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Global Positioning System/GIS-Based Approach for Modeling Erosion from Large Road Networks

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Abstract: Sediment budget analyses require watershed scale evaluation of road erosion and delivery. The Watershed Erosion Prediction Project (WEPP) model, as developed by the USDA Forest Service, simulates sediment detachment and delivery for a road, fill, and buffer system. Time and budget constraints typically prevent a comprehensive sediment loading analysis using WEPP throughout a watershed. We present an automated approach to run the hillslope version of WEPP to simulate sediment detachment and delivery for a large road network. Road attributes are acquired from global positioning system-assisted road surveys and mapped in a geographic information system (GIS). After data manipulation in GIS and Excel, the required input files for WEPP are built. The approach can be applied to multiple road designs and climate regimes, with unique attributes for each road segment. We applied the automated approach to the 3,040 km² South Fork Clearwater River watershed for 1,017 km of road divided into 6,955 road segments. The availability of analysis capabilities of the WEPP results from large road networks within GIS provides a spatially explicit tool for the management and evaluation of sediment production throughout large road networks.


CE Database subject headings: Sediment; Runoff; Watershed management; Erosion; Roadside hazards.

Introduction

In forested watersheds, road erosion can provide a large portion of the total sediment load to streams. Burroughs (1990) estimated that in the mountains of the western United States, forest roads contribute as much as 85–90% of the sediment reaching streams in disturbed forest land. In many forested watersheds improper management has lead to excessive delivery of sediment to water bodies, adversely affecting water quality and spawning habitat. Idaho Department of Lands (IDL 2000) identified roads as the primary source of sediment from management activities in forested areas. In order to remediate these problems, in accordance with the Clean Water Act, watershed managers have been court mandated to develop total maximum daily loads (TMDLs), which include evaluating both natural background pollutant loading and current pollutant loading, identifying how the pollutant is delivered from the watershed and the source of the pollutant. In Idaho alone there are over 900 water bodies which have required TMDL assessments.

Since there seldom are any observed data to quantify how much sediment is coming from road erosion, mass wasting processes, hillslope erosion, etc., and since there is not enough time or resources to develop an intensive monitoring plan, watershed managers have relied mainly on either regional empirical models (WATSED [USFS 1992], BOISED [Potyondy et al. 1991], NEZSED [Gloss 1995], or WATBAL [Patten 1989]); or inventory techniques [Washington Forest Practices [WFPB 1995] or CWE methodology (IDL 2000)] to account for sediment loading from a watershed. The advantages of these models and techniques are that they are simple, have limited input requirements, and can be easily applied to large watersheds. The disadvantages are that they rely heavily on interpretation by field crews, include many general assumptions, often ignore key hydrologic processes, and are limited to the areas for which they were developed or calibrated. Despite these limitations, which are usually acknowledged in the TMDL reports, these methods are widely used because they are "the best available method at hand" (IDEP 2001).

With the ever growing advancement of computer technology and programming, more complex physically based models [WEPP (Flanagan and Livingston 1995); DHSVM (Wigmosta et al. 1993); SMR (Frankenberger et al. 1999)], which have been used primarily in research applications, are becoming a valid alternative to the more empirical modeling techniques in management applications. These physically based models explicitly represent the interaction between multiple hydrologic processes throughout complex landscapes to predict the cumulative effect of multiple management practices. Since these models are based more on the physical hydrologic processes they are better suited than empirically based models to be adapted to different climate regions. Often these models work with geographic information system (GIS) software which assists in management decisions over a wide range of spatial scales. The disadvantages of physically based modeling are that models are more complex, requiring a significant amount of training to learn how to properly apply the