DRY CREEK LONG-TERM WATERSHED STUDY: EFFECTS OF TIMBER HARVEST ON HYDROLOGY AND SEDIMENT EXPORT IN HEADWATER STREAMS IN SOUTHWEST GEORGIA

W.B. Summer, C. Rhett Jackson, D. Jones, and M. Miwa[1]

Abstract—Properly established streamside management zones (SMZs) reduce potential impacts of timber harvesting on stream hydro-period and sediment fluxes. Effects of upland silvicultural practices on stream hydrology and effects of partial harvesting within SMZs on water quality are not well documented. The objectives of this study are to determine the effects of these forest practices on hydrology and sediment export of first-order streams. The study design includes two reference and two treatment watersheds. After 29 months of baseline data collection, the treatment watersheds were harvested, except for SMZs, which were divided into upper and lower sections. The upper section remained as an intact SMZ, while the lower section was thinned to 50 square feet of basal area per acre. Flow and sediment concentrations were continuously monitored at the outlet of treatment and control watersheds. Sediment data has not been analyzed in time for this conference. Twenty-nine months of pretreatment flow data and 12 months of post-treatment data will be discussed in addition to results of breakthrough and windthrow surveys.

INTRODUCTION

Sediment is the largest contributor by volume to non-point source water pollution in the United States (Neary and others 1988) and the most important potential pollutant from managed operational forested lands (Phillips 1989). When soil is exposed as a result of a timber harvest or site preparation, sediment has an increased potential 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, typically causes a reduction in biodiversity and biomass in aquatic systems (Waters 1995).

Much of the land use in the Southeastern United States is currently in forestry. In Georgia alone there are 23.6 million acres of commercial forest land, comprising nearly 10 percent of the state (Georgia Forestry Commission 1999). Thousands of miles of waterways could potentially 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. BMPs are defined as methods, measures, practices, and techniques designed to maintain water quality within forested watersheds (Aust and others 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 surface runoff from reaching the stream. Intact vegetation in SMZs 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 and others 1987). This implies that the ability of storm flow to carry sediment is reduced as it enters the SMZ. SMZs have been shown to be an effective BMP for reducing the effects of timber harvesting on sediment flux in streams (Rivenbark and Jackson 2004, Ward and Jackson 2004).

BMP standards 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 adjacent hillside increases (Georgia Forestry Commission 1999). Georgia's recommendations allow some timber to be harvested within SMZs. 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 percent canopy cover remaining. The effects of this practice are not well-known, and few studies include partial harvesting treatments.

Research publications regarding buffer effectiveness are numerous. However, few studies have been conducted in the coastal plain of the Southeastern United States. Furthermore, the effects of partial harvesting within SMZs on water quality are not well-documented. Researchers need to fill in gaps in knowledge that currently exist regarding SMZ effectiveness in the coastal plain and effects of partial harvesting within SMZs. The objective of this study is to evaluate the hydrologic and sediment transport behavior of four headwater streams and their initial response to timber harvest and site preparation. Results from this study will 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 southwestern corner of Georgia in the Coastal Plain physiographic province approximately 16 km south of Bainbridge, GA (fig. 1). The physiographic

[1] M.S. Candidate and Associate Professor, University of Georgia, Warnell School of Forest Resources, Athens, GA 30602; and Research Associate and Forest Hydrologist, International Paper, Southlands Forest, Bainbridge, GA 31717, respectively.

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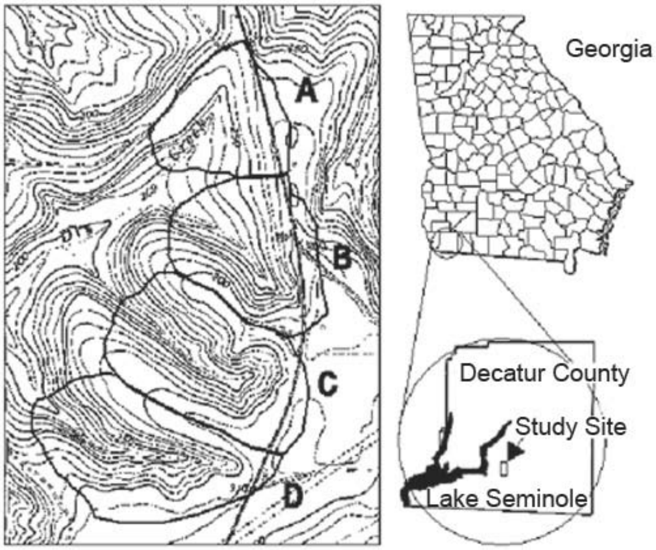

Figure 1—The study site, located 16 km south of Bainbridge, GA.

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. 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 soil survey, unpublished).

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. These geomorphologic differences were used to pair the watersheds into what was initially believed to be the most optimal groups (A+B and C+D).

Study Design

This study is part of a larger multi-disciplinary study designed to examine the effects of forest practices. The statistical design is BACI (Before After Control Impact) consisting of two watershed pairs. The contributing area for these streams varies from 26 to 48 ha (table 1). Watersheds A and D were selected as references and did not receive any silvicultural treatments. The remaining two watersheds (B and C) were clearcut in the fall of 2003, with the exception of the SMZs, which were divided into an upstream and downstream section. The upstream section remains completely intact while the downstream section was thinned in accordance with Georgia BMPs. We chose to use basal area as a guideline for thinning and measured every tree to meet minimum BMP guidelines.

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 connected to a 9-inch Parshall flume. Sediment samples are collected by an Isco Model 6712 automated sampler stormflow on 15-minute intervals and are analyzed for total suspended solids (TSS) and organic and inorganic portions. Precipitation, temperature, relative humidity, wind speed, wind direction, and solar radiation are recorded at the weather station which is located on a ridge. There is also a second tipping-bucket rain gage located on the other side of the study site to detect any spatial variation in precipitation.

Several surveys were performed to quantify and record other events such as windthrow and sediment breakthrough. The windthrow survey was performed 8 months after the harvest to determine how many trees were lost to windthrow. The break-through surveys were done before and several times after the harvest to assess where water and sediment were flowing across the SMZ boundary. The boundary was walked, and details of any occurrence were recorded, such as evidence of sediment movement intruding into the SMZ.

RESULTS AND DISCUSSION

Hydrology

The calibration period revealed variation in hydrologic characteristics between watersheds that were contrary to some expectations: Similarities in watershed size and morphology were not reflected in the hydrology. The assumptions were that adjacent watershed pairs with similar geometry and size would have similar base flow and storm response in relation to catchment area.

Using peakflow data from 54 storms which resulted in peakflow values > 10 L per second in all of the four watersheds, a pre- and post-treatment relationship was established within each of the pairs of reference and treatment watersheds (figs. 2 and 3). The data suggest an increase in peakflow trend

Table 1—Watershed characteristics for pre-treatment period

Watershed	Area	Min Q	Mean Q	Max Q	Zero flow days (#/822 days)
	ha	*L/s/ha*	*L/s/ha*	*L/s/ha*	*#/%*
A	25.8	0	0.055	8.37	163 (20%)
B	34.7	0	0.074	14.08	6 (0.07%)
C	42.7	0	0.073	9.91	2 (0.02%)
D	48	0	0.042	7.17	206 (25%)

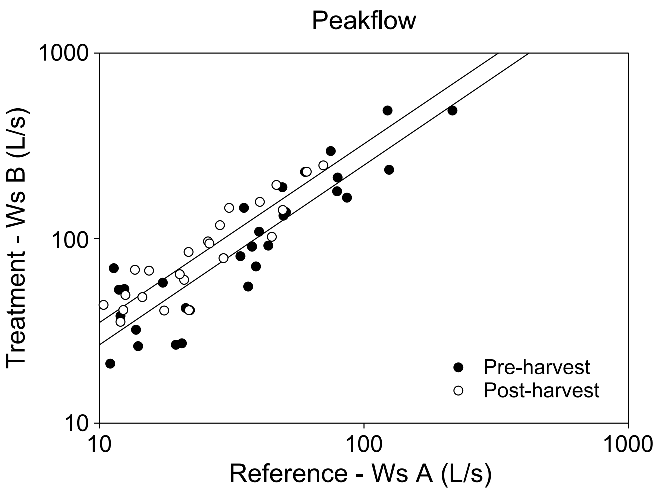

Figure 2—Pre- and post-treatment peak flow relationships between watersheds A and B. Regression slope and y-intercept are not statistically different.

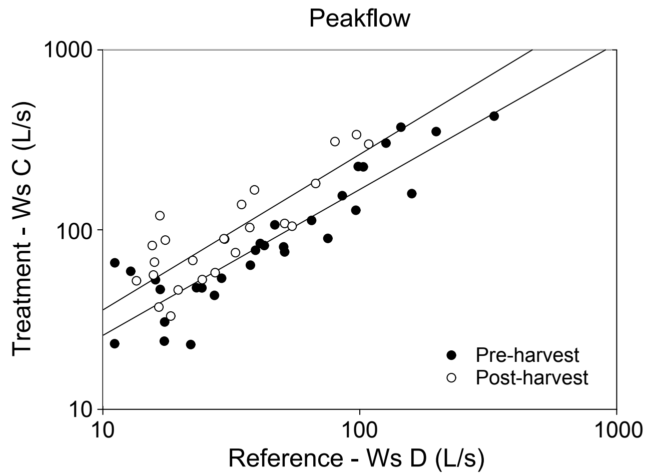

Figure 3—Pre- and post-treatment peak flow relationships between watersheds C and D. Regression slope and y-intercept are not statistically different.

due to treatment, but analysis using ANCOVA reveals that the pre- and post-treatment regressions are not significantly different at $\alpha = 0.05$. This could be due a high variance among the data sets, and there may be potential to improve the relationship by using additional factors. Such factors would account for different responses due to antecedent moisture or seasonal differences. Preliminary comparisons of the cumulative flow data and cumulative rain fall indicate an increase in the overall flow of the treatment watersheds following harvest (fig. 4). However, the amount of increase is not yet clear due to differences in the predictions based on the reference watersheds. These results show that the actual relationships among these four streams were different, indicating a potential difference in groundwater interaction or near-surface geology. Though the flow characteristics were different in magnitude, useful predictive relationships were established.

Breakthrough

The breakthrough surveys revealed little evidence of sediment or concentrated flow movement across the proposed SMZ boundary before the harvest in any of the four watersheds. The historic agricultural gullies, though present, were stable and showed no signs of activity. There were expectations of potential re-activation of these gullies after the harvest, though

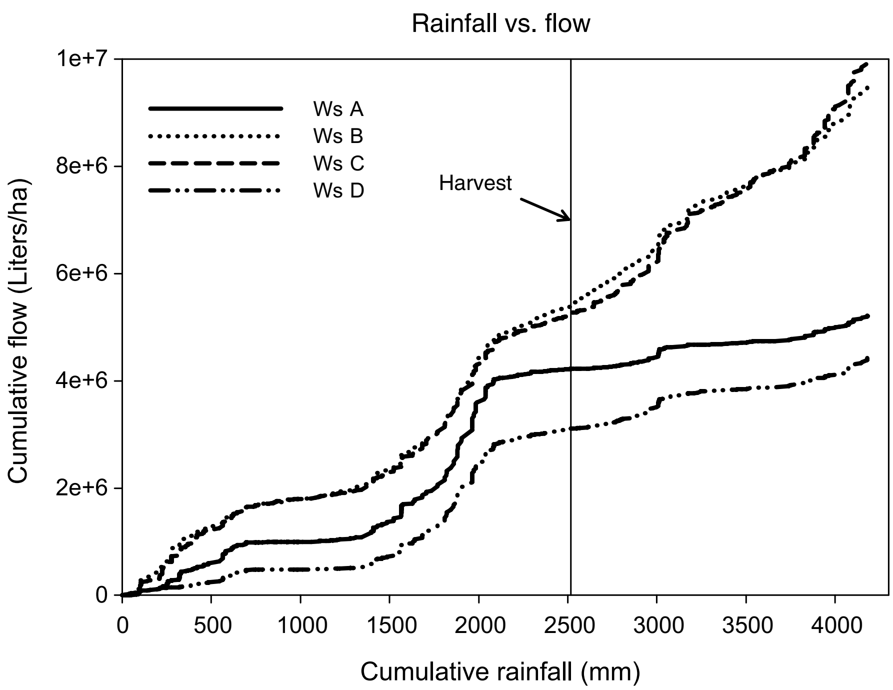

Figure 4—Relation between cumulative rainfall and cumulative flow. Effects of harvest on overall flow are suggested by a change in the slope of the lines representing the treatment watersheds shortly after the harvest.

very few showed any change in the year after harvest and before site preparation.

There were many seeps that appeared in the treatment watersheds. Many of them occurred at the toeslope within approximately 10 m of the SMZ boundary, on average, and flowed across the boundary into the stream. Because they occurred at the bottom of the slope, they likely lack any real power to entrain and move sediment. However, they do increase the variable source area and are therefore of some management concern. Care needs to be taken to avoid application of forest chemicals in those areas to prevent the seeps from functioning as a direct pathway for herbicide to enter the stream.

Windthrow

Reference watersheds had no windthrow within the boundary of what would have been an SMZ for those watersheds had they been harvested. Treatment watersheds had a total of 36 stems fall, with average and maximum d.b.h.s of 13.9 and 25.9 inches, respectively. Thinned sections of SMZ had more basal area loss per acre and more stem loss per foot than those of unthinned counterparts on both harvested watersheds (figs. 5 and 6).

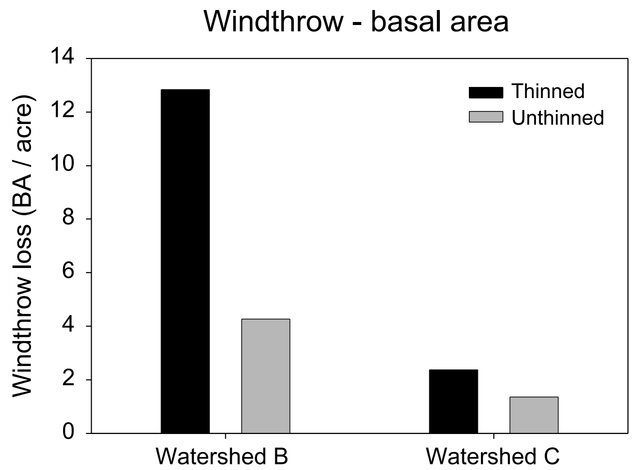

Figure 5—Basal area loss from windthrow per acre of SMZ. Data reflects 9 months after the harvest.

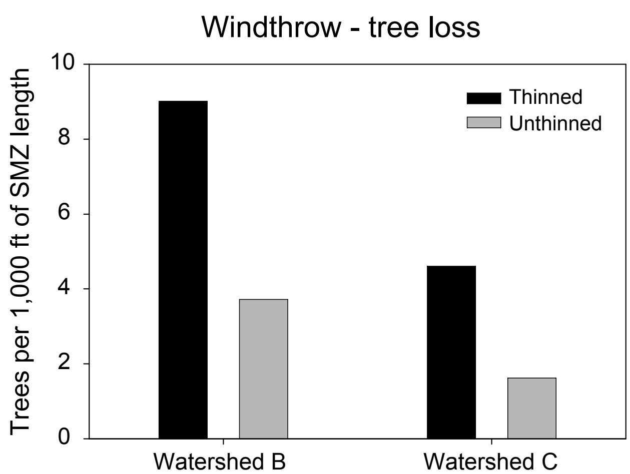

Figure 6—Tree loss from windthrow per 1,000 feet of SMZ boundary. Data reflects 9 months after the harvest.

The harvested watersheds as a whole lost many trees to windthrow, while the reference watersheds lost none. This can be attributed to two things: (1) loss of shelter and support from mature forest and (2) loss of soil "strength" due to elevated water tables. The largest and most abundant trees in the SMZ are the tulip poplar (*Liriodendron tulipifera* L.) and swamp tupelo (*Nyssa sylvatica* var. biflora). However, one out of every two trees to succumb to windthrow was a tulip poplar, while only three total (8 percent) were tupelo (two of which were knocked over by other trees). The conditions in the SMZ as a result of the harvest seem to favor trees adapted to a swampy environment, such the tupelo with its buttressed trunk.

When examined individually, the partially harvested sections of SMZ lost more trees than the unthinned SMZ. While the effects of the thinning (less canopy, more machine traffic, and less wind protection) may appear to be the only contributing factors, there are other site-specific factors independent of the treatment to be considered. In Watershed B, the section now designated "thinned" appeared to be wetter and generally swampier than the upper unthinned section before the harvest; and it is more so after harvesting. In addition, despite the deep, confined channel in the downstream section of Watershed C, there is a large area on the terrace that appears to be wetter since the harvest and is unique to that section of the stream. Also, because much of the unthinned section of Watershed C contains meandering and braided channels, often separated by 10 m or more, the overall width of that section may make it less susceptible to damaging winds. More investigation needs to done on this subject.

CONCLUSIONS

Preliminary results indicate the changes in hydrology due to harvesting on these headwater streams are similar to those previously studied. Overall stream flow appears to have increased while peakflow increase is not statistically significant, leaving the source of the increased flow to likely be increase summer baseflows. While suspended sediment data has not yet been analyzed, the results from the SMZ breakthrough surveys indicate that very little sediment is moving from the harvested areas into the stream. Two observations from the surveys that should be of concern to managers are: (1) the toe-slope seeps and their ability to link upland forest practices to the stream and (2) the potential for many trees to be lost to windthrow in the thinned SMZs, especially those with near surface water tables.

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