HYDOGRAPH RESPONSES TO TIMBER HARVESTING IN THE MISSOURI OZARKS[1/]

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Abstract.--A paired watershed study in the Missouri Ozarks determined that while hardwood clearcutting may increase total storm yields and peak flows, the magnitudes are not important in terms of management of small headwater catchments.

Keywords: harvesting, hydrology, hydrograph-response

INTRODUCTION

There is little question that forest hydrologic research in the Central Hardwood Region, as elsewhere in the country, received a major transfusion of both dollars and renewed effort from Section 208 of PL 92-500 as of 1972 (Revised 1977). Although studies have, by necessity, been focused initially on water quality implications of forest land use, within the last few years several researchers have been looking more closely at related questions tied to individual storm hydrology phenomena.

Most paired watershed studies of the 1970s and early 1980s conducted in the eastern United States have verified that forest clearcut harvesting may increase stormflow (quickflow) total yields from zero to 50 magnitude and watershed characteristics (Hewlett and Helvey, 1970; Hewlett, 1983; Swank, et.al., 1982; and Settergren, et.al., 1980). Both Hewlett and Swank noted that the greatest increases in quickflow occurred during the smaller storm events.

In examining individual storm hydrograph parameters Swank, et.al., 1982, found an increase in peak flow rate following clearcutting at Coweeta of 15 percent. Although other hydrograph changes including initial flow rate, quickflow volume prior to peak, duration of quickflow, and recession times were found to be significantly altered, Swank concluded that the relative magnitudes were of minor importance. Hewlett and Helvey, 1970, found that peak discharges were increased an average of 7 percent but that these data were not to be considered conclusive. Time to peak (time of rise), recession time and quickflow duration were not affected by the clearcutting treatment. In Hewlett's more recent study (1983) peak flows immediately below the logging operation increased by as much as 30 to 45 percent. He noted that while these high flow rates had some limited design implications, they were more important as possible causes for increased local channel cutting and sediment yield.

Hewlett and Helvey, 1970, and Hewlett, 1983, discuss the effect of clearcutting on reducing evapotranspirational drawdown of soil moisture. The subsequent reduced availability of retention storage prior to the storm event they claim is responsible for the somewhat higher peak flows. The measured increases in total quickflow volume, in turn, are attributable solely to the higher peaks.

Although these and other studies in the eastern hardwood region are, for the most part, applicable to forest management conditions which prevail further west in the Ozark region of Missouri, Arkansas and Oklahoma, some notable differences exist which warranted more local investigations. Annual precipitation, which generally averages less than 45 inches, generates little perennial flow from the small upstream watersheds. The dry antecendent mois-

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ture conditions typical during the summer season when high intensity convective storms are prevalent may lead to somewhat different hydrograph responses to timber harvest.

THE STUDY

Research was begun by the University of Missouri School of Forestry, Fisheries and Wildlife at its University Forest facility in southeast Missouri during the late 1960s to determine the impact of timber harvesting and other land-use practices on the quantity, quality and timing of Ozark water yields. In 1969, as part of the overall study, two small adjacent oak-hickory watersheds, 4.03 and 6.58 hectares in size, were gauged with H-type flumes to monitor stormflow. Following calibration, one watershed was designated to receive a regeneration harvest during the winter of 1978-79 employing local silvicultural procedures. All sawlogs, mostly oak, were harvested first. Pulpwood was then cut down to a 4-inch dbh. limit and removed from the watershed. The remaining stems were subsequently felled, lopped and scattered along with the slash. Logging was completed by March, 1979.

Stormflow Analysis

Stormflow hydrographs from the control watershed (watershed 1) and the treated watershed (watershed 2) were analyzed for the period 1969 thru 1978 to generate calibration regressions for, 1) total stormflow (quickflow), 2) peak discharge, 3) time to peak (time of rise), and 4) total stormflow duration. Whenever necessary, quickflow hydrograph separation was accomplished using the procedure outlined by Hewlett and Helvey (1970). The effect of clearcutting on each hydrograph parameter was estimated by determining the difference between the actual measured post treatment value and that calculated from the calibration regression model. The differences were then subjected to a simple T-test to establish statistical significance.

Hydrograph Selection

Not every hydrograph produced during pre and post treatment storm runoff events were suitable for detailed analysis. Relatively few of the many hydrographs produced during the seventeen-year duration passed a rigorous test for further consideration. All complex hydrographs were discarded and only those simple hydrographs produced by fairly uniform intensity storms were selected. Since the graphical synchronization of timing was necessary for the accurate determination and correlation of two regimen characteristics, only those hydrographs where these points could be established with certainty were used. Both time to peak and total stormflow duration are dependent on the accurate identification of the beqinning of the rise. Unfortunately, because of instrument limitations and problems encountered during routine analysis over the long duration of this study the location of this point in time was the limiting factor which tended to exclude the greatest number of hydrographs from further consideration. Therefore, only hydrographs or, more accurately, hydrograph pairs which were cleared through this screening were considered to be clean enough for comparison.

Results

Stormflows in the selected hydrographs ranged from 0.005 to 3.360 centimeters for the control watershed. Several larger storm events during the seventeen-year study period, as previously explained, had to be discarded from the data set. The hydrograph regression statistics for the calibration period are found in the following tabulation for 32 pretreatment storms.

Parameter	Slope	r^2
Time to peak (hours)	.99	.99
Flow duration (hours)	.90	.98
Peak discharge (#/sec.)	1.45	.86
Total flow (cm.)	.91	.79

The hydrographs produced by the two watersheds are very similar in most respects. The control watershed has a slightly longer time to peak and stormflow duration. And, the control watershed has higher total flows in areal centimeters. On the other hand, the larger catchment, watershed 2, as might be expected, has peak discharges which average 50 percent higher.

The calibration regressions for time to peak and stormflow duration are presented in figures 1 and 2 respectively. The post-harvest data are plotted on the linear models for comparison. When the "T" test was applied

for comparison. When the "T" test was applied to the differences between the calibrations and the post treatment data, neither time to peak nor stormflow duration proved to be statistically significant. The mean difference for time to peak was .09 hours while that for flow duration was 1.30 hours.

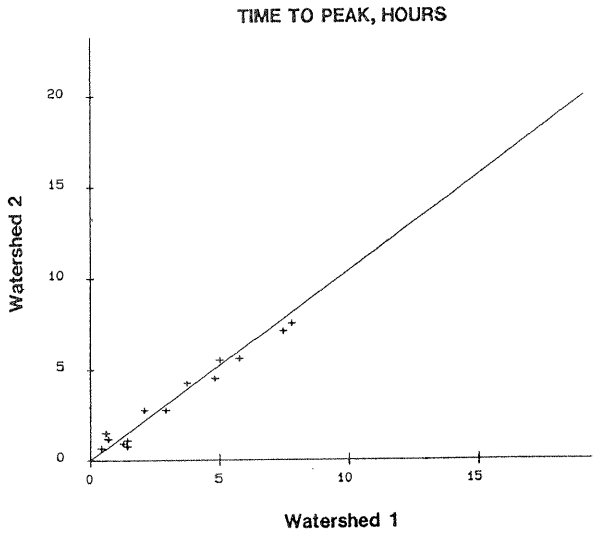

Figure 1.--Time to peak calibration and treatment data

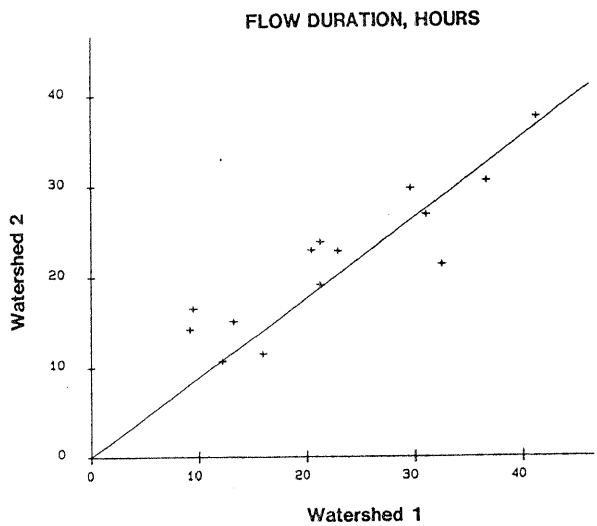

Figure 2.--Flow duration calibration and treatment data

Total stormflow was significantly increased (.05 level) following logging (fig. 3). However, the average increase was only 0.087 centimeters. Although most stormflows were increased less than 10 percent, a few of the smaller events produced as much as 5-times the volume predicted from the calibration model.

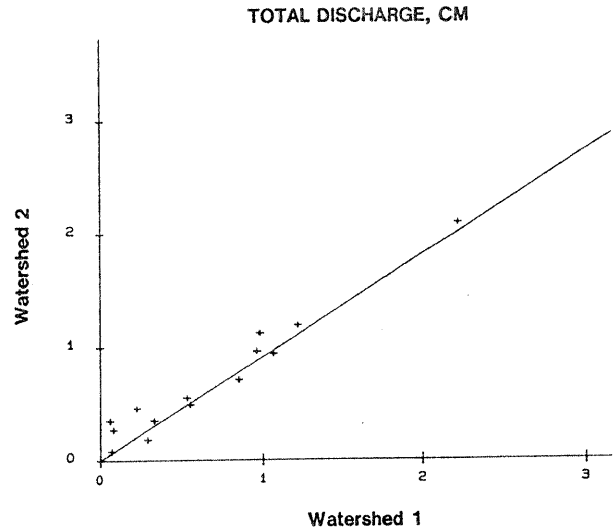

Figure 3.--Total stormflow calibration and treatment data

Harvesting produced highly significant changes in the observed peak discharges (.01 level); although again, the average increase amounted to only 6.55 liters per second (fig. 4). Increases ranged from 11 percent to over 9-times the predicted peak for a small, 0.05 centimeter, stormflow. The actual magnitude of the increase was only 0.045 liters per second over the predicted.

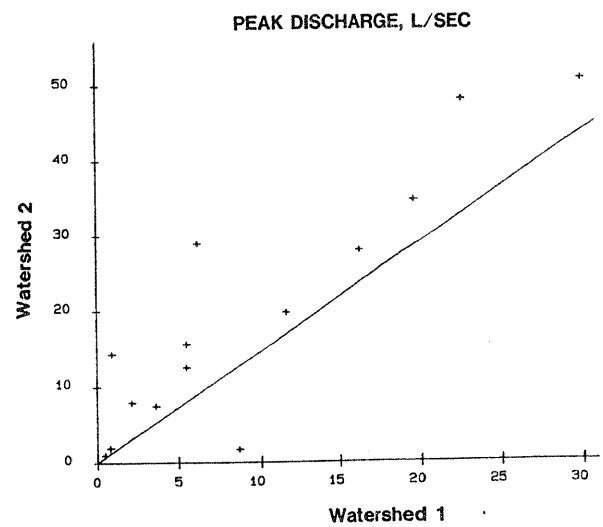

Figure 4.--Peak discharge calibration and treatment data

DISCUSSION

It is interesting to note that this research produced much the same results as those studies previously noted from the east. That is, clearcutting generally leads to slightly increased stormflow yields and produces higher peak discharges. Speaking in terms of relative increases, that is, the percentage increase above the predicted, may lead to spurious conclusions. While the average relative increases in total flow and peak discharge were somewhat higher in this study than those reported in the east, 68 and 124 percent respectively, the absolute amounts are insignificant. Such increases which might be expected following clearcutting on the headwater hardwood watersheds such as the ones used in this study provide no particular management problems with respect to either flood flow generation or design. However, there is probably some added risk of increased channel cutting due to the higher peaks below the clearcut as noted by Hewlett (1983).

The fact that total flows and peaks (controlled primarily by antecedent moisture conditions modified by vegetation removal) were changed while time to peak and total flow duration (controlled to a great extent by basin geomorphology) were not may suggest that unit hydrograph theory principles are at work.

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