CHATTOOGA RIVER WATERSHED ECOLOGICAL/SEDIMENTATION PROJECT

By Bruce A. Pruitt[1], Watershed Hydrologist; Dave L. Melgaard[2], Aquatic Ecologist; Hoke Howard[1], Aquatic Ecologist; Morris C. Flexner[2], Fluvial Geomorphologist; Anthony S. Able[2], Geologist; *FISC Proceedings, Federal Interagency Sedimentation Conference, Reno, Nevada, March 26-30, 2001*

[1]U.S. Environmental Protection Agency, Science and Ecosystem Support Division, Athens, GA, 980 College Station Rd., Athens, Georgia, 30605, (706) 355-8713, fax (706) 355-8726, pruitt.bruce@epa.gov; [2]U.S. Environmental Protection Agency, Water Management Division, SNAFC, 61 Forsyth St. SW, Atlanta, GA 30303

Abstract As an integral part of the comprehensive water quality investigation of the Chattooga River watershed, an ecological and sedimentological study was conducted on selected stream reaches within the study area. The objective of this study was to conduct a sediment yield study and determine if sediment was a primary cause of physical and biological impairment to streams within the watershed. As result of this study, accelerated sedimentation has been identified to be the leading determinant in loss of habitat and reduction in bedform diversity within the study area. Good correlation was observed between aquatic ecology and normalized total suspended solids (TSS) data. Based on overlaying the biological index on TSS normalized to discharge/mean discharge, TSS concentrations greater than 284 mg/l adversely affected aquatic macroinvertebrate community structure. However, based on historic regional suspended-sediment concentrations, a normalized TSS concentration of 58 mg/l or less during storm flow provides an adequate margin of safety and is protective of aquatic macroinvertebrates in the Blue Ridge physiography. Corresponding turbidity limits of 69 and 22 NTU established the threshold of biological impairment and margin of safety, respectively. Previously, a similar turbidity of 25 NTU has been recommended for stream restoration management plans. Relative to reference streams, impaired streams yielded higher bedload and suspended load. The results of this study showed that road density and associated sediment sources accounted for 51% of the total sediment loading.

INTRODUCTION

In response to issues included in the settlement of the Georgia Total Maximum Daily Load (TMDL) lawsuit, EPA was required to conduct an evaluation of the Chattooga River watershed to determine if waters within the watershed were not meeting designated uses (Sierra Club, Georgia Environmental Organizations, Inc., Coosa River Basin Initiative, Inc., Trout Unlimited, and the Ogeechee River Valley Association, Inc., Versus: U.S. Environment Protection Agency (EPA); Carol Browner, Administrator, EPA and John Hankinson, Regional Administrator, EPA Region 4). For those waters not meeting designated uses, EPA was required to determine the cause of non-support and develop the appropriate TMDL.

Sedimentation has been reported to be the leading determinant in loss of habitat and reduction in bedform diversity within the study area. The State of Georgia is initiating a statewide effort and geographic calibration of reference conditions for assessing the ecological status of its water resources using biological assessment. However, the effort has not been completed. As an interim solution, it was necessary to develop reference conditions at the scale of the Chattooga Basin. The objective of this study was to conduct a sediment yield study and determine if sediment was a primary cause of physical and biological impairment to streams within the watershed. The results were correlated with aquatic ecological data to develop an overall condition of the watershed.

Setting The Chattooga River watershed, located in northeast Georgia, northwest South Carolina, and southwest North Carolina, has a total drainage area of approximately 180,000 acres, and is entirely within the Blue Ridge Ecoregion. Land cover within the watershed is primarily forested, with some areas of commercial development, urban and residential use, and agriculture. Although the average "forested" land cover within the watershed is greater than 96%, there has been concern that gradual increases in sediment inputs to streams may be causing ecological impairment. Consequently, EPA Region 4 began an evaluation of water quality conditions within the Chattooga River watershed, and how they may have changed due to forestry or forestry-related practices. To accomplish this, sampling and analysis was undertaken in 1997-2000 by U.S. EPA Region 4 for biological and habitat quality, channel morphology, selected water chemistry, and sediment yield.

METHODS

Aquatic Ecology A total of 3 reference sites and 56 other sites were sampled from six subwatersheds: Headwaters (n = 14), Lower Chattooga (n = 3), Middle Chattooga (n = 10), Stekoa Creek (n = 7), West Fork (n = 11), and Warwoman Creek (n = 11). Biological sampling methods were focused on benthic macroinvertebrates and used modified rapid bioassessment protocols (RBP) (Plafkin et al. 1989, Barbour et al.1999, and U.S. EPA's Region 4, Ecological Assessment Branch-*Draft* Standard Operating Procedures 1999). Reference sites were selected prior to initiation of sampling based on habitat condition, *in situ* water chemistry and surrounding land use. Reference sites R1 and R2 were located in the Chattooga River watershed and reference site R3 was on the upper Chattahoochee River outside of the Chattooga watershed. It was determined that the reference sites were representative of least-impaired conditions of the Blue Ridge Ecoregion. Data for all 59 stations were analyzed using a multimetric approach, in agreement with the recommendations of U. S. EPA (Gibson et al. 1996). From the raw data, 17 metrics were calculated including: total taxa, number of Ephemeroptera , Plecoptera, and Trichoptera (EPT) taxa , number of clinger taxa (clingers),percent clingers, percent most dominant taxon, percent 2^{nd} dominant taxa, percent tolerant organisms, number of intolerant taxa, percent diptera, percent Chironomidae, percent EPT, North Carolina Biotic Index (NCBI), percent collectors, percent filterers, percent scrapers, percent shredders, and percent predators.

From the original list of 17 metrics, five were selected that had the greatest ability to detect impairment, determined by examining the position of the *a priori* reference sites to the overall distribution of metric values. For the most appropriate metrics, scoring criteria were determined based on the 95^{th} percentile of all metric values for those metrics that decrease with impairment (Barbour et al.1999). For those that increase with impairment, the 5^{th} percentile was used. This approach was used since there were no *a priori* impaired sites against which to calibrate. Each metric was scored according to its relation to the 95^{th} (or 5^{th}) percentile standard (Table 1). Eighty-five percent (85%) of the area below the 95^{th} percentile standard (or 15% above the 5^{th} percentile) was equally divided into four ranges and each range is given a numeric value of 0, 2, 4, or 6. A score of zero was the farthest away from the percentile standard (i.e., zero was most unlike the best attainable conditions and 6 was the score closest to the percentile standard). One exception was the "North Carolina Biotic Index" (NCBI), for which the scoring criteria developed by Lenat (1993) were used.

Table 1. Table of metrics and percentile distribution for each.

Metric	Min	05^{th}	Median	95th	Max	Percentile Standard	Expected Response to Stressors
EPT taxa	3	10	15	21	25	95	Decrease
% EPT	27.9	36.7	66.7	85.0	95.4	95	Decrease
% 2 dominant taxon	19.2	22.0	30.0	52.8	65.4	5	Increase
NCBI	2.6	2.7	4.1	5.6	6.2	5	Increase
Clinger taxa	7	7	17	23	24	95	Decrease

A final biological index was assigned to each site based on a simple sum of the scores for the five metrics. An assessment rating was then assigned by dividing the range of the overall index scores into 5 categories. Narrative descriptions of the assessments correspond to:

- **Very Good** - best attainable conditions indicating no impairment to the aquatic community;
- **Good** - close to best attainable conditions but at risk and possibly influenced by limited stressors;
- **Fair** - some biological impairment observed, due to minor stressor input;
- **Poor** - substantial impairment of stream biota observed, due to moderate stressor input; including habitat degradation;
- **Very Poor** - severe impairment of stream biota observed, due to major stressor input, including habitat degradation.

Sediment Sampling Seventeen stream reaches were selected for storm flow investigations based on the following criteria: (1) relative degree of biological impairment as measured using RBP; (2) position within the watershed; (3) relative geomorphic condition; and (3) access logistics. The storm flow investigations were conducted during three storm events (March 28-30, 1998, June 15-17, 1999 and March 16-17, 2000). Prior to storm flow sampling, tape downs were established and appropriate cross-sections for gaging and sediment collection were identified. Base flow discharge and sediment samples were collected prior to the storm initiation. Precipitation was measured at Clayton, Georgia for response planning and rapid deployment of sample teams during the storm flow study. In addition, several rain gages were strategically deployed within the watershed to address rainfall distribution. Also, stream stage was monitored in Stekoa Creek at Clayton for response planning.

A total of 58 observations were made across the 17 stations. *In-situ* measurements at each station included tape downs (start and finish), stream discharge, turbidity, and collection of suspended and bedload sediment. Stream discharge was gaged simultaneously with sediment collection. Water column samples were collected using a depth integrating suspended hand-line sampler (US DH-59). Field turbidity was determined *in-situ* at ambient air conditions using a HACH™ Model 2100P Turbidity Meter. Turbidity was field determined for future use by EPA Region IV and state water quality personnel as a rapid means of identifying potential sediment impaired streams ("red flags"). Consequently, sample temperature was not adjusted prior to measuring turbidity. Laboratory determination of total suspended solids (TSS) and total dissolved solids (TDS) followed USEPA Methods 160.2 and 160.1, respectively. Whole samples were filtered for TSS analysis. Because the TSS data were produced without subsampling, they should be directly comparable to suspended-sediment concentration data (SSC) (Gray et al. 2000 and personal communication with John Gray, USGS). Bedload sediment samples were collected utilizing a 6-inch cable suspended bedload sampler or a 6-inch wading type bedload sampler, transported to the laboratory in 1-liter containers, and processed for particle size determination (PSD) in the laboratory using the EPA-SESD wet sieve method (SESD-EAB Draft SOP, Jan. 99). The procedure was followed with the exception of the silt/clay separation step that was not required since the samples were collected in coarse Nitex™ mesh bags (250 :m).

Laboratory results of dry-weight, bedload samples (M_b, grams) were converted to bedload transport rate (Q_b, tons/day) by the following equation (Edwards and Glysson 1988):

$$Q_B = K(W_T/T)\,M_T \qquad (1)$$

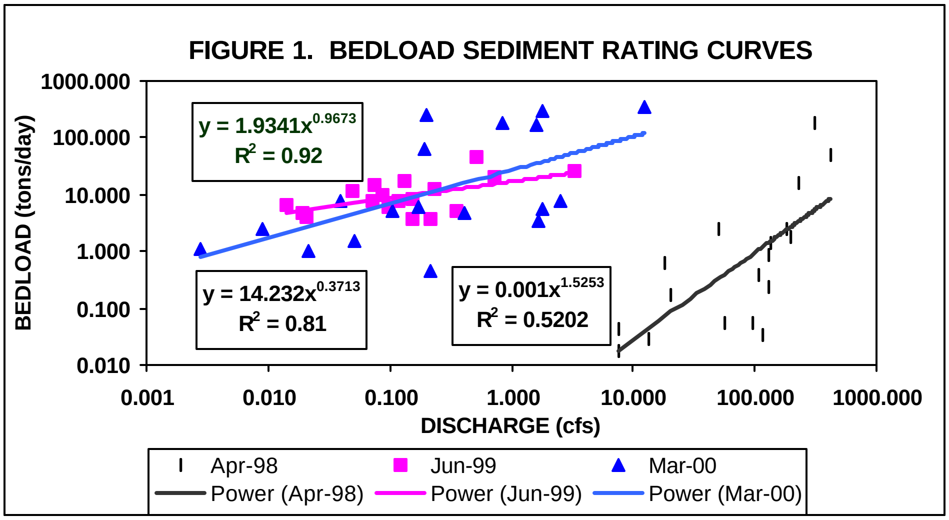
where Q_B = bedload discharge (tons/day);
K = converts grams/second/foot to tons/day/foot
W_T = wetted surface (ft);
T = total time sampler on bottom (seconds);
M_T = total mass of samples (grams)

Regression relationships were tested against ANOVA at a 95% confidence level. Consequently, unless otherwise noted hereafter, significance was determined at $\alpha = 0.05$, based on a t-test using advanced regression.

RESULTS

Aquatic Ecology Biological conditions in most streams sampled in this study show little or no impairment. Seventy-eight percent (78%) of the sites were rated as "very good" (22 sites) or "good" (24 sites). Since greater than 96% of the watershed land cover is classified as forested, this result was expected. Streams rated as "good" (41% of all stream sites sampled) are defined as possibly being influenced by some stressors. Eleven sites (19%) were rated as "fair", and two sites (3%) were rated as "poor". No sites were rated as "very poor". Although some sedimentation, or the habitat effects of sedimentation, may have been evident at many sites, a negative biological response was not always evident. The sedimentation also may not have reached a level that would cause a biological response. Due to the fact that this project used multihabitat sampling of benthic invertebrates, samples were taken from some stream subhabitats that were not adversely affected by sediment deposition resulting in habitat loss. The three reference sites had high biological scores: 24, 22, and 28, respectively, out of a maximum possible score of 30. The most degraded biological community was observed in the Stekoa Creek subwatershed. This subwatershed has a higher percentage of bare land and less forest cover than other subwatersheds in the Chattooga River basin. Consequently, none of the sample stations were rated as "very good" (i.e., zero out of seven stations). Two stations were rated "good", four stations were rated as "fair", and one station was rated as "poor".

Bedload Sediment Bedload over the three storm events averaged 13.32 tons/day (range 0.02-176.96 tons/day, standard deviation = 41.28). Median bedload particle sizes (D_{50}) ranged from fine sand to very coarse sand. Bedload accounted for only 14 percent of the total sediment load (on average). By plotting bedload against discharge, bedload sediment rating curves for each of the three storm events were created (Figure 1). Relatively good regression coefficients were observed within each storm event. However, regressed slopes varied between storm events.



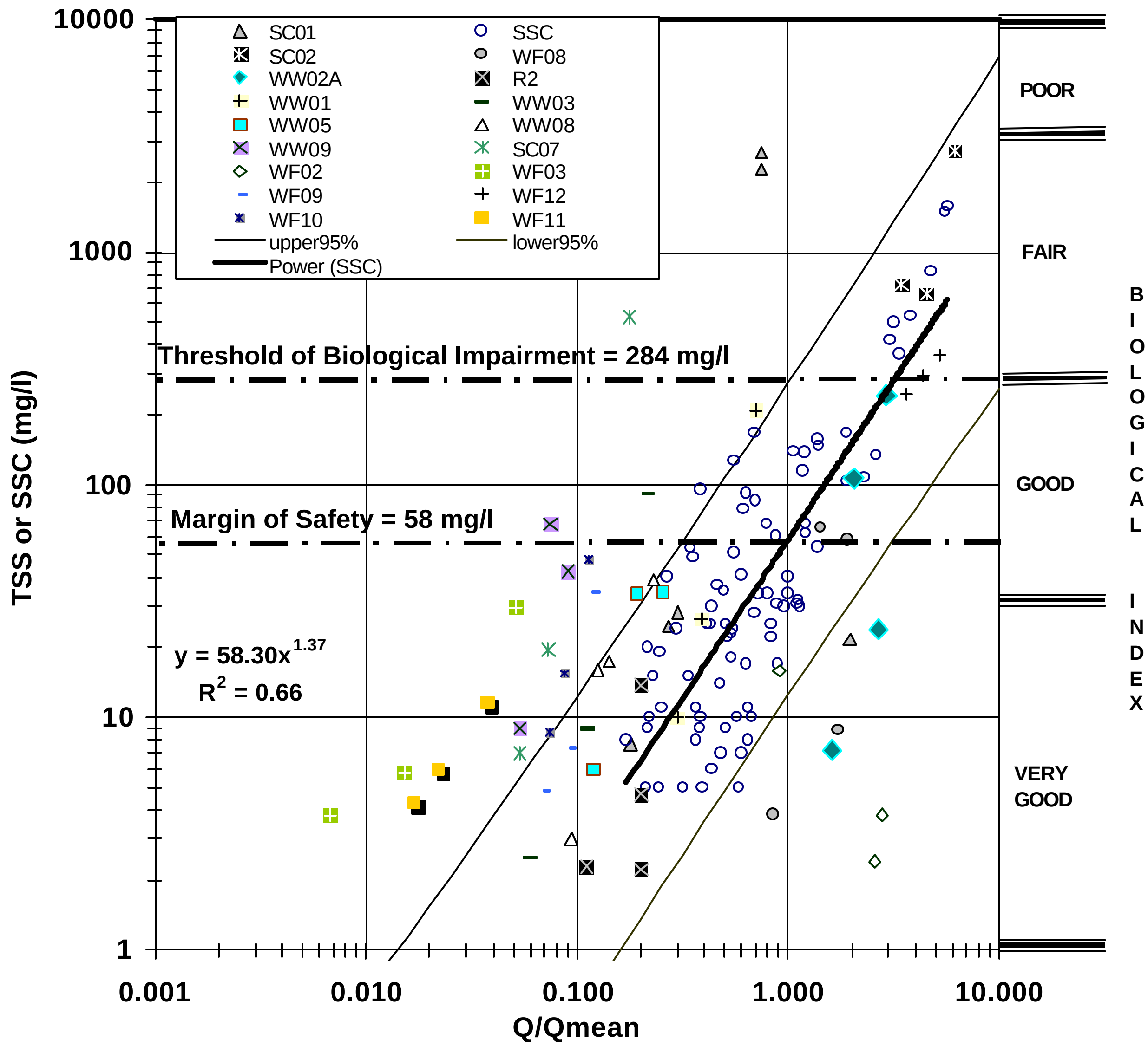
Suspended Sediment (Regional) Regional SSC data, compiled from the United States Geologic Survey records (Perlman 1984), were regressed against discharge normalized to mean discharge (Q/meanQ) (Holmbeck-Pelham and Rasmussen 1997). The USGS stream station utilized in development of the regional sediment curve was the Chattahoochee River near Leaf (Station no. 02331000) for the period of record, 1958 - 1984. TSS data from the Soque River station near Cornelia (02331250) and the Chestatee River near Dahlonega (02333500) were not used due to the difference in slope of the regression as compared to the Chattahoochee River station in the former and shift upward in the regression of the latter. An improvement was observed in the regression coefficient from 0.54 to 0.66 and, consequently, confidence in using the regional data set improved as a reference. In addition, SSC data from the Chattahoochee River was the most protective as compared to the other two datasets. Regional SSC (from the Chattahoochee River) regressed against Q/Qmean was observed to be significant (R^2=0.66, log transformed), given by (Figure 2):

$$\text{TSS or SSC} = 58.3(Q/Q\text{mean})^{1.37} \qquad (2)$$

Suspended Sediment (this study) TSS over the three storm events averaged 85.3 tons/day (range 0.0002-3136.2 tons/day, standard deviation = 418.0). TSS accounted for the majority (86 %) of the total sediment load over the three storm events (on average). TSS, collected by vertical integration of the water column, was regressed against discharge (Q) and was observed to be highly variable between stations during the same storm event and between different storm events. In contrast, the log transformed relationship between TSS and NTU was significant (Figure 3). TSS data were compared against regional SSC by overlaying the two and constructing 95% confidence bands (Figure 2). Six stations, SC01, SC07, WW09, WF03, WF10 and WF11, were observed above the upper 95% confidence band (i.e., 6 out of the 17 stations during the three stormflow investigations). In general, data points that plot above the upper 95% confidence band are indicative of higher than “normal” concentrations of TSS for a given discharge to mean discharge. Other stations were observed to be below or within the normal range of the regional SSC data set. In addition, three stations, WW02A, WF02, and WF08, were below the lower 95% confidence band.

Total Sediment Bedload and TSS loadings were combined into total sediment load and plotted against discharge (Figure 4). Total loads were also plotted against road density (road length / corresponding drainage area) (Figure 5). Road density ranged from zero (R2 - Addie Branch, reference) to 6.60 (SC01 - Stekoa Creek. Road density represents the net impacts of road construction and maintenance, interception of subsurface interflow, routing of other non-point sources to the stream, and entrainment, mobilization, and transport of sediment to the stream. In contrast to drainage density, a significant increase in peak total loads in response to road density was observed at the two Stekoa Creek stations (SC01 and SC02).

FIGURE 2. OBSERVED TSS OVERLAYING COMBINED REGIONAL SSC



Historic regional data (SSC) from USGS Station 02331000 (Chattahoochee River @ Leaf, GA)

CONCLUSIONS

Good correlation was observed between the biological index and normalized total suspended solids (TSS) data (Figure 2). TSS concentration normalized to discharge/mean discharge greater than 284 mg/l adversely affected biological community structure. However, based on regional suspended-sediment concentrations, a normalized TSS concentration of 58 mg/l or less during storm flow provides an adequate margin of safety and is protective of aquatic macroinvertebrates in the Blue Ridge physiography. Furthermore, corresponding turbidity limits from the above TSS estimates can be calculated from the NTU versus TSS relationship (Figure 3) as 69 and 22 NTU for the threshold of biological impairment and margin of safety, respectively.

FIGURE 3. Turbidity vs. Total Suspended Solids (All Stations)

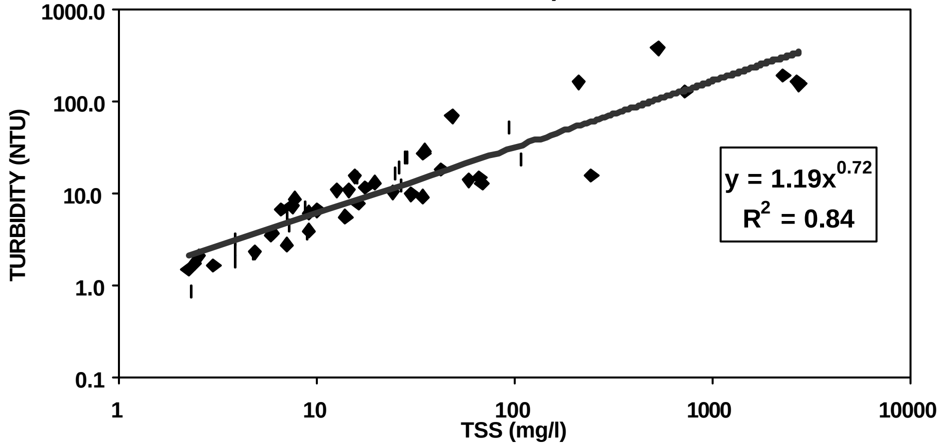
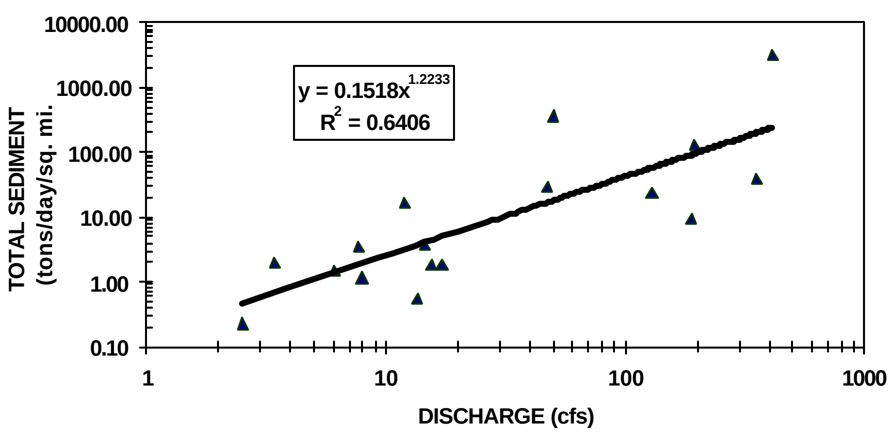


FIGURE 4. TOTAL SEDIMENT RATING CURVE (All Stations)

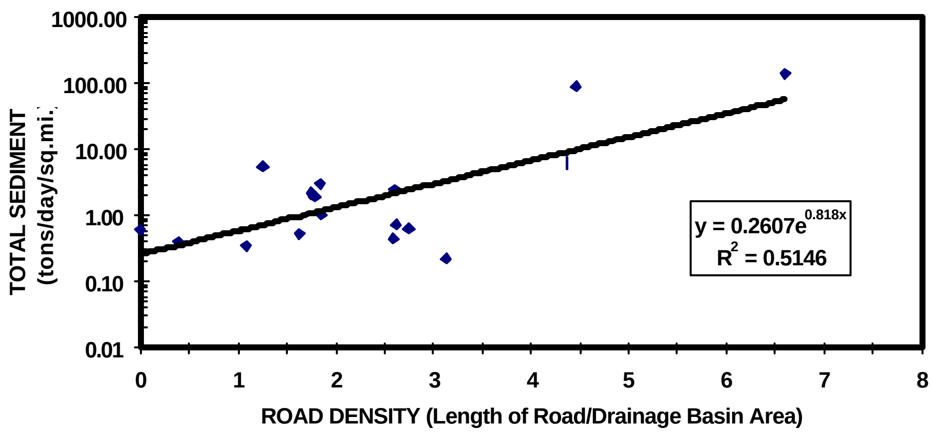


Relative to the reference stream (R2), impaired streams yielded higher bedload and suspended load. Based on the results of this study and comparison against regional sediment data, Stekoa Creek (SC01 and SC07) exhibits greater than "normal" suspended sediment loads. TSS concentrations from Addie Branch (R2) were within or below "normal" regional TSS concentrations. Total storm flow sediment load and peak total sediment loads did not increase significantly with drainage density. Increased sediment loads were correlated with an increase in road density. Road density and associated sediment sources accounted for 51% of the total sediment loading. Assuming that every road has at least one road ditch, road density nearly doubled the effective drainage density at the Stekoa Creek stations. The condition of the macroinvertebrate community of Stekoa Creek is rated as "fair" and is evidence of the impact of the accelerated sediment loads in the stream at stations SC01, SC02, and SC07.

DISCUSSION

Presently, several states are evaluating their water quality standards to include narrative or numeric turbidity and/or TSS standards. For example, Georgia has recently enacted a narrative standard for turbidity that is based on "visual contrast in a water body due to man-made activity" (DNR 2000). In addition, Alabama and Florida use 50 and 29 NTU above background, respectively; South Carolina allows a increase of ten percent above background; North Carolina uses 10 NTU for trout streams, 50 NTU for non-trout streams, and 25 NTU for non-trout lakes; Tennessee uses a standard that does not allow any material effect on fish or aquatic life (Kundell and Rasmussen 1995). Holmbeck-Pelham and Rasmussen (1997) recommended a reduction in average turbidities to below 25 NTU for stream restoration plans in Georgia. In addition, a turbidity of 25 NTU was recommended by the Georgia Board of Regents' Scientific Panel as an instream turbidity standard (Kundell and Rasmussen 1995). Also, the report cited a TSS concentration of 80 mg/l as a threshold between moderate and low levels of protection for fish and aquatic invertebrates (NAS 1972).

FIGURE 5. PEAK TOTAL SEDIMENT LOAD DURING STORM EVENT



Similar findings were observed in this study. TSS concentrations greater than 284 mg/l resulted in biological impairment of macroinvertebrate communities. Also, TSS concentrations of 58 mg/l or less during storm flow provided an adequate margin of safety and were protective of aquatic macroinvertebrates in the Blue Ridge physiography. Furthermore, corresponding turbidity limits of 69 and 22 NTU established the threshold of biological impairment and margin of safety, respectively.

A relationship between TSS and turbidity (NTU) can be developed within a specific hydro-physiography. Turbidity can be used as a surrogate to TSS with the following assumptions and cautions: 1) the relationship between TSS vs. NTU is hydro-physiography specific; 2) turbidity includes inorganic and organic constituents including phyto- and zooplankton which can be extreme during the growing season; and 3) stream discharge and/or stage should be measured at the time of turbidity measurements and compared against a regional regression curve.
A biological endpoint is critical to addressing stream condition and beneficial uses. An index of biological integrity overlaying a sliding, sediment scale (concentration or load) is recommended. Additional surrogates need to be developed and tested between bedload versus embeddedness (MacDonald et al. 1991), bedload versus one-third lower bar (Rosgen 1996), and sediment load versus Pfankuch (1975) or RBP habitat assessments (Plafkin et al. 1989).

The relationship between suspended-sediment concentration and total suspended solids needs to be established for specific physiographies. In addition, in physiographies with high concentrations of clay particle sizes, filtration of the whole sample needs to be explored *in lieu* of withdrawing the supernatant using a J-tube.

The findings of this study emphasize the importance of incorporating aquatic ecological assessments into addressing the effects of accelerated sedimentation and deposition within a watershed. Biological endpoints (e.g., clinger-burrower ratio) can be directly applied to designate beneficial uses such as fishing and recreation. Consequently, comprehensive aquatic ecological studies are a critical component of identifying reference stream reaches and determining whether designated or beneficial uses are being met. Additional research should focus on developing fisheries and aquatic macroinvertebrate indices that are sensitive to impacts caused by accelerated sedimentation.

REFERENCES

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish. Second Edition.* EPA/841-B-98-010. U.S. EPA, Office of Water, Washington, D.C.

DNR. 2000. Rules and regulations for water quality control. Chapter 391-3-6. Georgia Department of Natural Resources, Environmental Protection Division, 205 Butler St., SE, Floyd Towers East, Atlanta, GA.

Edwards, T.K. and G.D. Glysson. 1988. Field methods for measurement of fluvial sediment. U.S. Geological Survey. Open File Report 86-531. Reston, VA.

Gray, J.R., G.D. Glysson, L.M. Turcios, and G.E. Schwarz. 2000. Comparability of suspended-sediment concentration and total suspended solids data. U.S. Department of the Interior, U.S. Geological Survey, Water-Resource Investigation Report 00-4191, Reston, VA.

Gibson, G.A., M.T. Barbour, J.B. Stribling, J. Gerritsen, and J.R. Karr. 1996. *Biological criteria: Technical guidance for streams and rivers*. EPA/822-B-94-001. U.S. EPA, Office of Science and Technology, Washington, DC.

Holmbeck-Pelham, S.A. and T.C. Rasmussen. 1997. Characterization of temporal and spatial variability of turbidity in the upper Chattahoochee River. *Proceedings of the 1997 Georgia Water Resources Conference*, K.J. Hatcher, Editor, University of Georgia, Athens, GA.

Kundall, J.E. and R.C. Rasmussen. 1995. Erosion and sedimentation: Scientific and regulatory issues. Developed for Georgia Board of National Resources. Georgia Board of Regent's Scientific Panel on Evaluating the Erosion Measurement Standard Defined by the Georgia Erosion and Sedimentation Act.

Lenat, D. R. 1993. A biotic index for the southeastern United States: derivation and list of tolerance values, with criteria for assigning water-quality ratings. *Journal of the North American Benthological Society* 12(3): 279-290.

MacDonald, L.H., A.W. Smart, and R.C. Wissmar. 1991. Monitoring guidelines to evaluate effects of forestry activities on streams in the Pacific Northwest and Alaska,. EPA Region 10, Seattle, WA. EPA/910/9-91-001. pp. 121-124.

NAS. 1972. National Academy of Science and the National Academy of Engineering. Water quality criteria. Report of the committee on water quality criteria. Environmental Studies Board. Washington, D.C. 594 pp.

Pfankuch, D.J. 1975. Stream reach inventory and channel stability evaluation. U.S. Department of Agriculture, Forest Service/Northern Region, Lolo National Forest, Missoula, MT.

Perlman, H.A. 1984. Sediment data for Georgia streams, water years 1958-82. U.S. Gelogical Survey. Open-file report 84-722. Doraville, GA.

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. 1989. *Rapid bioassessment protocols for use in streams and rivers: Benthic macroinvertebrates and fish*. EPA/440/4-89/001. U.S. EPA Office of Water, Washington, DC.

Rosgen, D. 1996. *Applied River Morphology*. Wildlands Hydrology, Pagosa Springs, CO.

U.S. EPA. 4/99. *Draft* Ecological Assessment Branch, Standard Operating Procedures. U.S. Environmental Protection Agency, Region 4, Science and Ecosystem Support Division, Ecological Assessment Branch, 980 College Station Rd., Athens, GA.