CHARACTERIZATION OF HYDROLOGIC AND SEDIMENT TRANSPORT BEHAVIOR OF FORESTED HEADWATER STREAMS IN SOUTHWEST GEORGIA

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Abstract. Properly established streamside management zones (SMZs) reduce impacts of timber harvesting on stream sediment fluxes. However, effects of partial harvesting within SMZs on water quality are not well documented. The objectives of this study are to characterize hydrology and sediment export in undisturbed first-order streams to provide baseline data for a long-term paired watershed study. The study design includes two control (no harvest) and two eventual treatment watersheds (all are between 26 – 48 hectares in size). The entire treatment watersheds will be harvested except for SMZs, which will be divided into upper and lower sections. The upper section will have an intact SMZ, while the lower section will receive partial harvesting according to Georgia best management practices (BMP) guidelines. Flow and sediment concentrations will be monitored at the outlet of each treatment and control watershed for two years prior to harvest and for several years following harvest. Eighteen months of pretreatment flow and sediment data from the four study watersheds are available for analysis. These data reveal significant differences in hydrologic behavior among four adjacent watersheds with similar soils and nearly identical forest cover.

INTRODUCTION

Sediment is the largest contributor by volume to non-point source water pollution in the U.S. (Neary et al., 1988). Sediment is also the most important potential pollutant from forested lands (Phillips, 1989). When soil is exposed as a result of a timber harvest or site preparation, sediment has an increased risk of being transported down slope and into a stream. Elevated sediment inputs can bury gravel and cobble substrates, reducing the quality of habitat for macro-invertebrates and fish. This process, known as sedimentation, causes a reduction in biodiversity and biomass in aquatic systems (Waters, 1995).

Much of the land use in the Southeast U. S. is currently in forestry. For example, in Georgia alone there are 23.6 million acres of commercial forest land (Georgia Forestry Commission, 1999) and therefore thousands of miles of waterways have potential to be impacted by forestry activities.

BACKGROUND

Like most states that have significant forestry operations, Georgia has developed a set of best management practices (BMPs) to minimize non-point source pollution from forestry activities. Best management practices are defined as methods, measures, practices and techniques designed to maintain water quality within forested watersheds (Aust et al., 1996). An example of a BMP is a streamside management zone (SMZ). SMZs are areas adjacent to a stream in which vegetation is managed and maintained to protect stream water quality (Georgia Forestry Commission, 1999). SMZs are intended to reduce the amount of sediment and other pollutants from reaching the stream in overland flow from storm runoff. Intact vegetation in SMZ's is expected to slow runoff which in turn allows water to infiltrate into the ground and reduces its capacity to transport sediment (Hewlett, 1982). For example, more and larger sediment particles are trapped at the edges of SMZs than are deposited within SMZs (Cooper et al., 1987). This implies that the competence of storm flow to carry sediment is reduced as it enters the SMZ. Streamside management zones have been shown to be an effective BMP for reducing the effects of timber harvesting on sediment flux in streams (Ward 2002, Rivenbark 2002).

BMPs vary from state to state, as do requirements for SMZ widths. Georgia's recommended buffer width for a perennial stream begins at 40 feet and increases as slope of the contributing area increases (Georgia Forestry Commission, 1999). Georgia's recommendations also allow some timber to be harvested within SMZ's. This practice, known as thinning or partial harvesting within SMZs, may be conducted until there is a minimum of 50 square feet of basal area per acre or 50% of the canopy cover remaining. The effects of this practice are not well known, and there are few studies that include partial harvesting treatments.

Research regarding buffer effectiveness has been done by many researchers. However, few studies have been conducted in the coastal plain of the southeast United States. Furthermore, the effects of partial harvesting within SMZs on water quality are not well documented. Research needs to be done to fill in gaps that currently exist regarding SMZ effectiveness in the coastal plain and effects of partial harvesting within SMZs. Conclusive results from this study would aid regulatory agencies in determining / revising forestry BMPs and provide needed information about the effects of particular forest practices on stream hydrology in the coastal plain.

METHODS

Study Site

The study site is located in the southwest corner of Georgia in the Coastal Plain physiographic province approximately 16 km south of Bainbridge. (Figure 1) The physiographic district of the study site is the Pellham escarpment, which is the scarp between the Tifton upland and the Dougherty plain. The soils in the study sites are dominated by Ultisols with the riparian area being comprised of the Cheifland and Esto series which are classified as well drained fine sands over clay loams. The slopes are Eustis series soils, which are loamy sands over sandy loams and classified as somewhat excessively well drained, and the upland soils are comprised of Wagram, Norfolk, Lakeland, Orangeburg, and Lucy which are generally well drained loamy sands over sandy clay loams, with the exception of the Lakeland Unit which has a sandy texture throughout and is characterized as excessively well drained (International Paper, 1980).

The streams in this study drain four adjacent watersheds with similar aspect, size, shape, soils and vegetative cover type. One of the few apparent differences is the valley floor geometry. Watersheds A and B have broader, flatter valley floors with several wetlands areas while C and D have more channelized streams running through steeper, v-shaped valleys.

Study Design

The statistical design will be BACI (Before After Control Impact) consisting of four watersheds. The contributing area for these streams varies from 26 to 48 ha (Figure 1 and Table 1). Watersheds A and D have been selected as references and will not receive any silvicultural treatments for the duration of the study. The remaining two watersheds (B& C) will be clearcut with the exception of the SMZs which will then be divided into an upstream and downstream section. The upper section of SMZ will remain completely intact while the lower section will receive a partial harvest in accordance with Georgia BMPs, which currently allows timber harvesting to be conducted until there is a minimum of 50 square feet of basal area left or 50% of the canopy cover remaining.

Data Collection

Most of the data is automatically collected at six sites: one in the stream at the outlet of each watershed (4 sites) and one in the stream at the lower boundary of the upstream SMZ treatment (2 sites). Stream stage and discharge is recorded every 15 minutes by Isco Model 4230 Bubbler Flow Meters. Sediment samples are collected by an Isco Model 6712 automated sampler during baseflow using flow proportioned sampling and stormflow on 15 minute intervals and are analyzed for total suspended solids (TSS) and suspended sediment concentrations (SSC). Precipitation, temperature, relative humidity, wind speed, wind direction and solar radiation are recorded at the weather station which is

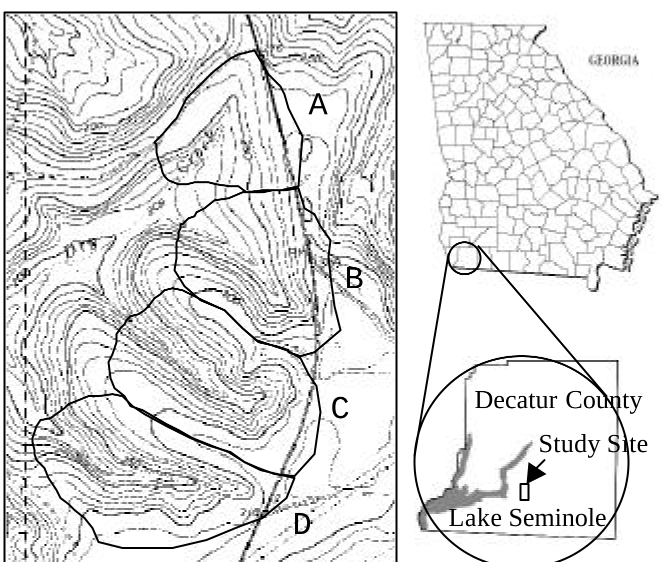

Figure 1. Study site (left), study location (right).

located on a ridge in the center of the study. There is also a second tipping bucket rain gage located on the other side of the study site in place to detect any spatial variation in precipitation.

RESULTS AND DISCUSSION

Selected Flow Characteristics

Stream discharge statistics for the first eighteen months of pretreatment data are summarized in table 1. Despite assumptions made about these watersheds based on their appearance, baseline data reveal their flow characteristics to be quite different (Figure 2). Flows ranged from 233.4 L/s to no flow during the driest periods. Peak flow rates were calculated for 35 rain events during this period. Using forward stepwise regression, a relationship was established between the treatment and control watersheds. For each treatment watershed (B & C), a combination of both control

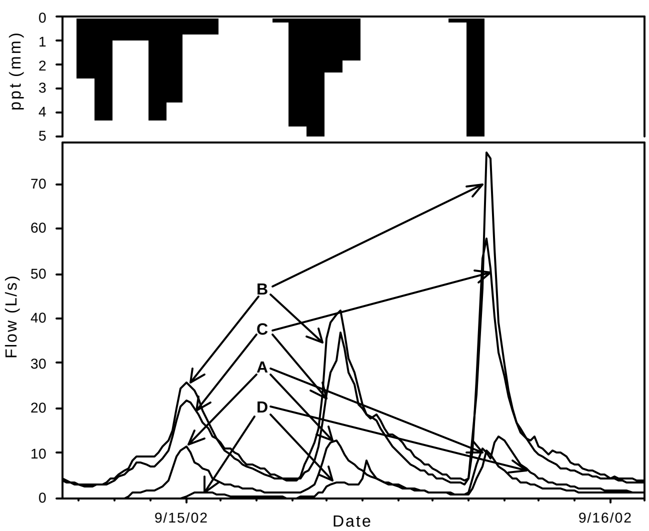

Figure 2. Hydrograph for four experimental watersheds.

Table 1. Flow statistics for first 18 months

Site	*Area (ha)*	*Min Q (L/s/ha)*	*Mean Q (L/s/ha)*	*Max Q (L/s/ha)*	*Zero Flow Days (/578)*
A	26.2	0	.048	4.74	165 (29%)
B	39.7	0	.060	5.88	6 (1%)
C	47.7	.00004	.059	4.62	0 (0%)
D	43.9	0	.021	2.40	216 (38%)

Table 2. Water budget for first 18 months

Site	*Precipitation (mm)*	*Runoff Depth (mm)*	*Yield (%)*
A	1460	226	15%
B	1460	284	19%
C	1460	279	19%
D	1460	98	7%

watersheds together were found to have the best predictive ability, so that:

$$LogQ_{Peak}T = C + aLogQ_{Peak}C_1 + bLogQ_{Peak}\,C_2$$

where T equals the treatment watershed of interest, and C_1 and C_2 are the two control watersheds. Flows were log transformed to reduce heteroscedasticity. Regression analysis for actual and predicted peakflows demonstrates the predictive relationship (Figure 3).

While the flow data suggest the original selection of treatment and control is not optimal from a hydrologic standpoint, other biological studies accompanying this project require adherence to the original study design. Although the hydrographs for the control and treatment streams are quite different (Figure 2), the control streams still provide a very good regression model for predicting peak flows in the treatment streams. The study design therefore will allow direct analysis of changes in peak flows after harvest.

Assessing post-treatment changes to overall flows using the existing study design presents a problem. Typically in paired watershed studies, the control stream flows are used to develop a predictive model of treatment stream flows. Changes in treatment stream hydrology are assessed by looking at deviations from the model predictions. Because of the large number of zero flow days in the control streams this method will not be useful for this project. Instead, the analysis will be reversed, and predictive models of control stream flows will be created from the treatment stream flows.

Sediment Data

Six hundred samples were collected and analyzed representing TSS and SS+C concentrations during stormflows for all four watersheds. The r-squared between TSS and SSC for all these samples combined ranged from .973 (Figure 4). Values for TSS were plotted against streamflow to establish a sediment rating curve (Figure 5).

Sediment behavior varies between the four streams, and does not show the typical positive correlation with flow. Watersheds A and B clearly show a dilution effect with stormflow. We hypothesize that sediment concentrations in these watersheds are driven by processes within the wetland areas of the channel.

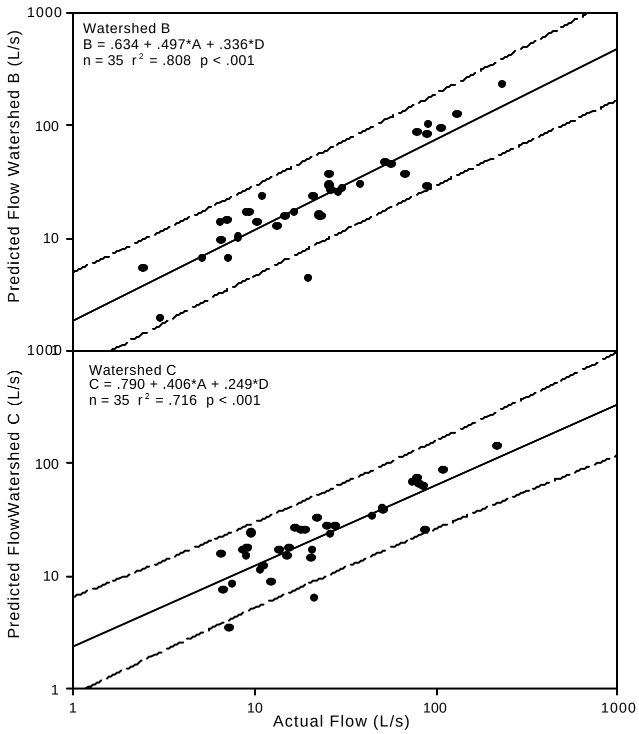

Figure 3. Actual vs. predicted peakflow scatter and regression.

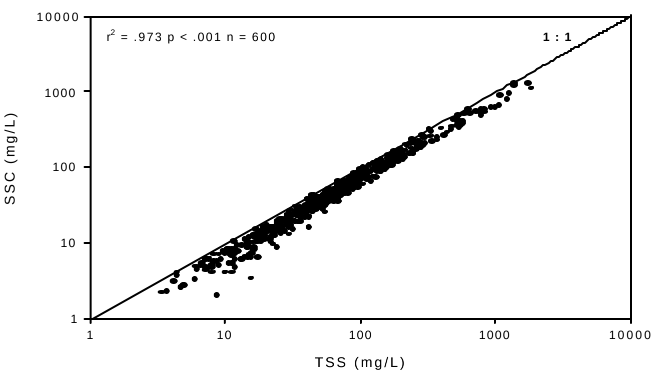

Figure 4. TSS vs. SSC for all four watersheds combined.

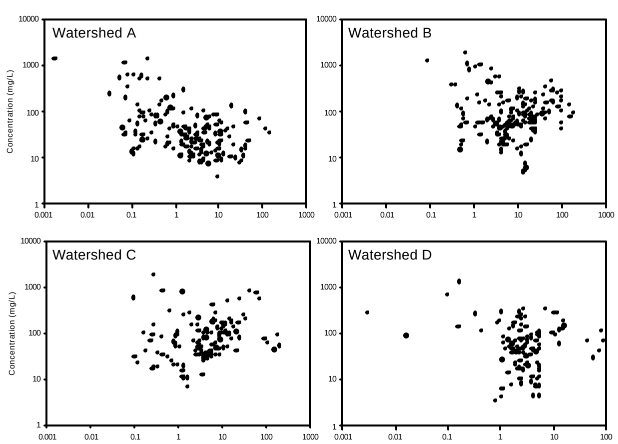

Figure 5. Flow vs. TSS.

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