# SEDIMENT DEPOSITION FROM FOREST ROADS AT STREAM CROSSINGS AS INFLUENCED BY ROAD CHARACTERISTICS

**A.J. Lang, W.M. Aust, M.C. Bolding, and K.J. McGuire[1]**

**Abstract--**Recent controversies associated with ditched forest roads and stream crossings in the Pacific Northwest have focused national attention on sediment production and best management practices (BMPs) at stream crossings. Few studies have quantified soil erosion rates at stream crossings as influenced by road characteristics and compared them to modeled rates. Soil erosion rates were measured and modeled from forest roads that represented a range of road classes (permanent high standard to temporary low standard). Forty road approaches were identified in the Piedmont and Mountain regions of Virginia and categorized into four general road classes. Road attributes were characterized at each crossing (BMPs used, road width, grade, gravel, cover, cut and fill slope ratios, ditch characteristics, etc.). At each stream crossing, conveyor belts were installed as water-control devices across the road to divert sediment from the stream crossing approach into silt fence sediment traps. Sediment pins were installed adjacent to the silt fence to allow periodic measurement of sediment depths. Additionally, erosion potentials for approaches were modeled with the Universal Soil Loss Equation (USLE) as modified for forestry and compared to actual sediment deposition near the stream. Data presented represents < 1year of sediment measurements from the stream crossings.

## INTRODUCTION

Erosion from unsealed road surfaces is a primary contributor of sedimentation within forests in the United States (Hewlett 1982, Stuart and Edwards 2006, Yoho 1980). Sedimentation, regardless of its origin, can negatively impact aquatic stream life and society (Gibson and others 2005, Hewlett 1982). Forestry best management practices (BMPs) are methods and practices designed to minimize water quality problems associated with forest management practices (Sohngen and others 1999). BMPs have been designed to focus on forest operations with the greatest risks of environmental degradation, such as stream crossings, skid trails, landing sites, and roads (Aust and Blinn 2004). Although BMPs address a variety of nonpoint source pollutants, including nutrients, temperature, organics, and chemicals, the primary purpose of BMPs is to reduce erosion and subsequent sediment yields. Many states throughout the United States commonly use forestry BMPs at stream crossings to reduce negative impacts to waters (Shepard and others 2004).

In forest management, significant attention has been directed to BMPs applied at stream crossing because of the proximity to stream networks (Aust and Blinn 2004). Road construction disturbances, such as clearing vegetation, constructing ditches, and compaction of the road surface on stream crossings and their approaches, alter the hydrology, increasing the probability overland flow and subsequent soil erosion and sediment delivery to the stream (Ziegler and others 2007). Planning road location, increased water control structures, increased surface coverage, and decreased approach grades, among others, have been shown to reduce erosion rates and sediment delivery at stream crossings (Luce and Black 1999, Swift 1985).

Several equations and soil loss models have been developed to evaluate the effectiveness of BMPs and other methods to curb soil losses from stream crossings. Erosion models have a great potential to aid land managers and other stakeholders in planning for and selecting preventative measures (Fu and others 2010). The complexities of soil erosion over spatial and temporal scales and a lack of quantified values over time create difficulty within the modeling processes (Jetten and others 1999, Sukhanovskii 2010). The Universal Soil Loss Equation (USLE) method of estimating soil erosion is the most widely used in the United States because of its ease and ability to generate estimations in the field (Christopher and Visser 2007). While the estimates are imperfect, several studies have shown the USLE estimations to be capable of accurately ranking erosion rates from different treatments (Sawyers and others 2012, Wade and others 2012).

Additional legal focus has been placed on forest road stream crossings. In the Pacific Northwest, a series of lawsuits have challenged the status of forest operations to construct stream

[1]Graduate Research Assistant, Professor, Associate Professor, and Assistant Professor, respectively, Virginia Polytechnic Institute and State University, Department of Forest Resources and Environmental Conservation, Blacksburg, Virginia, 24061.

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crossings under the silviculture exemption without additional Environmental Protection Agency oversight (Boston 2012, Boston and Thompson 2009). While the U.S. Supreme Court ruling has reversed the decision of the Ninth Circuit Court, further litigation is likely to ensue. The issue emphasizes the need for better understanding of sediment delivery from stream crossings and further research assessing the effectiveness of BMPs (Anderson and Lockaby 2011). The objective of this study was to quantify sediment deposition across different road standards and compare them to modeled erosion estimates.

## MATERIALS AND METHODS

### Study Sites

Twenty-four stream crossing approaches were located on six tracts of timber in the Piedmont physiographic regions of Virginia on MeadWestvaco (MWV) managed lands. MWV was managing stands of loblolly pine (*Pinus taeda* L.) for 18- to 25-year rotations, and hunt clubs leased the land for recreational purposes. An additional 16 stream crossing approaches were located on three tracts in the Ridge and Valley physiographic region of Virginia on USDA Forest Service and Virginia Tech school forest managed lands. Forest Service roads were gated and received low traffic throughout the study. The Virginia Tech school forest had moderate to high levels of traffic, as it was utilized for teaching exercises and by municipal personnel. All streams are classified as intermittent or perennial.

### Installation

A rubber conveyor belt was installed at approximately a 45° angle across the roads at the lowest topographic point nearest the stream crossing using hand tools. At each stream crossing approach, a narrow trench was excavated at a 30° to 45° angle across the road. A conveyor belt with the dimensions of approximately 30-cm wide by 1.25-cm thick was cut to length according to road width and buried, leaving approximately 15 cm of the belt exposed above the surface in order to divert water and sediment from the road into the adjacent silt fence catchment area (Robichaud and Brown 2002). Several pins were placed in the catchment area for periodic measurements of sediment depths (Lakel and others 2010). The rubber conveyor belt allowed for passage of vehicular traffic. To prevent the belts from being pulled out of the trench, two 0.9- by 46-cm rebar stakes were driven in on the edges of the belt (away from the travel surface) at an angle. In addition to the stakes, three pairs of scrap boards were affixed to each side of the belt using screws to fasten them to the bottom portion of the conveyor belt. Some locations also required the conveyor belt to be altered further to disperse the tension generated by traffic. In these instances, vertical slits were made in the belt to alleviate additional force and prevent the belt from being removed by traffic passes. Installations occurred between June and November 2012.

### Data Collected

The following approach characteristics were collected: GPS location, aspect, distance to nearest water control structure, length to natural grade break, width of the running surface, template, road surfacing type and coverage, grade, soil texture, slope shape, canopy coverage, crossing type, number of water control structures, ditch length, width, and depth, cut and fill slope dimensions and the percent vegetation coverage, and time since last road maintenance. Road classes were assessed and assigned by a panel of professional foresters and were used as a basis for comparison (table 1). Sites were revisited seasonally to re-examine canopy and surface coverage. Precipitation data were collected from the nearest known weather stations to study sites. Periodic measures of sediment depth were taken using an electronic total station to the nearest 0.01 foot.

### Sediment Delivery Calculation

Sediment yield is the ratio of sediment delivery and total gross erosion (Glymph 1954, Lu and others 2006, Williams 1977). This study compared trapped sediment deposition (sediment yield) verses USLE model estimates of total potential erosion to estimate sediment delivery ratios. Factors that affect sediment delivery ratios include sediment source, proximity to water, watershed and soil characteristics, and topography (Lu and others 2006).

**Table 1--Road class sampling by physiographic region**

| Road class | Mountains | Piedmont | Total |
|---|---|---|---|
| Class 1 | 0 | 4 | 4 |
| Class 2 | 8 | 3 | 11 |
| Class 3 | 8 | 12 | 20 |
| Class 4 | 0 | 5 | 5 |
| Total | 16 | 24 | 40 |

## RESULTS AND DISCUSSION

### Road Characteristics and Sediment Deposition

Higher road classes were found to produce less sediment than lower class roads (table 2). However, the individual road characteristics that collectively created the road classes were not good indicators of trapped or modeled sediment deposition. Specifically, mean percent slope, road area, percent bare soil and distance to the nearest water control structure varied in predicted and measured sediment deposition by assigned road classification. The variance observed can be understood and justified by realizing the spatial and temporal complexity of road approaches. Each approach is a complex combination of road characteristics. Better characteristics for one attribute may offset poorer characteristics of another and vice versa. Documented characteristics of approaches in different road classes are important for calibration of sediment delivery models.

**Table 2--Mean trapped and predicted sediment yield and sediment delivery ratio (SDR) by assigned road class**

| Road Class | Trapped sediment yield | Predicted sediment yield | SDR |
|---|---|---|---|
| | *------tons/acre/year------* | | *percent* |
| Class 1 | 0.05 | 1.93 | 3 |
| Class 2 | 1.23 | 0.61 | 100 |
| Class 3 | 1.48 | 1.59 | 93 |
| Class 4 | 6.92 | 6.18 | 100 |

### Sediment Delivery

The mean modeled (USLE) gross erosion rates by road class were similar to the trapped deposition (table 2). None of the road classes exceeded a mean of 7 tons per acre per year of trapped sediment deposition. Mean trapped sediment increased with decreasing road standards. Mean (USLE) predicted soil erosion increased in classes 2 through 4, while the class 1 mean predicted (USLE) was greater than class 2 and 3. Several of the class 1 roads in this study had steep approaches that may have increased predicted means (USLE) since the USLE model emphasizes slope. If sediment delivered to silt fence catchment areas equated to sediment delivered to streams, then the sediment delivery ratio for class 1 roads was only 3 percent, while all other classes were at or near 100 percent (table 2).

## CONCLUSION

Assemblages of road characteristics collectively control the variation in sediment yield. Lower standard roads have a greater erosion potential on a per unit area basis, but may erode less than higher standard roads due to smaller areas. Research has been conducted regarding road characteristics and their influence on erosion, but less research has examined the sediment delivery ratio attributable to BMPs and road standards. Observed road approaches in this study captured a range of road characteristics that enabled us to make simple calculations of sediment delivery ratios. These sediment delivery ratios are an index of BMP efficiency. Additionally, the range of data should provide information to better calibrate erosion models. Overall, it appears that the enhanced BMPs used by the higher class roads decreased the sediment delivery to streams.

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