# STORM FLOW FROM DUAL-USE WATERSHEDS IN SOUTHWESTERN WISCONSIN

**Richard S. Sartz**

In southwestern Wisconsin's Driftless Area, known as the "Coulee Region" because of its many narrow, steep-sided valleys, the landscape typically consists of flat or gently rounded ridges, steep slopes, and coulees. Ridgetops and coulees are usually farmed, and the steeper slopes sandwiched between the two are usually forested (fig. 1). This distinctive land-use pattern has an important effect on floods, since runoff from upland fields must pass through the forest zone on its way to valley streams.

The forest zone rarely contributes to floods; and then only insignificant amounts compared with open land (Sartz 1969). Curtis (1966) has shown that the forest zone also absorbs runoff from upland fields, and that only large flows reach valley streams. This paper presents some quantitative comparisons of storm flow from upland fields and outflow at the bottom of the wooded slopes below.

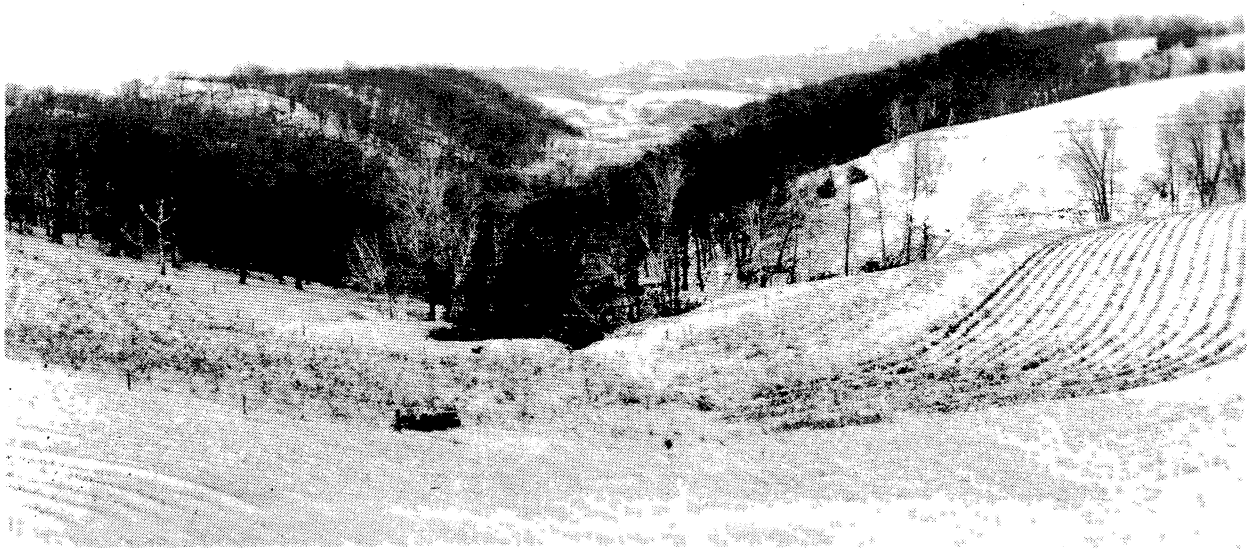

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Figure 1. — *Looking down a coulee from top of the ridge.*

## THE WATERSHEDS

The study watersheds, which are made up of forested slopes rimmed by a segment of open land at the top, are all on the Coulee Experimental Forest. The open uplands rim the watersheds in a rough contour belt that averages about 300 feet wide on a slope of about 15 percent. Gullies carved by overland flow from upland fields slash the forested slopes from top to bottom. The gullies may be 50 feet wide and 25 feet deep on the steeper slopes, and they often form a dendritic pattern, following the natural shape of the watershed (fig. 2). In some places they are washed to bedrock (dolomite in upper reaches, sandstone in lower reaches), and between flows they may become clogged with leaves and debris. The forest is oak-hickory and associated species, typical of high-graded farm woods in the region.

Only four of seven dual-use watersheds studied yielded flow enough times at the lower gage to give a reasonable comparison between upland and total watershed runoff. Total areas ranged from 28 to 83 acres, and upland areas from 6 to 23 acres. The open uplands made up 12 to 31 percent of the study watersheds. Ridgetops are about 350 feet above the lower gaging stations, and slopes range up to about 40 percent.

It was not feasible to gage the entire upland areas because they do not form natural basins. Instead, upland runoff was measured on sample areas. These were simply parts of the upland bounded by natural

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Figure 2. — *Woodland gully on C2 watershed, Coulee Experimental Forest. Note man holding rod (lower left).*

divides on the sides and top and terraced at the field-forest border to channel water through a measuring device. Seven such sample areas that ranged from 1.4 to 2.8 acres were instrumented (fig. 3). The areas chosen approximated natural basins, and thus gave a maximum sample area for a minimum number of measuring stations.

The objective of the study was to determine the effectiveness of the forest zone in disposing of runoff water from fields above. To produce variable amounts of field runoff, the uplands were planted to both high (corn, oats, and field peas) and low (alfalfa meadow) runoff-producing crops during the study period.

Watershed C2 was gaged from 1962 to 1967, and the other three from 1962 to 1969. The upland sample watersheds were gaged concurrently. The upland areas of watersheds C1, C2, and C3, which were treated alike, were planted annually to row crops from 1962 through 1965. In 1965 alfalfa was seeded along with oats. C4 upland was seeded to alfalfa in 1962 and remained in meadow for the duration of the study. Row-crop runoff was, of course, much greater than meadow runoff (Sartz 1970), but the differences are immaterial here except that they provided variable amounts of field runoff for the field versus total watershed runoff comparison. Because the objective of the study was to determine how much of the field runoff passed through the forest zone, lower station runoff is given in terms of inches depth on the upland area.

Runoff was measured by 1.5-foot H flumes at upper stations and by 2-foot San Dimas flumes at lower stations (fig. 4). Suspended sediment was measured as described by Sartz and Curtis (1967). Upland runoff from watersheds C2, C3, and C4 was assumed to equal the mean runoff from their respective sample areas, and upland runoff from C1 was assumed to equal that of adjacent watershed C2 (fig. 3). Most of the water measured at the lower stations was assumed to have come from the upland areas of the water-

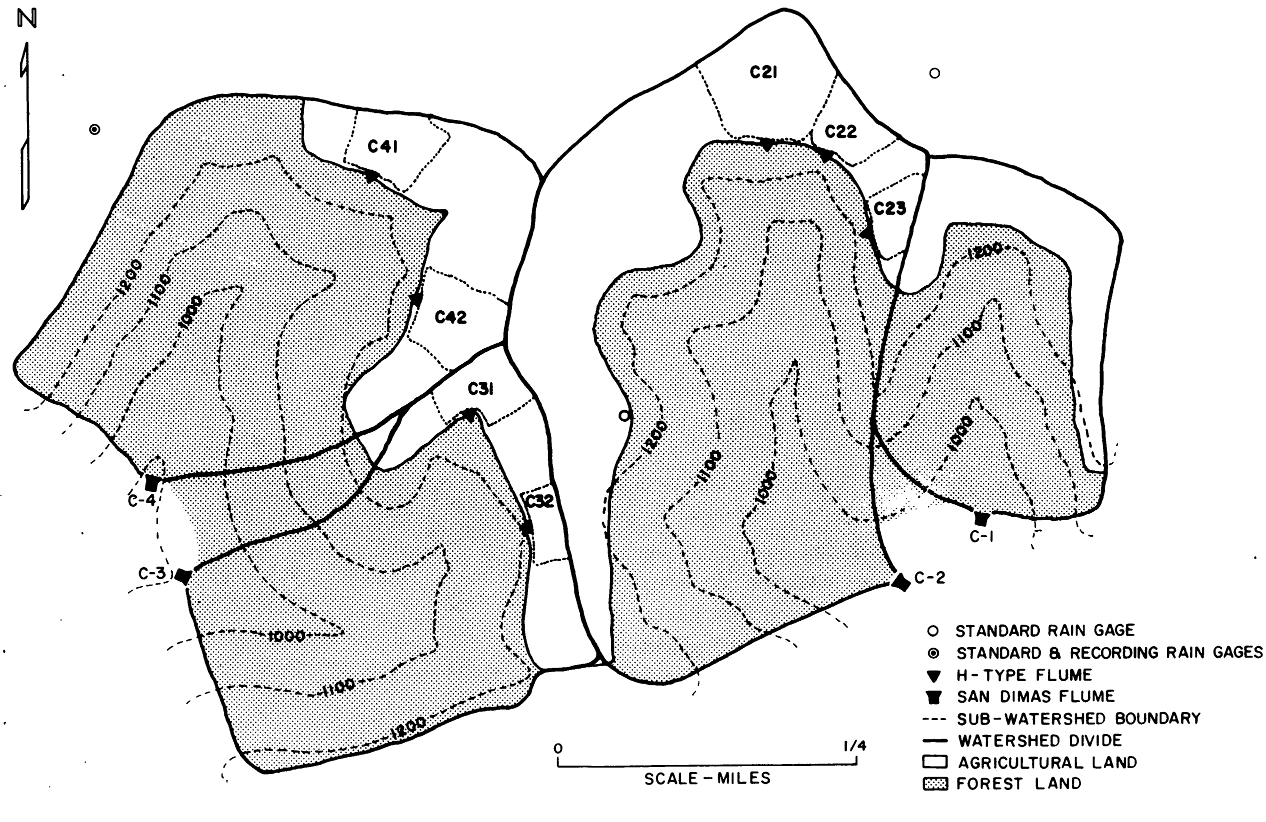


Figure 3. — *Map of study watersheds.*

sheds. Although some may have come from channel or forest areas during major storms, the amounts would have been small compared with the upland component (Sartz 1970).

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Figure 4. — *San Dimas flume used at lower stations.*

## RESULTS

As previously reported by Curtis (1966), most of the upland flows never reached the bottom of the forested slopes. The number of flows recorded at upper and lower stations on three watersheds (C1 had no upland gages) in a 6-year period was:

| *Watershed* | *Upper* | *Lower* |
|---|---|---|
| C2 | 118 | 40 |
| C3 | 89 | 13 |
| C4 | 69 | 3 |

Minimum upland flows that produced lower station flows ranged from 0.02 to 0.08 area inches. In general, the larger the upland flow, the larger the lower station flow and the larger the proportion of upland runoff that reached lower stations; but there were many exceptions. For example, the largest flow on watershed C3 (produced by a 3-inch, high-intensity storm) was 1.49 inches from the upland and 1.00 inch at the lower station. Assuming no contribution from the forest zone, only 67 percent of the upland flow reached the bottom of the forested slope. But a much smaller upland flow of only 0.19 inch from another storm produced a lower station flow of 0.16 inch, or 84 percent. Similar examples could be cited for the other three watersheds.

Lower station flow as a percentage of upland flow for individual storms ranged from 0 to 110. Lower station flows exceeded the estimated upland runoff (reflecting some contribution from forest and/or gullied channel areas) once on three of the four catchments. Lower station flows as mean percentage of upland runoff for eight large storms were as follows: C1, 84; C2, 94; C3, 79. C4 was not included because it yielded flow at the lower station from only one of the eight storms. In six other major storms when C4 did have flow at the lower station, the flow was 56 percent of the upland flow, while for the same storms, the value for C3 was 62 percent.

Maximum peak flows at lower stations ranged from 0.21 (C4) to 0.99 (C1) inch per hour, based on total watershed area. Considering only the uplands as the contributing area, the values were 1.71 and 4.96 inches per hour. The corresponding upper station peaks were 2.62 and 2.37 inches per hour. Timing of flow at upper and lower stations is illustrated by the hydrographs for a short, high-intensity rain (fig. 5) and for a longer, but less intense rain (fig. 6). Rainfall for the former was 1.25 inches in 35 minutes, for the latter, 2.50 inches in 150 minutes. Both rains fell on wet soil. Although the larger storm produced more flow on two of the three watersheds, the smaller storm produced considerably higher peak flows at both upper and lower stations.

Some differences between watersheds in the response of lower station flow to upland flow have already been shown. Data from the May 25, 1965, storm, which produced the greatest amount of flow and the highest peaks, offer an additional comparison:

| *Upper stations* | *Total flow Inches* | *Peak-flow Inches per hour* |
|---|---|---|
| 21 | 1.40 | 1.89 |
| 22 | 1.82 | 2.14 |
| 23 | 1.75 | 3.08 |
| 31 | 1.36 | 2.48 |
| 32 | 1.62 | 3.14 |
| *Lower stations* | | |
| 1 | 1.61 | 4.96 |
| 2 | 1.59 | 1.88 |
| 3 | 1.00 | 3.27 |

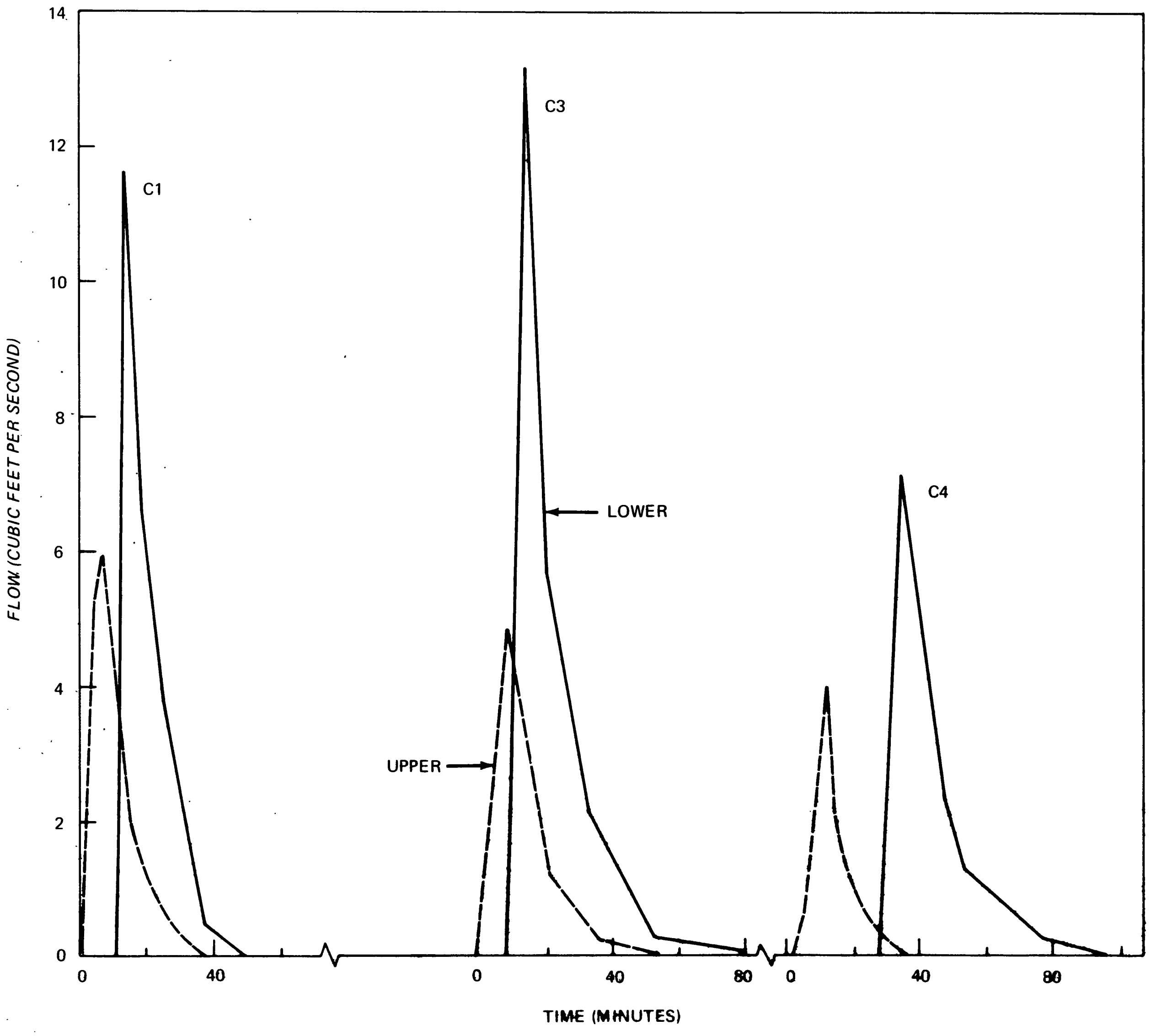


Figure 5. — *Hydrographs for three upper and lower stations, storm of June 8-9, 1967. Flow is in cubic feet per second. Comparative size of the individual watersheds can be seen in figure 3.*

Both total and peak flows for lower as well as upper stations are based on upland watershed areas. The upland areas of all three watersheds were newly seeded to oats and there was little cover at the time of the storm. C4 upland was in third-year meadow, and although it produced an estimated 0.20 inch of runoff, there was no flow at the lower station. Suspended sediment in the runoff water was generally higher at lower stations than at upper stations (table 1).

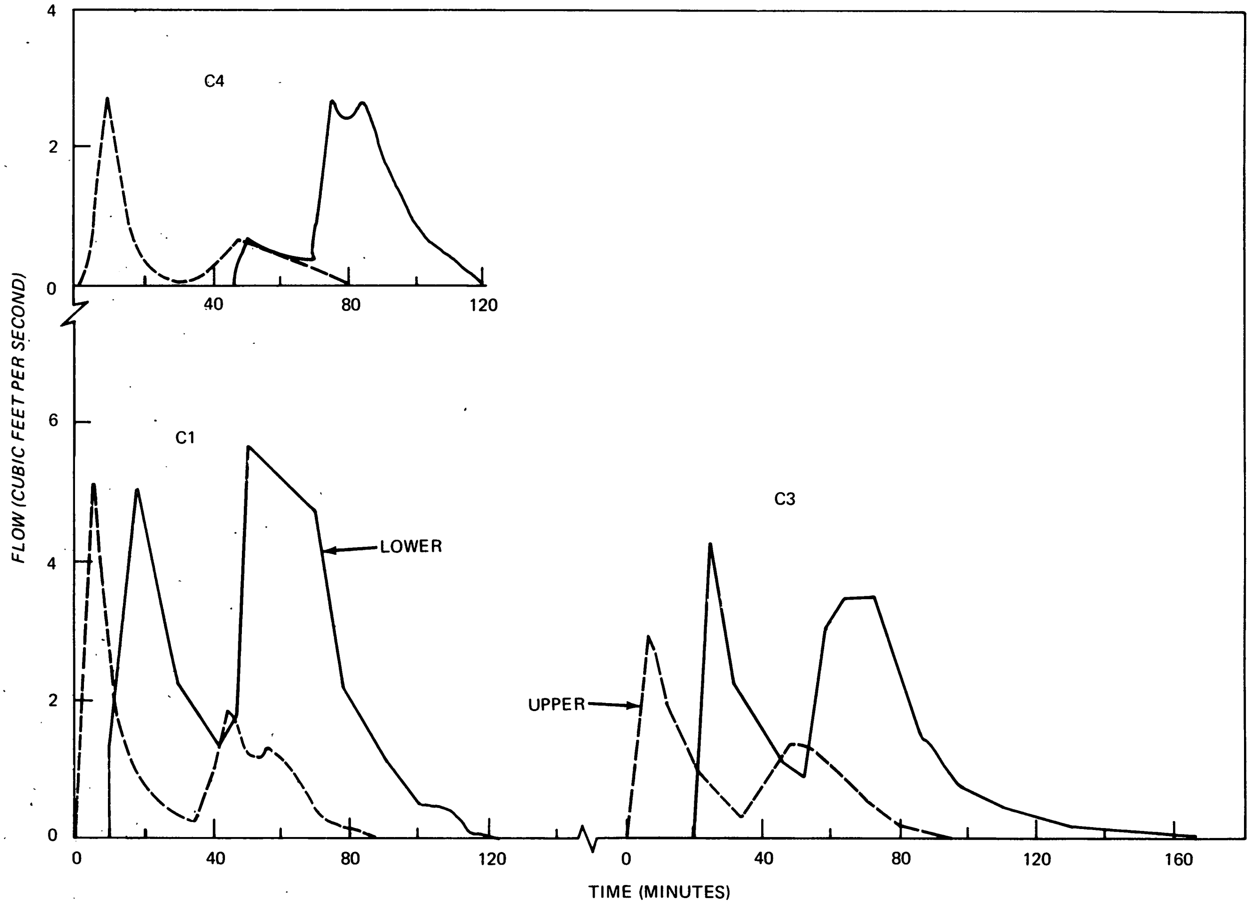


Figure 6. — *Hydrographs for three upper and lower stations, storm of June 26, 1969. Flow is in cubic feet per second. Comparative size of the individual watersheds can be seen in figure 3.*

Table 1. — *Mean suspended sediment content at upper and lower stations on watersheds C2 and C3*
(In parts per million/100)

| Date of storm | C2 | | C3 | |
|---|---|---|---|---|
| | Upper | Lower | Upper | Lower |
| May 21, 1965 | 1,667 | 1,969 | 716 | 918 |
| May 25, 1965 | 1,956 | 1,392 | 818 | 1,406 |
| July 9, 1965 | 232 | 431 | 80 | 432 |
| August 14, 1965 | 40 | 205 | 36 | 83 |
| August 17, 1965 | 58 | 129 | 22 | 86 |
| August 27-28, 1965 | 24 | 59 | 11 | 97 |
| June 9, 1967 | 103 | 375 | 46 | 1,800 |
| Average | 583 | 651 | 247 | 689 |

## DISCUSSION

Although the forest zone disposed of much of the upland runoff, its effectiveness varied greatly from storm to storm and from watershed to watershed. Storm-to-storm variation resulted from differences in rainfall amount, intensity, interaction of the two, and in the amount of water in the soil when the storm began. The amount of channel debris also may have been a factor. The lower channels of watersheds C3 and C4, which had much less frequent flows than those of watersheds C1 and C2, sometimes had 2- or 3-year accumulations of leaves and branch material, and this would have slowed the flow, allowing more channel infiltration.

Water flow differences among watersheds could result from differences in the size and shape of the watersheds, channel areas, debris, meander patterns, the forest litter cover, storm rainfall, the relative size and shape of the upland, and the reliability of the upland runoff estimate.

Although we did not survey the forest litter cover on each watershed, a comprehensive survey of the experimental forest showed uniform litter and humus depths on similar ungrazed areas (Knighton 1970). Storm rainfall was generally uniform, particularly for the larger storms (Sartz 1966). Of the geomorphic features that we measured (total area, upland and forest areas, and gullied channel area), only the ratio of upland to forest areas appeared related to the response of lower station flow to upland flow. The relationship was most evident for larger storms:

| | *Watershed* | | | |
|---|---|---|---|---|
| | *C2* | *C1* | *C3* | *C4* |
| Lower station flow as percent of upland runoff | 96 | 80 | 71 | 56 |
| Ratio of upland to forest areas | 1:3 | 1:5 | 1:7 | 1:8 |

Some lower station peak flows were higher (based on the upland area) than their corresponding upper station peak flows. This might be expected. Lower station runoff came from the entire upland area of the watershed while upper station runoff came from small sample areas. The larger contributing area could have generated higher peaks because of timing effects. Channel interception of rainfall may also have contributed to the higher peaks. However, as recently pointed out by Hewlett and Helvey (1970), peak flows on small, upstream tributaries have less effect on downstream floods than the total volume of storm flow from the tributaries.

Higher sediment contents in lower station flows was not surprising. We have seen muddy water flowing through lower station flumes when upland runoff (from snowmelt) was clear. Apparently the water picks up sediment deposited by earlier, smaller flows or by bank sloughing as it flows through the steep, eroded channels of the forest zone.

The method of estimating upland runoff by measuring the flow from sample watersheds may have tended to increase both the flow and sediment content measured at lower stations on those watersheds (C2, C3, and C4) that had upland sample areas. The sample watersheds made up 31 to 53 percent of the upland areas. Their runoff was cut off by the artificial terraces and thus concentrated in the channels in larger amounts than would have occurred naturally. Without the terraces the water would have flowed into the forest in a more diffuse pattern, and some of it would have infiltrated before it reached runoff channels.

The study showed that the forest zone in the Driftless Area does reduce the contribution of upland fields to flooding streams. Further reductions can be made by simple practices along the field-forest border (Curtis 1967). Information is now being sought on how the forested slopes might be improved as the disposing ground for field runoff.

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