GRAIP_Lite and Slope Stability: Nation-wide Model Runs for Watershed Condition Framework Assessments – About these Data

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****For those looking here for which fields to use, the most directly applicable for the WCC update using the current watershed classification guide (Potyondy and Geier, 2011) are `WCF_RdDen_FSOp` and `WCF_RdCon_FSOp`. These are, respectively, the "open road density" and "proximity to water" attribute scores under item 6. "Roads and Trails Condition Indicator." In addition, the `FSOp_SumPos` field, which includes stability Index information, may be of interest given its relevance to the "mass wasting" attribute. That said, as described below, interpretation of the stability data is more complex, and their application to WCF is less direct than it is for the other attributes. Besides these three fields, there are many additional fields available that provide important contextual information that may be useful in rating road conditions. More details are provided below.**

Introduction

These datasets were produced to provide consistent, broad-scale, science-based datasets for analyzing the effects of roads on watershed condition as part of the Watershed Condition Framework. The metrics provide information based on uniform methods across the country that specifically consider road design and management differences (surfacing, location relative to potential stream networks, maintenance) while largely setting aside broad-scale differences caused by geologic and climatic factors, other than those represented by the topography of the landscape.

Units

GRAIP_Lite (Nelson et al. 2019) performs calculations in the SI unit system commonly used in scientific and academic work (the National_SI and Regional_SI geodatabases). Since most users of this data are more likely to be using the U.S. Customary units (USC), and the thresholds for condition classes also use those units, we have done the appropriate unit conversions to provide a dataset using the USC units (the National_USC and Regional_USC geodatabases). It is important to note that, since we are using a unit baserate, any sediment production and delivery values are index values and are not representative of actual sediment masses. If a baserate is known or can be reasonably approximated, those values can be multiplied by the index values to estimate actual sediment masses. However, baserate data is not currently widely available. Similarly, all slope stability values are index values and local knowledge is needed for interpretation.

Data Fields

The Watershed Condition Framework considers four different types of potential road impacts. GRAIP_Lite provides direct information for two of these impacts, open road density and proximity to water, and we provide WCF attribute scores for these two metrics across three populations of roads: all roads, only Forest Service system roads, and only open Forest Service system roads. The WCF attribute scores (i.e., condition class 1, 2, or 3) for road density are listed in the **`WCF_RdDen_All`**, **`WCF_RdDen_FS`**, and **`WCF_RdDen_FSOp`** attribute fields, and are calculated based on the **`tden`**, **`tdenFS`**, and **`tdenFSOp`** attribute fields. The WCF attribute scores for proximity to water are based on the modeled connection rates, defined as the length of connected road normalized by total road length, which are in the **`con`**, **`conFS`**, and **`conFSOp`** fields; the WCF scores from those fields are in the **`WCF_RdCon_All`**, **`WCF_RdCon_FS`**, and **`WCF_RdConFSOp`** attribute fields. These calculated scores, found in each of the regional Geodatabases and the National_USC and National_SI geodatabases, can be directly incorporated into watershed condition assessments, as they are calculated to directly assess the specific metrics listed in the Watershed Condition Classification (WCC, Potyondy and Geier, 2011).

Data for three populations of roads, as described above, are provided because while some of WCC rating criteria (e.g., “open road density” attribute) suggest that only “open roads” (i.e., maintenance level 2-5) should be evaluated, other language suggests otherwise. For example, the criteria note that: 1) the term “road” is broadly defined to include roads and all lineal features on the landscape that typically influence watershed processes and conditions in a manner similar to roads; and that 2) if roads have a closure order but are still contributing to hydrological damage they should be considered open for the purposes of road density calculations. Given these criteria, Forest-level staff are best positioned to determine which of these fields are most suitable for the landscapes that they manage. Importantly, all of these fields are based solely on the roads data in the FS-INFRA database.

Additional Road Surface Erosion Estimate Information

These geodatabases contain data on other potentially relevant metrics and indices in addition to those specified directly for WCF assessments. We developed GRAIP_Lite (https://www.fs.fed.us/GRAIP/GRAIP_Lite.html) to model road surface sediment production and delivery to stream networks, which provides some additional detail for possible consideration. The most useful as a companion to the density and proximity metrics might be the sediment delivery ratios, defined as the mass of delivered sediment normalized by the mass of produced sediment, or percent delivery. The data for sediment delivery ratios, for each of the three road classes, can be found in the **`sdr`**, **`sdrFS`**, and **`sdrFSOp`** attribute fields, where they are listed as fractional delivery; percent delivery would be calculated by multiplying these numbers by 100. We also provide specific sediment indexes for both production and delivery, which represent sediment mass normalized by the HUC area (i.e., index values analogous to tons/acre, e.g. **`specdelFSOp`**). This measure summarizes segment scale calculations using the combined effects of road slope, road location relative to streams, surfacing (as recorded in INFRA), and information about the maintenance level to estimate the fine sediment effects of roads. The explicit influences of local geology and climate data are excluded from this measure so it just reflects the integrated effects of road density, proximity to streams, and design factors like surfacing and slope. It will be high where there are many miles of steep, unsurfaced roads close to streams, and lower where roads are targeted towards ridgetops and near-stream roads are surfaced with gravel or pavement and kept to low gradients.

Slope Stability Index Information

We estimate the risk from roads increasing landslide risk, via shallow landsliding, in steep colluvial hollows prone to such failures. Our slope stability metrics were developed by modifying the method used in SINMAP (Pack, et.al., 2005) which calculates a factor of safety for slope stability. Assuming a soil density of 1600 kg/m^3 and an internal friction angle of 45 degrees, we calculate the minimum dimensionless cohesion value (C) that would result in a stable slope. Higher values of C imply less stability and lower values imply greater stability. The road layer is then intersected with the resultant grid of C values to identify where roads cross ground of varying stability. This approach is not intended to assess road-related mass wasting risks associated with other processes (e.g., earthflows), which need to be assessed by other methods.

The slope stability data can be found in the National_SlopeStability and Regional_SlopeStability geodatabases. For each HUC12 watershed, we provide the number of grid cells representing each of the three road classes; we also provide the number of grid cells that have a C value greater than 0. We provide sums of all road grid cells, and of only the positive values, for each of the three road classes, as well as the means and standard deviations for each road class and for the landscape as a whole.

Given the assumptions for soil density and internal friction angle, **positive values would be predicted to be unstable**. This means that a larger sum of positive C values would represent a larger potential risk of mass wasting events associated with roads within the watershed (**`FSOp_SumPos`**). Since the amount of road in each watershed varies greatly, a watershed could have a lot of only slightly unstable road and have a higher sum than a watershed with less road on somewhat riskier terrain. Keeping this in mind, dividing the sum by the total number of road grid cells would give a representation of the average risk for roads within a given watershed, and the sum itself indexes the cumulative total potential risk of mass wasting events. Since uniform parameters were used across the country, this index provides a value that could be used to compare one watershed with others, but it is important to recognize that it is only an index value. Depending on local variations in climate (e.g. precipitation intensity), drainage density, and soil density and internal friction angle, a local stability threshold may be greater than or less than the index value. These index values should be used by comparing basins in an area based on local knowledge to gain a sense of where those stability relationships may be, and what sort of values represent actual risk issues associated with the road network. Consideration of 'endmembers' (i.e., different watersheds with known high risk and others with known low risk) would be especially informative.

References

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