# LAND USE EFFECTS ON SUSPENDED SEDIMENT YIELD IN SIX SMALL GEORGIA WATERSHEDS

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**Abstract.** In Georgia, over 600 stream segments are scheduled for TMDL development due designated use. Seventy-seven stream segments are listed for excessive sediment. The state does not have quantitative standards for the regulation of sediment concentration. The development of sediment yields using appropriate reference streams with minimum development may be a way to determine what the maximum daily sediment loading should be for impaired streams. This study was initiated to compare water quality in six streams with differing land use. This paper focuses on suspended sediment comparisons among the six streams. Two streams drain areas that are entirely forested and these represent reference streams for the purpose of this study. Two streams drain areas that are predominately agricultural (one dairy and the other a combination of poultry and cattle), and two streams drain areas that are in subdivisions with septic systems. Suspended sediment concentrations (SSC) and stream stage were measured during base flow and storm flow conditions. Annual sediment and water yields were calculated and for each stream for the years 2003 and 2004. Average SSC ranged from 155 to 720 mg/L and was lowest in one of the forested steams and highest in the dairy stream. Sediment yield ranged from 0.91 to 10.11 Mg/ha/yr and was lowest in one of the forested steams and highest in the dairy stream. In general, the forested streams had the lowest sediment yields, the agricultural watersheds had the highest sediment yields, and the suburban streams were intermediate.

## INTRODUCTION

The Clean Water Act of 1972 requires that each state identifies water bodies that do not meet the state ambient water quality standards (Reckhow, 2001). In terms of TMDL documents listed on the state Environmental Protection Division's website there are 7 reports listed for biota, 13 listed for metals, 15 listed for dissolved oxygen and 38 listed for fecal coliform contamination (EPD, 2005). Increased sediment concentrations adversely affect the biota of a stream. Excessive sediment loads can prevent aquatic plant growth and destroy reproductive habitats for fish (Cooper, 1993). TMDL reports for sediment are listed under the biota TMDL report category. The Environmental Protection Agency (EPA) has recommended several methods for determining the acceptable maximum load for water body contaminants. One of these methods to determine acceptable maximum loads is to compare different land uses to reference streams. Reference streams can be defined as streams that represent characteristics of their region and have been subject to minimal human disturbance (The Sediment TMDL Technical Advisory Group, 2002). The purpose of this study was to compare sediment yields from different land uses using reference streams. The reference waters used in this study were small first-order streams located in two forested watersheds. These reference streams were compared with two agricultural second-order streams and two suburban first-order streams.

## MATERIALS & METHODS

### Site Descriptions

There are two small, paired, forested watersheds located at the BF Grant Wildlife Management Area in Putnam County, Georgia. At the beginning of this project both of the forested streams were designated as reference streams. However, in one of these watersheds timber has recently been harvested and the site is being evaluated to determine the effects of clear cutting. The reference site will be referred to as BF1 and the logged site will be referred to as BF2. The watershed areas are shown in Table 2. The landuse in these watersheds was entirely forest. Flumes were installed in both of these streams in the 1970's (Hewlett, 1979).

The two suburban streams are located in Oconee County, Georgia. Both of these sites are located in subdivisions where septic systems are used to manage household wastewater. Measurements were taken in open channels at both sites. The suburban sites will be referred to as Idylwood (IW) and Covered Bridge (CB). Landuse in these watersheds was entirely low density residential.

The two agricultural watersheds are located in different counties. One watershed is located in Morgan County, Georgia. The primary land use in this site is for dairy cattle and the site will be referred to as Dairy (D). Landuse in this watershed is 55% pasture, 26% forest, and 10% row crops (NRSAL, 1998). The second agricultural watershed is located in Oconee County, Georgia. The primary land use in this site is poultry and beef cattle production and this site will be referred to as Rose Creek (RC). Landuse in this watershed is 55% pasture, 28% forest, and 6% row crops (NRSAL, 1998). Measurements were taken at road culverts for both of the agricultural sites.

Monitoring at each of these sites began in 2002 and continued through the end of 2004.

### Procedure

Automated ISCO 6700 water samplers, designed to measure gage height and collect storm samples, were placed at each of the watersheds described above. The ISCO stations operate using 12-volt batteries and solar panels and are controlled using data loggers. The samplers were programmed to measure stream stage at 5-minute intervals and to take flow-weighted samples during storm events. Samples were picked up from the ISCO stations within 24 hours of collection and stored in a refrigerator until analyzed. Flow equations were developed for each site (using standard equations for flumes at BF1 and BF2, culvert dimensions and Manning's equation at RC and D, and stream cross-sections and Manning's equation at IW and CB) so that gage height could be converted to stream discharge. Base flow grab samples were collected weekly. Suspended sediment concentrations (SSC) were analyzed using the evaporation method (Guy, 1969).

Sediment rating curves were developed by plotting log SSC vs. log ($Q/Q_o$) where Q was stream discharge at the time SSC was measured and $Q_o$ was mean discharge for the stream. Using the rating curve, the SSC was estimated at each 5-min time interval when gauge height was measured and annual sediment loads were calculated by summing the loads for 5-min intervals. Annual sediment loads for each watershed were converted to sediment yields by dividing by the total watershed area. The total annual flow and water yield was also calculated for each site in a similar manner.

The rating curves for the forested watersheds were

## RESULTS

Sediment rating curves are shown in Fig. 1.

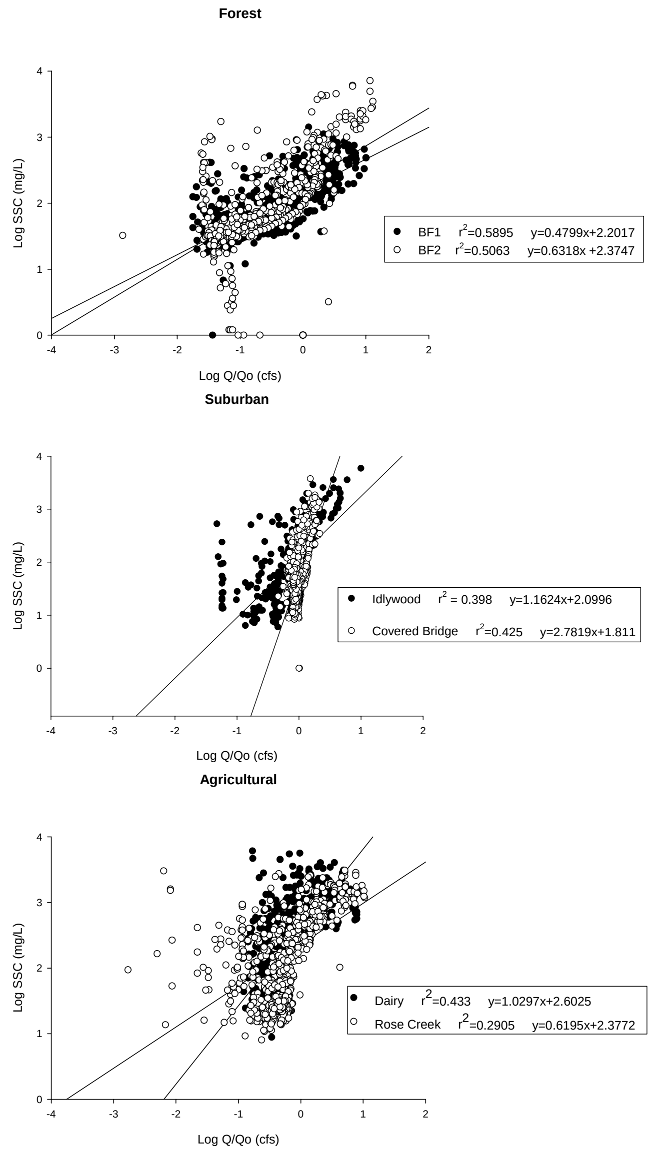


**Figure 1. Sediment rating curves 2002-2004.**

similar. Regression correlation coefficient ($r^2$) for the rating curves ranged from 0.29 to 0.58 (Fig. 1). The rating curve for the Rose Creek watershed was similar to the forested watersheds in terms of the regression equation slope and intercept (Table 1). The other three watersheds had steeper slopes than the forested watersheds.

Mean SSC ranged from 155 to 720 mg/L (Table 2). The lowest mean SSC occurred in the CB* suburban watershed and the undisturbed forest watershed (BF1). The highest mean SSC occurred in the D agricultural watershed. The RC agricultural watershed, IW suburban watershed, and BF2 logged watershed had intermediate

**Table 1. Slopes and intercepts of rating curve log-log equations.**

| Watershed | Slope | Intercept |
|---|---|---|
| BF1 | 0.48 | 2.20 |
| BF2 | 0.63 | 2.37 |
| IW | 1.16 | 2.10 |
| CB | 2.78 | 1.81 |
| D | 1.03 | 2.60 |
| RC | 0.62 | 2.38 |

**Table 2. Watershed characteristics and sediment and water yields.**

| Watershed | Yr | Water shed Size (ha) | Mean SSC (mg/L) | Annual Suspended Sediment Yield (Mg/ha/yr) | Annual Water Yield (cm/yr) | Annual Water Yield (%)[1] |
|---|---|---|---|---|---|---|
| BF1 | 2003 | 43 | 155 | 2.03 | 37.2 | 31 |
| | 2004 | | | 1.56 | 24.4 | 20 |
| BF2 | 2003 | 32 | 322 | 6.28 | 39.5 | 33 |
| | 2004 | | | 6.31 | 33.2 | 28 |
| IW | 2003 | 74 | 358 | 3.76 | 59.5 | 41 |
| | 2004 | | | 4.12 | 41.2 | 31 |
| CB* | 2003 | 188 | 190 | 7.19 | 445.2 | 309 |
| | 2004 | | | 6.05 | 299.2 | 228 |
| D | 2003 | 295 | 720 | 10.11 | 65.6 | 54 |
| | 2004 | | | 8.22 | 63.6 | 53 |
| RC | 2003 | 855 | 395 | 1.74 | 21.4 | 15 |
| | 2004 | | | 0.91 | 25.6 | 19 |

[1]As a percent of rainfall.
*Insufficient structure for measuring stage

and similar mean SSC.

Sediment yields ranged from 0.91 to 10.11 Mg/ha/yr (Table 2). However, it must be noted that in 2004 at the Rose Creek site there was an equipment malfunction and flow and sediment data were not taken for a period of about 1 month. With this in mind we can assume that the lowest sediment yields occurred in the BF1 watershed and the highest sediment yields occurred in the D watershed. Sediment yields were intermediate in the IW suburban watershed and relatively low in the RC agricultural watershed. In general, sediment yields were similar in 2003 and 2004 for a given watershed, except in the RC agricultural watershed where sediment dropped sharply in the second year which is potentially due to the equipment malfunction mentioned previously.

Water yields ranged from 21.4 to 65.6 cm/yr. Our calculations indicate that the highest water yields occurred in the CB suburban site, however our confidence in these values is low because there is not a suitable structure installed at this site to measure stage height or flow, as indicated in Table 2. Therefore, we will not be considering the data at the CB site in this paper. The highest water yields occurred in the D agricultural watershed. The lowest water yields occurred in the forested watersheds.

There seemed to be preliminary evidence of the effect of logging in the forested watershed rating curves. In Fig. 2, we have plotted the data before and after the date when timber harvesting began in BF2 (January, 2004) for both BF1 and BF2. In BF1 (the undisturbed watershed), there was no evidence that SSC values were higher after this date. In BF2 (the logged watershed), it appeared that SSC values tended to be higher after harvest began.

## DISCUSSION

**Forested watersheds.**

At the beginning of this study the streams in the BF1 and BF2 watersheds were designated as reference streams. However, in January of 2004 timber was harvested in the BF2 watershed, introducing a major anthropogenic change. Because of this change BF2 could no longer be considered a reference stream. However, differences in sediment yields between the logged BF2 site and the BF1 reference site could be compared. There was a noticeable increase in SSC in the BF2 stream from 2003 to 2004. Note that best management practices were utilized during harvest.

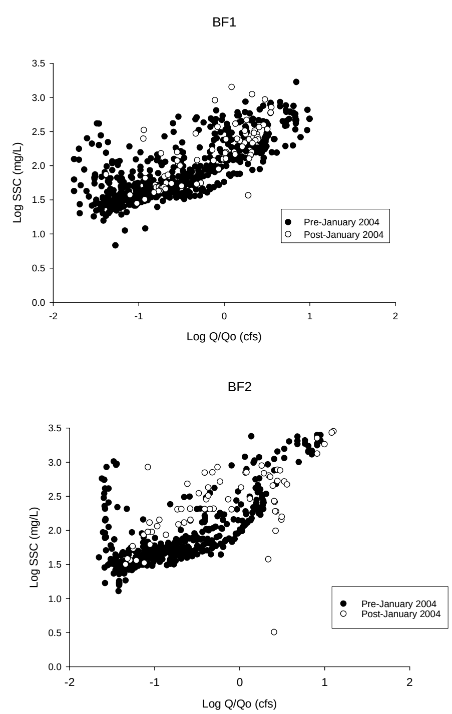


**Figure 2. Pre- and post-treatment sediment relationships in the reference and clear-cut watersheds.**

**Suburban watersheds.**

Sediment yield at the Idylwood watershed was considerably higher than at the BF1 reference site. Higher sediment levels can be partly attributed to differences in vegetation between the forested and suburban watersheds.

The annual water yield at the suburban site was higher than the forested sites and this may have been partly due to less forested area and more impervious surfaces in the suburban watersheds. Part of the increased sediment yield from the suburban site likely resulted from this higher runoff.

**Agricultural watersheds.**

The Dairy watershed had the highest mean SSC and sediment yield and the Rose Creek watershed relatively low values. No attempt was made to adjust the sediment yield for the percent of the agricultural watersheds that were in pasture (55%) vs. forest (26 and 28%). If this had been done, the sediment yields would have been even higher in the agricultural watersheds. The high sediment yield in the Dairy watershed is potentially due to the large number of dairy cattle (nearly two animals per ha) in this watershed. Cattle have access to the stream in some fields and this probably adds to the sediment load. In the Rose Creek watershed there are fewer animals (cattle and horses) and there is less access to the stream.

## CONCLUSIONS

Comparing different land uses to reference streams is an accepted EPA method for developing maximum daily sediment loads for impaired waters. Total maximum daily load (TMDL) development using reference streams is important to the future of TMDL development. Reference streams are less influenced by humans, which makes them ideal for comparison to streams where humans have made a considerable impact on water quality. The ability to compare impaired streams to reference streams that are located in the same geographic region will make the TMDL development process a much easier task to complete in the future.

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