

Summary of Geohazards Data and Data Layers for The Blue Ridge Parkway in North Carolina, and the Carl Sandburg Home National Historic Site

North Carolina Geological Survey

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1. Geohazards database (BRP_Geohaz_Points.mdb, BRP_Geohaz_Points.xls, BRP_Geohaz_Points_Stats.xls).

The geohazards database for the Blue Ridge Parkway is in Microsoft Access™ (mdb) and Excel™ (xls) formats. The database includes locations (latitude and longitude coordinates) and geologic, geomorphic and soil and rock data on known slope movements, potential rock slope movements, and slope movement deposits obtained primarily from field data collected by NCGS staff, and other published sources. Classification of slope movement type is in general accordance with Cruden and Varnes (1996) and Varnes 1978. Summary statistical information for slope movements by type, slope configuration and activity level; and slope movement deposits by type.

2. Deposit point location data layer (deposit_points.shp).

This data layer shows the locations for field verification points for slope movement deposits mapped along the Blue Ridge Parkway and in adjoining National Park Service land (e.g., Doughton Park). Generalized deposit attributes for each point are given in the geohazards database.

3. Deposit polygon data layer (deposit_polygon.shp).

These polygons outline the areal extent of slope movement deposits (e.g., block streams, block fields, talus, colluvium, and debris fans) mapped along the Blue Ridge Parkway. NCGS staff delineated the approximate outlines of the deposits primarily from field investigations, but used 7.5-minute topographic maps, LiDAR DEMs and other published sources where available. Because these features are often quite large in extent, the boundaries of these polygons only extend to the National Park Service boundary; the actual features will often extend further upslope or downslope from the boundary.

4. Outlines of recent slope movements data layer (tracks_outlines.shp).

This data layer outlines the areal extent of relatively recent, individual slope movements such as debris flow tracks and the outlines of slow-moving landslides. Outlines were determined from field investigations and features visible in aerial imagery. Outlines are shown only for those features mappable at a scale of 1:24,000. Smaller features are indicated by point locations in the process point data layer (process_points.shp). Features that initiate outside but cross National Park Service boundaries have been included due to the potential impacts to the Blue Ridge Parkway.

5. Process point data layer (process_points.shp).

This data layer gives point locations for the different types of slope movement processes (i.e., landslides) identified along the Blue Ridge Parkway during this study. The point location represents the initiation zone or head scarp of the slope movement. The point locations are presented by type, activity level, and rock slope hazard ranking. The types



of slope movement are classified in general accordance with Varnes (1978) and Cruden and Varnes (1996). Activity levels are categorized as past active, active, potential, or a composite of activity levels such as “past active/potential,” meaning the location shows evidence of past, and potential future movement. Several types of landslide activity occur along the Parkway. Two of the more prevalent types of slope movement processes identified in the study are summarized below.

Rock slope instability. Rock slope instability in cut slopes is the most frequent and widespread landslide hazard on the Blue Ridge Parkway. Geologic hazard ratings for rock slopes identified as having the potential for significant instability are given a geologic hazard ranking of low, moderate or high. The geologic hazard ratings of low, moderate, and high are generalized rankings for the relative probability of rock fall and/or rock slide activity at a given location. The rankings are based on the kinematic analyses (stereonet) shown on the rock slope analysis sheets, (pdf images linked to this data layer), the size (height, length and angle) of the cut slope, observed seepage zones, relative numbers of dilated or open rock discontinuities, and the presence of sulfidic (potentially acid-producing) rock. All rock slopes given a high hazard rating” are estimated to have a high probability of rock slide and/or rock fall activity in the long term. The high ranking is subdivided into two categories, Priority 1 and Priority 2. Priority 1 rock slopes show indications for rock slide and/or rock fall activity in the near term. Priority 2 rock slopes are judged to have a high potential for rock slide and/or rock fall activity in the long term.

Embankment instability. Embankment failures are also a significant slope movement hazard along the Blue Ridge Parkway. As a result of the heavy rainfall from the remnants of Hurricane Frances in September 2004, several embankment failures mobilized into destructive debris flows that traveled beyond the Blue Ridge Parkway corridor (Collins, 2008, Sas and others, 2008). Debris flows are a type of rapidly moving landslide made up of a mixture of water, soil and rock fragments. The tracks of these embankment failure-debris flows are shown in the data layer tracks_outlines.shp. A detailed study of the existing and potential embankment failures was beyond the scope of the geohazards inventory of the Parkway; however, many obvious areas where embankment subsidence coincided with arcuate cracks in the pavement or road shoulder material were identified. These points identify locations where the potential for continued embankment failure exists. With the addition of sufficient moisture, some of these sites could mobilize into destructive debris flows that travel downslope beyond the Parkway corridor.

6. Slope stability analysis sheets. These sheets are in a pdf format and are hot-linked to stations in the process points data layer (process_points.shp) identified as having past active, active, and/or potential instability. The sheets show images of representative areas of rock cut slopes, locations and orientations of rock slope discontinuities (e.g.,



foliations, compositional layering, fractures) related to the stability of the rock slope. A kinematic rock slope stability analysis in the form of a stereonet plot (Watts and others, 2003) is included on all but a few of the sheets. A few deposit points also have analysis sheets; these sheets are primarily to illustrate what these features look like along the Blue Ridge Parkway.

7. Stability index data layer (BRP_SINMAP raster).

Debris flows are a type of landslide made up of a mixture of water, soil and rock fragments. Debris flows are particularly dangerous because they usually happen without warning, and move rapidly downslope, sometimes in excess of 30 miles per hour. Mountain slopes like those along the Blue Ridge Parkway corridor are prone to debris flows during heavy rainfall events. Debris flows have affected the Blue Ridge Parkway in the past as evidenced by debris flow tracks and debris fan deposits mapped in this study. The stability index map provided for the Parkway corridor is a planning tool to help identify those areas where debris flows on unmodified (i.e., “natural”) slopes are more likely to initiate

The stability index (BRP_SINMAP raster, and BRP_SINMAP.mxd) data layers contain a color-coded raster file that delineates the potential, relative hazard rankings (high, moderate, and low) for the initiation of naturally occurring, shallow, translational slope movements (i.e., debris/earth flows, and debris/earth slides) in response to approximately 5 inches (125 mm) of recharge within a 24-hour period. The three relative hazard rankings are generalized from the six predicted stability zones delineated on the map. Figure 1 provides the definitions and additional information related to the hazard rankings, and the corresponding stability index categories and stability zones. SINMAP does not predict that shallow translational slope movements will occur, but it predicts that if they do, where they are more likely to initiate given the assumptions and input parameters used in the analysis. Debris/earth flows and debris/earth slides typically originate where thin (usually less than 6 ft or 2 m thick) soil overlies relatively low permeability layers such as bedrock or weathered bedrock on steep slopes, typically those greater than 20 degrees (36 percent). This map is intended to indicate the distribution of high and moderate hazard areas where further slope stability analysis and assessment, including field verification, are recommended prior to undertaking ground disturbing activities in areas susceptible to debris flow initiation. SINMAP does not predict where failures on modified ground will occur (i.e., embankment failures).



Map Color Code	Stability Class	Relative Debris/Earth Flow/Slide Hazard ¹	Stability Index (SI) 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	$0.0 > SI > 0.0$	Maximum FS < 1	100%	Range cannot model stability	Stabilizing factors required for stability.
	Upper Threshold of Instability		$0.5 > SI > 0.0$	$> 50\% \text{ of FS } \leq 1$	$> 50\%$	Optimistic half of range required for stability	Stabilizing factors may be responsible for stability.
	Lower Threshold of Instability	Moderate	$1.0 > SI > 0.5$	$\geq 50\% \text{ of FS } > 1$	$< 50\%$	Pessimistic half of range required for instability	Destabilizing factors are not required for instability.
	Nominally Stable	Low	$1.25 > SI > 1.0$	Minimum FS = 1	—	Cannot model instability with most conservative parameters specified	Minor destabilizing factors could lead to instability
	Moderately Stable		$1.5 > SI > 1.25$	Minimum FS = 1.25	—	Cannot model instability with most conservative parameters specified	Moderate destabilizing factors are required for instability
	Stable		$SI > 1.5$	Minimum FS = 1.5	—	Cannot model instability with most conservative parameters specified	Significant destabilizing factors are required for instability

Figure 1. Stability class definitions for stability index map units delineated using SINMAP. Modified from Pack and others (1998, Table 1).

Explanatory notes for Figure 1:

- ¹ **Relative Debris/Earth Flow/Slide Hazard Ranking.** This column designates the relative hazard ranking for the initiation of shallow translational landslides on unmodified (i.e. natural) slopes.
- ² **Stability Index.** The stability index is a numerical representation of the relative hazard for initiation of shallow translational slope movements based on the factors of safety computed at each point on a 20 ft (6 m) digital elevation model grid derived from LiDAR (Light Detecting and Ranging) elevation data. The stability index is a dimensionless number based on factors of safety generated by SINMAP that indicates the probability that a location is stable considering the most and least favorable parameters input into the model.
- ³ **Factor of Safety (FS).** The factor of safety is a dimensionless number computed by SINMAP using the infinite slope equation that represents the ratio of the stabilizing forces that resist slope movement to destabilizing forces that drive slope movement. A FS > 1 indicates a stable slope, a FS < 1 indicates an unstable slope, and a FS = 1



indicates the marginally stable situation where the resisting forces and driving forces are in balance.

⁴ **Probability of Instability.** This column shows the likelihood that the factor of safety computed within this map unit is less than one ($FS < 1$, i.e., unstable) given the range of parameters used in the analysis. For example, a <50% probability of instability means that a location is more likely to be stable than unstable given the range of parameters used in the analysis.

⁵ **Possible Influences of Stabilizing or Destabilizing Factors.** Examples of stabilizing factors include increased soil strength, root strength and improved drainage. Destabilizing factors include increased wetness due to road drainage or loading, or loss of root strength.

8. Visible sulfide minerals point data layer (Visible_Sulfide_Stations.shp). This data layer shows locations where field observations identified visible sulfide mineral(s) in exposures along the Parkway (see Appendix B).

9. Acid-producing rock test locations data layer (NNP_testing.shp). This shape file shows the locations of stations where bedrock was sampled and tested for their acid producing potential using the net neutralization potential (NNP) test. Ranges of values for the NNP test results for each station are color-coded. The sample descriptions and NNP test values for each are also included in the geohazards database. (see Appendix B).

10. Acid-producing rock potential ranking polygon data layer (Acid_Potential.shp). This shape file shows the relative ranking of the major rock units mapped along the Parkway for the occurrence of acid-producing rock (see Appendix B).

11. Mines. Mine locations and near the BRP (BRP_mines.shp). This layer shows the locations of known mines in the Blue Ridge Parkway corridor within the National Park Service Boundary. Mine data as of September 2008 were accessed through the Minerals Resource Data System (<http://tin.er.usgs.gov/mrds/>) maintained by the U.S. Geological Survey.

12. LiDAR Elevation Data (Hill Shades\County Name). Hillshade (shaded relief) maps for the counties crossed by and adjacent the Blue Ridge Parkway in North Carolina are included in the BRP SINMAP.mxd data layer. These hillshade maps were generated using the 6 m pixel resolution LiDAR digital elevation data provided by the North Carolina Floodplain Mapping Program.



13. Appendix A. Stability Index (SINMAP): Map Production, Infinite Slope Equation and Input Parameters.

Map Production. The map was produced using SINMAP software, an ArcView™ 3.x extension developed by Pack and others (1998) for use in a geographic information system (GIS). SINMAP computes a factor of safety (FS) for each pixel on a 20 ft (6 m) LiDAR-derived digital elevation model (DEM). The FS is calculated from the input hydrologic, soil and topographic data using the infinite slope model (Figures A1-A3) (Pack and others, 1998; Hammond and others, 1992). The FS is a dimensionless number that represents the ratio of the stabilizing forces to destabilizing forces at a location. A $FS < 1$ indicates unstable conditions, whereas a $FS > 1$ indicates stable conditions given the assumptions and parameters input into the model. SINMAP then assigns a stability index based on the computed factors of safety. The six stability zones are assigned relative hazard rankings (high, moderate, and low) based on the calculated stability index ranges and known slope movement occurrences (see Figure 1).

Model input parameters include upper and lower bounded values for recharge, soil transmissivity (soil hydraulic conductivity multiplied by soil thickness), and other soil properties (i.e., unit weight, thickness, effective friction angle, effective cohesion). SINMAP randomly samples the bounded input parameter values from a uniform probability distribution to account for the variability and uncertainty inherent in natural systems. Visual-manual soil classifications and soil descriptions along the Parkway augmented with laboratory soil test results from the NCGS soil database were used to assign basic soil properties. These soil classifications, descriptions and test results, along with values for soil properties used for similar geologic units found in Macon and Watauga Counties (Wooten and others, 2006 and 2008), and literature values for soil properties given in Hammond and others (1992) were used to constrain reasonable ranges of soil input parameters for the stability index modeling along the Parkway. The stabilizing affect of vegetation is accounted for as root cohesion in the dimensionless cohesion parameter (see **Input Parameters**). Input values for root cohesion were constrained using the results of recent research at the U.S. Forest Service Coweeta Hydrologic Laboratory (Hales and others, 2007). SINMAP uses slope and topographic convergence derived from the LiDAR elevation data to model saturation in convergent hollow areas.

The 5-inch (125 mm) steady state recharge value used in the SINMAP analysis approximates an equivalent amount of rainfall within a 24-hour period. This recharge value is used because historical evidence (Eschner and Patric, 1982; Neary and Swift, 1987; and Witt, 2005) and recent examples in North Carolina indicate that 5 inches (125 mm) of rainfall within a 24-hour period is an approximate threshold for triggering debris/earth flows and slides. Watershed studies at the U.S.D.A. Forest Service Coweeta Hydrologic Laboratory in Macon County show that 3-19% of rainfall from storms is direct runoff (storm flow) rather than recharge (Hewlett and others, 1984). If this is the case, then as much as 6 inches (154 mm) or more of rainfall may be required to produce the 5 inches (125 mm) of recharge used in the SINMAP analysis.



SINMAP uses topographic catchment areas derived from digital elevation data to model soil wetness where shallow groundwater flow lines are assumed to converge in areas of concave topography. For this reason, and to avoid anomalous boundary effects in the SINMAP model along artificial landscape boundaries, it was necessary to run the SINMAP model using watershed boundaries that extend well beyond the Parkway corridor. We input generalized soil property values to reflect those more consistent with those found along the Parkway (i.e., thinner, less cohesive soil, and clast-supported block stream and block field deposits) than those considered representative of the distribution of properties across entire watersheds. For display purposes the SINMAP model results were then clipped to a 500 m buffer along the National Park Service boundary.

Model Calibration

The model calibration (i.e., the parameter adjustment process) was performed as recommended by the developers of SINMAP (Pack and others, 1998). Initial model runs used ranges of parameter values selected and constrained from the sources described above. Parameter values (primarily dimensionless cohesion, soil thickness, internal angle of friction, and hydraulic conductivity) were then adjusted within reasonable ranges so that the majority of the slope movement locations used for calibration were captured in the high hazard (upper threshold and unstable) zones.



Infinite Slope Equation. The variation of the infinite slope equation shown below is used by SINMAP to calculate factors of safety and derive stability indices used to generate the stability index map.

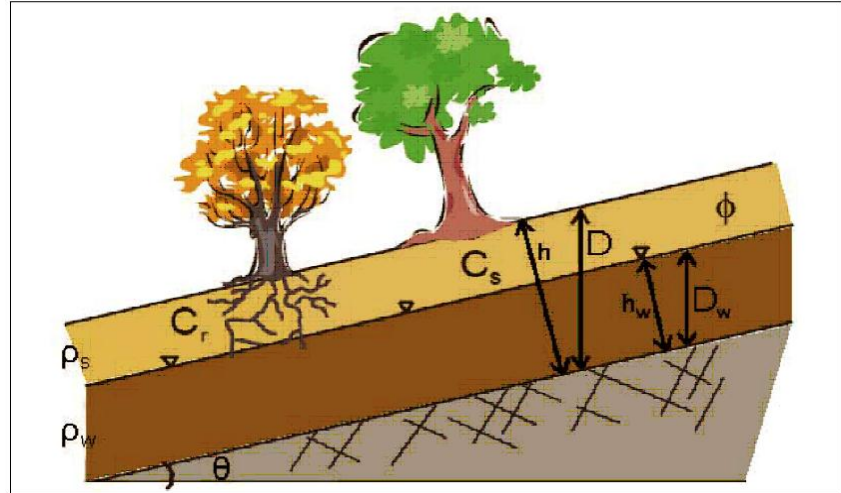
$$FS = \frac{C + \cos \theta \left[1 - \min \left(\frac{R}{T} \frac{a}{\sin \theta}, 1 \right) r \right] \tan \phi}{\sin \theta}$$


Figure A1. Schematic of showing the modified version of the infinite slope equation and a cross section of generalized hillslope conditions used to compute factors of safety in SINMAP (adapted from Pack, Tarboton, and Goodwin, 1998).

FS = Factor of Safety: Ratio of forces resisting slope failure to the forces driving slope failure. A $FS > 1$ indicates stable conditions whereas a $FS < 1$ indicates unstable conditions. SINMAP computes a factor of safety at each point on the 20ft(6m) LiDAR DEM grid to derive the stability index.

a = Topographic catchment area (see diagram below).

C = Dimensionless cohesion = (soil cohesion + root cohesion) / (soil depth x soil density x gravity constant). See **Input Parameters**.

R = Recharge (5 in./24hr assumed).

T = Soil transmissivity = soil hydraulic conductivity (K_{sat}) x soil thickness.

ϕ = Soil internal angle of friction.

θ = Slope.



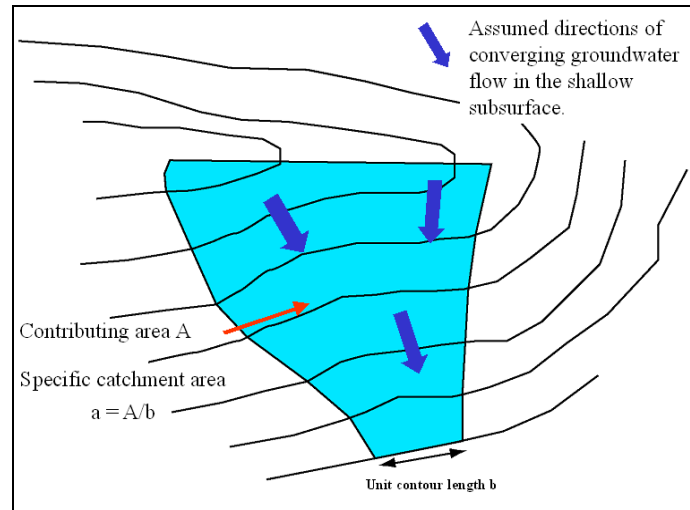


Figure A2. Schematic showing an example of a topographic catchment derived from digital elevation data and used by SINMAP to model soil wetness. Shallow groundwater flow lines are assumed to converge in areas of concave topography.

Input Parameters. This section defines the parameters and explains the parameter value input and sampling procedure used by SINMAP. The parameter values for each of the calibration regions used to produce the stability index map for the Blue Ridge Parkway corridor are shown in Table 1 on the Blue Ridge Parkway Project.mxd stability index layer.

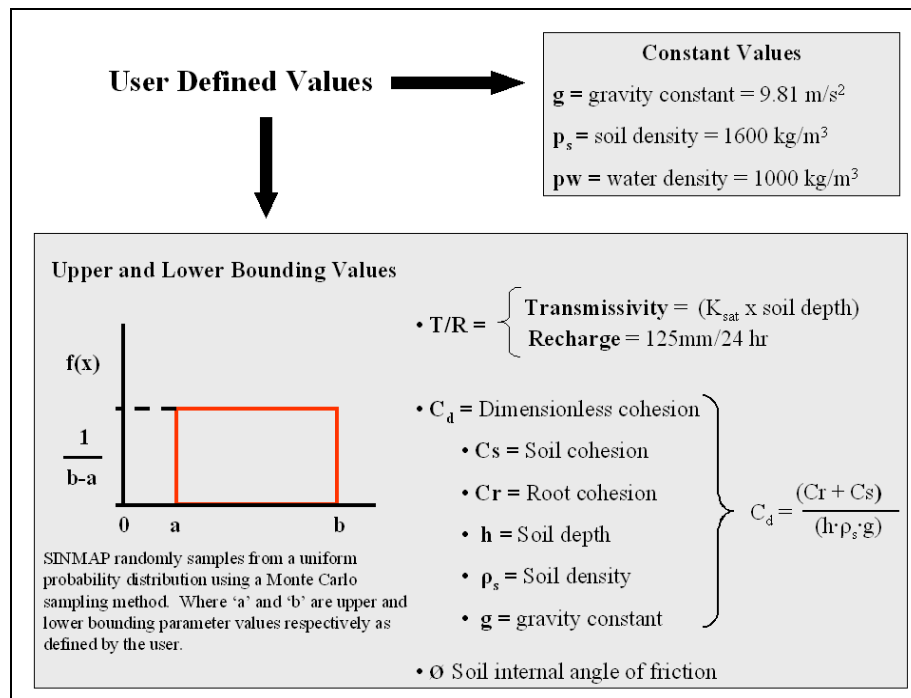


Figure A3. User-defined values used as input parameters for the infinite slope equation in the SINMAP model.

For each calibration region SINMAP allows the user to define constant values, and upper and lower bounding values for certain parameters (Figure A3). SINMAP uses upper and lower bounded values to define uniform probability distributions for T/R (transmissivity to recharge ratio), C_d (dimensionless cohesion), and ϕ (soil internal angle of friction). SINMAP then uses these constant values, and values randomly sampled from the uniform probability distributions, for input into the modified infinite slope equation to compute factors of safety and derive the stability indices.

14. Appendix B. Acid-producing Rock Potential: Summary and Guidelines.

Background. Acid-producing rocks are common in the western Blue Ridge of North Carolina. Most rocks in the western Blue Ridge contain at least trace amounts of sulfide minerals, but at concentrations below that necessary to produce harmful environmental impacts when exposed. Schaeffer and Clawson (1996) and Douglas and others (2007) report acid-producing rock, primarily within the Murphy Belt and Great Smoky Group rocks in western North Carolina, that contains concentrations of sulfide minerals sufficient to warrant mitigation measures when encountered in engineering projects. Bryant and others (2003) summarize many of the engineering and environmental problems associated with acid-producing rocks. The acid-producing potential of rocks results from the naturally occurring iron sulfide minerals contained in them. Numerous rock types exposed along the Blue Ridge Parkway (BRP) contain iron sulfide minerals. Pyrite (FeS), pyrrhotite (Fe_{1-x}S), and, to a lesser extent, chalcopyrite (CuFeS_2) are the most common iron sulfide minerals found in these rocks.

Excavation greatly increases the exposed area of the rock and constituent minerals and accelerates weathering of sulfide-rich rock types. Oxidation and hydrolysis of the freshly exposed sulfide minerals produces sulfuric acid runoff with a pH as low as 2.5. This runoff can cause a sudden decrease in pH in nearby streams. Migration of acid runoff into surface waters can degrade water quality and kill aquatic life as happened in 1963 during reconstruction of U.S. Highway 441 near Newfound Gap in the Great Smoky Mountains National Park. Acidic runoff is usually greatest shortly after road construction; however, acidic runoff can continue at a decreased level for years after construction. Acid-producing rocks can also adversely affect slope stability, particularly if untreated material is used in embankments and in some cases when the rocks are exposed in road cuts.

Identification of Potential Acid-Producing Rock on the Blue Ridge Parkway. Field observations, geologic mapping, and laboratory testing of rocks sampled at selected locations were used to assess the areas most likely to have acid-producing rock along the Blue Ridge Parkway (see *NNP_testing.shp*, *Visible_Sulfide_Stations.shp*, and *Acid_Potential.shp*). The North Carolina Department of Transportation – Asheville



Geotechnical Unit performed net neutralization potential (NNP) tests on sixteen rock samples collected from cut slope exposures along the Parkway. The NNP test, also known as the Acid Base Accounting (ABA) test, consists of testing the Acid Potential (AP) and the Neutralization Potential (NP) of rock samples. The results are reported as the Net Neutralization Potential (NNP), which equals the Neutralization Potential (NP) minus the Acid Potential (AP). Test procedures are described in detail in Sobek and others (1978) and summarized in Byerly (1996).

Test results for the Blue Ridge Parkway samples are shown in Figure B1. In practical terms the NNP test value equals the number of tons of calcium carbonate (CaCO_3) needed to neutralize 1,000 tons of acid-producing material. Test values less than -5 indicate rocks with a significant acid-producing potential. For example, an NNP value of -5 means that 5 tons of CaCO_3 are needed to neutralize 1,000 tons of the tested material.

The purpose of the testing along the Parkway was to confirm the presence of sulfide minerals made from visual observations; therefore, the test data are biased towards those exposures suspected of having sulfide minerals present. A few control samples were tested that were suspected to have only trace amounts of iron sulfide mineral, i.e., a NNP value > -5 . The NNP test data help quantify the range of values of acid producing potential that can be expected for rock types exposed along the Parkway.

NNP test values ranged from a high of 19.7 to a low of -273.3. The seven schistose rock samples make up the majority of test results with an NNP less than -5 and occur in all the major geologic divisions tested (Figure B1). The lowest NNP test value of -273.3 is very localized muscovite schist containing a visible zone of concentrated sulfide minerals sampled from the Ashe Metamorphic Suite sampled from the same outcrop sequence shown in Figure B2. The occurrence and concentration of iron sulfide minerals in rocks varies widely; therefore, it is important to note that the NNP test values presented do not characterize entire map units, but represent localized, acid-producing rock types interlayered with those that may not be acid producing.

The geologic units mapped along the Parkway are subdivided into segments that are assigned a high, medium or low potential for the occurrence of acid-producing rock types. The rankings of these segments are based on the presence of graphitic, sulfidic schist layers and observed sulfide minerals (Visible_Sulfide_Stations.shp), and the results of NNP testing (NNP_testing.shp). Rocks of the Great Smoky Group and part of the Otto Formation are ranked as having a high potential for acid-producing rock. Rocks of the Ashe Metamorphic Suite and Alligator Back formation are ranked as having an overall moderate potential for acid-producing rock. All other map units delineated along the Parkway are ranked as having a low acid-producing rock potential. These subdivisions and corresponding rankings are shown in the Acid_Potential.shp data layer. Specific outcrop locations identified to contain graphitic, sulfidic schist or sulfide minerals are given in the geohazards database (BRP_Geohaz_Points.mdb and/or



BRP_Geohaz_Points.xls), and shown on an accompanying data layer (processes_points.shp)

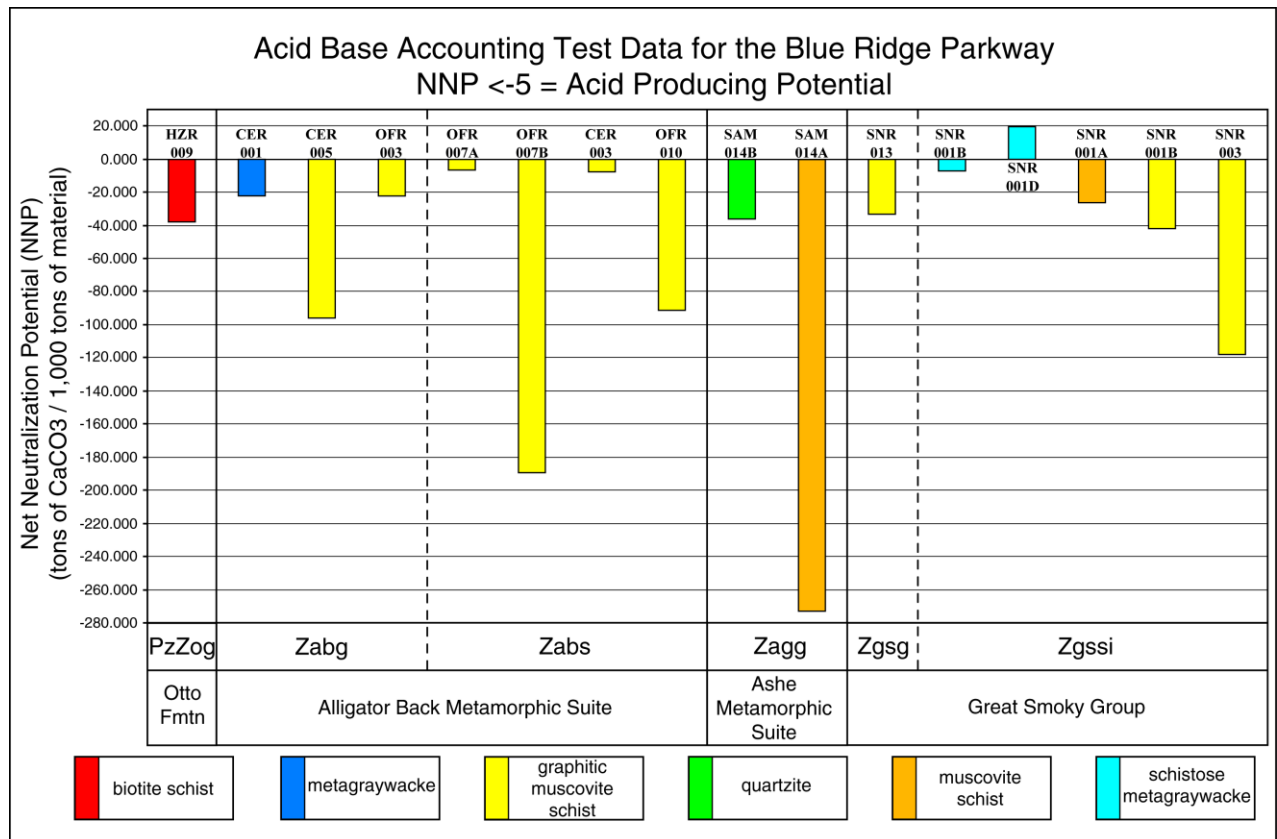


Figure B1. Chart showing the NNP test results for sixteen samples categorized by rock types and grouped within mapped bedrock units along the BRP. Data point numbers for outcrop locations are shown for each color bar. Letters after the same data point numbers indicate different samples tested from one data point location (e.g., OFR-007A, OFR-007B).

Recognition Criteria. Recognizing rocks that have acid-producing potential is the critical first step in avoiding potential problems with acid runoff or slope instability (Figures B2-B4). The weathered surfaces of these rocks are commonly highly stained with an orange-brown color from iron oxides, and can be covered with secondary white to yellowish sulfate minerals (Figures B2 and B3). In some cases secondary, white gypsum “blooms” stand in relief on exposed bedrock surfaces. Some rock types in southwestern North Carolina contain about one to five percent of these iron sulfide minerals, whereas other rock types contain less than one percent. The high-sulfide rock types include dark-gray to black, graphitic, sulfidic schist and phyllite, as well as associated metagraywacke. Graphitic rocks typically have a silvery gray sheen on fresh surfaces (Figure 4) and will leave a dark gray smear of graphite on paper.



The technology and expertise to mitigate the adverse affects of acid-producing rocks exists within the Federal Highways Administration and the North Carolina Department of Transportation. During construction, mitigation measures usually involve isolating or neutralizing the acid-producing rock. Isolation can be achieved using low permeability clays to encapsulate acid-producing materials, whereas neutralization is typically done with calcium carbonate (CaCO_3) derived from limestone or marble. Byerly (1996) and Bryant and others (2003) describe various handling and mitigation methods.



Figure B2. Close up view of shiny pyrite crystals (blue arrows) surrounded by dark orange, iron oxide staining on a fracture surface in quartzite (SAM-014B).





Figure B3. White gypsum blooms, and yellow (jarosite?) and dark orange oxide coatings on sulfidic metagraywacke exposed adjacent to the June 15, 1999 rockslide (CER-001) near Crabtree Meadows. The NNP test value for this rock was -22.02 as shown on Figure 1.



Figure B4. Left – August 18, 2006 rockslide (SNR-001) near the Cranberry Ridge overlook in metagraywacke and graphitic, sulfidic schist. NNP test values here range from -19.7 in schistose metagraywacke (SNR-001D), to -41.9 in graphitic sulfidic schist (SNR-001C) shown on Figure 1. **Right** – Close up view of broken rock fragments of rock slide debris with parts of the vehicle totaled in the slide. Iron oxide stained weathering surfaces and a dark gray sheen on the freshly exposed broken faces of the rock fragments typifies graphitic, sulfidic rocks.

Mitigation Measures. Our field observations did not identify any locations where acid runoff appears to result in obvious adverse environmental impacts; therefore, we do not recommend any measures to mitigate the affects of acid-producing rock at this time. If in the future, substantial quantities of acid-producing rock are freshly exposed through road reconstruction or rock slope failures, then mitigation measures such as isolation or treatment of the rock material may be warranted. For example, if large volumes of acid-



producing rock need to be removed from the roadway as in the case of the August 18, 2006 rockslide near the Cranberry Ridge overlook, then it is recommended that the acid-producing waste material: 1) be isolated; or, 2) not be stockpiled where runoff can enter streams; or 3) not be stockpiled on steep slopes where it could contribute to slope instability.

15. Appendix C. Geologic Hazards at the Carl Sandburg Home National Historic Site.

NCGS staff reviewed literature and made field traverses at the Carl Sandburg Home National Historic Site (CSHNHS) to identify any geologic hazards present on the property. The only significant geologic hazard noted at the CSHNHS was the potential for radon in both the indoor air and in drinking water wells on the property. This potential radon hazard occurs as a result of the uranium rich rock in the area, particularly in the Henderson Gneiss.

The EPA recommended maximum contaminant level (MCL) for radon in groundwater is 300 pCi/L. They have proposed an alternate MCL of 4000 pCi/L for wells and have an established mitigation program for indoor radon. Figure 1 shows the location of the CSHNHS and the peak of Glassy Mountain relative to wells in the area that were tested for radon. Many of the wells around CSHNHS have levels of radon well above the EPA's recommended MCL and alternative MCL. Information on radon in this area was obtained from Campbell (2006) and is included with this deliverable for your reference in BRP2008\Peripherals).



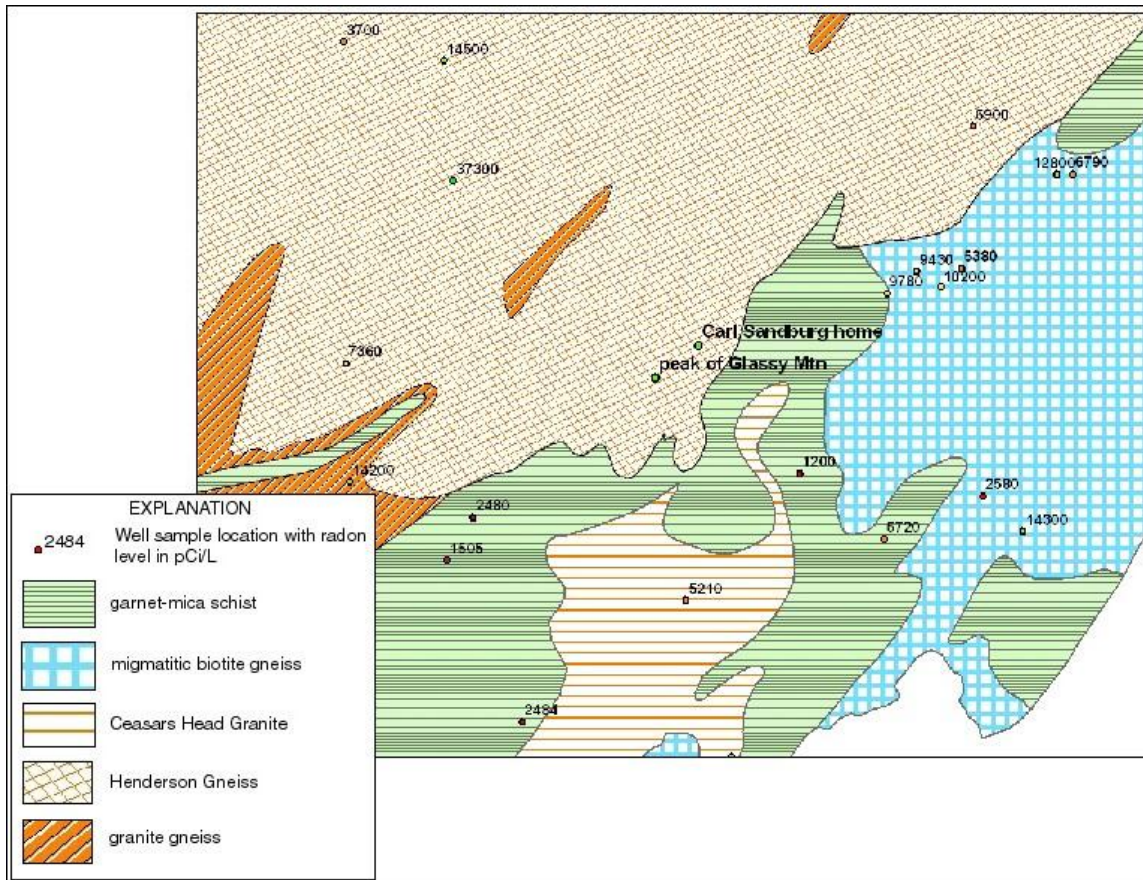


Figure C1. Radon levels in water wells near the CSHNHS. All points exceed the EPA's recommended MCL, and most exceed the EPA's alternate MCL.

16. References

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