PROSPECTS IN THE NORTHEAST FOR AFFECTING THE QUANTITY AND TIMING OF WATER YIELD THROUGH SNOWPACK MANAGEMENT

By

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Every spring, snowmelt in the Northeast swells the streams and occasionally produces damaging flood flows. Most of this snowmelt comes from forest lands.

Foresters have shown in a few studies that snow-water accumulations and rates of melt vary according to forest type. But there have been no studies to tie forest snowmelt and streamflow together. We still need to find out if the snowpack can be so influenced by forest management practices as to affect the quantity and timing of water yield--and if so, the extent of these effects. It is reasonable to assume that water yield may be so affected at least for small watersheds where channel storage is limited and the hydrograph would immediately reflect changes in snow accumulation and melt.

The lack of evidence makes snowpack-management prospects highly speculative. Before the question can be considered, we must first have information on snow accumulation and melt in the snowpack zone, snowpack-streamflow relationships as evidenced by annual hydrographs, and the effect of forest cover on the snowpack. This elementary approach affords some rationale for speculation.

The Snowpack Zone

The snowpack zone is here arbitrarily delineated as that area receiving 60 inches or more of snow annually (fig. 1). It includes 4 states: New York, New Hampshire, Vermont, and Maine. It coincides closely with the area where snow falls on 40 to 60 days during the winter and covers the ground about 90 to 120 or more days (Kincer, 1922).

In northern Maine the snow cover will last from December 1 to April 15 and even into May in the forested mountains. In the southern half of the state, snow is usually not found before December 15, and by April 1 no snow remains on the ground (Fobes, 1942).

In the White Mountains and in the Adirondacks, snow water accumulation begins in late November or early December and tends to rise rather steadily to a peak of 10 to 11 inches of water in March or early April (fig. 2). Melting is rapid; the snow disappears before May 1. An accumulation of 10 to 11 inches of water represents about one-fourth to one-third of the annual precipitation.

Snowpack Influence on Streamflow

The influence of snowmelt on spring streamflow is evident in figure 3, a hydrograph for a 32-acre forested watershed at the Hubbard Brook Experimental Forest in New Hampshire. For 1956 (which appeared representative among the 4 years of record) 9.44 inches of runoff was measured in April, 29 percent of the total annual flow. In May, 5.80 inches were measured. The two months combined accounted for 47 percent of the annual flow. In 3 of the 4 years of record, peak flows during the snowmelt period were exceeded by peak flows recorded from summer and fall rain storms. The January thaw, evident in figure 3, occured in all 4 years, its peak reaching less than one-half the spring peak flows.

Recession of the snowpack and spring runoff for the four years of record are illustrated in figure 4. Peak flows, for the most part, were influenced by rainfall. The low snowpack in 1957 produced, as can be noted, a low runoff for that season.

Daily peak flows, when derived from snowmelt only, were closely related to mean daily air temperature. The regression of this relationship is given in figure 5.

To determine the influence of spring snowmelt on larger watersheds, the percent runoff by months was calculated for the Pemigewasset and Merrimack watersheds in New Hampshire and for two areas of the Hudson river watershed in New York (fig. 6). For comparison, the Hubbard Brook distribution is also given. Runoff from melting snow and spring rain during April and May, the two principal snowmelt months, makes up about 45 to 50 percent of the annual flow of the two smaller watersheds; for the larger watersheds, it comprises about 35 percent of the flow.

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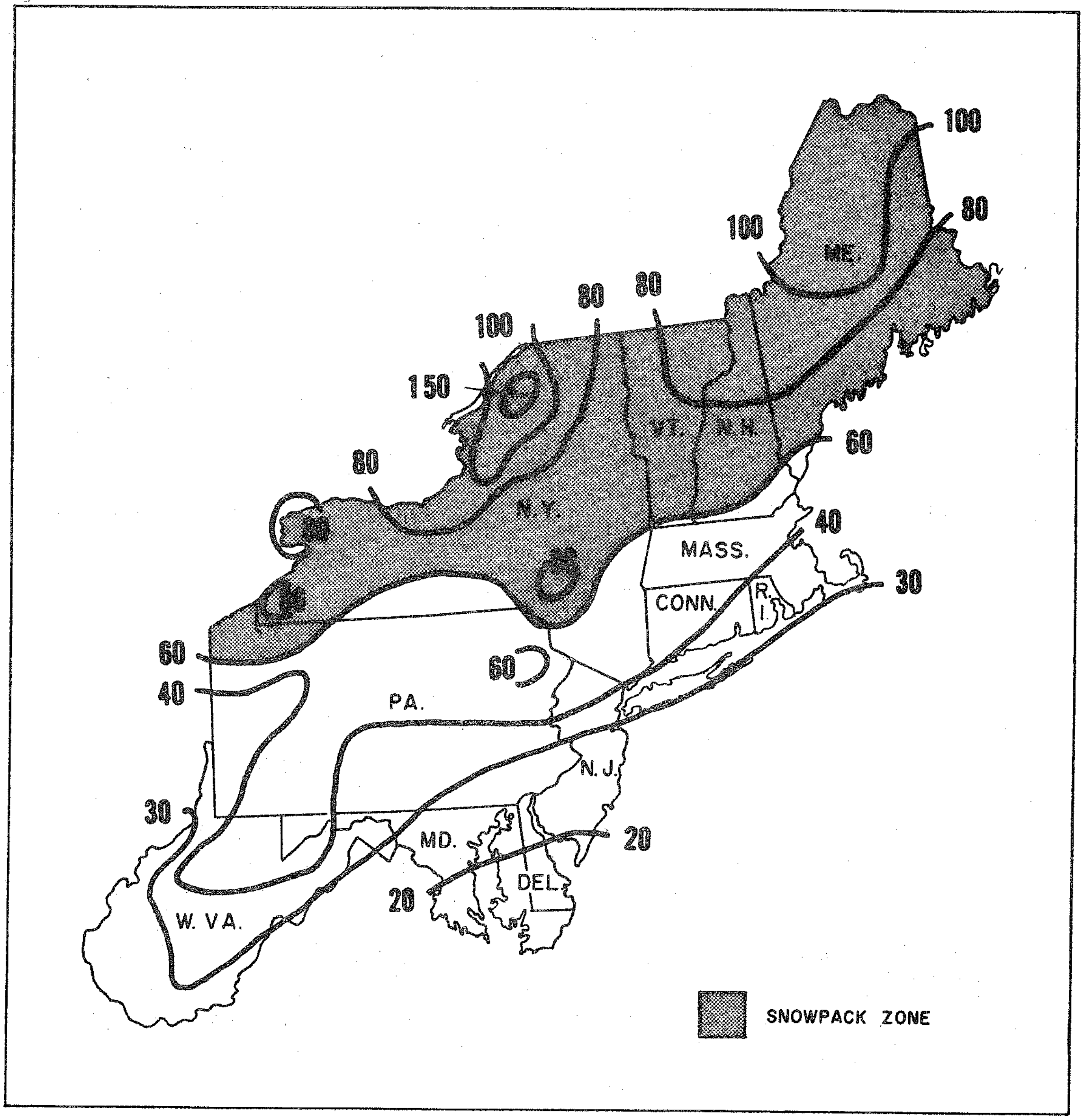

Figure 1.—Average annual snowfall (inches)

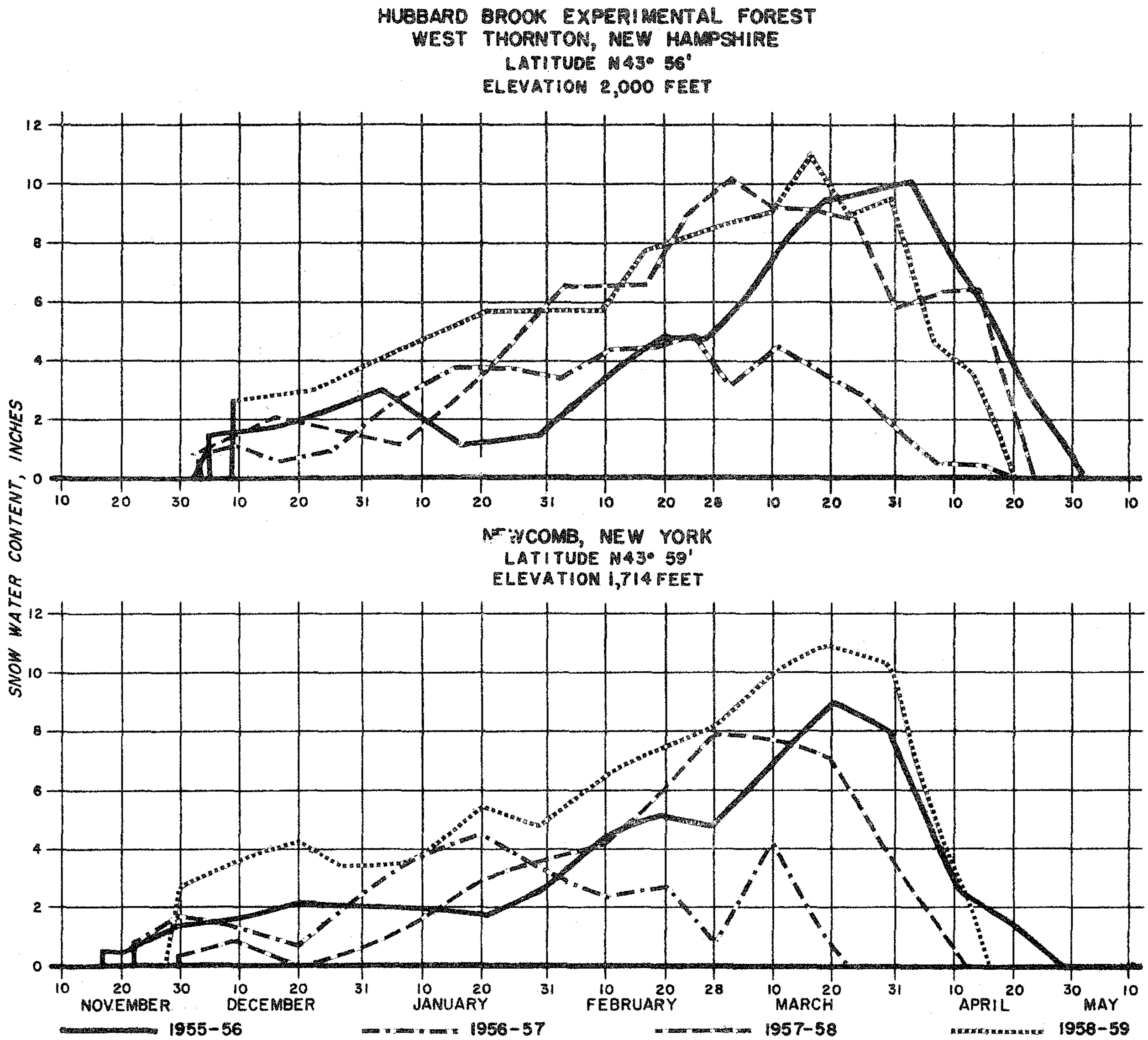

Figure 2.—Snow water accumulation in the White Mountains and in the Adirondacks, 1955-59.

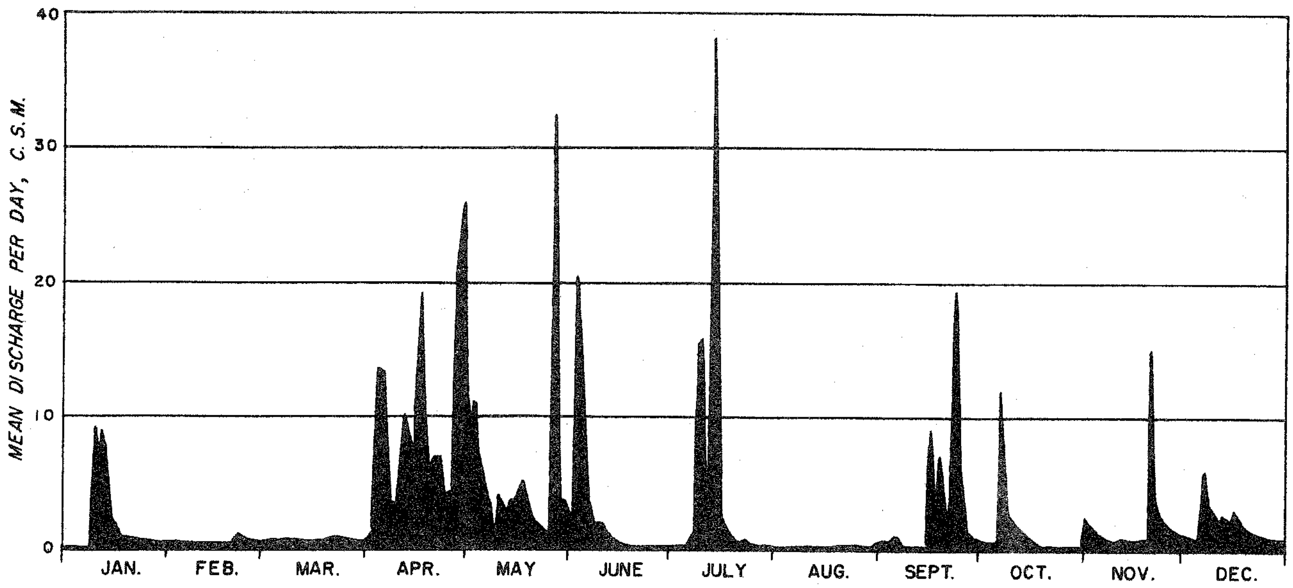

Figure 3.—Hydrograph of Watershed 1, Hubbard Brook Experiment Forest, 1956.

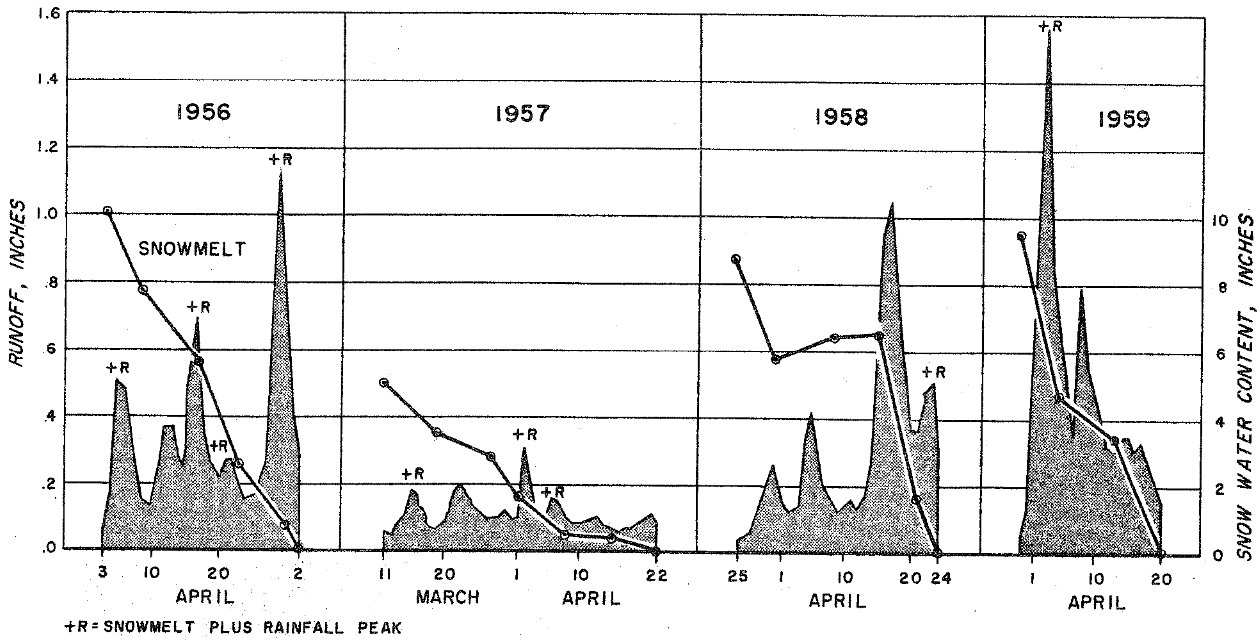

Figure 4.—Snowmelt and spring runoff.

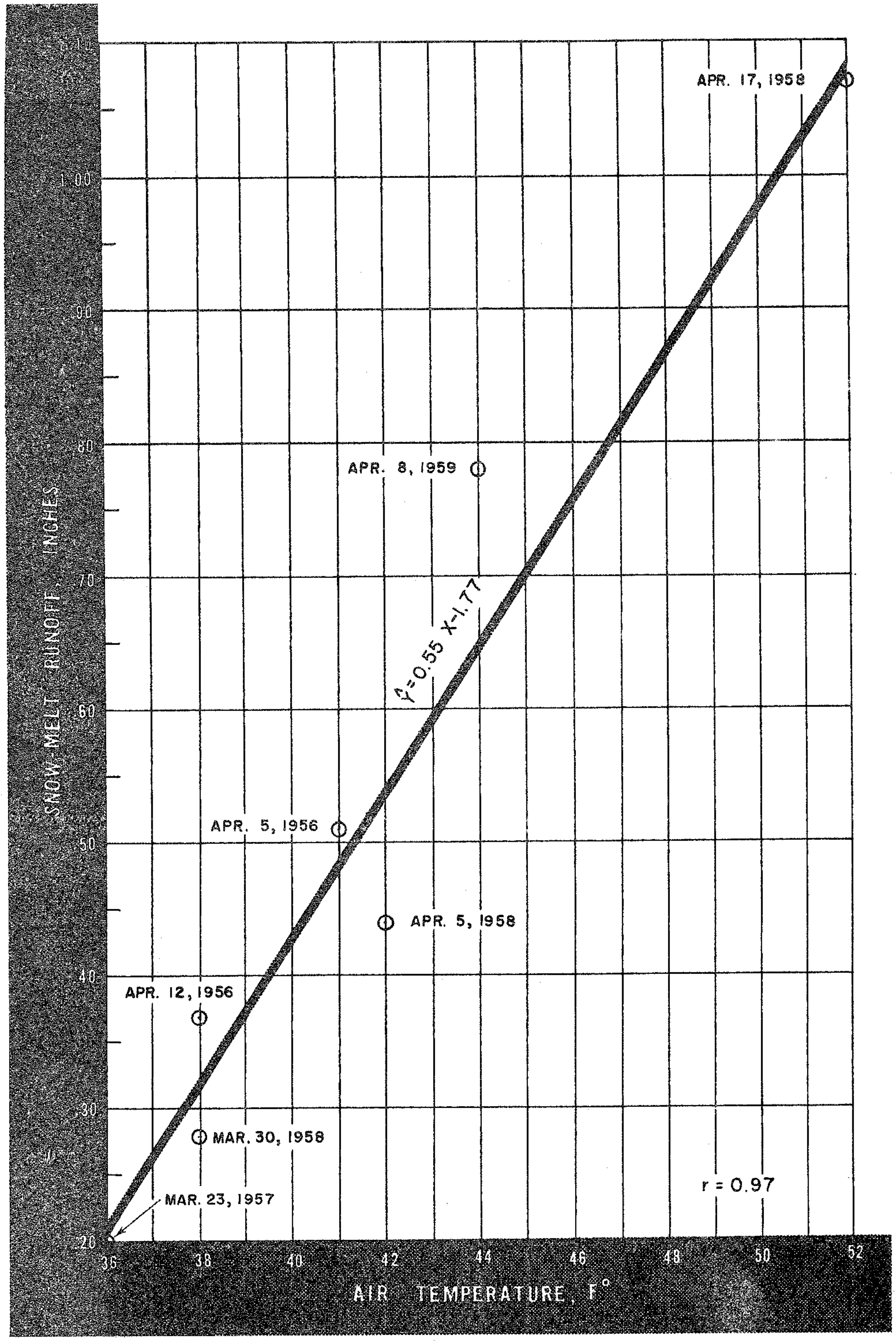

Figure 5. Snowmelt runoff in relation to mean daily air temperature.

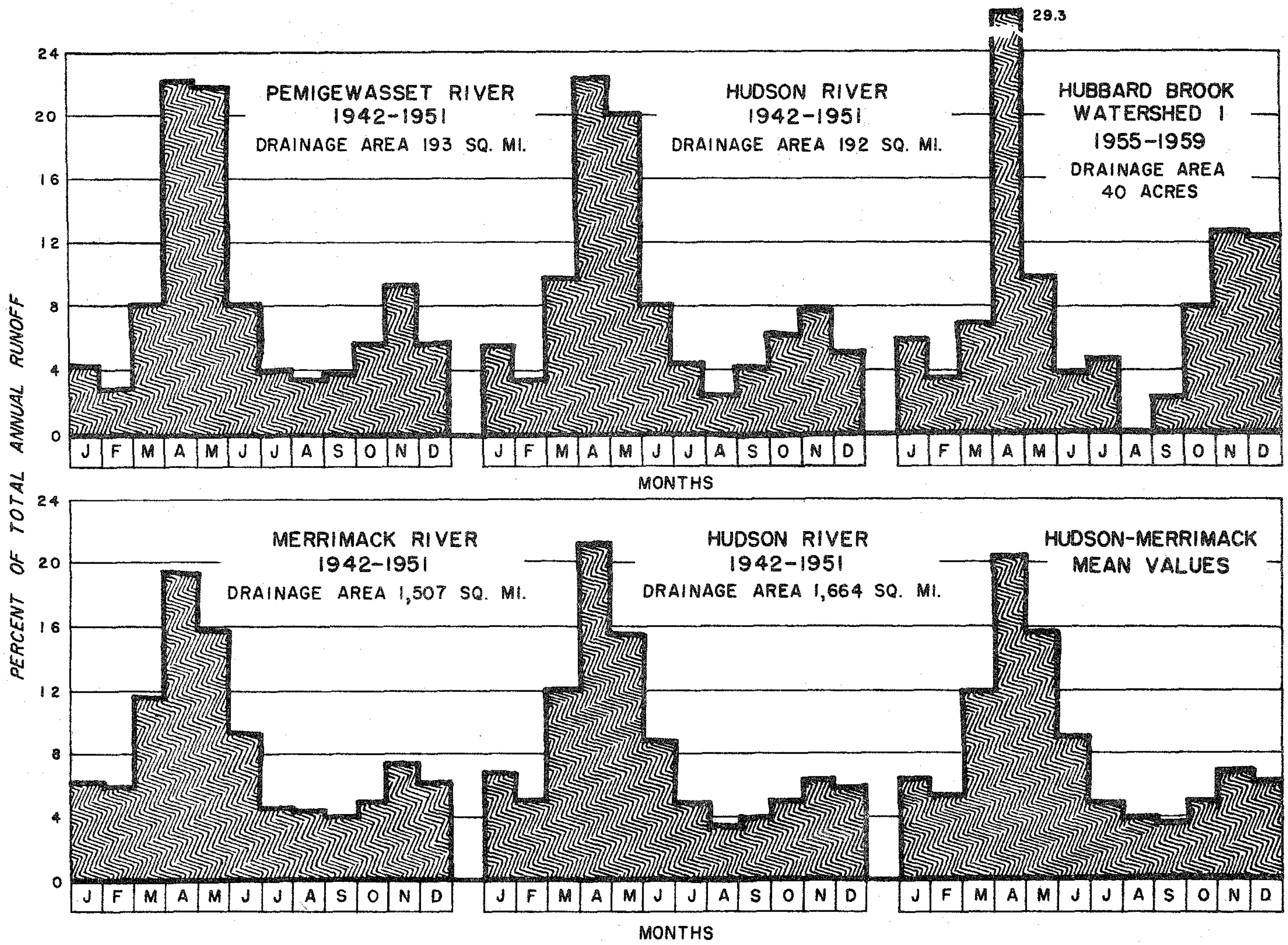

Figure 6.—Percent runoff by months.

Effect of Forest Cover on Snowpack

Possibilities of snowpack management through forest management are indicated from results of a recent study of snow accumulation and melt in conifer (red spruce, balsam fir), hardwood (beech, maple, birch), and cut-over plots in the Adirondacks near Paul Smiths, N. Y.[2/]

Greatest accumulation of snow water--in mid-March--was in the hardwoods, averaging 9.01 inches as compared to 6.92 inches in the conifers (table 1). By mid-April the greater melt rate in the hardwoods had erased this 2-inch difference. Thereafter, until snow disappeared in early May, the conifer areas possessed the greater snow-water contents. After peak accumulation, snow melted in the hardwood stands in 34 days and in the conifer stands in 43 days. Degree-day melt rates (above 32°F.) were twice as great for the hardwood plots as for the conifer plots.

TABLE 1

Snow-water content at maximum accumulation, number of days to melt, and melt rate at experimental plots near Paul Smiths, N. Y., 1959

Condition	Snow-water content	Percent of maximum (by areas)	Days to melt	Mean degree-day melt rate
	Inches			Inches
Hardwood sawtimber	8.92	98	34	0.06
Hardwood sapling	9.10	100	34	.06
Conifer sawtimber	6.85	75	40	.03
Conifer sapling	6.98	76	46	.03
Forest road, semi-open	9.68	96	36	.06
Commercial clearcut	9.25	91	36	.05
Selective cut, 25-35 yr. cycle	10.08	100	36	.06
Selective cut, 15-20 yr. cycle	10.12	100	38	.06
Selective cut, 5-10 yr. cycle	9.30	92	38	.05
Control	8.25	82	41	.03

Different cutting practices had much less effect on accumulation and melt. Maximum accumulation was in the more heavily cut selection plots. Accumulations of 91 and 96 percent of the maximum were found in the clearcut plot and in the road area, perhaps because of their greater exposure and greater melting during initial snow accumulation. Smaller accumulations of 92 percent in the most lightly cut plot and 82 percent in the uncut plot may have been due to increased interception by their greater conifer component. The differential in days of melt amounted to 5 days at most, and only the control plot had a substantially lower melt rate.

The observations on difference in maximum accumulation between spruce-fir and hardwoods in the above study tie in well with Trimble's (1959) estimate of average annual snow interception as derived from a review of the literature:

Type	Net interception
	Percent
Northern hardwoods	10
Aspen-birch	7
Spruce or spruce-fir	35
White pine	25
Hemlock	25
Red pine	30

2/ Snow accumulation and melt under certain forest conditions in the Adirondacks. Unpublished manuscript, Northeastern Forest Experiment Station.

The relative orders (decreasing) of snow accumulation and snow retention, by cover types, were established by Maule (1934) as follows:

Type	Snow accumulation	Snow retention
White pine	4	1
Red pine	5	2
Norway spruce	6	3
Hemlock	3	4
Hardwoods	2	5
Open fields	1	6

To catch as much snow as possible and prolong the melt period as long as possible, he recommended plantations of mixed hardwoods and softwoods that would catch more snow than softwoods and would have a lower melting rate than hardwoods.

Working in hardwood stands only, Sartz and Trimble (1956) found 4 to 10 percent more snow water in openings than in the woods. They concluded that narrow strips cut in an east-west direction would increase snow accumulation and prolong melt.

Prospects for Snowpack Management

The greatest immediate need for snowpack management in the Northeast is to reduce flood peaks. These peak flows are produced by combinations of rainfall and snowmelt--with rainfall the major contributor. However, snowmelt alone can cause floods. For example, the record flood of April 1928 in the Black River in the western Adirondacks resulted from a 5-day snowmelt period when the temperature was in the 70's (Hoyt and Langbein, 1955).

Floods during the snowmelt season have been common: in the flood history compiled by Hoyt and Langbein (1955), 29 spring floods are listed as occuring in the four snowpack states since 1801.

The greatest spring flood in the snowpack zone came in 1936 as a result of combined rainfall and snowmelt: in the Northeastern States it caused loss of 107 lives and property damage of $270,000,000.

The contribution of forest areas to snowmelt flood peaks could be reduced either by reducing the snow-water accumulation or by slowing the rate of melt. As has been shown, conifers are superior to hardwood cover for both purposes. The retarding influence of dense conifer cover on snowmelt during the 1936 flood was observed by Baldwin (1956):

> Prior to the flood a deep snow blanket covered both forest and open but after the torrential rains and thaw snow remained only in the woods. Open fields were completely bare even in northernmost New Hampshire and on the summit of Mt. Washington all but one inch of the 20.5 in. of dense snow and ice melted. In the forest on the other hand, while the snow level sank to less than one-half the original depth, this snow layer absorbed and held not only much of the melt water but some of the rain that fell.

Thus, to increase the flood protection function of the forest areas, conifers should be encouraged. As shown in table 2, they occupy at present 40 percent of the commercial forest land. Because of cutting, this proportion is decreasing, even though most planting is with conifers. Difficulties inherent in making any major change in forest type are apparent in the pattern of forest ownership. Only 6 percent of the forest land is publicly owned; the great bulk of the area is owned by industry, much of it in large holdings.

Flood protection through snowpack management can come only if research demonstrates a substantial protection potential for both small and large watersheds. If the potential exists, broad-scale tests of measures might then be made on various public lands. Their extension to private lands would depend on their coordination with forest management objectives, a careful evaluation of costs and benefits, and possibilities of subsidies. Right now the burden is on research to determine the relationship between forest-management practices, snow accumulation and melt, and streamflow.

Just as the few data collected indicate that flood peaks might be reduced by converting hardwood forest to conifers, they also indicate that water yield could be increased by the reverse conversion, and by cutting openings in forest stands. Presently, there appears little need for this practice, though with the increasing demands in the Northeast for water and the importance of municipal watersheds, this possibility may achieve practicality in the years ahead.

TABLE 2

Forest area, type, and ownership in snowpack states

State	Total commercial forest land		Forest type		Forest ownership			
			Hardwood	Softwood	Federal	State, county, municipal	Industrial and other private	Farm forest
	Thousand acres	Percent of total area	Percent of total commercial forest area		Percent of total commercial forest area			
Maine	17,169	87	42	58	1/	1	87	12
New Hampshire	4,682	81	58	42	13	2	63	22
Vermont	3,713	63	72	28	5	3	50	42
New York	12,002	39	84	16	1	6	64	29
TOTAL	37,566	60	60	40	3	3	73	21

1/ Less than one percent

What, then, can we conclude about the prospects for snowpack management in the Northeast?

The area of possibility lies largely in New York and northern New England. Here from one-third to one-half of the average annual streamflow comes from snowmelt and rainfall in April and May. Snowmelt, in conjunction with rainfall, is responsible for damaging floods. Snow-water accumulation can be about 25 percent greater in hardwoods than in conifers, and the snowmelt period in conifers is longer by perhaps 20 percent. Cutting practices in hardwoods have much smaller effects on snow accumulation and melt.

The relationships of snowpack management, by forest manipulation, to water yield have not been determined. If strong relationships are found, applying the necessary practices to large areas would be difficult because of the ownership pattern. There is a need for snowpack management; and there is a possibility: but there are no prospects in the near future. Research holds the key.

LITERATURE CITED

1. Baldwin, Henry I. 1956. The effect of forest on snow cover. Eastern Snow Conf. Proc. 4: 18-22.
2. Fobes, Charles B. 1942. Snowfall in Maine. Geog. Rev. 32: 245-251.
3. Hoyt, William G. and Langbein, Walter B. 1955. Floods. Princeton Univ. Press, 469 pp., illus.
4. Kincer, J. B. 1922. Precipitation and humidity. 48 pp., illus. In Atlas of American Agriculture (1936).
5. Maule, W. L. 1934. Comparative values of certain forest cover types in accumulating and retaining snowfall. Jour. Forestry 23: 760-765.
6. Sartz, Richard S. and Trimble, George R., Jr. 1956. Snow storage and melt in a northern hardwoods forest. Jour. Forestry 54: 499-502.
7. Trimble, George R., Jr. 1959. A problem analysis and program for watershed-management research in the White Mountains of New Hampshire. U. S. Forest Serv., Northeast. Forest Expt. Sta. Paper 116, 46 pp.
8. United States Department of Agriculture. 1941. Climate and man. Yearbook of agriculture, 1,248 pp., illus.