SEDIMENT FLUX AND STORAGE IN A SOUTHEASTERN PIEDMONT RIVER SYSTEM

John Kirkwood Martin[1], C. Rhett Jackson[2], David S. Leigh[3] and Larry T. West[4]

AUTHORS: [1]Graduate Student, Warnell School of Forest Resources, The University of Georgia, Athens, GA 30602; [2]Assistant Professor, Warnell School of Forest Resources, The University of Georgia, Athens, GA 30602; [3]Associate Professor, Department of Geology, The University of Georgia, Athen, GA 30602; [4]Professor, Department of Crop and Soil Sciences, The University of Georgia, Athens, GA 30602.
REFERENCE: Proceedings of the 2001 Georgia Water Resources Conference, held March 26-27, 2001, at the University of Georgia. Kathryn J. Hatcher, editor, Institute of Ecology, The University of Georgia, Athens, Georgia.

Abstract. Total Maximum Daily Load sediment limits need to be assessed for Georgia. There is a need to create sediment budgets to prioritize sediment reduction efforts loadings for Non Point Source Pollution. Early analysis for Murder Creek reveal that there is a large source of sediment in floodplain storage. Volume analysis of exported sediment indicate that there has been large amounts of sediment mobilized after 1950. Dendro-geomorphology data reveal that there has been slight floodplain accretion over that time period. These factors suggest that constant erosion of stored sediments from past land uses may lead to elevated and continued levels of sediment in Georgia's waterways.

INTRODUCTION

Sediment is the single most important water quality problem and the largest contributor by volume of Non Point Source Pollution (NPSP) in the U.S. (Neary et. al. 1988). In Georgia, especially the Piedmont Province, there is a past and present problem with Non Point Source Pollution entering the state's waterways. The Clean Water Act (1972) has mandated that all of the nations' states develop a Total Maximum Daily Load (TMDL) program that will protect the nation's water from many specific pollutants, including sediment. Currently, Georgia is required by court order (Sierra Club vs. John Hankinson) to develop TMDLs for several of the state's waterways that are not meeting designated uses. The relative role of silvicultural activities among contributors of sediment to state waters is unknown. The objective of this project is to create a sediment budget for Murder Creek (near Eatonton, Georgia) to determine to what degree the forest industry may be responsible for the current problem of sediment in the state's waterways and to prioritize water quality improvement efforts.

One way to evaluate the relative contribution of silvicultural activities to sediment loads is to calculate a basin-wide sediment budget for a "representative" basin, which includes a typical mix of rural land uses. A sediment budget attempts to quantify sediment inputs to a stream system, internal storage volumes, and sediment export from a stream system. In rural basins in the Georgia Piedmont, typical sediment sources include silvicultural activities, row-crop agriculture, livestock operations, unpaved county roads, and eroding roadside ditches. One of the benefits of a sediment budget is that a relative ranking of sediment inputs by activity will help prioritize water quality improvements through the TMDL process.

We selected the Murder Creek (539 km^2) basin as our representative basin for several reasons. Dominant land uses are forestry and cattle farming, and there is some row-crop agriculture and rural residential land use. The basin includes a small town (Monticello), but no active urbanization. The basin drains into Lake Sinclair, which was constructed in 1949-1950, and sediment deposition in Lake Sinclair can be used to calculate a long-term average bedload estimate. Also, Murder Creek has a long term USGS gage that includes prior measurement of suspended sediment concentrations.

REVIEW OF SEDIMENT BUDGETS

Use of reservoir surveys has been found to be a valuable tool in volumetric analysis of sediment exported from the watershed (Schick 1993). For example, Beach (1992) used reservoir sedimentation to calculate an average rate of soil loss for two watersheds. He combined reservoir survey data with an estimated Sediment Delivery Ratio to obtain an average rate of soil loss for the watershed. Similarly, in a arid watershed in Israel, reservoir surveys were used to improve suspended and bedload sediment export estimates from a previous sediment budget created on the same watershed (Schick 1993). Dendy and Bolton (1976), used reservoir sedimentation surveys to evaluate the effect of drainage area and mean annual runoff on sediment yield. They found that as basin size increased sediment yield decreased. This indicates that less sediment is being transported out of the basin and more sediment is going into storage as basin area increases.

"Empirical based models estimate erosion based on field studies of the statistical soil losses that result from specific land uses on specific soils on specific slopes" (Beach 1992), and they are the prevailing type of model for large watershed erosional studies. Researchers use USLE because it is a predictive model that can be widely used and has been validated to predict soil erosion from the landscape. The USLE has been used to estimate erosion in numerous sediment budget studies (Beach 1992, Trimble 1983, Phillips 1991, USGS 1980). For example, Beach (1992) showed that reservoir sedimentation data and predicted total erosion by the USLE showed strong convergence in two different watersheds. The similarity between these numbers verify the validity of using the USLE in estimating erosion rates from watersheds.

It has long been recognized that unpaved roads are a major contributor of sediment to water systems (Reid and Dunne 1984, Swift 1988, Ketcheson and Megahan 1996, Megahan and Kidd 1976). Sediment production from roads can be attributed to various factors such as road prism and drainage design, aggregate quality and traffic volume (Foltz 1996). In the Southern Appalachian Region, Swift (1988) attributed variations in sediment production on roads, with similar traffic volume, to differing types of road aggregate. They found that soil loss from a lightly graveled road was similar to the soil loss from an ungraveled road. Foltz (1996) found that "poor" quality aggregate roads produced 4 to 17 times the amount of sediment runoff from roads than the study sections that had "high" quality aggregate. Reid and Dunne (1984) found that forest roads with heavy (loaded trucks) traffic volumes generated sediment concentrations of up to 31,000 mg/L. In contrast, they found that if traffic is reduced to light vehicular traffic, sediment production may be reduced to 0.8% of the heavy traffic road. Clearly roads must be accounted in a sediment budget as a source of sediment production in a watershed.

Silvicultural operations have been implicated as a source of sediment in Georgia's streams. Rasmussen and Green (1997) noted an increase in turbidity from Piedmont ephemeral streams that was due to improper construction of roads and skid trails, unstabilized stream crossings, rutted streamside management zones, and logging debris left in the stream. A similar study in Eastern Kentucky looked at harvesting effects on streamwater quality with respect to Best Management Practices (BMPs). Three watersheds were selected: an uncut reference watershed (A), a clearcut watershed with BMPs employed (B), and a clearcut watershed with no regard for BMPs (C). The authors found that "[the] sediment flux from Watershed C was double that of Watershed B during the treatment period, and one and a half times greater then [Watershed B] during the post-harvest period," (Arthur et. al 1998). The higher and persistent sediment yield from Watershed C was attributed to the lack of BMPs on road construction and skid trails (Arthur et. al 1998).

Previous studies in the field have attempted to quantify sediment inputs from forestry operations. While the studies have helped quantify NPSP in watersheds, they fail to take into account the resident sediment moving through the system. We suggest that this slug of sediment was deposited years ago and is mostly responsible for the elevated and continued levels of turbidity in some of Georgia's streams. Trimble (1975) calculated that, within the Savannah River watershed, only four percent of the soil eroded from the Piedmont uplands since the 1700's has been carried past Augusta, Georgia. This project will attempt to quantify the historical and modern flux of sediment through a Piedmont watershed as a result of forestry and other land use activities by creating a sediment budget. The information obtained should aid in the development of a sediment TMDL for Georgia Piedmont streams and determine to what degree silvicultural activities may be responsible for sediment entering the state's waters.

STUDY DESIGN

Sediment contributions by land use activity, export from suspended and bedload sediment, and total floodplain storage will be measured and analyzed to create the sediment budget for Murder Creek.

Contributions of Sediment:

The addition of sediment into Murder Creek will be analyzed from three potential sources. First, gross erosion from the landscape will be calculated. The Revised Universal Soil Loss Equation (RUSLE) is the standard method to analyze overland erosion for large scale studies (Beach 1992). Land cover data will be interpreted and used to define land use within the watershed. Land use data from 1998 LANDSAT satellite photos will be used to run the RUSLE model and determine gross erosion from the landscape. In addition to the RUSLE estimate of erosion, Total Suspended Solids (TSS) from first order streams on forested and clear-cut sites, will be assessed to determine export of sediment into the watershed from silvicultural activities. Inputs of sediment from county roads will be estimated using WEPP:Road (1999), a model developed by the USDA Forest Service.

Storage of Sediment:

To estimate historical sediment storage, data on depth to the prehistoric floodplain soil surface will be collected. The historical floodplain consists of stratigraphic layers of sediment over a prehistoric soil boundary. This transitional zone is marked by a change in texture of soil that has high mica content to soil that has a reduced or gleyed clay textural horizon (West and Leigh pers. comm.). Floodplain soil series from the Natural Resources Conservation Services' maps will be digitized and geo-referenced into ArcView. If depth to the pre-historical floodplain show no relationship with stream order, drainage area, elevation or slope the floodplain area will be multiplied by an average depth to the pre-historic floodplain to obtain a current volume of sediment storage in the watershed.

Estimates of annual rates of floodplain sediment accretion will be done using dendro-geomorphology techniques (Sigafoos 1964). Depth of sediment deposition will be obtained by excavating trees that have their root crowns buried. The trees will then be cored to determine the trees' age. Depth to the buried root crown and the age of the trees will then be used to quantify annual sediment accretion rates.

Export of Sediment:

Sediment data from the United States Geological Survey (USGS) will be used to calculate a flow duration curve from a gage located on Murder Creek. From the flow duration a curve, a cumulative frequency curve will be developed to represent the percentage of time that a flow is equaled or exceeded. TSS export can then be estimated by entering TSS, at a specific discharge, into the cumulative frequency curve. The data will then be presented as the amount of TSS export, in Murder Creek, expressed as a percentage of time.

Bedload export will be calculated by conducting a reservoir survey. Sediment depths in the Murder Creek arm of Lake Sinclair will be collected. A Trimble GPS unit will be used to obtain x y values (through differential correction) and z (elevation) values will be calculated by subtracting sediment depth from the pool elevation. This data will then be imported into ArcView and added to the original, geo-referenced contour survey of the reservoir before dam closure. Grid data will be constructed to define the sediment depths for current and original reservoir volumes. In ArcInfo, the CUTFILL command will be used to change in volume from current depths to original depths. Since most reservoirs have high sediment retention rates, this volume will be assumed as the bedload export from Murder Creek.

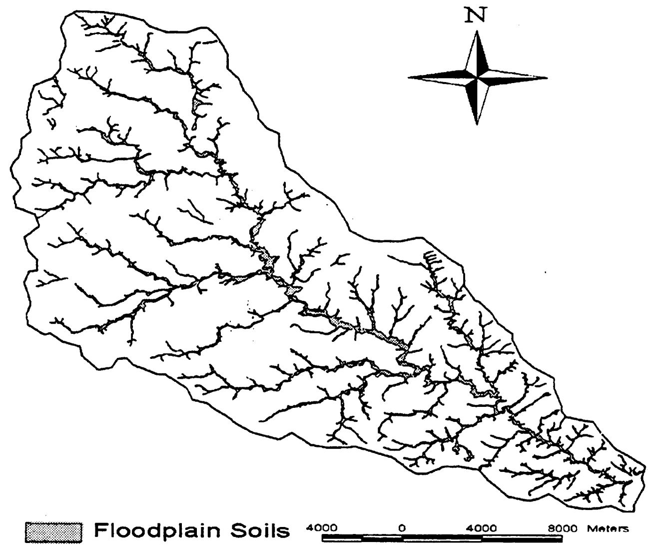

Figure 1: Digitized floodplain soil series.

RESULTS

Storage of Sediment:

Analysis of depth to historical floodplain show no relation with respect to slope, drainage area, elevation and stream order. Therefore, an average depth of 1.6 meters to the historical floodplain was used to estimate floodplain storage of sediment. The digitized alluvial floodplain series resulted in a total area of 41.98 km^2 (Figure 1). Total volume of sediment in storage is .067 km^3 (110,827,200 Megagrams). This results in approximately 12 cm of eroded soil from the watershed that is currently in storage.

Export of Sediment:

Reservoir survey results show that there is a large volume of sediment in storage since dam closure. ArcInfo CUTFILL analysis indicate approximately 160,000 cubic meters (232,131 Mg) of sediment in storage in the Murder Creek arm of Lake Sinclair. Bedload sediment volume indicates a depth of erosion from the watershed of .03 cm with an average export of 4,632 Mg (.0006 cm) per year since dam closure. Regression analysis of TSS from USGS data, estimate the total TSS export volume as 322,611 m^3 (15,044 Mg/year). This translates into an estimated total of .061

cm (.0028 cm/year) of soil eroded and exported as TSS from the watershed over the 21 year period of record.

DISCUSSION

Although all target data has not been collected and analyzed at this time, it is apparent that a major portion of sediment export will come from sediment currently in storage. Preliminary analysis of dendrogeo - morphology indicate that there has only been a slight accretion of sediment on the floodplain in the past 50-60 years. This insinuates that modern land management practices, better soil conservation techniques and resource management have led to less erosion of soil from the Murder Creek watershed as compared to pre-1950 conditions.

ACKNOWLEDGMENTS

We would like to thank the National Council for Air and Stream Improvement (NCASI) for funding this project. Also, we would like to thank the Weyerhauser Company and The Timber Company for allowing access and use of their lands for purposes of gathering information for this project.

LITERATURE CITED

Arthur, M.A., G.B. Coltharp., and D.L. Brown, 1998. Effects of Best Management Practices on Forest Streamwater Quality in Eastern Kentucky. *JAWRA* 34:481-495.

Beach, Timothy, 1992. Estimating Soil Loss from Medium-Sized Drainage Basins. *Physical Geography.* Vol. 13, No. 3. pg. 206-224.

Clean Water Act 1972. Section 303(d).

Dendy, F.E. and G.C. Bolton, 1976. Sediment yield-runoff-drainage area relationships in theUnited States. *Journal of Soil and Water Conservation.* Nov-Dec.

Foltz, Randy B., 1996. Traffic and No-Traffic on an Aggregate Surfaced Road: Sediment Production Differences. USDA Food and Agriculture Seminar: Environmentally Sound Forest Road and Wood Transport. Sinaia, Romania., June 17-22.

Ketcheson, G.L. and Walter Megahan, 1996. Sediment Production and Downslope Sediment Transport from Forest Roads in Granitic Watersheds. USDA Forest Service Research Paper. INT-RP-486.

Megahan, W.F. and Walter J. Kidd, 1972. Effect of Logging Roads on Sediment Production Rates in the Idaho Batholith. USDA Forest Service Research Paper. INT-123.

Neary, D.G., W.T. Swank, and H. Riekerk, 1988. An overview of non-point source pollution in the Southern United States. In: Proceedings of the symposium The Forested Wetlands of the Southern United States. Orlando, FL, July 12 -15, 1988. Forest Service General Technical Report SE-50.

Phillips, Jonathan D. 1991. Fluvial sediment budgets in the North Caroling Piedmont. *Geomorphology* Vol. 4. 231-241.

Rasmussen, T.C. and F. Green, 1997. A Study of Stream Turbidity Following Forest Harvesting in Georgia. Georgia Environmental Protection Division.

Reid, Leslie and T. Dunne, 1984. Sediment Production from Forest Road Surfaces. *Water Resources Research.* Vol. 20. No. 11:1753-1761.

Schick, Asher P. and Judith Lekach, 1993. An Evaluation of Two Ten-Year Sediment Budgets, Nahal Yael, Israel. *Physical Geography* Vol. 14, No. 3. pg. 225-238.

Sierra Club vs. John Hankinson 1996. Civil Action 1:94-cv-2501-MHS. United States District Court for the Northern District of Georgia, Atlanta Division.

Sigafoos, R.S. 1964. Botanical evidence of floods and flood-plain deposition. USGS Professional Paper 485 A.

Swift, L.W., 1988. *Forest Access Roads: Design, Maintenance, and Soil Loss in Forest Hydrology and Ecology at Coweeta.* ed. W.T. Swank and D.A. Crossley, Jr. Springer-Verlag. New York.

Trimble, Stanley W. 1975. A Volumetric Estimate of Man - Induced Soil Erosion on the Southern Piedmont Plateau, in Present and Prospective Technology for Predicting Sediment Yields and Sources: U.S. Dept. Agriculture, Agr. Res. Serv. Ars-S-40.

Trimble, Stanley W. 1983. A Sediment Budget for Coon Creek Basin in the Driftless Area, Wisconsin, 1853-1977. *Am. Journal of Science.* Vol. 283. Pg. 454-474.

USGS. 1980. Erosion, Sediment Discharge, and Channel Morphology in the Upper Chattahoochee River Basin, Georgia. USGS Professional Paper 1107.

WEPP:Road. 1999. WEPP Interface for Predicting Forest Road Runoff, Erosion and Sediment Delivery. USDA Forest Service Lab.