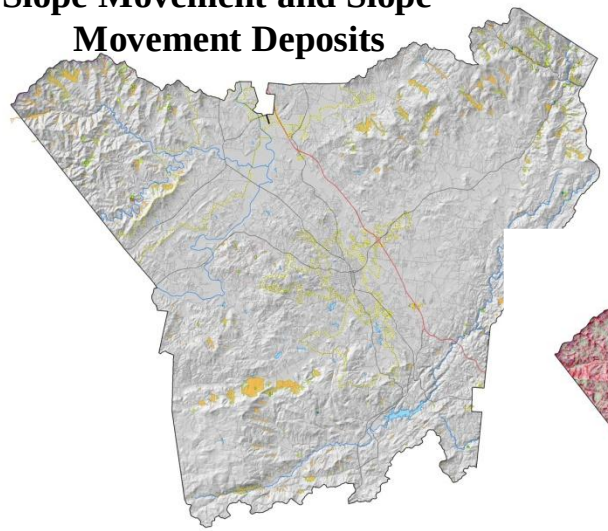
For Additional Information:

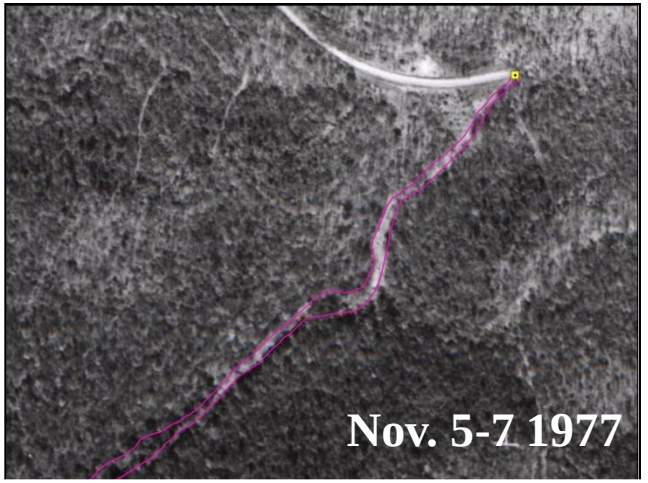
Richard M. Wooten, P.G.
Senior Geologist for Geohazards and Engineering Geology
North Carolina Geological Survey

828-296-4500
rick.wooten@ncdenr.gov
www.geology.enr.state.nc.us

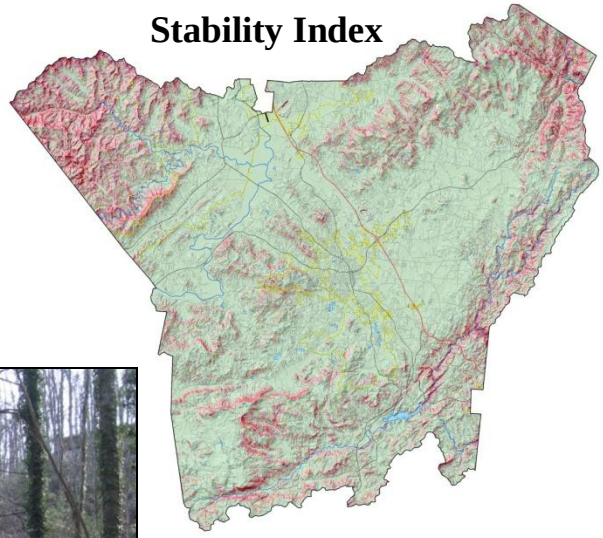
Landslide Hazard Maps for Henderson County
Henderson County Planning Board June 16, 2011

Slope Movement and Slope Movement Deposits

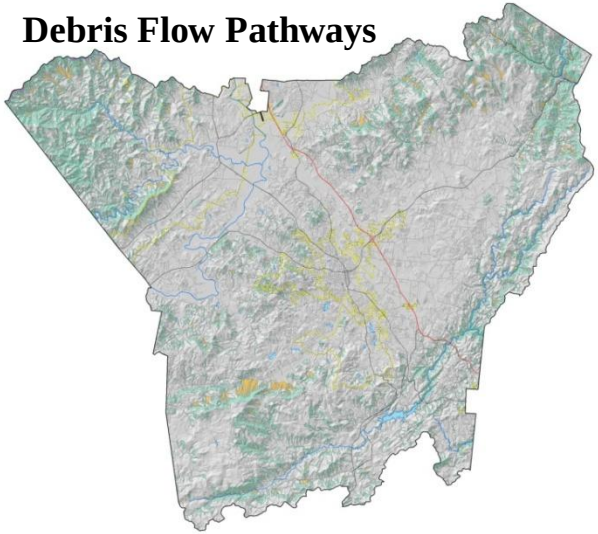




Stability Index



Debris Flow Pathways



Rick Wooten, P.G., Tommy Douglas, P.E, P.G., Anne Witt, Ken Gillon, P.G., Stephen Fuemmeler, P.G., Jennifer Bauer, P.G, Rebecca Latham, E.I.

Hurricane Recovery Act of 2005

- **G.26. Provides funds for geological studies on priority landslide areas. The purpose is to better inform homeowners of potential risks stemming from potential landslides.**

- **VI.6.(ii) …maps indicating the areas vulnerable to landslides are made available for the same multicounty area. (19 Declared disaster counties)**

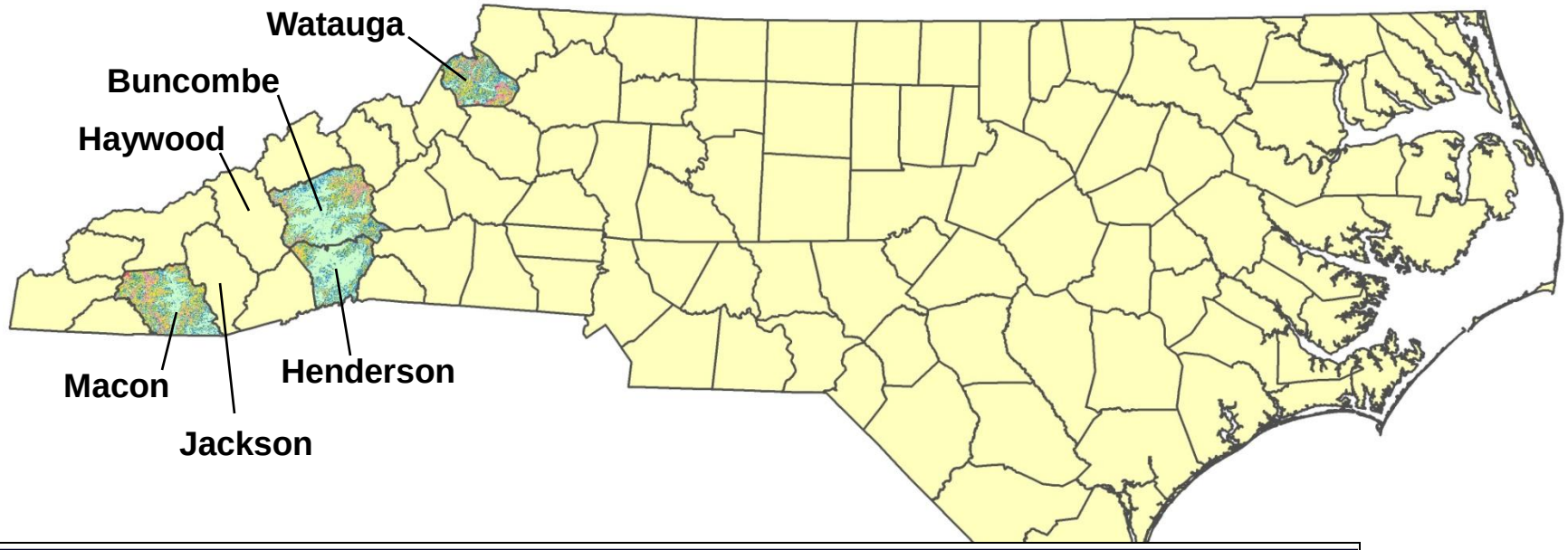
The intent of the Landslide Hazard Maps is to:

- To protect public safety, provide the public, local government, and local and state emergency agencies with a planning tool that describes and locates areas…

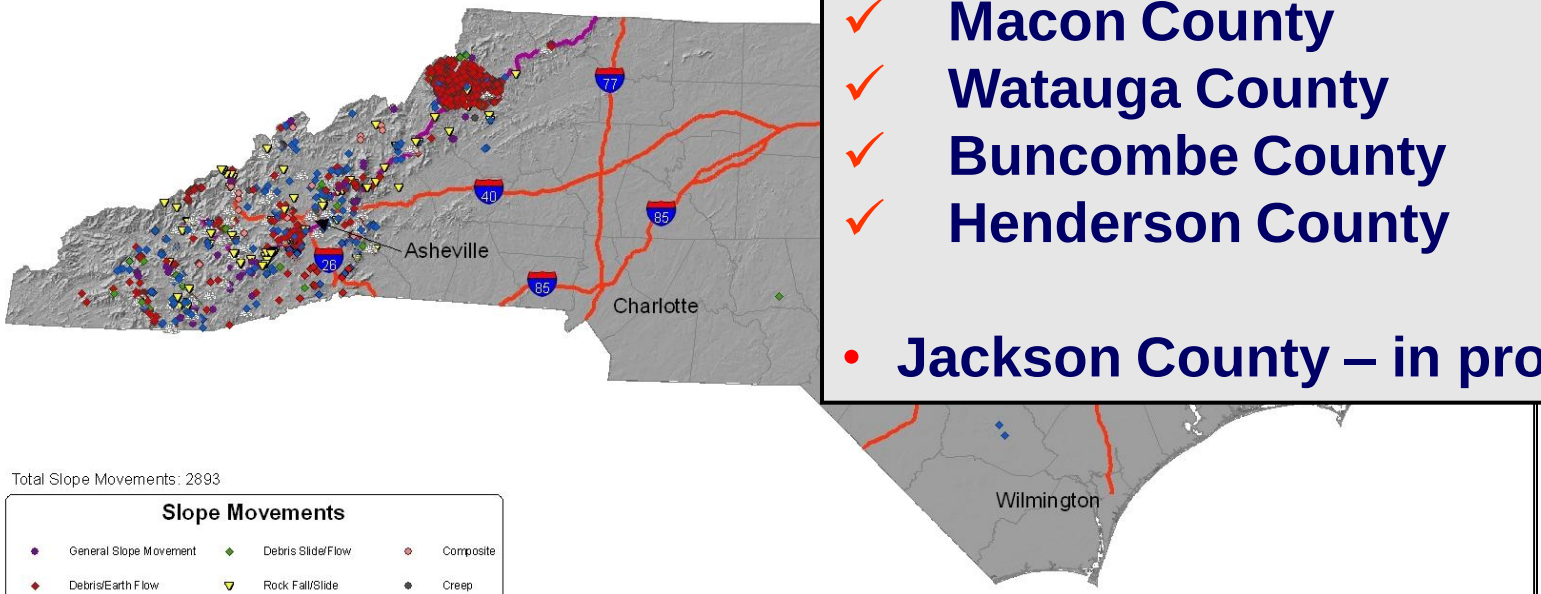
- Where landslides have happened or are happening,

- Where they are likely to occur in the future, and

- The general areas downslope that are at risk from these landslides.



North Carolina Slope Movement Geodatabase



- ✓ **Macon County**
- ✓ **Watauga County**
- ✓ **Buncombe County**
- ✓ **Henderson County**

- **Jackson County – in progress**

North Carolina Geological Survey

Henderson County Landslide Hazard Mapping

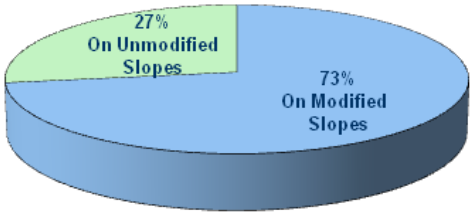
Data and Mapping Products

- Where landslides occurred – **Slope Movements/Deposits**
- Where landslides might start – **Stability Index Map**
- Where landslides might go – **Potential Debris Flow Pathways**

Landslide Facts For Henderson County

- 88 modern landslides in the last 94 years
- 3 homes destroyed, 6 deaths attributed to landslides in 1916
- 6% of county (4.4% of private land) is high hazard based on Stability Index Map
- 14% of county (10.2% of private land) within Potential Debris Flow Pathways
- 96% of landslides starting on unmodified ground are on slopes of 28° (53%) or steeper
- Slope failures on modified ground have occurred where pre-modified ground slopes were as low as 22° (40%)

Where landslides have started in Henderson County



MORE LANDSLIDES HAVE OCCURRED ON MODIFIED SLOPES

For Additional Information:

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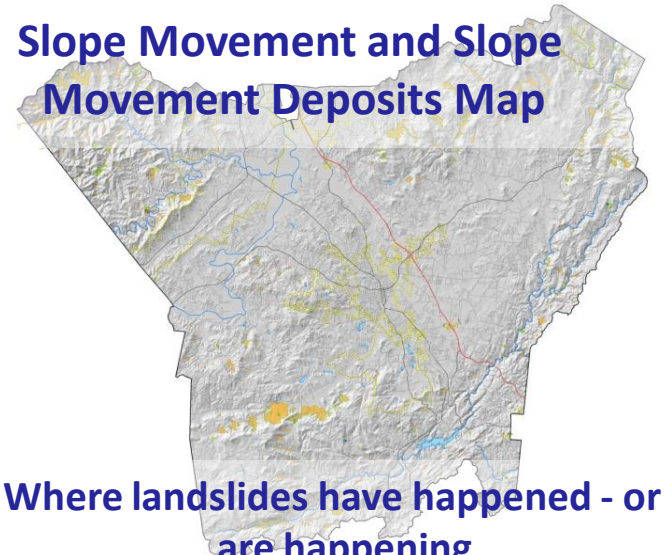
88 landslides

- **64 (73%) on modified ground.**
- **24 (27%) on unmodified ground.**
- **421 landslide deposit areas – areas of past landslide activity**

Slope Movement and Slope Movement Deposits Map



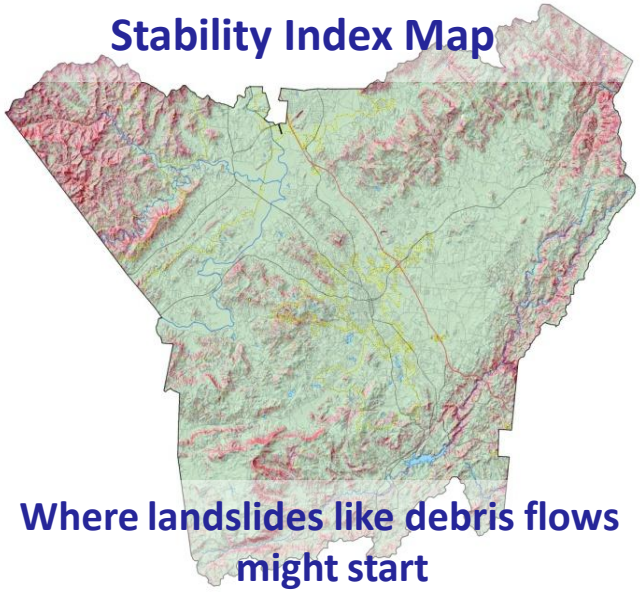
Where landslides have happened - or are happening

GIS Digital Products

- Geodatabase - Specific information on:

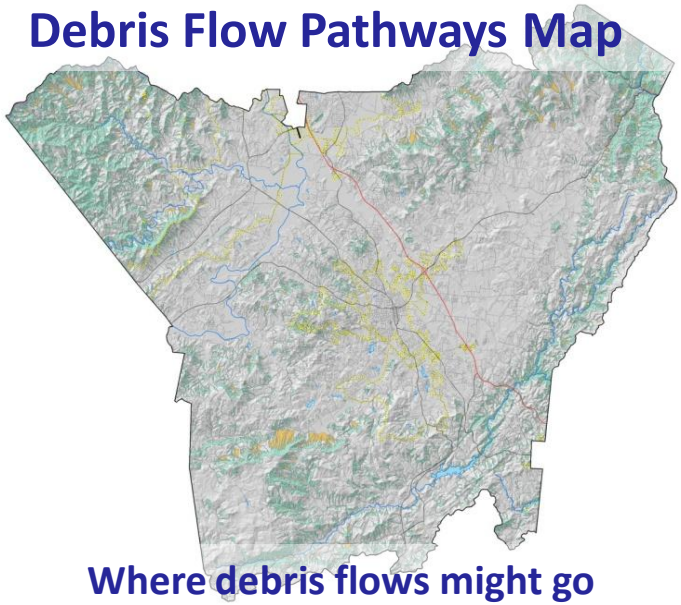
- Landslide (slope movement) type
- Location coordinates
- Landform
- Slope angle
- Soil
- Rock
- Vegetation
- Type of slope: unmodified; modified - cut, fill

Stability Index Map



Where landslides like debris flows might start

Debris Flow Pathways Map



Where debris flows might go

Slope Movement – Slope Movement Deposit Database March, 2010

- 3,140+ Landslides
- 2,900 Landslide Deposit Areas
- 46 Fatalities since 1916

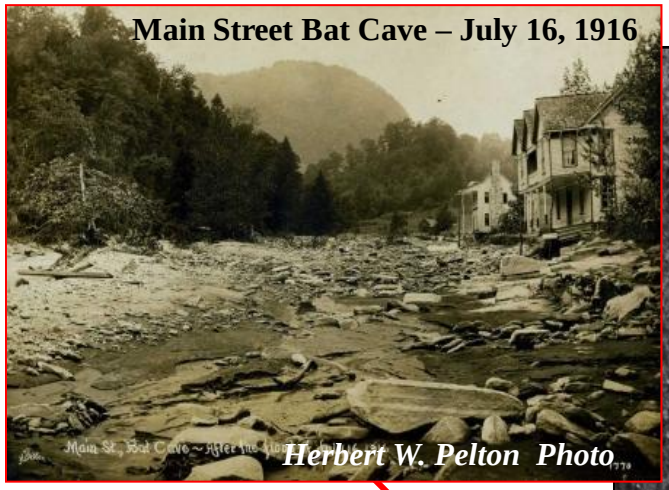
N.C. Landslides 1990 - 2010

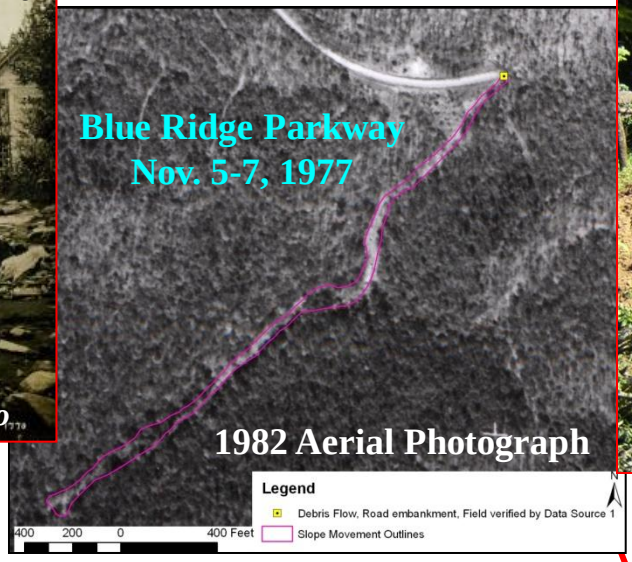
Total

- 6 Fatalities
- 48 Structures Destroyed - Condemned

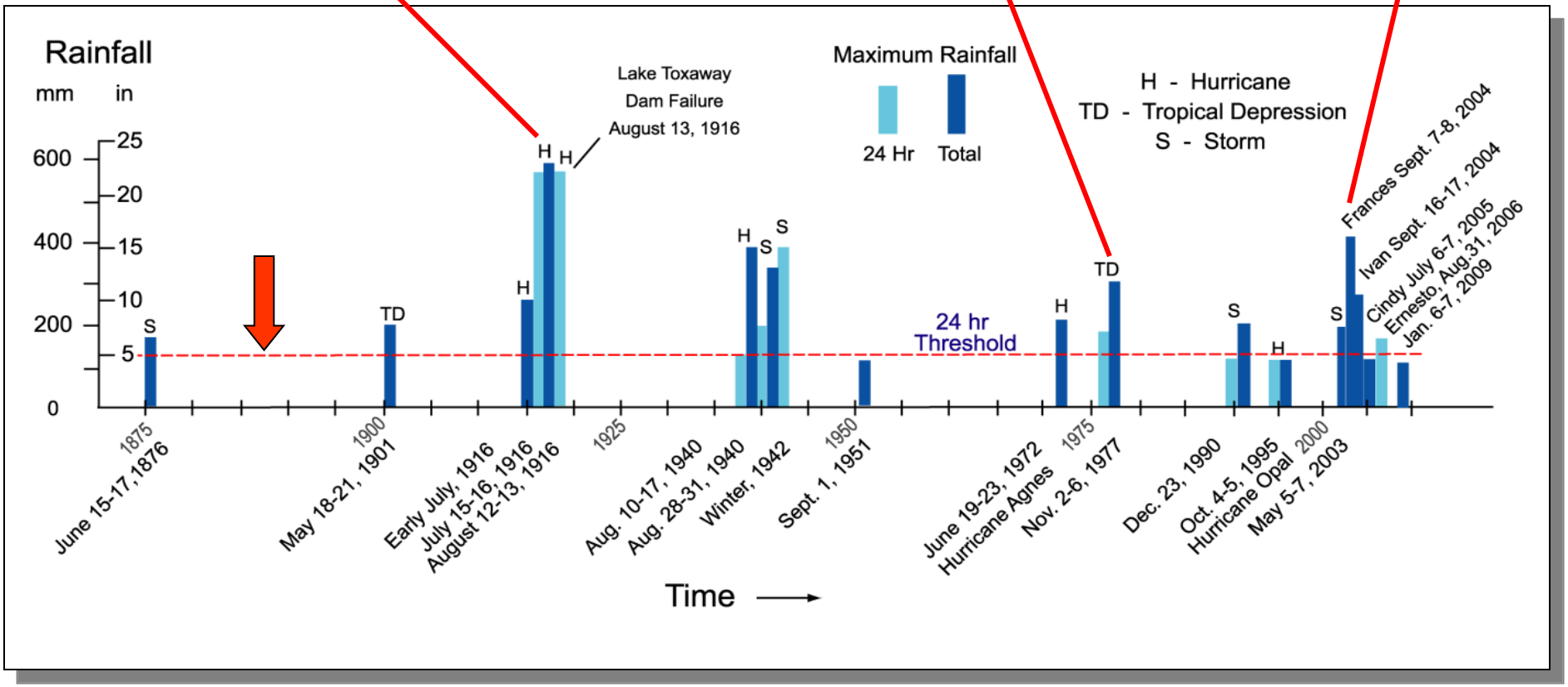
Modified Slopes

- 1 Fatality
- 30 Structures Destroyed - Condemned


Main Street Bat Cave – July 16, 1916
Herbert W. Pelton Photo


Blue Ridge Parkway
Nov. 5-7, 1977
1982 Aerial Photograph
Legend
Debris Flow, Road embankment, Field verified by Data Source 1
Slope Movement Outlines
400 200 0 400 Feet


Old CCC Road Frances -
Sept. 6-8, 2004


Rainfall
mm
in
600
400
200
0
25
20
15
10
5
Lake Toxaway
Dam Failure
August 13, 1916
Maximum Rainfall
24 Hr
Total
H - Hurricane
TD - Tropical Depression
S - Storm
24 hr
Threshold
S
TD
H
H H
H S S
H
TD
S
H
S
Frances Sept. 7-8, 2004
Ivan Sept. 16-17, 2004
Cindy July 6-7, 2005
Ernesto, Aug.31, 2006
Jan. 6-7, 2009
1875
June 15-17,1876
1900
May 18-21, 1901
Early July, 1916
July 15-16, 1916
August 12-13, 1916
1925
Aug. 10-17, 1940
Aug. 28-31, 1940
Winter, 1942
1950
Sept. 1, 1951
June 19-23, 1972
Hurricane Agnes
1975
Nov. 2-6, 1977
Dec. 23, 1990
Oct. 4-5, 1995
Hurricane Opal
2000
May 5-7, 2003
Time

Slope Movement Type	Modified	Unmodified	Public	Private	Public		Private		Total	% of Total
					Modified	Unmodified	Modified	Unmodified		
Debris or Earth flow	21	20	21	20	9	12	12	8	**41**	46.6%
Debris or Earth slide and flow	4	1	3	2	2	1	2		**5**	5.7%
Debris or Earth slide	13	1	6	8	5	1	8		**14**	15.9%
Debris or Earth slide-rotational	0	1	0	1			1		**1**	1.1%
Debris or Earth slide-translational	12	0	3	9	3		9		**12**	13.6%
Rock fall	1	0	0	1			1		**1**	1.1%
Rock slide-general	5	0	4	1	4		1		**5**	5.7%
Rock slide-translational	1	0	1		1				**1**	1.1%
Weathered rock slide	2	0	0	2			2		**2**	2.3%
Weathered rock slide-rotational	1	1	1	1		1	1		**2**	2.3%
Weathered rock slide-translational	4	0	1	3	1		3		**4**	4.5%
Total	**64**	**24**	**40**	**48**	**25**	**15**	**40**	**8**	**88**	100.0%
% of Total	72.7%	27.3%			62.5%	37.5%	83.3%	16.7%	100.0%	

National Floodplain Insurance : Mudflows (or Debris Flows) Landslides

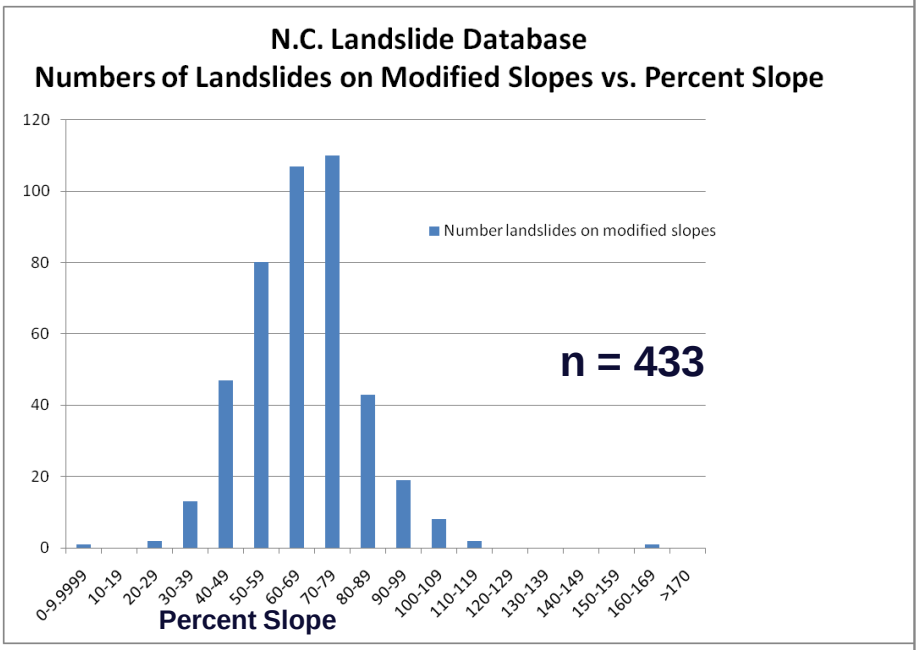
Mudflows (or debris flows) are rivers of rock, earth, and other debris saturated with water."

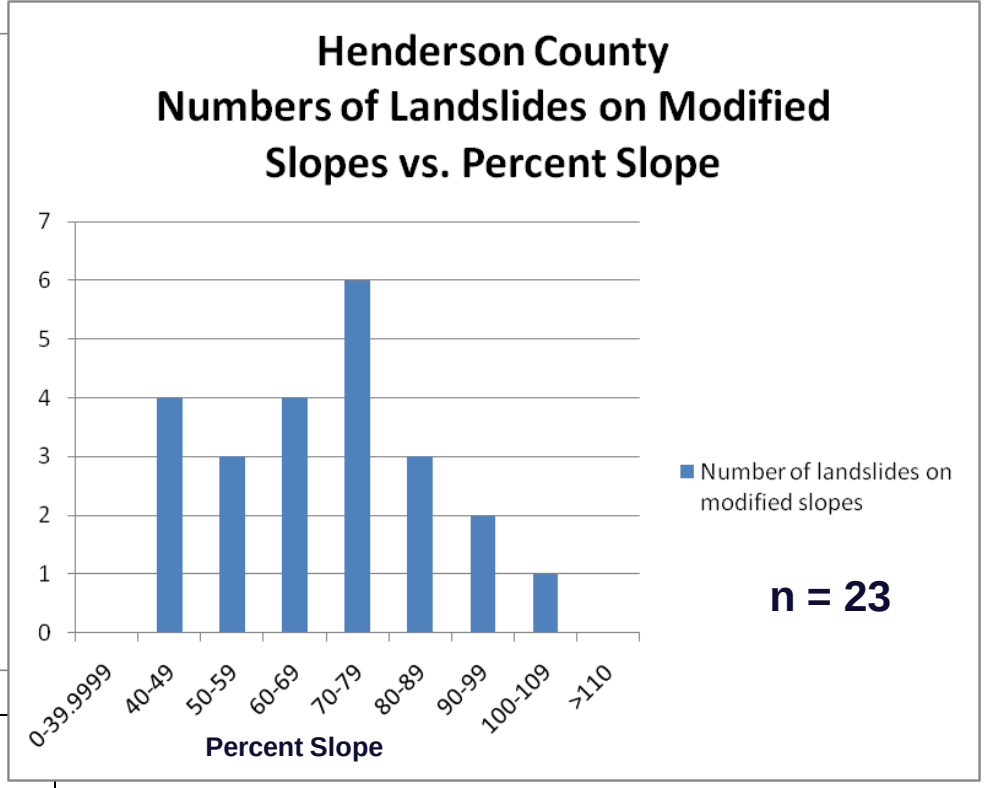
"Although floods and mudflows are covered under the NFIP, landslides are not covered. Under a flood insurance policy a property is covered for the portion of the damage to the insured building or contents caused by the flood and mudflow, but not the portion of damage caused by the landslide."

FEMA Special Hazards Supplement to the CRS Coordinator's Manual 2006

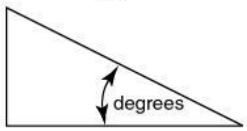
Debris Flow (Peeks Creek)

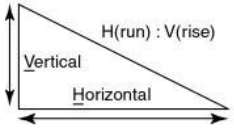
Landslide (weathered-rock slide)

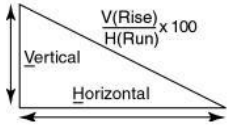




Slope Measurements

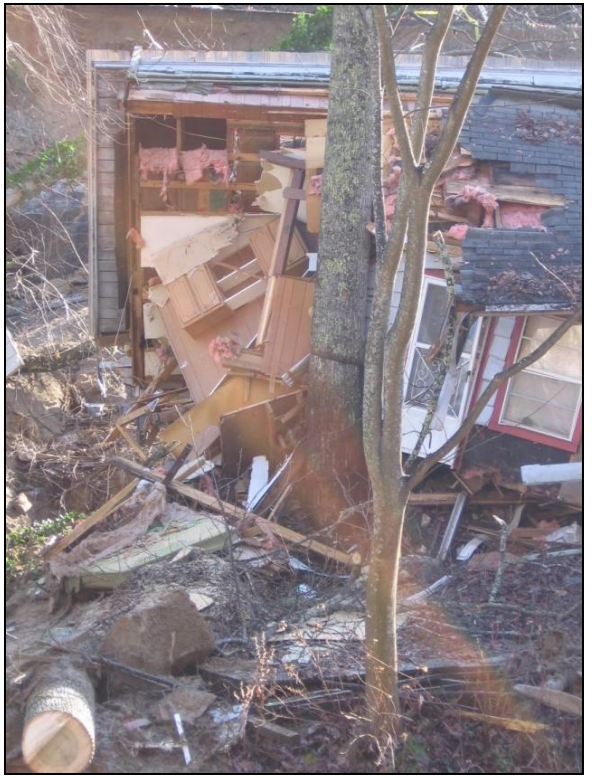


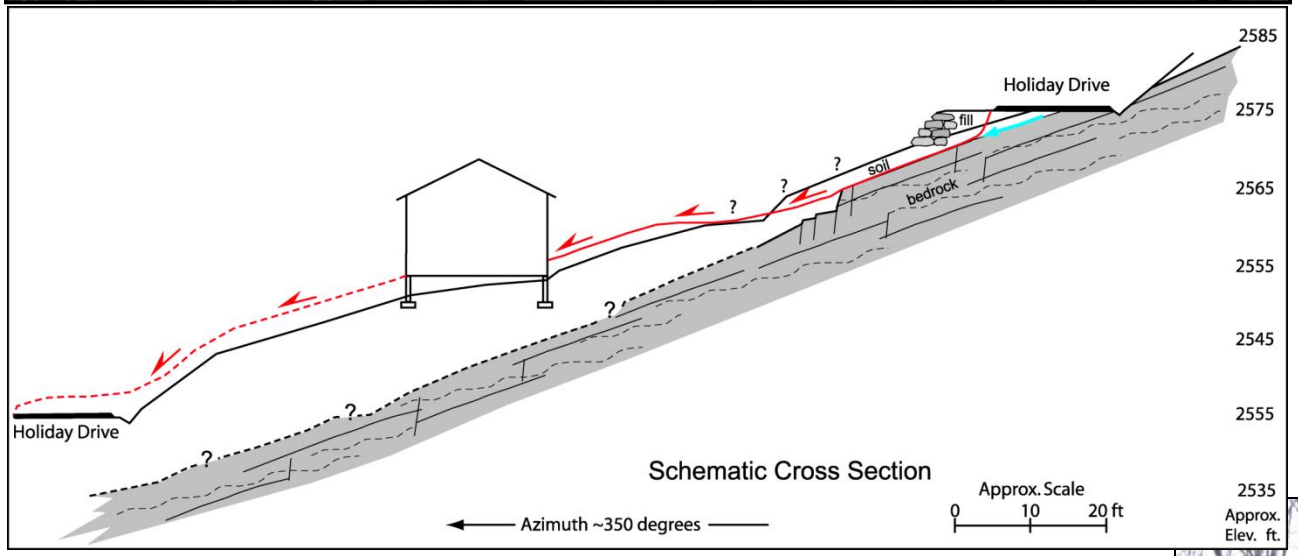




45°	1 H : 1 V	100%
39°	1.25 H : 1 V	80%
34°	1.5 H : 1 V	67%
30°	1.75 H : 1 V	57%
27°	2.0 H : 1 V	50%
22°	2.5 H : 1 V	40%
18°	3 H : 1 V	33%

Landslides *vs.* Slope on Modified Slopes





Holiday Drive

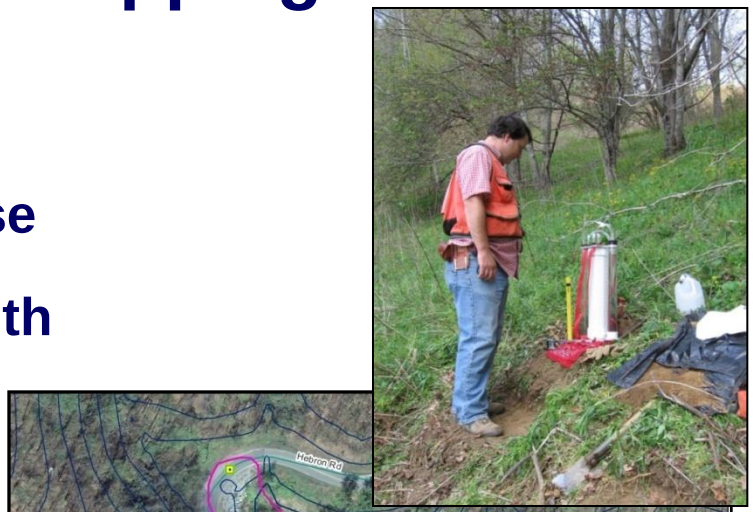
9:45 p.m. 11/30/19

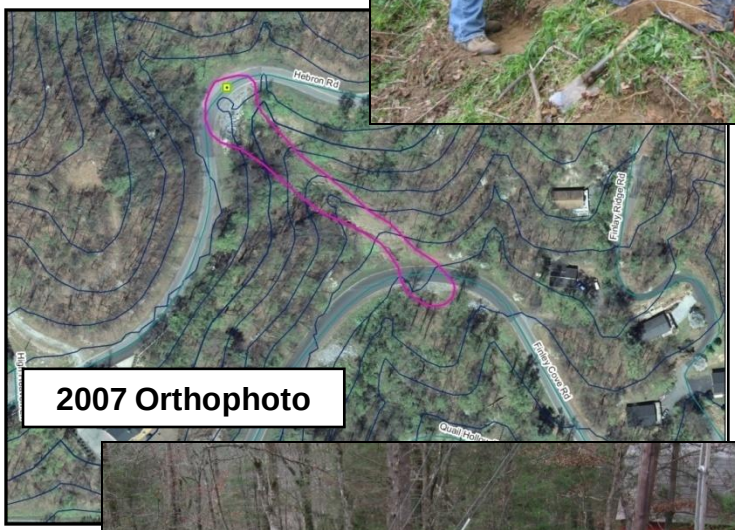
~2:00 a.m. 12/1/10

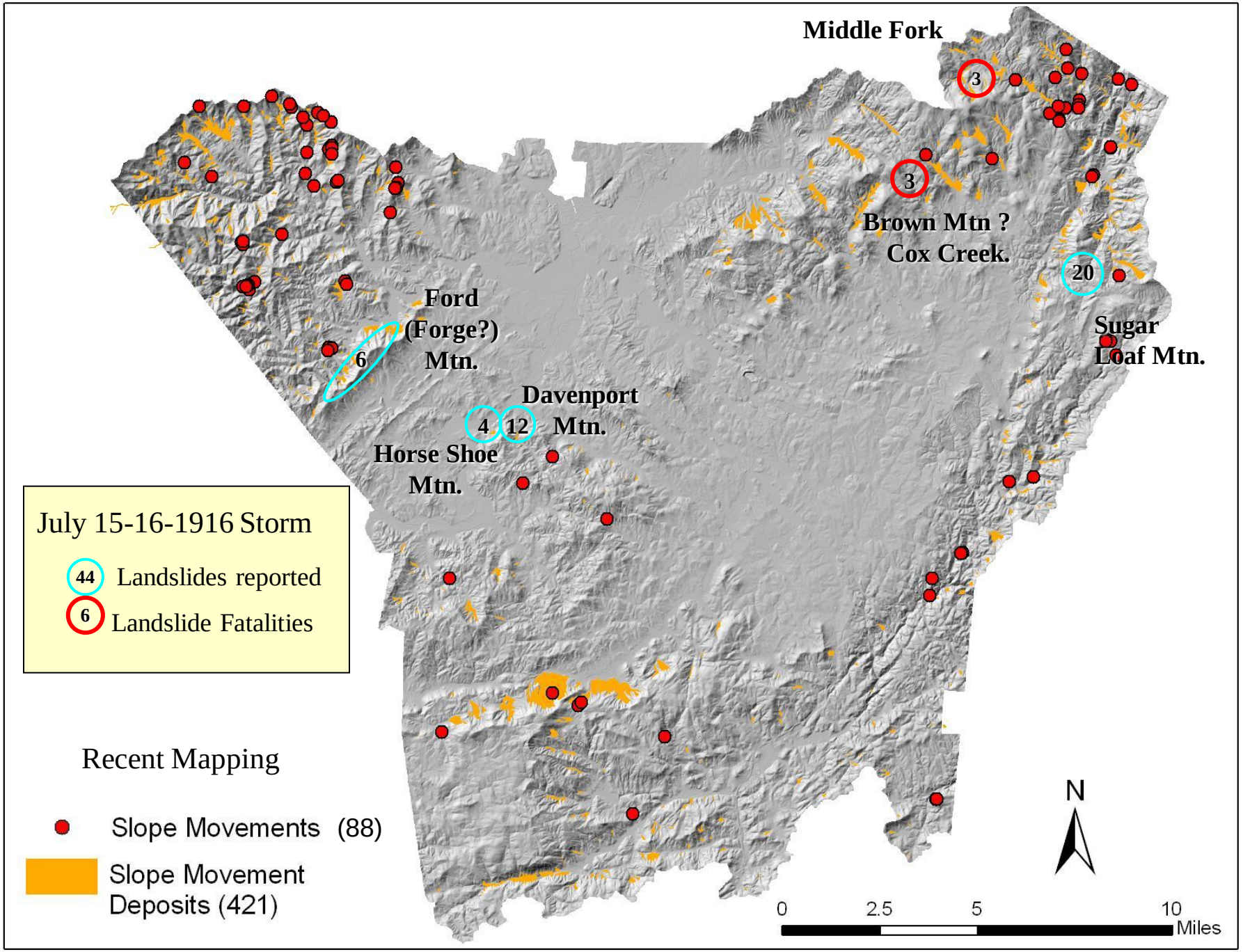
~7-8 inches of rain in 24 hrs

Henderson County Landslide Mapping Process

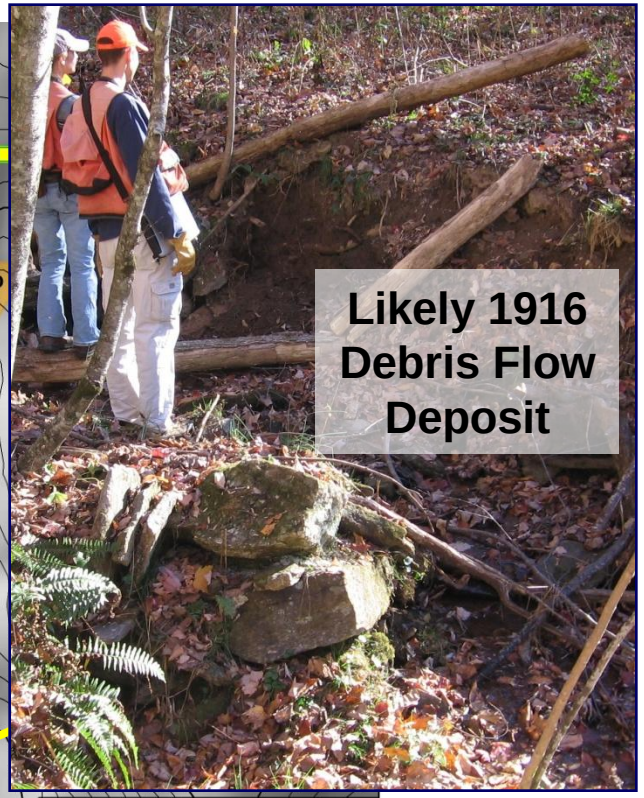
- ~ 2,000 field data points.
- 26 soil tests (NCDOT) + NCDOT Database
- 5 detailed study sites: incl. shear strength hydraulic conductivity (2 - DuPont S.F. – Transylvania)
- 400 miles of ground covered; >43 miles on foot
- Aerial / orthophotography: 1951, 1982, 1984, 1993, 2001, 1998, 2007 (cost share).
- USDA Soil Survey – 2008.
- Geologic Maps
- Field review by geologists, soil scientists, hydrogeologists, County Planning &GIS staff

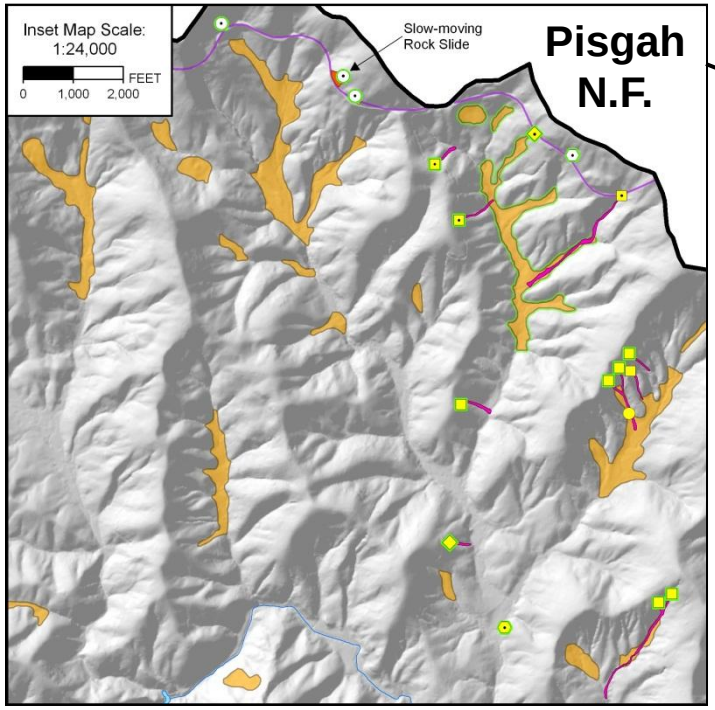


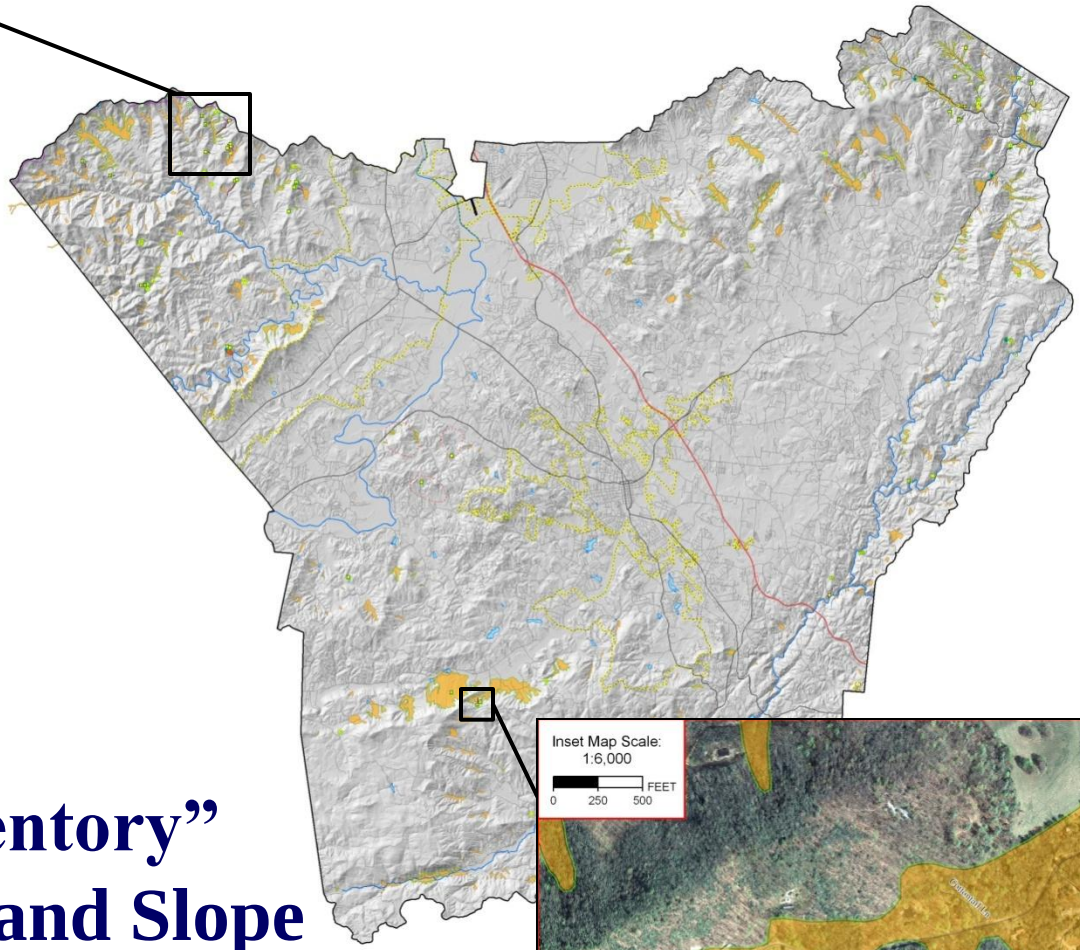


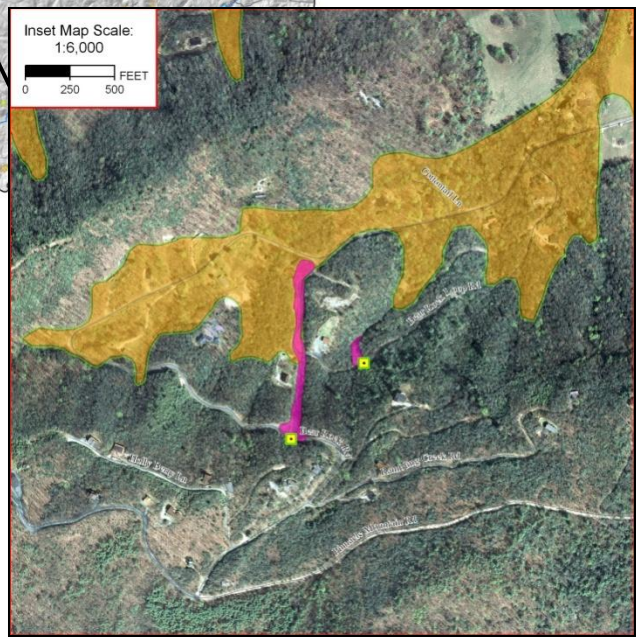

Middle Fork
3
3
Brown Mtn ?
Cox Creek.
20
Sugar
Loaf Mtn.
Ford
(Forge?)
Mtn.
6
Davenport
Mtn.
4
12
Horse Shoe
Mtn.
July 15-16-1916 Storm
44 Landslides reported
6 Landslide Fatalities
Recent Mapping
Slope Movements (88)
Slope Movement
Deposits (421)
N
0
2.5
5
10
Miles

July 15-16, 1916 Storm
Middle Fork "Burntshirt Mountain" Debris Flow







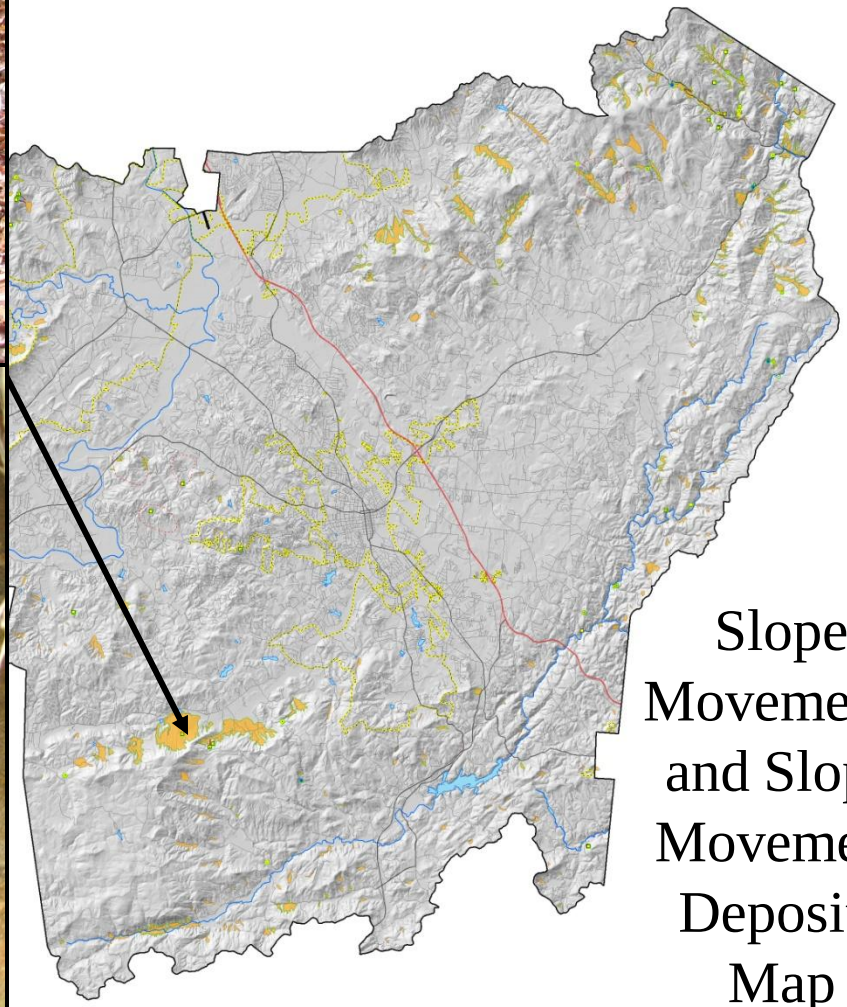


"Landslide Inventory" Slope Movements and Slope Movements Deposits Map

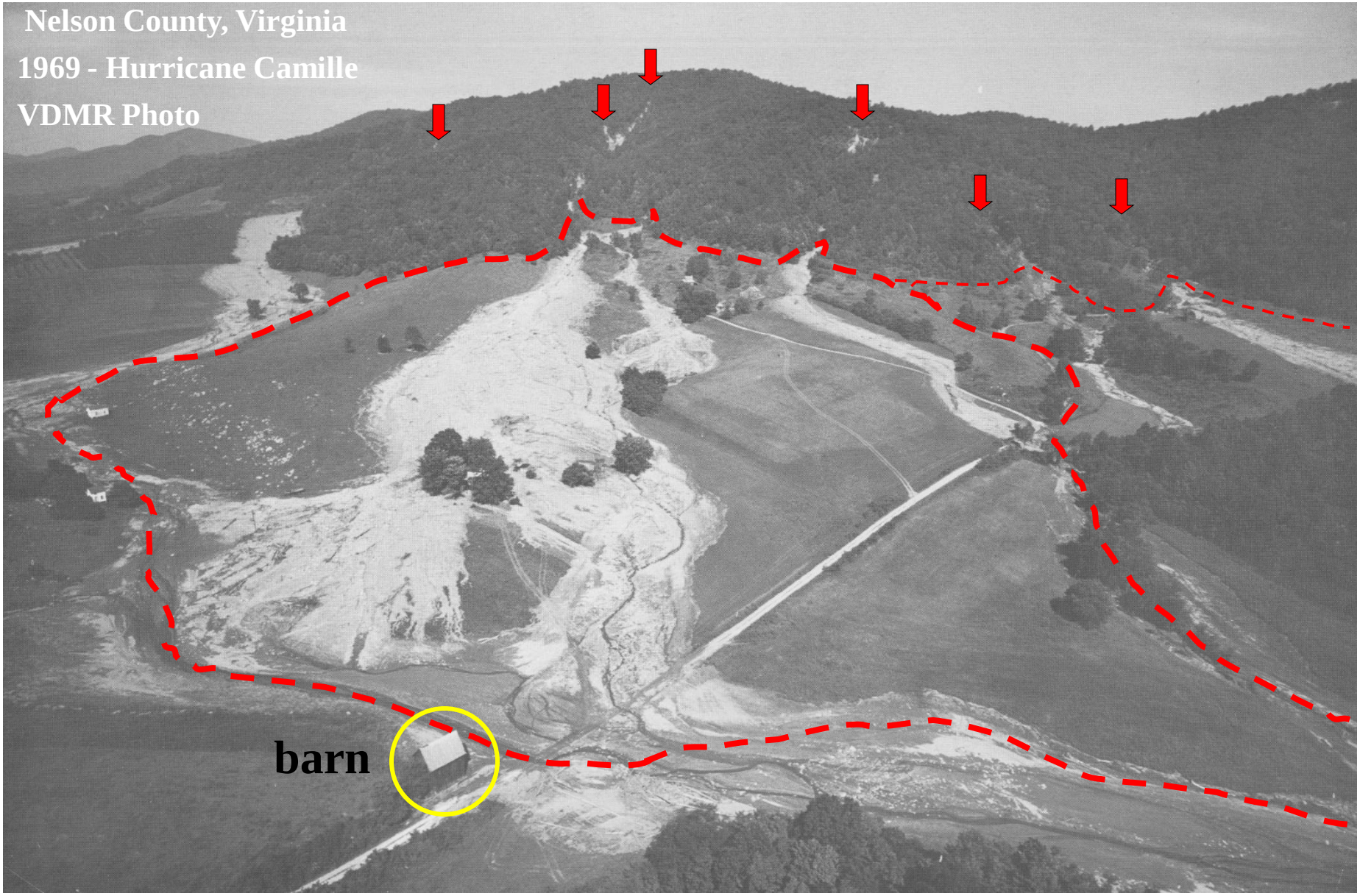
Where landslides have happened or are happening.

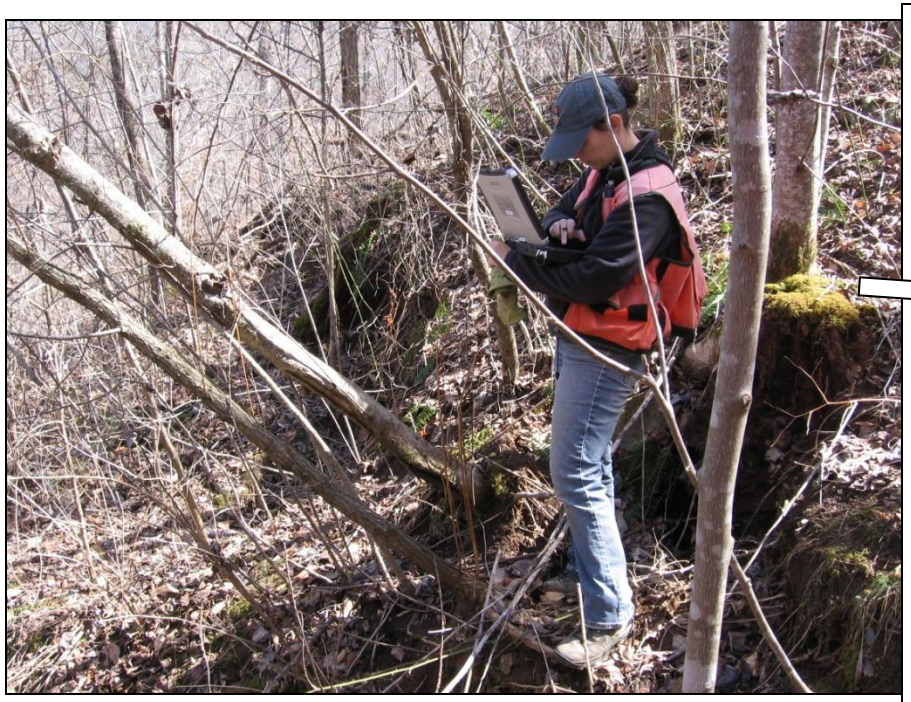
“Younger” and “Older” debris fan deposits

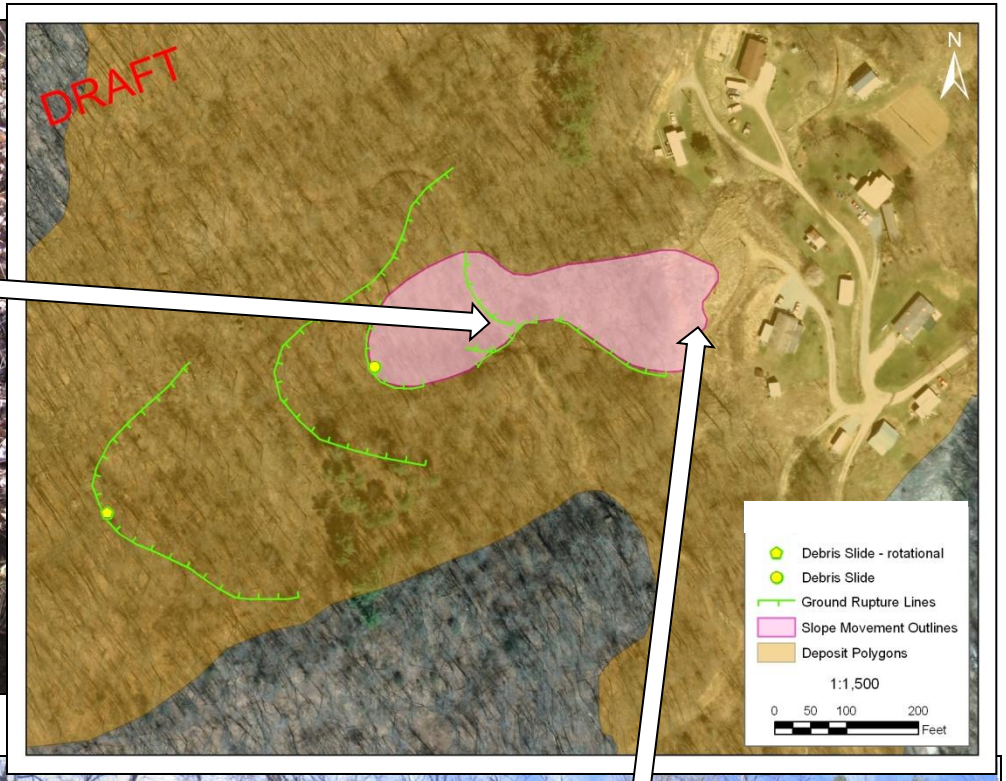
North slopes of Pinnacle Mountain



Slope Movements and Slope Movement Deposits Map


Nelson County, Virginia
1969 - Hurricane Camille
VDMR Photo
barn
Pre-existing debris fan deposits
1969 debris flows initiation zones

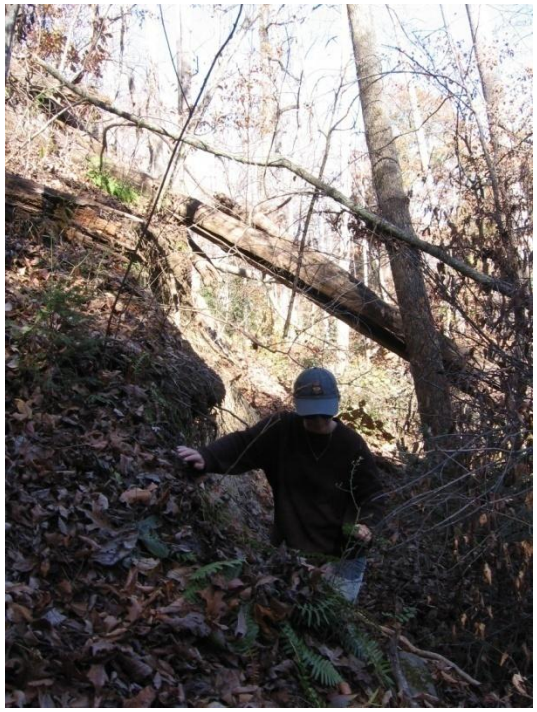




Active Landslide developed within pre-existing debris deposits

Jackson County

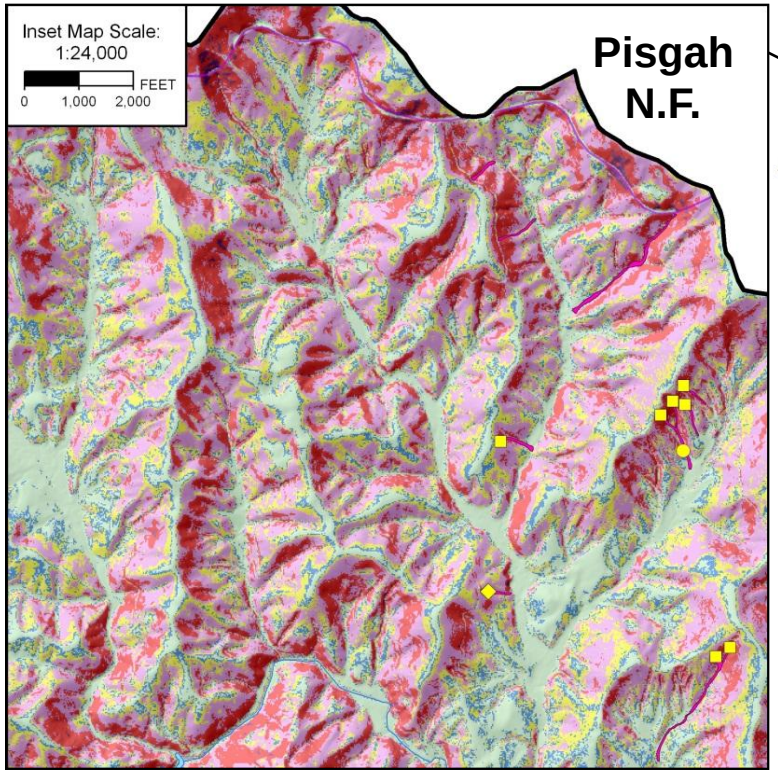
Slope Movements - Slope Movement Deposits Map: Outlines of slow-moving landslides

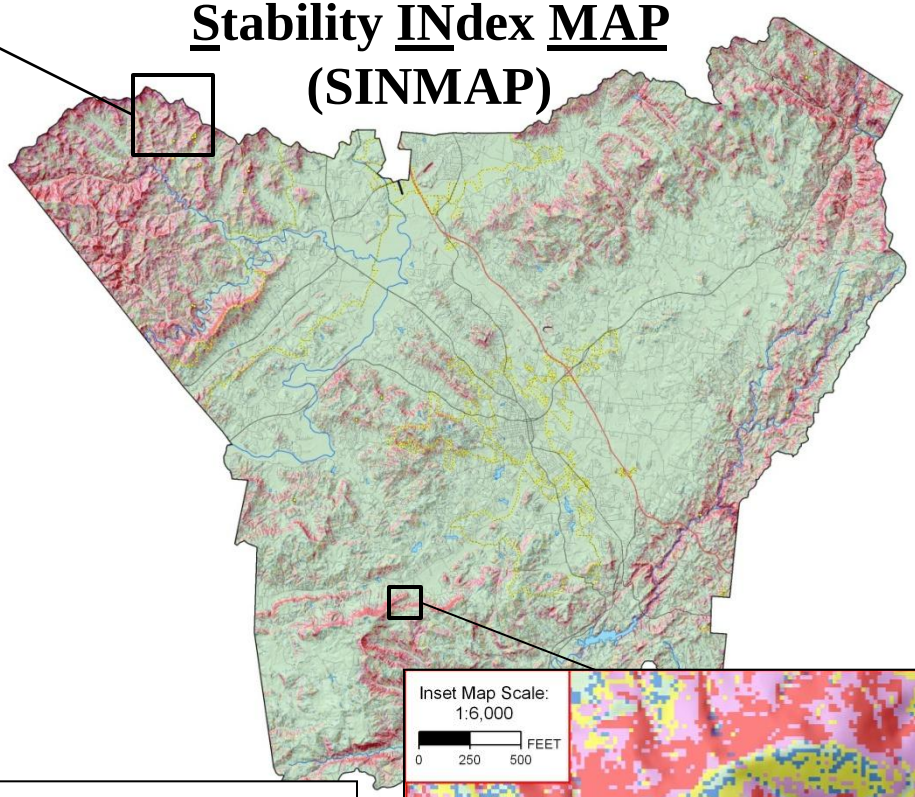


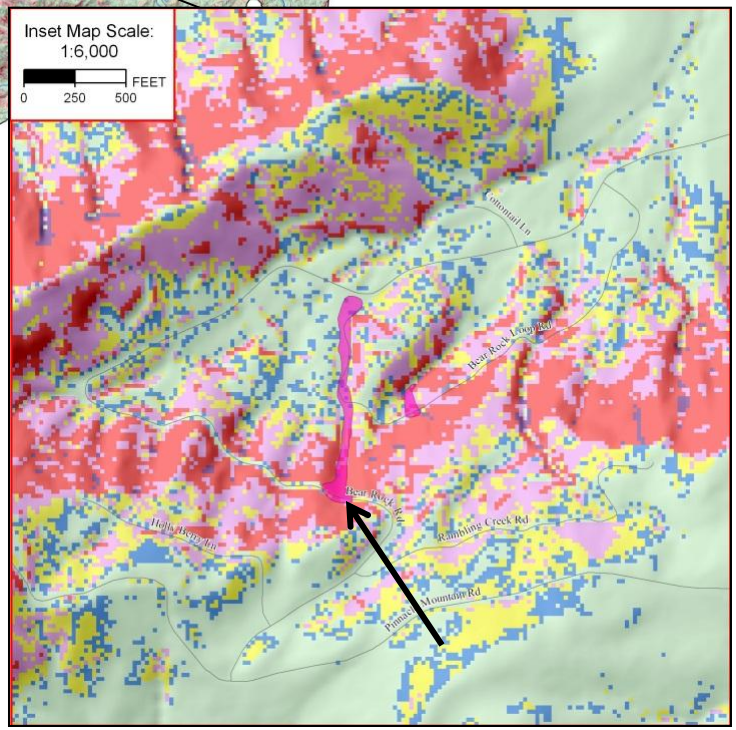
U.S. 64
Bat Cave

Active
Cut Slope
Failure

Stability INdex MAP (SINMAP)







Stability Index Map Zones and Rankings

Map Color Code	Predicted Stability Zone	Relative Debris/Earth Flow/Slide Hazard Ranking [1]	Stability Index Range [2]	Factor of Safety (FS) [3]	Probability of Instability [4]	Predicted Stability With Parameter Ranges Used in Analysis	Possible Influence of Stabilizing or Destabilizing Factors [5]
	Unstable	High	0	Maximum FS <1	100%	Range cannot model stability	Stabilizing factors required for stability
	Upper Threshold of Instability		0 - 0.5	>50% of FS ≤1	>50%	Optimistic half of range required for stability	Stabilizing factors may be responsible for stability
	Lower Threshold of Instability	Moderate	0.5 - 1	≥50% of FS >1	<50%	Pessimistic half of range required for instability	Destabilizing factors are not required for instability
	Nominally Stable	Low	1 - 1.25	Minimum FS = 1	___	Cannot model instability with most conservative parameters specified	Minor destabilizing factors could lead to instability
	Moderately Stable		1.25 - 1.5	Minimum FS = 1.25	___	Cannot model instability with most conservative parameters specified	Moderate destabilizing factors are required for instability
	Stable		>1.5	Minimum FS = 1.5	___	Cannot model instability with most conservative parameters specified	Significant destabilizing factors are required for instability

Stability INdex MAP (SINMAP)

- **Where landslides like debris flows and debris slides might start – locations where the factor of safety is likely to be less than 1.**

- **GIS model built and calibrated with field data to identify potential debris flow initiation zones.**

- **$\geq$ 5 inches of rainfall in 24 hours.**

- **Unmodified or "natural slopes." 23 calibration landslides in Henderson County.**

STABILITY INDEX MAPPING[1] (SINMAP) INPUT PARAMETERS

Modified Infinite Slope Equation

Slope parallel seepage Steady-state shallow groundwater flow

$$FS = \frac{C + \cos\theta\,[1 - \min\left(\frac{R}{T}\frac{a}{\sin\theta}, 1\right) r]\tan\phi}{\sin\theta}$$

C = dimensionless cohesion

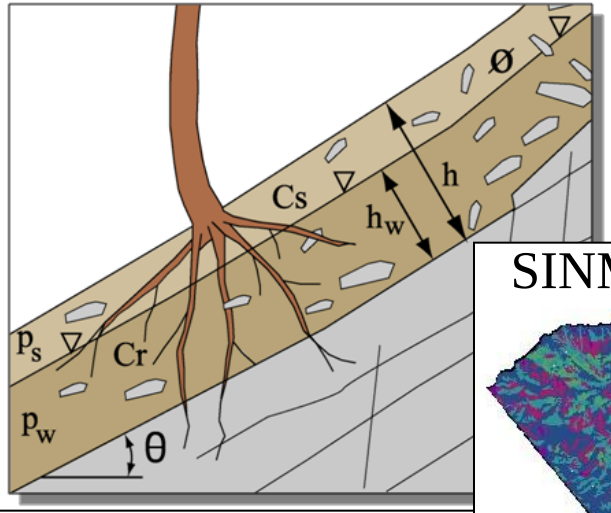
a = catchment area

R = recharge

T = transmissivity

θ = slope

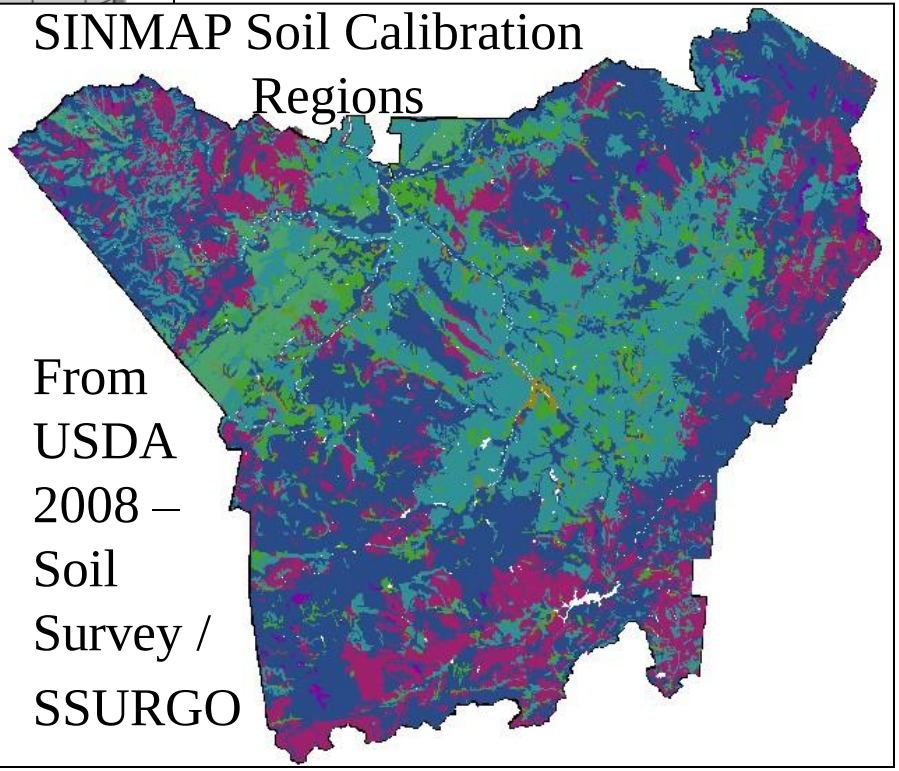
ϕ = soil friction angle



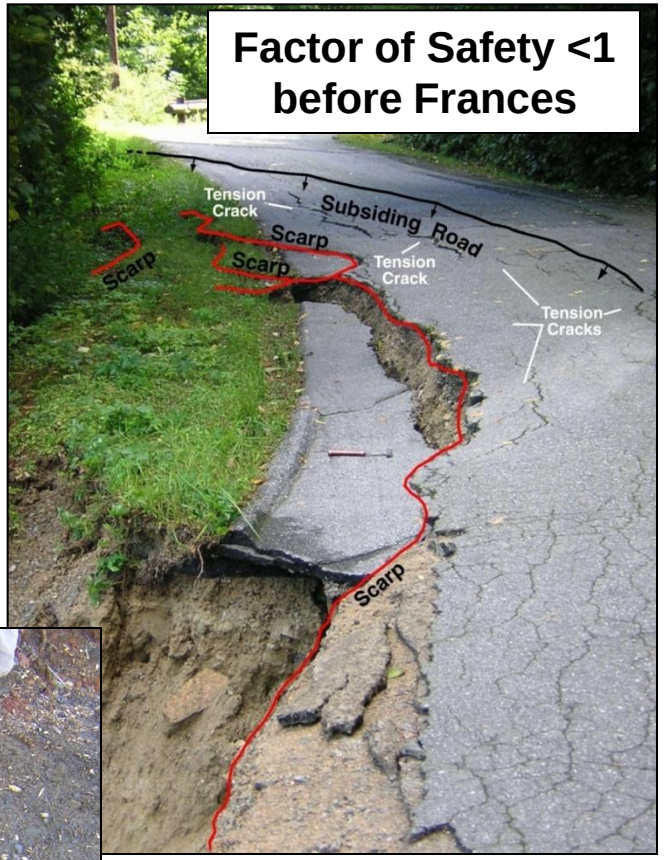
[1]Pack, Tarboton, Goodwin, 1998

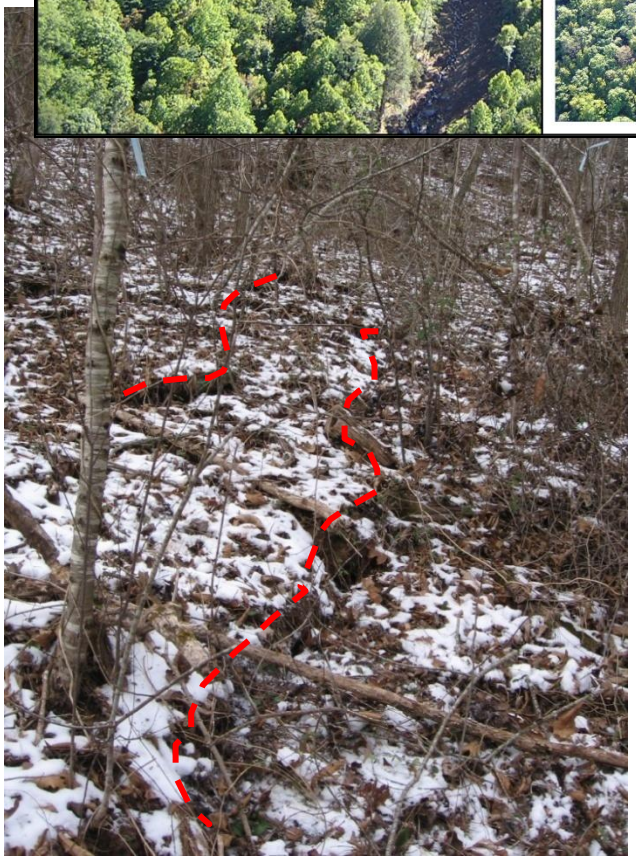
Minimum – Maximum range of values used for input

SINMAP Soil Calibration Regions



From USDA 2008 – Soil Survey / SSURGO



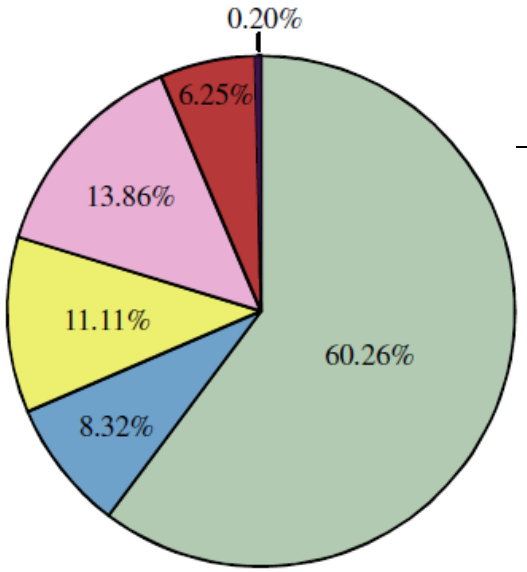


Examples:

Factors of Safety <1

Stability Index Map Stability Zones and Rankings

Map Color Code	Predicted Stability Zone	Relative Debris/Earth Flow/Slide Hazard Ranking [1]	Stability Index Range [2]	Factor of Safety (FS) [3]	Probability of Instability [4]	Predicted Stability With Parameter Ranges Used in Analysis	Possible Influence of Stabilizing or Destabilizing Factors [5]
	Unstable	High	0	Maximum FS <1	100%	Range cannot model stability	Stabilizing factors required for stability
	Upper Threshold of Instability		0 - 0.5	>50% of FS <1	>50%	Optimistic half of range required for stability	Stabilizing factors may be responsible for stability
	Lower Threshold of Instability	Moderate	0.5 - 1	≥50% of FS >1	<50%	Pessimistic half of range required for instability	Destabilizing factors not required for instability
	Nominally Stable	Low	1 - 1.25	Minimum FS = 1	—	Cannot model instability with most conservative parameters specified	Minor destabilizing factors could lead to instability
	Moderately Stable		1.25 - 1.5	Minimum FS = 1.25	—	Cannot model instability with most conservative parameters specified	Moderate destabilizing factors are required for instability
	Stable		>1.5	Minimum FS = 1.5	—	Cannot model instability with most conservative parameters specified	Significant destabilizing factors are required for instability



County-wide

Relative Hazard

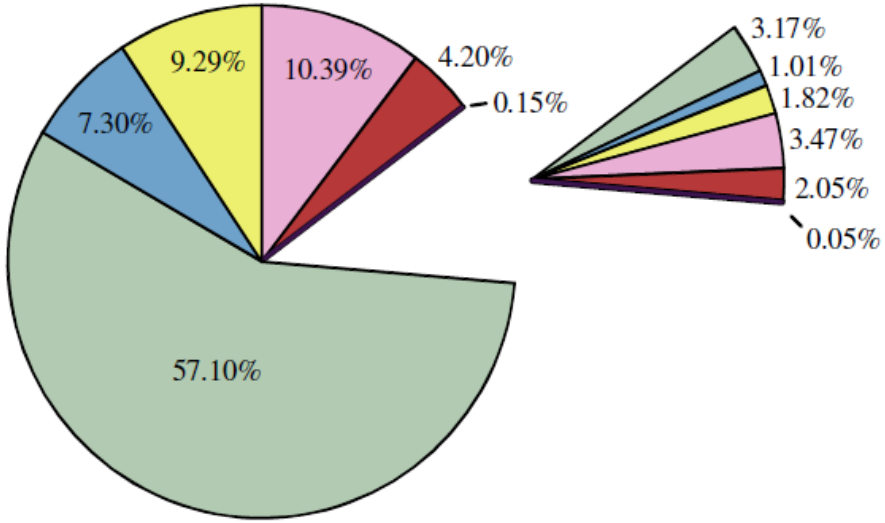
6.5% - High

13.9% - Moderate

79.7% - Low

Relative Hazard – Private Lands

	% of County	% of Private Land
High	4.4%	4.9%
Moderate	10.4%	11.8%
Low	73.7%	83.3%

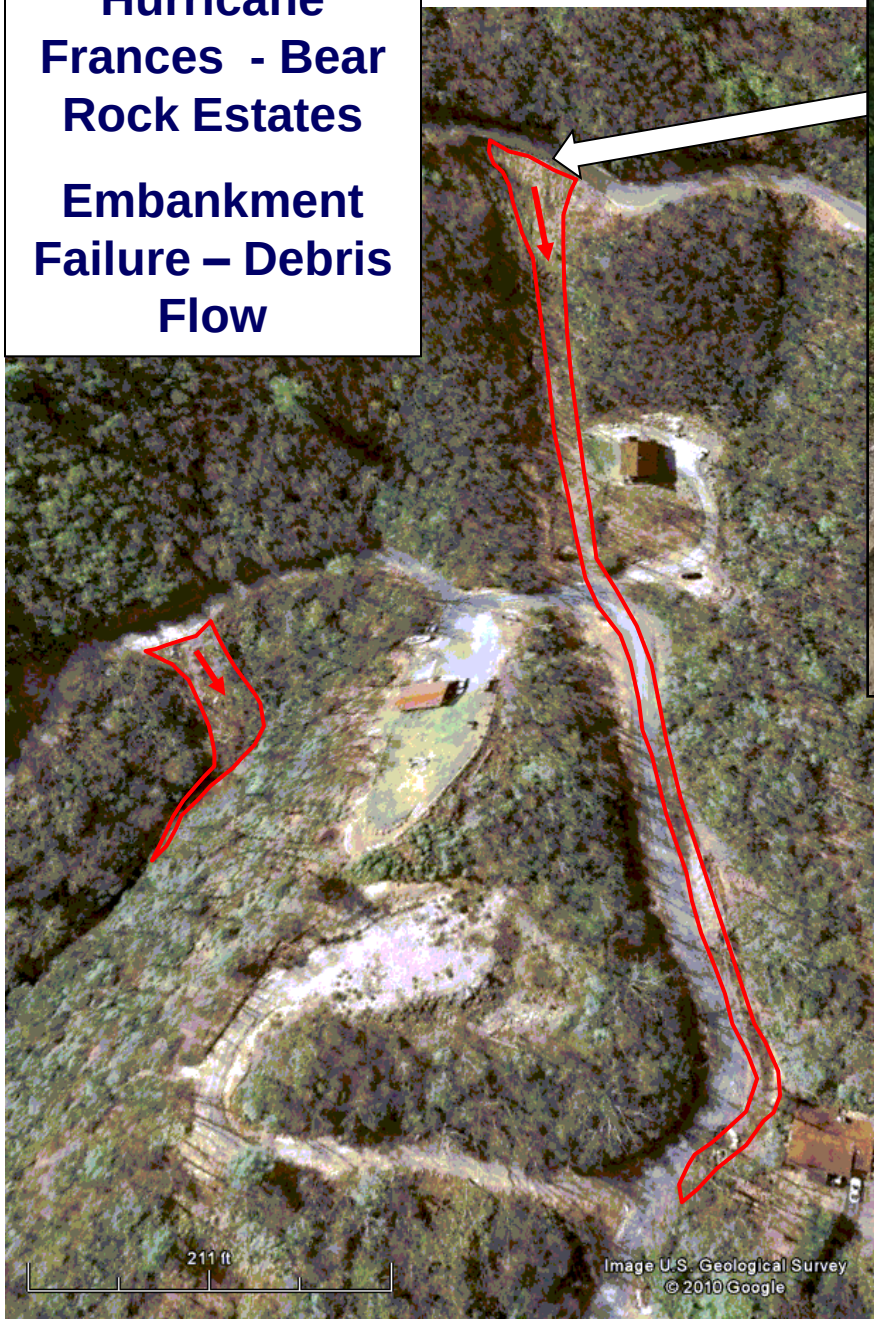


Private Lands
(88.43% of county)

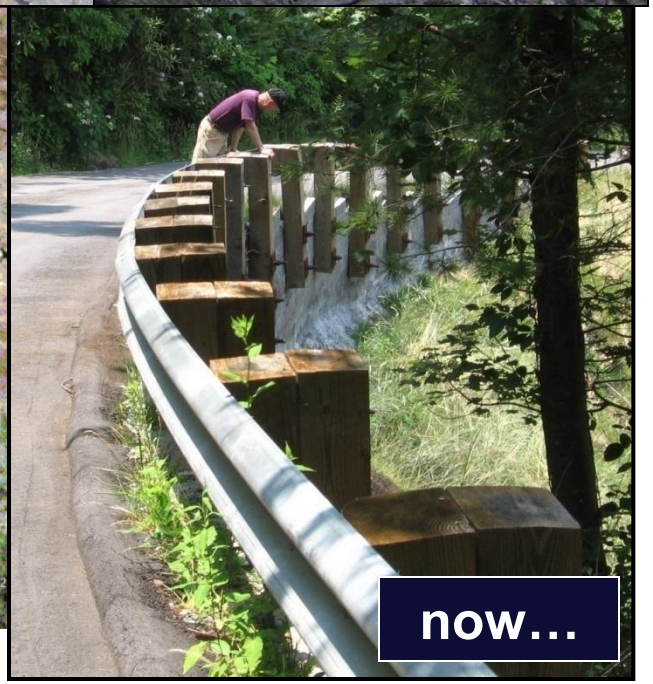
Public Lands
(11.57% of county)

Hurricane Frances - Bear Rock Estates

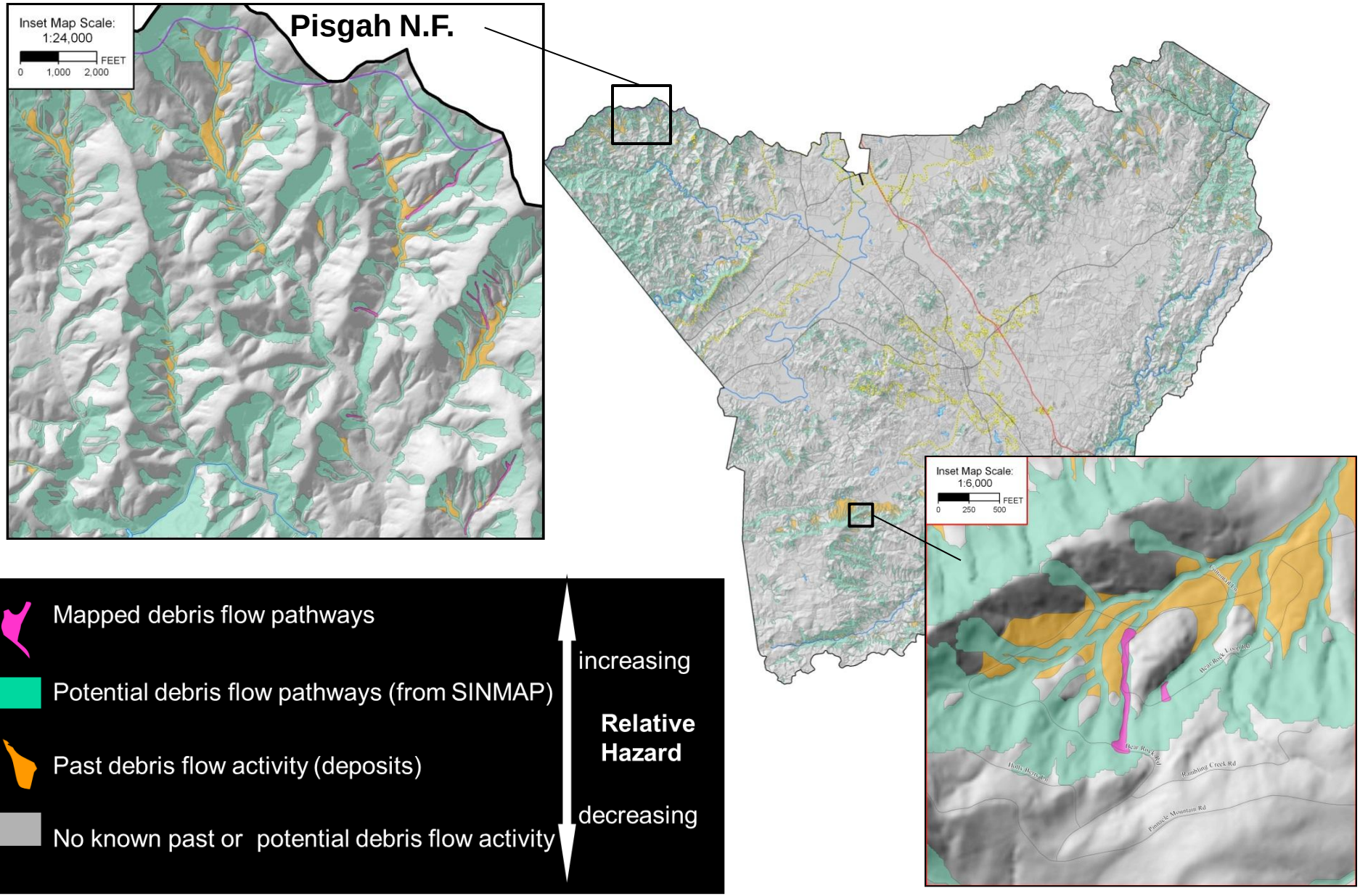
Embankment Failure – Debris Flow



then…



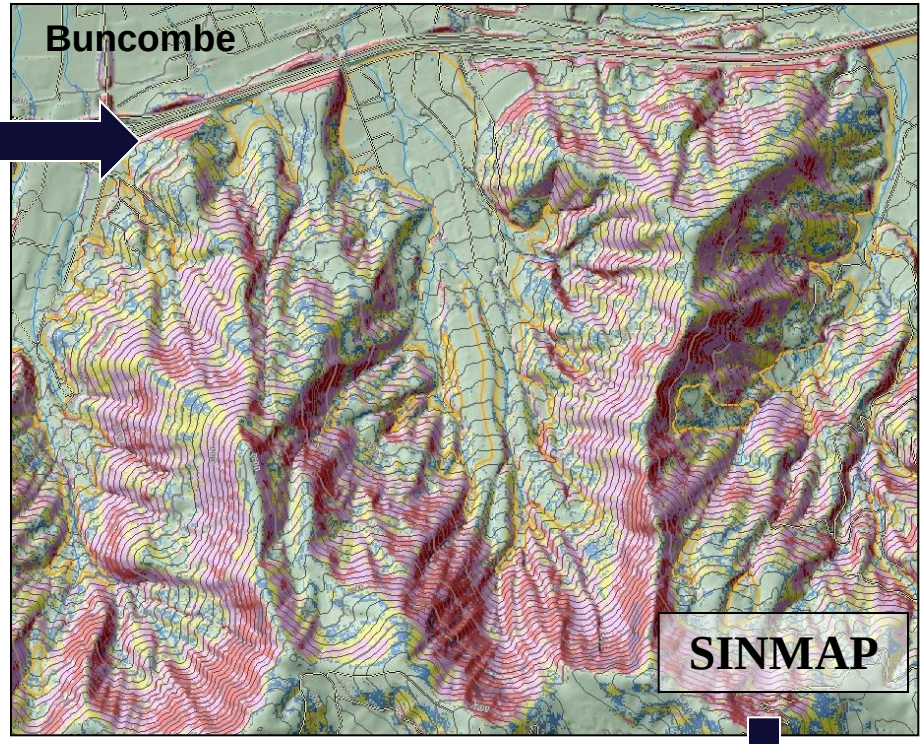
now…

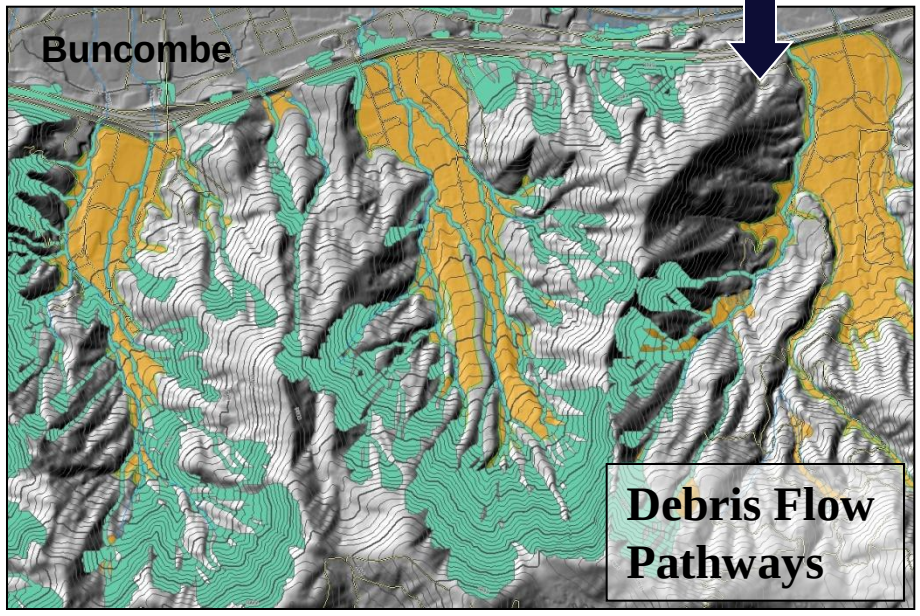


Debris Flow Pathways – where debris flows might go.

Methodology

- Hydrologic Flow paths generated from high hazard SINMAP zones using LiDAR DEM.
- Flow paths buffered to 65 ft (20 m) wide.
- Flow paths terminated:
  - At slopes of 3 degrees in areas > 0.25 acres.
  - When they encounter the 500-year floodplain boundary as mapped by the N.C. Floodplain Mapping Program.
  - When they encounter mapped impoundments > 0.25 acres.
  - At bases of cut slopes.





Mapped debris flow pathways

Potential debris flow pathways

Past debris flow activity (deposits)

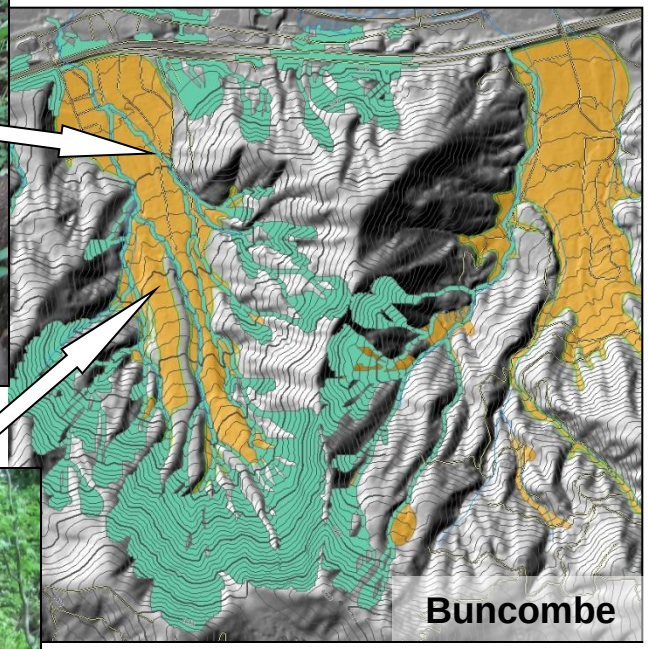
No known past or potential debris flow activity

increasing

Relative Hazard

decreasing

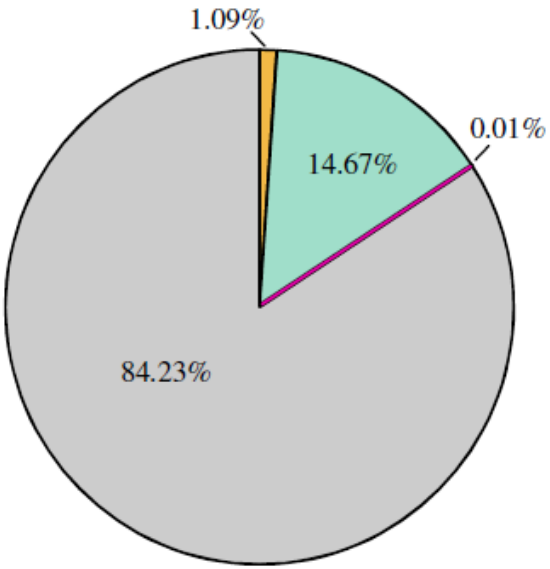
Debris Flow Deposits in Drainages



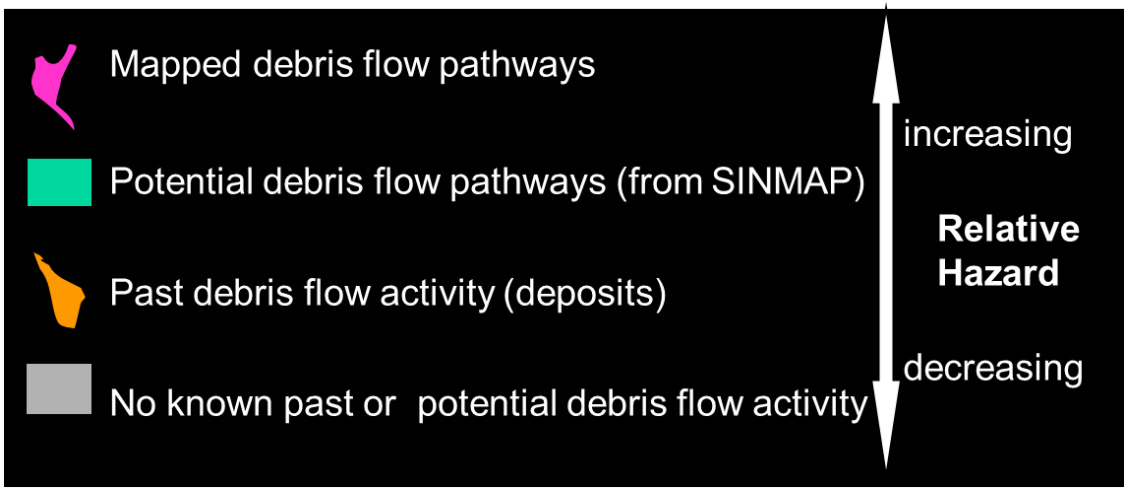
Buncombe

Debris Fan Deposits on Upland Surfaces of Drainage Divides

Debris Flow Pathways – Where debris flow might go if they start

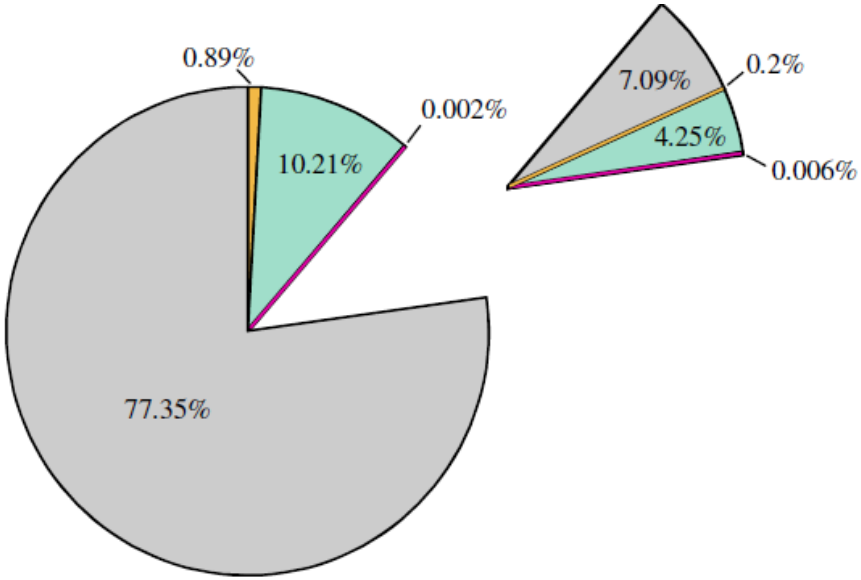


Countywide



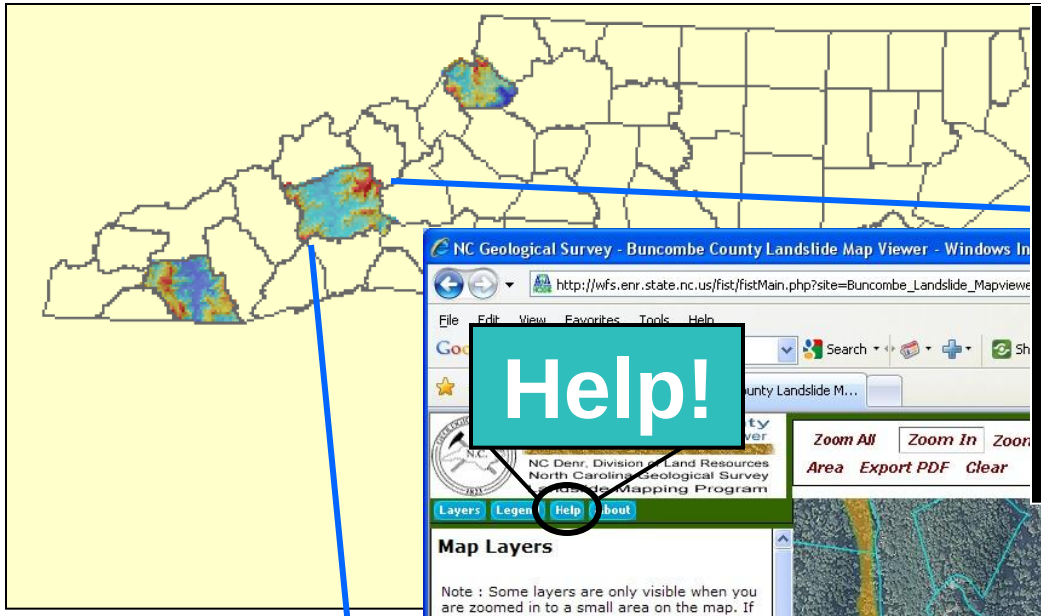
Relative Hazard – Private Lands

Debris Flow Activity	% of County	% of Private Land
Potential and known	10.2%	11.5%
Past	.9%	1%
No known	88.4%	87.4%



Private Lands
(88.45% of county)

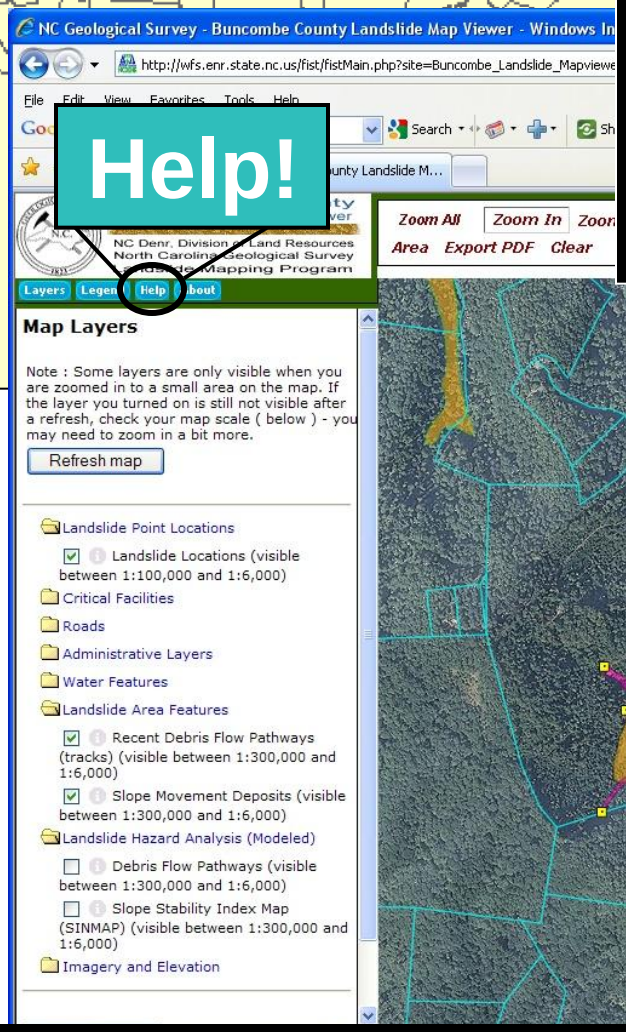
Public Lands
(11.55% of county)



Debris flow initiation zone

Mapped debris flow pathways

Past debris flow activity (deposits)



Landslide Web Map Viewer

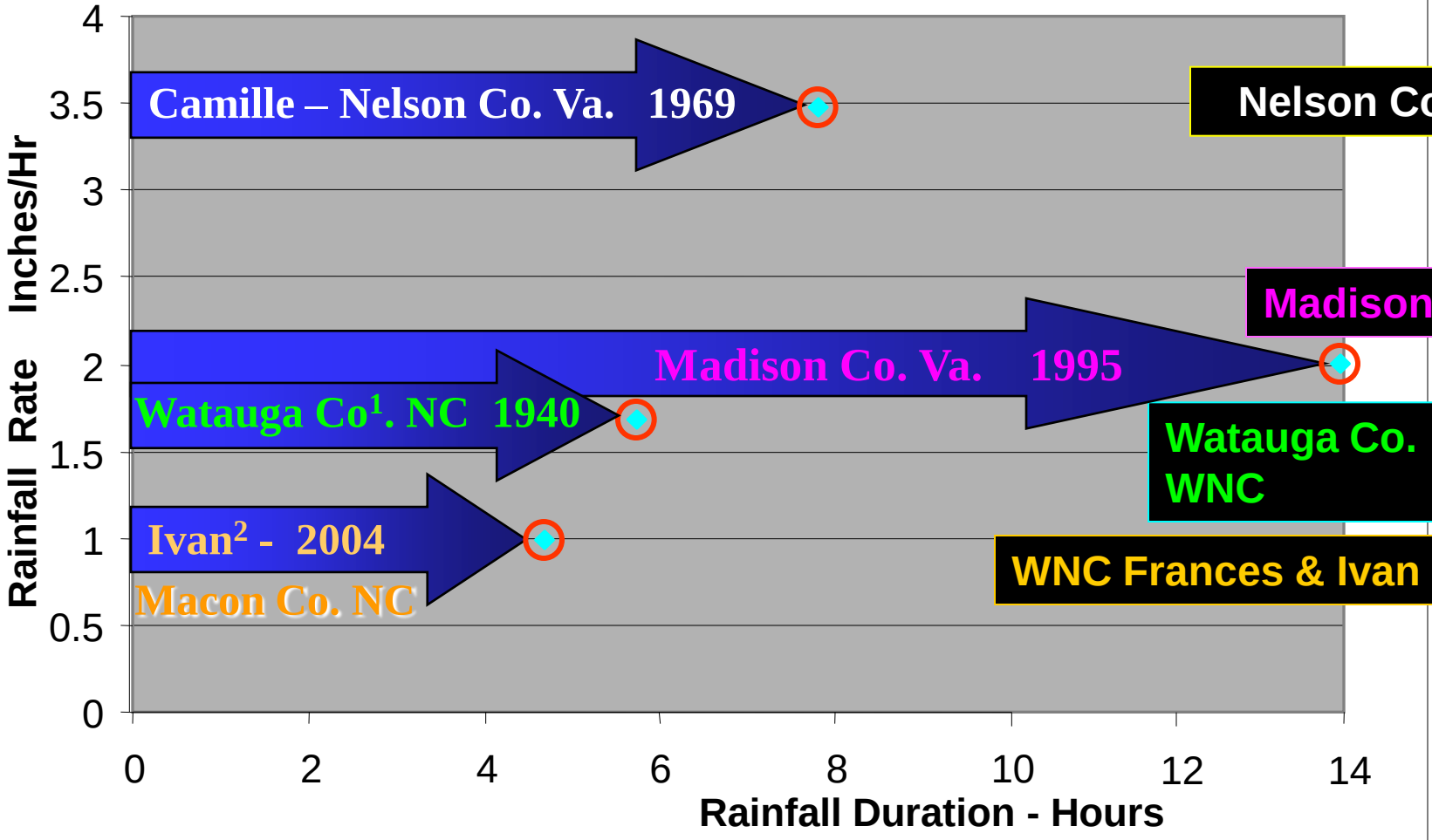
Buncombe County

http://wfs.enr.state.nc.us/fist/

click on '_____Landslide_Mapviewer'

- **Planning and screening tool for local governments, emergency management, and the public.**
- **Delivered to County in a Geographic Information System.**
- **Not regulatory at state level.**
- **Can be used at the parcel-parcel group level.**
- **Not the final word at the parcel - parcel group level.**
- **Do not substitute for a site-specific investigation.**
- **Identify areas where detailed investigations by qualified individuals are warranted and recommended before ground-disturbing activities.**
- **Provides the 'big picture' perspective beyond the site.**

Maximum Rainfall Rate and Duration
- Landslides and Storm Events -



Numbers of Landslides

Nelson Co.	3,793
Madison Co.	629
Watauga Co.	2,100
WNC	>3,000
WNC Frances & Ivan	~400

1 Measured at Laurel Springs , Ashe/Allegheny County line

2 Ivan Storm Total RG 31 Coweeta: 11.34 in / 38 hr. = 0.3 in/hr

(Data for Camille, Madison Co., and rainfall for Watauga Co. from Wieczorek and others, 2004)

Acknowledgements:
NCDOT, USGS, NRCS, NCDWQ-APS, ASU, UNC-CH, N.C. General Assembly, N.C. YAIO, Local Government, Henderson County Residents

QUESTIONS ?

North Carolina Geological Survey

828-296-4632

Rick.Wooten@ncdenr.gov

http://www.geology.enr.state.nc.us

http://www.geology.enr.state.nc.us/Landslide_Info/Landslides_main.htm

Web Map Viewers - http://wfs.enr.state.nc.us/fist/