SLOPE MOVEMENTS AND SLOPE MOVEMENT DEPOSITS MAP OF HENDERSON COUNTY, NORTH CAROLINA

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NORTH CAROLINA GEOLOGICAL SURVEY
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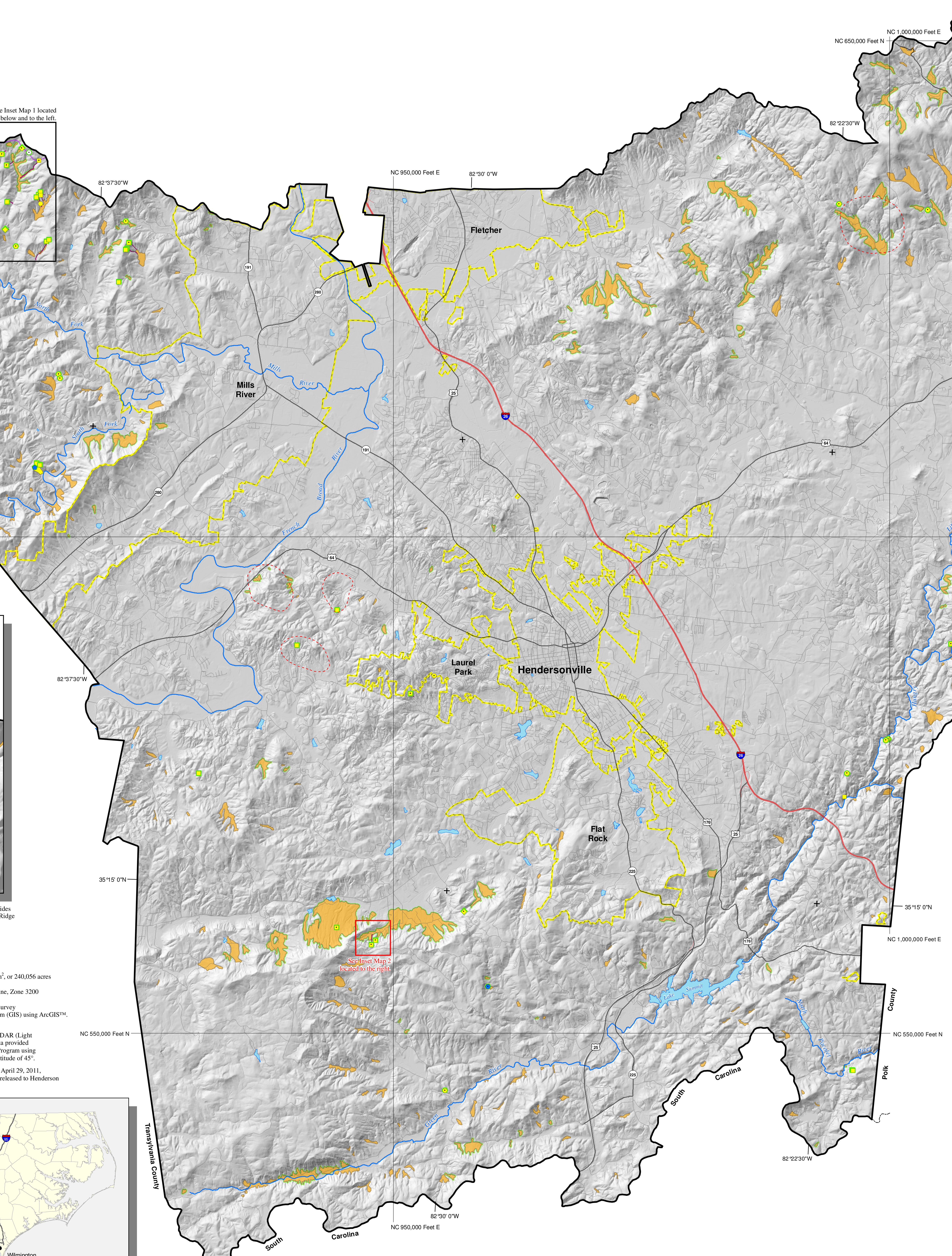
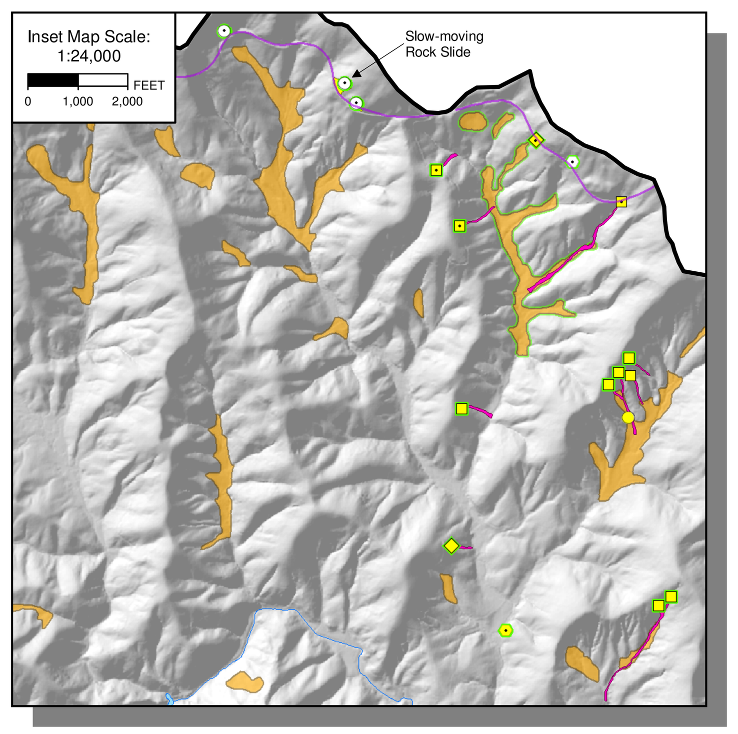
DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

GEOLOGIC HAZARDS MAP SERIES 5
SLOPE MOVEMENT HAZARD MAPS OF HENDERSON COUNTY, NORTH CAROLINA
SHEET 1 OF 3, VERSION: APRIL 29, 2011





Inset map 1. Detailed view of a portion of Pisgah National Forest showing a concentration of landslides triggered by the storm of November 3-6, 1977, and the slow-moving rock slide that closed the Blue Ridge Parkway from Oct 14, 2009 - July 2, 2010.

GRID NORTH

1:48,000

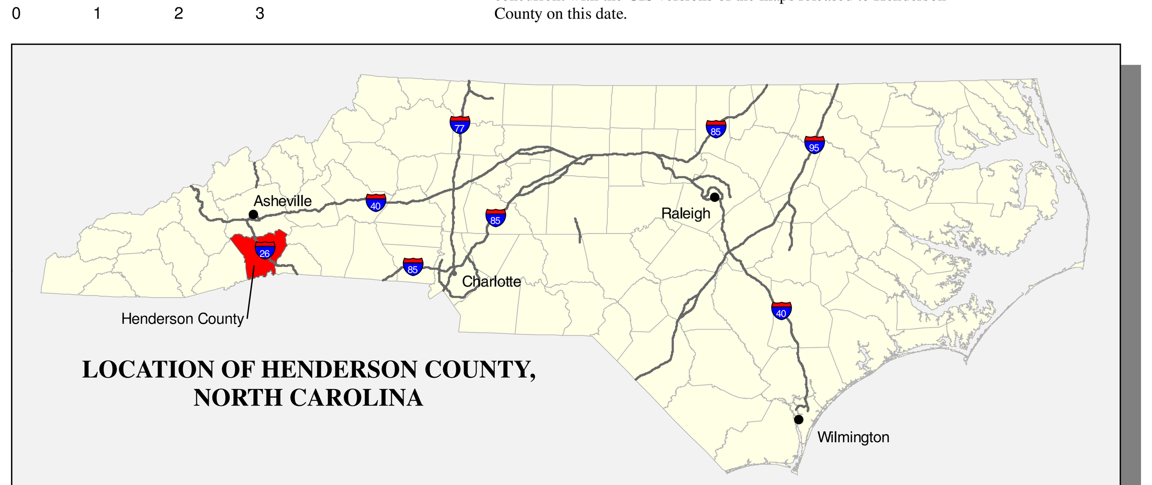
0 1 2 3 MILES

0 1 2 3 KILOMETERS

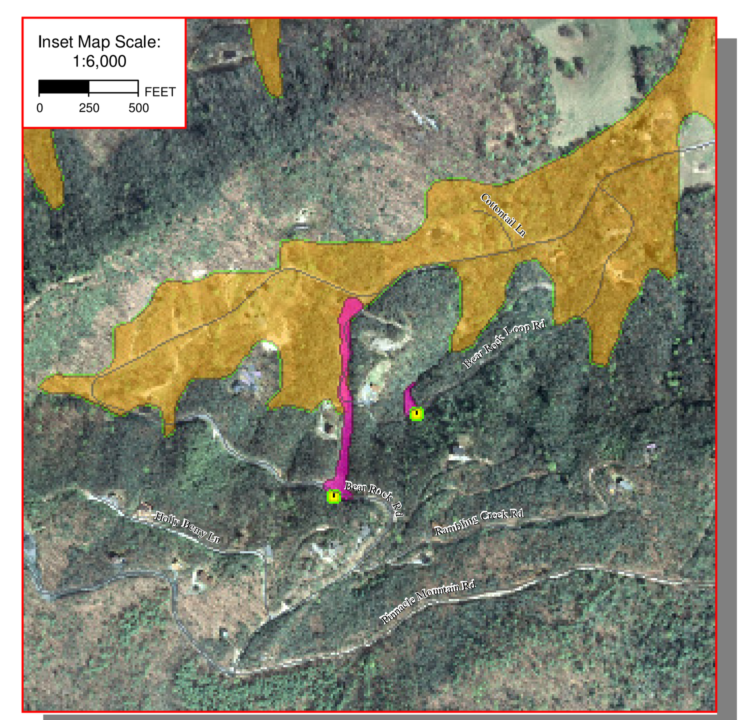
Map Information:
Area of Henderson County: $375 mi^2$, $971.5 km^2$, or 240,056 acres
Datum: North American Datum of 1983
Coordinate System: North Carolina State Plane, Zone 3200
Projection: Lambert Conformal Conic
Cartography by North Carolina Geological Survey
Produced in a Geographic Information System (GIS) using ArcGIS™.

Basemap:
Hillshade derived from 20-foot resolution LiDAR (Light Detecting And Ranging) digital elevation data provided by the North Carolina Floodplain Mapping Program using an artificial sun azimuth of 315° and a sun altitude of 45°.

Based on information and data available as of April 29, 2011, concurrent with the GIS versions of the maps released to Henderson County on this date.



LOCATION OF HENDERSON COUNTY, NORTH CAROLINA



Inset map 2. Detailed view of two debris flows in Bear Rock Estates, Henderson County, shown on a 2007 orthophotographic base. The larger debris flow occurred on September 8, 2004, during Hurricane Frances and the smaller debris flow reportedly occurred in the mid-1990s. This inset shows the maximum recommended scale (1:6,000) for using the landslide hazard map data.

EXPLANATION

MAP FEATURES

Slope movements
- Debris flow track
- Debris or rock slide
- Slow-moving slope movement

Initiation zones
- Debris or earth flow
- Debris or earth slide and flow
- Debris or earth slide
- Debris or earth slide-translational
- Rock fall
- Rock slide
- Rock slide-translational
- Weathered rock slide
- Weathered rock slide-rotational
- Weathered rock slide-translational
- Other

Approximate location of July 15-16, 1916 slope movements

Slope movement deposits
- Slope movement deposit

Modifiers
- Dot indicates slope movement initiated on modified ground
- Green halo indicates slope movement or slope movement deposit was field verified

Roads
- Interstates
- Primary roads
- Secondary roads
- Blue Ridge Parkway

Rivers
- Rivers
- Lakes

Political Boundaries
- Municipal boundaries
- Henderson County boundary

SLOPE MOVEMENT DEFINITIONS

Materials

debris – A soil that contains a significant proportion of coarse material; 20 to 80 percent of the particles are greater than coarse sand (0.08 inches or 2 millimeters), with the remainder finer than 0.08 inches or 2 millimeters.

earth – A soil in which approximately 80 percent or more of the particles are smaller than 0.08 inches (2 millimeters).

rock – An aggregate of one or more minerals, or a body of undifferentiated mineral matter.

weathered rock – A rock that is partly to completely decomposed (Williamson, 1984). This decomposition is the result of physical and chemical weathering processes.

Mechanisms

fall – A type of slope movement in which material abruptly breaks off or detaches from a steep slope or cliff surface. Little or no sliding (shear displacement) along the failure surface is involved, and the detached material descends mostly through the air by free fall, bouncing, or rolling (Varnes, 1987).

flow – A type of slope movement in which the water content in the displaced mass is sufficient for the material to liquefy and behave as a viscous fluid.

slide – Slides are slope movements initiated by outward or downward rupture of displaced material along a well-defined, typically planar or curvi-planar failure surface. Where the geometry of the failure surface is not known, the term slide is applied. Where known, the slide is classified as rotational or translational (see slide-rotational and slide-translational).

slide-rotational – A slide in which the displaced material experiences rotation (and characteristic backward tilting) as it progresses along a failure surface that is curved and concave upward.

slide-translational – A slide in which the displaced material experiences little to no rotation or backward tilting as it progresses downward along a failure surface that is typically planar.

Note: Unless referenced otherwise, the above definitions are in general accordance with Cruden and Varnes (1996) and Jackson (1997).

SLOPE MOVEMENT STATISTICS

Slope Movement Type	Modified	Unmodified	Public Land (11.5% of county area)			Private Land (88.5% of county area)			Slope Movement Total	% of Slope Movement Total
			Modified	Unmodified	Total	Modified	Unmodified	Total		
Debris or Earth flow	21	21	9	12	21	12	9	20	42	46.7%
Debris or Earth slide and flow	4	1	2	1	3	2	0	2	5	5.6%
Debris or Earth slide	13	1	5	1	6	8	0	8	14	15.6%
Debris or Earth slide-rotational	0	1	0	0	0	1	0	1	1	1.1%
Debris or Earth slide-translational	13	0	3	0	3	10	0	9	13	14.4%
Rock fall	1	0	0	0	0	1	0	1	1	1.1%
Rock slide-general	5	0	4	0	4	1	0	1	5	5.6%
Rock slide-translational	1	0	1	0	1	0	0	0	1	1.1%
Weathered rock slide	2	0	0	0	0	2	0	2	2	2.2%
Weathered rock slide-rotational	1	1	0	1	1	1	0	1	2	2.2%
Weathered rock slide-translational	4	0	1	0	1	3	0	3	4	4.4%
Total	**65**	**25**	**25**	**15**	**40**	**41**	**9**	**48**	**90**	**100.0%**
% of Slope Movement Total	72.2%	27.8%	27.8%	16.7%	44.4%	45.6%	10.0%	53.3%	100.0%	

Table 1. Slope movement type versus modified or unmodified slope configuration and whether the initiation zone occurred on private or publicly owned land. Modified slopes are slopes that have been subjected to ground-disturbing activities by humans. Unmodified slopes are slopes that have not been altered by human activity. Debris flows, and debris or earth slides and flows, account for about 83% of the movement types identified in Henderson County. Rock slides, rock falls and slow-moving, deep-seated debris and weathered rock slides are less numerous. Debris flows typically initiate in response to heavy rainfall events of 5 inches or more within 24 hours. These fast-moving slope movements travel downslope and can cause injury or death, and can damage or destroy homes and property.

OVERVIEW OF THE SLOPE MOVEMENTS AND SLOPE MOVEMENT DEPOSITS MAP

Background and Purpose

The North Carolina General Assembly authorized the North Carolina Geological Survey (NCGS) to produce landslide hazard maps for 19 western counties in response to the number of slope movements (landslides) and destruction caused by the remnants of Hurricanes Frances and Ivan in western North Carolina (N.C.) in September 2004. The intent of the landslide hazard program is to provide the public, local government and local and state emergency agencies with a description and location of areas where slope movements have occurred, or are likely to occur, and the general areas at risk from these slope movements. The locations of previous slope movements and their deposits are important because slope movements often reoccur in the same general areas, and they typically deposit material in areas where there are pre-existing slope movement deposits.

The slope movement hazard map series for Henderson County, N.C. consists of three maps (Geologic Hazards Map Series 5 (GHMS-5, Sheets 1, 2, and 3)) that are designed to be used in conjunction with each other. Brief descriptions of this map (Sheet 1) and accompanying maps follow.

1. Sheet 1 (this map), Slope Movement and Slope Movement Deposits Map, shows the extent and distribution of known historical slope movements (all types) and pre-existing slope movement deposits.
2. Sheet 2, Stability Index Map, shows where naturally occurring, shallow, translational slope movements (e.g., debris flows) may begin on slopes without prior ground disturbing activity in response to a major rainfall event.
3. Sheet 3, Map of Known and Potential Debris Flow Pathways, shows where debris flows may travel if they occur.

These printed maps are smaller scale representations of the digital spatial data that have been created for use in a Geographic Information System (GIS) (Wooten et al. 2011). The NCGS's landslide hazard map products are not intended to be a substitute for a detailed, site-specific analysis by a qualified geologist or engineer.

Slope Movements and Slope Movement Deposits Map (Geologic Map Series 5, Sheet 1)

This map consists of data from the N.C. Slope Movement Geodatabase, and is color-coded by entry type (slope movement or slope movement deposit). Definitions and descriptions of slope movements and slope movement deposits are given in the "Explanation" section of the map. Slope movements are classified in general accordance with Cruden and Varnes (1996). The N.C. Slope Movement Geodatabase and this map are compilations of information on slope movements and slope movement deposits derived from numerous sources including field observations by NCGS geologists and other geoscientists listed in the "Sources of Information." New information or future mapping may identify slope movements and slope movement deposits not currently shown on this map.

NCGS geologists mapped features using direct field observations; 1951 and 1982 aerial photography scanned and georegistered for use in a GIS; 1984, 1993, 1998, and 2007 ortho-photography; and, the LiDAR (Light Detecting And Ranging) digital elevation model (DEM). NCGS geologists conducted fieldwork from November 2009 through June 2010, and collected data at approximately 2,000 field locations. The N.C. Department of Transportation (NCDOT) performed soil quality testing on 82 soil samples collected by the NCGS and NCDOT. NCGS geologists completed detailed studies at three debris flow initiation zones in Henderson County, and at two potential debris flow initiation zones in DuPont State Forest in Transylvania County, adjacent to Henderson County. These detailed studies included field measurements of hydraulic conductivity and sampling for soil quality and triaxial shear strength testing performed by the NCDOT.

Individual point and map unit data types included on the map are described below.

1. **Slope Movement Initiation Zones.** These locations identify the initiation areas of slope movements from entries in the N.C. Slope Movement Geodatabase. Data points that identify these zones are symbolized by type of slope movement process.
2. **Debris Flow Tracks.** These map units outline the areal extents of relatively recent individual debris flows.
3. **Debris or Rock Slides.** These map units outline the areal extents of known translational and/or rotational slides that have developed in debris deposits, or bedrock. To be designated as a rock slide, the slope movement had to initiate in bedrock where the degrees of weathering were predominantly micro fresh, visually fresh, and/or stained states as defined by Williamson, 1984.
4. **Slow Moving Debris-Weathered Rock Slides.** These polygons define the areal extent of known, active, slow- to very slow-moving translational and/or rotational slides that have developed in deep (usually >10 ft or 3 m thick) debris deposits and/or weathered bedrock (partly- to completely-decomposed weathering states of bedrock as defined by Williamson (1984). Designation of these slides as active was made using field criteria such as the presence of leaning and curved trees, unvegetated scarps, and reported and observed damage to man-made structures. Movement rates of these slides appear to be on the order of inches to feet (i.e., centimeters to meters) per year, but may vary considerably depending on a number of factors including seasonal rainfall patterns and ground disturbing activities such as excavations. The slow- to very slow-moving velocity classifications used here are in accordance with Cruden and Varnes (1996).
5. **General Areas of 1916 Landslide Occurrence.** On July 15-16, 1916, rainfall from the remnants of a major hurricane tracked over Henderson County causing extensive flooding and triggering many landslides. Six people died from two separate debris flows that were among the 44 landslides reported in Henderson County. The outlines that show the approximate areas within which these landslides occurred are based on local newspaper and historical accounts, as well as limited field confirmation by NCGS geologists. Erosion and revegetation since 1916 have obscured many of the distinguishing features of these landslides, making their exact location difficult to recognize.
6. **Slope Movement Deposits.** These map units show the areal extents of significant volumes of earth, debris and rock fragments that have accumulated as a result of past debris flows and debris slides and, to a lesser extent, rock falls and rock slides. Debris flow deposits mainly occur in valleys and can grade upslope into debris slide, rock fall, and rock slide deposits nearer steep source areas. The mapped slope movement deposits are typically composite features that formed as a result of multiple slope movement processes and events of various ages from prehistoric to modern times. The bulk of the deposits are likely prehistoric in age, but their ages have yet to be verified by modern age-dating techniques. These deposits consist of heterogeneous mixtures of clay, silt, and sand particles with gravel- to boulder-sized rock clasts in various stages of weathering and decomposition. Areas mapped as slope movement deposits met two or more of the following criteria: 1) exhibited an elongate, lobate or fan shape, or other landform characteristic of a slope movement deposit, visible at a scale of 1:7,500 using the LiDAR DEM; 2) had an adequate upslope source area where past slope movements could have initiated; and/or, 3) were verified in the field to contain gravel- to boulder-sized clasts or other textures and depositional structures that characterize deposits produced by slope movements (i.e. matrix supported or imbricated clasts, or scour and fill structures). Many narrow stream valleys likely contain slope movement deposits that are not feasible to map at this scale. Refer to the Map of Known and Potential Debris Flow Pathways (Sheet 3 of 3) for the potential debris flow hazards in these narrow valleys.

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Sources of Information

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Acknowledgements

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