

# LYSIMETER SNOWMELT AND STREAMFLOW ON FORESTED AND CLEARED SITES

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## ABSTRACT

Snowmelt lysimeters have been operated for 2 years on cleared and forested watersheds in central New Hampshire in an experiment to improve measurements for determining how specific variables affect snowmelt-streamflow relationships. The lysimeters readily detected a several-day advance in meltwater contribution caused by forest clearing. On a daily basis, the lysimeter data showed that maximum meltwater contribution at the soil surface occurred about 1 hour ahead of daily streamflow peaks and that peak meltwater flow is moderated during passage through the soil. The continuous record of meltwater at the base of the snowpack provided by the lysimeter appears to be more useful and convenient for snowmelt studies than the interval measurement of snowpack changes obtained by the widely used snow-tube samplers.

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DETERMINING how specific variables affect snowmelt-streamflow relationships is a continuing objective of forest hydrology research. At the Hubbard Brook Experimental Forest in central New Hampshire, the principal approach to this problem has been to compare streamflow from small gaged watersheds with snow-survey data gathered on the watersheds, using the Mt. Rose snow sampler. The results have not been completely satisfactory because of sampling and measurement errors inherent with the snow sampler. Also, frequent large changes in the water equivalent of the snowpack, between sampling dates, cause difficulty in quantifying most factors affecting the snowmelt-streamflow relationships.

In an attempt to obtain better snowmelt data, we have been experimenting with snowmelt lysimeters. In 1969, single lysimeters were installed on a forested watershed (Hubbard Brook Watershed 1), and on a cleared watershed (Hubbard Brook Watershed 2). Under these two extreme forest conditions, we have been able to test the feasibility of the lysimeters and to use them to look for possible differences in snowmelt rates between the two areas. Because these locations are on gaged watersheds, we have also been able to compare snowmelt rates with streamflow.

Lysimeters offer at least two advantages over snow samplers as a means of gathering snowmelt data. First, the lysimeter provides a continuous record of snowmelt water as it leaves the bottom of the snowpack. In contrast, the snow sampler gives only an estimate of the change in water equivalent of the snowpack for the interval between measurements. Secondly, the lysimeter is stationary and thus eliminates both destructive sampling and the problem of extracting a complete sample that is inherent with the snow sampler. Unfortunately, the problem of variation in snowmelt over space (sampling error or spatial variation) inherent with the snow-survey data is

also a problem with the lysimeters.

This is the fourth Eastern Snow Conference paper to be presented concerning snowmelt on the cleared and forested watersheds at Hubbard Brook. The earlier papers showed that removal of the hardwood canopy caused important energy budget changes, and that snowmelt discharge was advanced by an average of 4 to 8 days during periods of major snowmelt contribution (Federer, 1968; Hornbeck and Pierce, 1969; Federer and Leonard, 1971).

#### INSTRUMENTATION AND STUDY AREA

The lysimeters used in this study were patterned after those developed by the USDA Forest Service at the Priest River Experimental Forest in Idaho (Haupt, 1969a and 1969b). Each lysimeter consists of a steel trough assembly installed in the soil and connected by an underground hose to a 50-gallon catchment tank. The surface areas of the trough and the catchment tank are approximately equal (2.72 square feet). So a unit of snowmelt passing from the trough causes an equal unit of rise in the catchment tank. The changing level in the catchment tank is recorded continuously with an FW-1 recorder.

The trough dimensions are 23 inches long by 17 inches wide by 10 inches deep, and when installed the sides are allowed to protrude slightly above the soil surface. The block of soil and humus that was removed at the site when the trough was installed was carefully replaced in the trough to approximate the undisturbed forest floor. The catchment tank was charged with antifreeze and a layer of light oil to prevent freezing and evaporation. One major departure that we made from the original lysimeter design was to eliminate a plastic barrier meant to prevent the lysimeter from receiving water that might flow over ice layers within the snowpack. We feel that such flow is of minor importance at Hubbard Brook. The total cost of materials for a lysimeter, excluding the recorder, is about \$25.

Single lysimeters were installed in a forested watershed and on an adjoining cleared watershed in late summer 1969. The aspect of both watersheds is generally southerly, and slopes average 20 to 30 percent. The forested watershed is a 29-acre tract of undisturbed uneven-aged northern hardwoods. The 39-acre cleared watershed was clear-felled in 1965 as part of a water-yield experiment (Hornbeck et al., 1970). Herbicides were used until 1969 to maintain vegetation-free conditions in the cleared watershed so that very little vegetative shading is present. One other characteristic of the watersheds is important: the soil organic layers and the annual snow accumulation usually prevent soil freezing in the winter (Hart et al., 1962).

Both lysimeters were located about 200 yards upstream and about 100 feet away from the main stream channels. The aspect (SSE), slope (less than 10 percent), and elevation (1,650 feet) were also about the same for both installations so that any snowmelt differences could be attributed primarily to the canopy removal.

## RESULTS AND DISCUSSION

After installation of the lysimeters in the fall of 1969, we anticipated collection of snowmelt data through the 1969-70 winter. However, because snow accumulation for the 1969-70 winter was both late in occurring and well below average in amount, a rare soil freeze occurred. The first weekly snow measurement on the forested watershed was not made until December 23, 1969. The peak snow accumulation for the 1969-70 snow season was only 24 inches, as compared with 47.5 inches during the 1970-71 season. As a result, the soil blocks within the lysimeters remained frozen until late in the snowmelt period and few usable melt data were obtained. We relate this experience only to point up that unfrozen soils are a requisite for lysimeter operation.

Snow accumulation for the 1970-71 winter more nearly approximated average conditions, and both lysimeters functioned satisfactorily. The sensitivity of the lysimeters is illustrated by the fact that they recorded daily increments due to groundmelt of several hundredths of an inch from the time of the first continual snow cover until the spring melt began. This groundmelt component is important in sustaining winter streamflow at Hubbard Brook (Federer, 1965).

The major snowmelt season at Hubbard Brook usually extends from early March through late April. Data from these two months of the 1971 snowmelt season will be considered in this paper.

A comparison of the monthly lysimeter totals (Table 1) shows a considerably greater snowmelt yield from the cleared watershed than from the forested watershed. This large difference was unexpected, particularly because a past study showed that forest clearing did not change the total quantity of snowmelt runoff from the two watersheds (Hornbeck and Pierce, 1969). For the present, we can only suggest that the difference in snowmelt outflow shown by the two lysimeters is the result of spatial variation. The 2.72 square feet that we chose to represent the several million square feet of cleared watershed apparently received above-average snowfall for the watershed, while the 2.72 square feet representing the forested condition received snowfall amounts below average.

Table 1.--Lysimeter outflow and streamflow for 1971,  
in area-inches

Month	Lysimeter outflow		Streamflow	
	Forested	Cleared	Forested	Cleared
March	1.2	2.2	1.5	1.5
April	10.5	15.6	11.5	13.9
Total	11.7	17.8	13.0	15.4



The spatial variation problem may also be illustrated when comparing lysimeter and streamflow totals (Table 1). The lysimeter unit area outflow at the cleared location exceeded streamflow, while the lysimeter in the forested location yielded less than the total unit area streamflow for the forested watershed. The difference in streamflow between the two watersheds (Table 1) is not a treatment effect, but represents an inconsistency that occurred even when both watersheds were completely forested (Hornbeck et al., 1970).

Useful comparisons of lysimeter outflow data and their relation to streamflow can be made despite the differences in monthly volumes by plotting cumulative percentage of the total for a selected period. Such plottings (Figs. 1 to 4) indicate two important pieces of

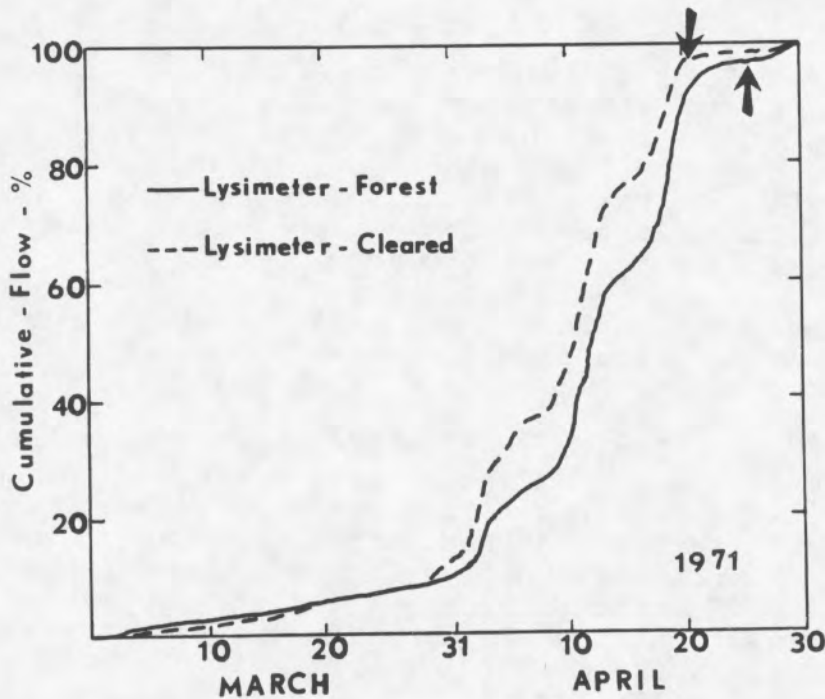
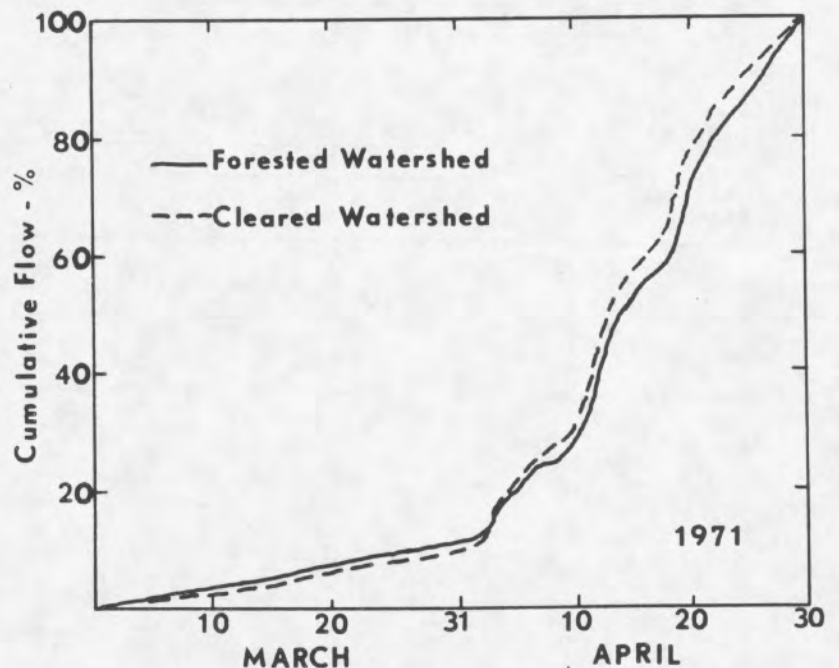


Figure 1.--Cumulative outflow from the lysimeters on the forested and cleared watersheds. Arrows indicate date of complete snow disappearance.

Figure 2.--Cumulative streamflow from the forested and cleared watersheds.



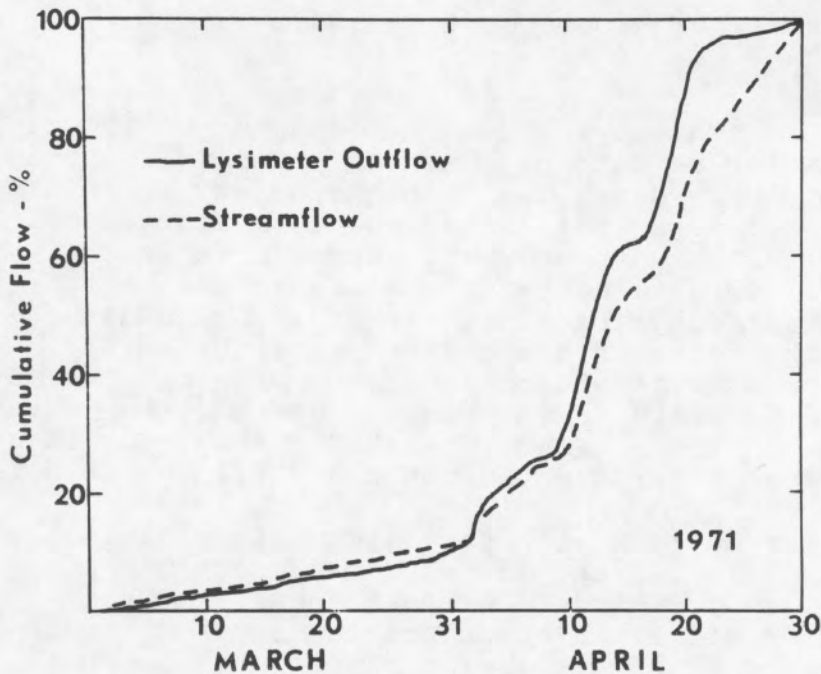
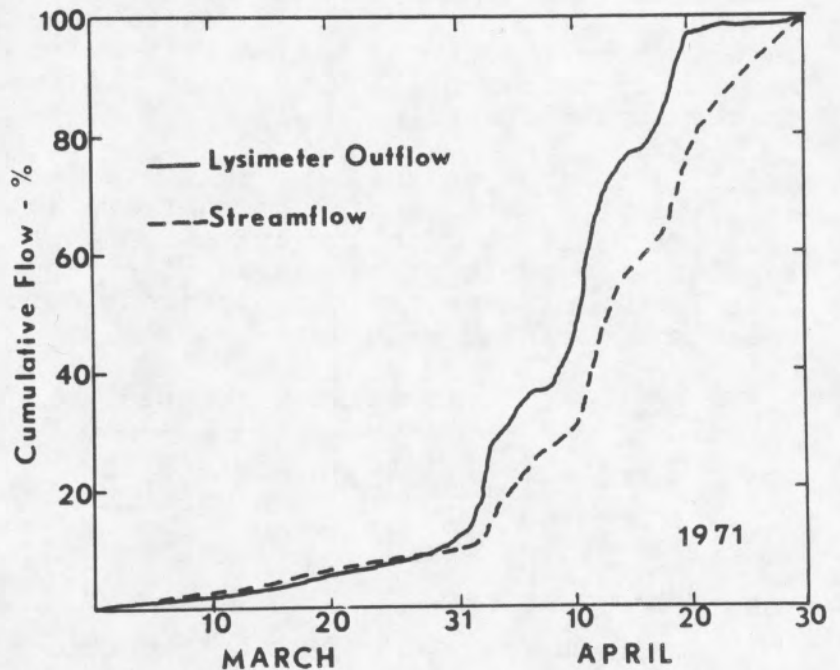


Figure 3.--Comparison of lysimeter outflow and streamflow from the forested watershed.

Figure 4.--Comparison of lysimeter outflow and streamflow from the cleared watershed.



information for any selected date: (1) the difference between the percentages of cumulative outflow; and (2) the number of days that cumulative outflow is advanced by the forest clearing.

During March, both lysimeters responded about the same (Fig. 1). For most of April, however, outflow from the lysimeter in the cleared watershed ran 2 to 5 days ahead of the forest lysimeter. This advance is due at least in part to the more rapid melt in the absence of vegetative shading on the cleared watershed. The advance is not

particularly large, possibly because of weather conditions during the 1971 melt season.

For a large advance to develop, a sizeable component of the melt must be caused by direct solar radiation. Much of the melt in April 1971 occurred during warm cloudy days, thus minimizing any effects of canopy shading. Also, the major portion of the 1971 snowmelt did not occur until after April 10. When snowmelt occurs late in the season, warmer temperatures tend to dampen any differences due to radiation. This is illustrated by the closeness of the cumulative curves of streamflow for the forested and cleared watersheds (Fig. 2). Streamflow in the cleared watershed seldom ran more than 2 or 3 days ahead of the forested watershed. In previous years with greater radiation melt, streamflow in the cleared watershed ran as much as 17 days ahead of the forested watershed (Hornbeck and Pierce, 1969).

Comparison of lysimeter outflow with streamflow shows a similar pattern for both locations (Figs. 3 and 4). Lysimeter outflow corresponds well with streamflow for March, but then shows a several-day advance in April. The spatial variation problem may be responsible for the more rapid response of the lysimeters to melt in April. The lysimeters are located at low elevations within the gaged watersheds. Warm air melt and snow water contributions may have occurred earlier in the vicinity of the lysimeters than at the higher watershed areas. Another probable explanation may be that the lysimeters have virtually no capacity for storing soil moisture. Thus, the later occurrence of snowmelt as streamflow shown by figures 3 and 4 may simply represent a delay while meltwater moves through the soil to the stream channel.

The delay from the time meltwater enters the soil surface until it leaves the watershed as streamflow can be examined by comparing lysimeter outflow with streamflow on a daily basis (Figs. 5 and 6). For these comparisons, we have chosen April 11 and April 12, two days for which snowmelt contributions were at a maximum. Totals for these two days, were in area-inches:

	<u>Forested watershed</u>		<u>Cleared watershed</u>	
	<u>Streamflow</u>	<u>Lysimeter outflow</u>	<u>Streamflow</u>	<u>Lysimeter outflow</u>
April 11	0.8	1.0	0.9	1.7
April 12	.9	1.1	1.2	1.7

During both days and at both locations, peak contributions from the lysimeters were between 1400 and 1500 hours, while peak streamflow rates were between 1600 and 1700 hours (Figs. 5 and 6). Thus there seems to be little delay in the response of watershed streamflow to snowmelt. However, the plottings indicate that the volume of snowmelt contributions is moderated as it passes through the soil. The daily lysimeter outflows occurred mostly within a time span of 6 to 7 hours and are characterized by a high peak rate. The rise and fall of streamflow, on the other hand, extends over a much longer interval and has lower peak rates of flow. Again, because of the spatial variation problem, it is impossible to state specific conclusions about the time and volume differences between the lysimeter and streamflow.

Figure 5.--Comparison of hourly lysimeter outflow and streamflow from the forested watershed.

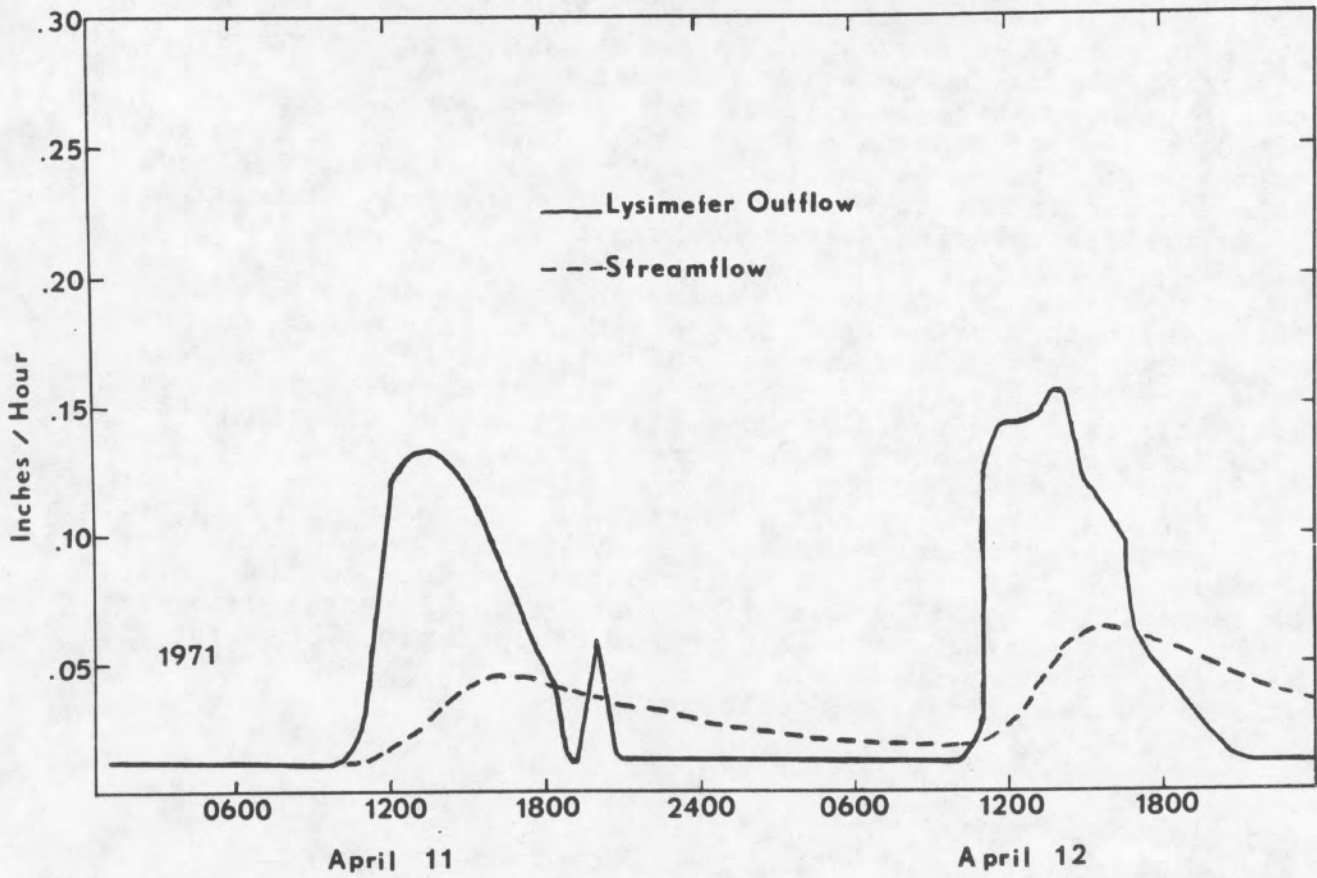
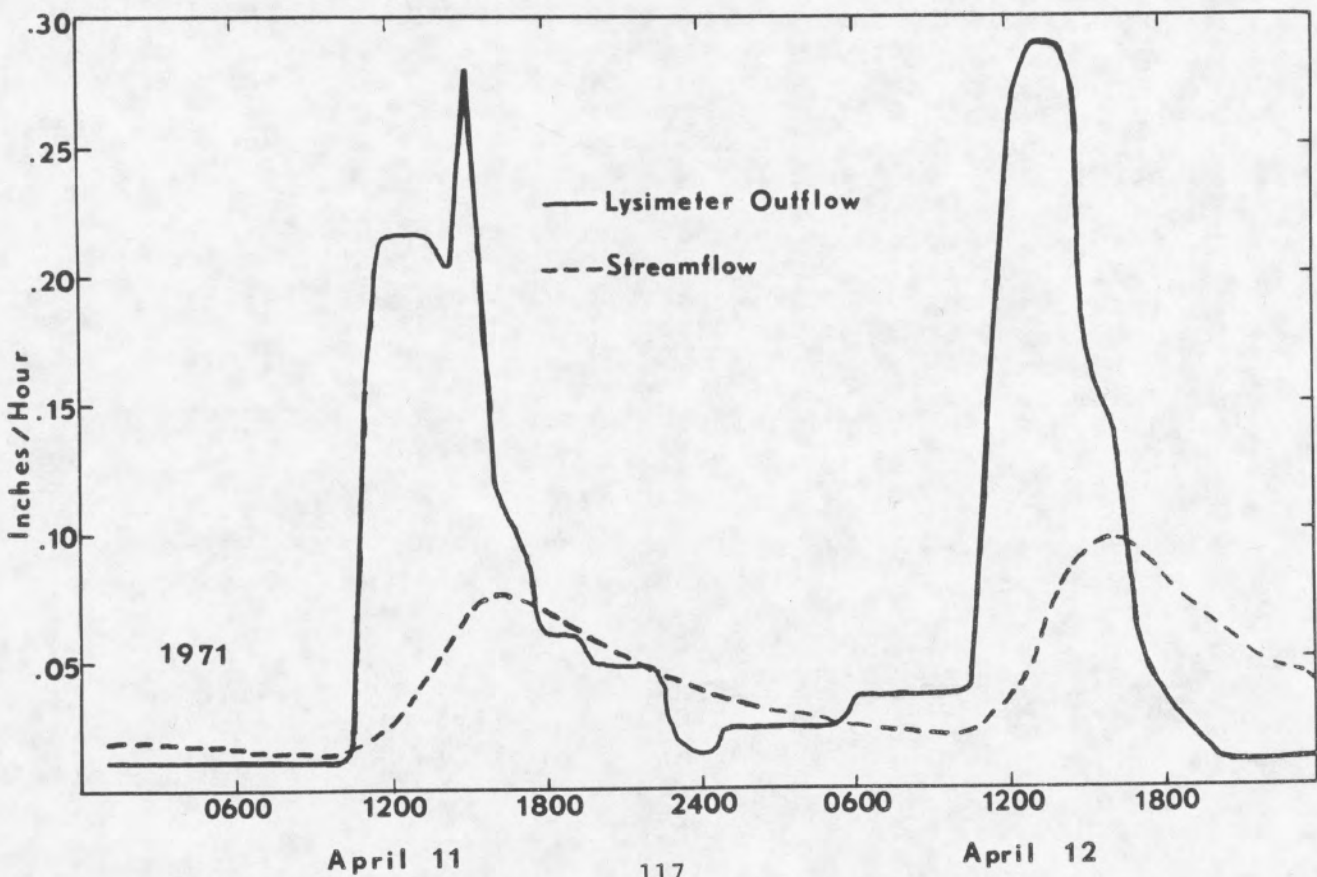


Figure 6.--Comparison of hourly lysimeter outflow and streamflow from the cleared watershed.





## CONCLUSION

From our experience during the 1970-71 snowmelt season, the lysimeters that we tested appear to be an important new method for obtaining useful snowmelt data. A restriction is that the lysimeters cannot be used where soil freezing is prevalent. Lysimeter installation and maintenance are inexpensive, and the continuous record of meltwater as it leaves the bottom of the snowpack is much more valuable and convenient to work with than the interval estimates of snowmelt obtained by using snow-tube samplers.

An advance in snowmelt due to forest clearing was readily detected with the lysimeters, suggesting that they may be useful tools for studying snowmelt under various canopy types and densities. Also, it appears that the continuous daily records obtained from the lysimeters will be useful in detailed studies of the timing relationships between snowmelt and streamflow.

The lysimeters present a spatial variation or sampling problem in that each lysimeter represents only a small part of the area being studied. We will determine the magnitude of this spatial variation by operating a multi-lysimeter network on the forested watershed. We hope that only a reasonable number of lysimeter locations will be necessary to quantify some of the factors affecting the snowmelt-streamflow relationships for forests.

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