A STUDY OF THE RUN OFF OF THE SACANDAGA RIVER SPRING OF 1936

THESIS FOR DEGREE OF C. E.

William Burns Hanlon

1937

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SYNOPSIS

An analysis of the sources of the stream flow and the relationship of their associated factors during the spring of 1936 forms the basis of this paper. Use has been made of the following data: amount of water available in the snow cover at the start of, and early in, the melting period; precipitation; temperature; and stream flow. All of the data were collected in or adjacent to the basin of the Sacandaga River above the gaging station near Hope, New York. Above the gaging station, the river is practically free from artificial regulation but its flow is affected slightly by natural storage in lakes. The watershed located on the slopes of the Adirondacks comprises an area of 491 square miles which is almost entirely wooded, largely with conifers. The topography is irregular and rugged with steep slopes producing rapid run-off of the rain falling on the area.

Starting on March 1, when the stream flow was low and probably due to flow from ground water and from natural storage in headwater lakes, the measurement of precipitation and stream flow is recorded until June 10. On this latter date, the stream flow was the same in amount as on March 1. Conditions directly effecting the stream flow on these dates are presumed to be identical, thus all of the flow in the interim would have been produced by precipitation and melting snow. The term run-off as used in this paper includes all flow past the gaging station regardless whether it reached there by surface or underground flow. As the initial and terminal flows are identical, the need for dividing run-off further is obviated in so far as total figures for the period are concerned.

Where run-off exceeds precipitation the difference has been used in combination with temperature data to determine melting characteristics of the snow.

INTRODUCTION

A blanket of snow on the ground may be considered to be a reservoir holding in store a certain quantity of water. When conditions become favorable to melting, the snow will be converted into water which is subject to several courses: return to the atmosphere through evaporation, replenishment of the ground water table, or to occur as surface run-off. As melting occurs at moderate temperatures and before plant growth is advanced the evaporation losses are relatively low. At the same time the ground is often frozen and thus conducive to a high rate of surface run-off. It is realized that generalizations relating to snow and its melting are difficult owing to the wide geographical differences within the belt of snow occurrence.

The importance of snow as a source of run-off is, of course, dependent upon the amount of the snow. In some areas practically all of the precipitation occurs as snow, while there are others which have no snow. However, in areas where snowfall is of an appreciable amount and occurs intermittently over a period of time it becomes of great importance as the precipitation for several months may be stored up, and then released, sometimes suddenly with resulting high flows and often floods, depending upon conditions attendant to the melting.

As the efforts to control and use water more efficiently have increased, the importance of prediction of the amount of water to be expected has become more pronounced. If one knew in advance exactly what amount of water would be available during a certain period definite and exact plans could be made for use of the water. To assist in filling this need for predictions, the use of snow surveys has been developed. Probably the most extensive use of snow surveys in this country is in the Sierra Nevada Mountains where the snow cover at high altitudes provides the major source of water for irrigation and other uses at lower elevations. Snow measurements although they have probably always been used in a general way for forecasting spring run-off have only more recently been put upon a more definite basis by the development of new methods and equipment. This has promoted a more widespread use of snow surveys so that now they are quite generally used, in some form, throughout the entire snow belt.

Although one may determine by snow measurements the potential supply of water in the snow, the amount which actually occurs as run-off is probably dependent upon many different factors. Despite the increasing use of snow-fall data in forecasting, relatively little investigation has been made of the actual melting and the effect of the different factors upon which it is dependent. Some early work along this line was done by R. E. Horton[1] and more recently by George D. Clyde[2]. It is this scarcity of data on melting which has prompted the author to bring together the various data included within this paper and to attempt by correlating them to learn from actual field observations what effect precipitation, temperature, and the resulting melting of snow had upon the flow of the Sacandaga River near Hope, N.Y. during the spring of 1936. It is felt that although the observations were made in one river basin and include but one melting season, some of the observed features may apply to snow melting in general.

1 The Melting of Snow, Monthly Weather Review, December, 1915

2 Change in Density of Snow Cover with Melting, Monthly Weather Review, August, 1929

Effect of Rain on Snow Cover, Monthly Weather Review, August, 1929

SNOW SURVEYS[1]

As the name indicates, a snow survey is an examination of the condition and amount of the snow covering the area included in the survey. The general procedure is to determine the depth, water content, and from these, the density of the snow cover at a number of representative points.

The points at which the determinations are to be made must be carefully chosen in order that they will be free from drifting and from local variations. To minimize the effect of drifting, long courses with as many as fifty observations, fifty to one hundred feet apart, are established at each chosen location. The measurements are averaged to give the mean at the point. A course sheltered by hardwood trees on reasonably level ground is usually very good. Evergreens will prevent the snow from reaching the ground, and, even though not covered with snow at the

1 Much material regarding apparatus and procedure used in snow surveys was obtained from the following publications:

Church, J.E. Principles of Snow Surveys as Applied to Forecasting Stream Flow. Journal of Agricultural Research, Vol. 51, No. 2

Proceedings of the Western Interstate Snow Survey Conference, Feb. 18, 1933; June 28, 1933

Cullings, E.S. The Adirondack Snow Survey. Transactions of the American Geophysical Union, Reports and Papers, Hydrology, 1936 time of the survey, may be the cause of spotty results owing to snow falling unevenly through them.

The main pieces of equipment are a snow-sampling tube and a weighing scale. The tube is usually of duraluminum or some other light-weight metal, about three inches in diameter, and of sufficient length to exceed the maximum depth of snow. The tube is equipped with a steel cutting edge of slightly smaller diameter than the tube. The cutter used by the Adirondack Snow Survey has a diameter of 2.655 inches so that ten inches of water will weigh two pounds. A removable hardwood plug is fitted into the upper end of the tube to give a surface to bear on when forcing the tube down through the snow. Where long tubes are required a cutting edge resembling a milling cutter is used and the tube provided with an adjustable handle by which the tube and cutter may be rotated and forced down through the snow. The tube should be graduated in inches on the outside so that the depth may be readily observed when taking the snow sample. A spring scale with a revolving hand is used. A scale which shows one revolution for each two pounds is very convenient for use with a tube equipped with a 2.655 inch diameter cutting edge. By dividing the dial into one hundred parts, each division equals 0.1 inch of water, and the water content may be read directly in inches and tenths without involving a conversion figure.

In making a determination, the tube is first weighed (before each trial) to allow for any ice or snow which may have stuck in or to the tube. The tube is then forced down vertically through the snow, making sure that it goes clear to the ground surface. With the cutting edge on the ground surface the depth of snow is observed and entered in the notes. The tube is then withdrawn carefully bringing with it the sample. Usually a layer of grass, soil, or litter will be brought up also. This material must be removed, taking care that none of the snow sample is lost. The tube and sample are then weighed and this value recorded. Subtracting the initial weight of the tube from that of the tube and sample, of course, gives the weight of the snow. Using the tube and scale described above the result is obtained directly in inches of water. Dividing this by the depth of snow gives the density.

In general there are two systems of using snow survey data in the prediction of run-off, the percentage or normal system, and the system of areas. In the percentage system the same courses must be used each year. After observations have been made for a few years, a normal water content value is established for each course. It has been found that the run-off from an area, in percent of normal, agrees very closely with the water content also in percent of normal of the snow on the area at the start of the melting season. Thus, by determining the mean percent of normal snow cover over the basin, the percent of normal run-off from the snow field is obtained. This method has been used with success in the western semi-arid areas where the streams are fed almost entirely by the snow melting at higher altitudes. Where the altitude of the basin varies widely, discrepancies in prediction are introduced by winter melting in the lower portions. For this reason, it is well to divide the basin into altitude zones, assigning representative courses to each zone. Usually, three zones are sufficient, the elevation of the gaging station or point on the stream where the water is to be used being the lower altitude limit and, of course, the summit of the watershed the upper. The area of each zone is then determined by planimetering and a normal determined for each zone. The expected run-off from the whole basin is computed by combining the individual percentages of normal for each zone using their relative areas as a basis of weighting to procure a mean for the entire basin.

The snow survey for the first year cannot be used for a prediction of the run-off for that year as no normals are available. For the next year, however, the results of the first year may be used as the basis of a provisional normal by making allowances for the general character of the first year. As more years of record are obtained the normals will become more definite.

The accuracy of this system of prediction, from its very derivation, is dependent upon the normality of all conditions affecting melting and run-off. The absence of fall rains with the resulting dry ground and extremes, either high or low, in the rate of melting, have a minor effect. The most disturbing factor, however, is a lack of normal precipitation during the melting period. Seasons of low precipitation show a marked shrinkage in the resulting run-off. In the Sierra region, the initial prediction of the run-off for the period April through July is made from the percentage of normal measured on April 1. As the season progresses, the prediction is revised or adjusted as conditions demand. By the middle of May the final estimate can usually be made. Over a period of nineteen years during which sixty-three forecasts were made for several Nevada basins about two-thirds were within ten percent of accuracy and all were within thirty-one percent. Nearly one-half were within five percent.

In the method of areas, an attempt is made to compute the actual amount of water stored in the snow cover. The most accurate manner of using the snow survey data is to plot the water content at each course on a map of the area and draw in the isohyetals, the lines of equal water content. The area of each division is obtained by planimetering. The areas are then combined with their respective depths and the total amount of water computed. Often this refinement is not applied, but the average of the individual observations is applied to the whole basin. This method predicts, after making allowances for losses, the minimum total spring run-off to be expected. The run-off from snow is, of course, supplemented in humid regions by rainfall in varying amounts, which, as yet cannot be definitely predicted. The value toward efficient operation of storage reservoirs by having advance notice of the minimum amount of water that may be expected is large.

SNOW SURVEY DATA

The records of ten snow survey stations and three snow stakes have been used. These are well distributed over the drainage area and provide a good determination of the amount of water stored in the snow blanket over the basin. A survey was made between February 28 and March 2, 1936, at which time no melting had occurred. This survey furnishes a good starting point as following it there was little precipitation in the form of snow before melting started.

In Figure 1 are shown the locations of the points and the method of computing the amount of water in the snow cover. The points were first plotted with the water content noted. Isohyetals were then drawn in by interpolation between points guided somewhat by topographic considerations. The areas between isohyetals were then determined by planimetering. It has been assumed that the mean depth of water on each area was the direct

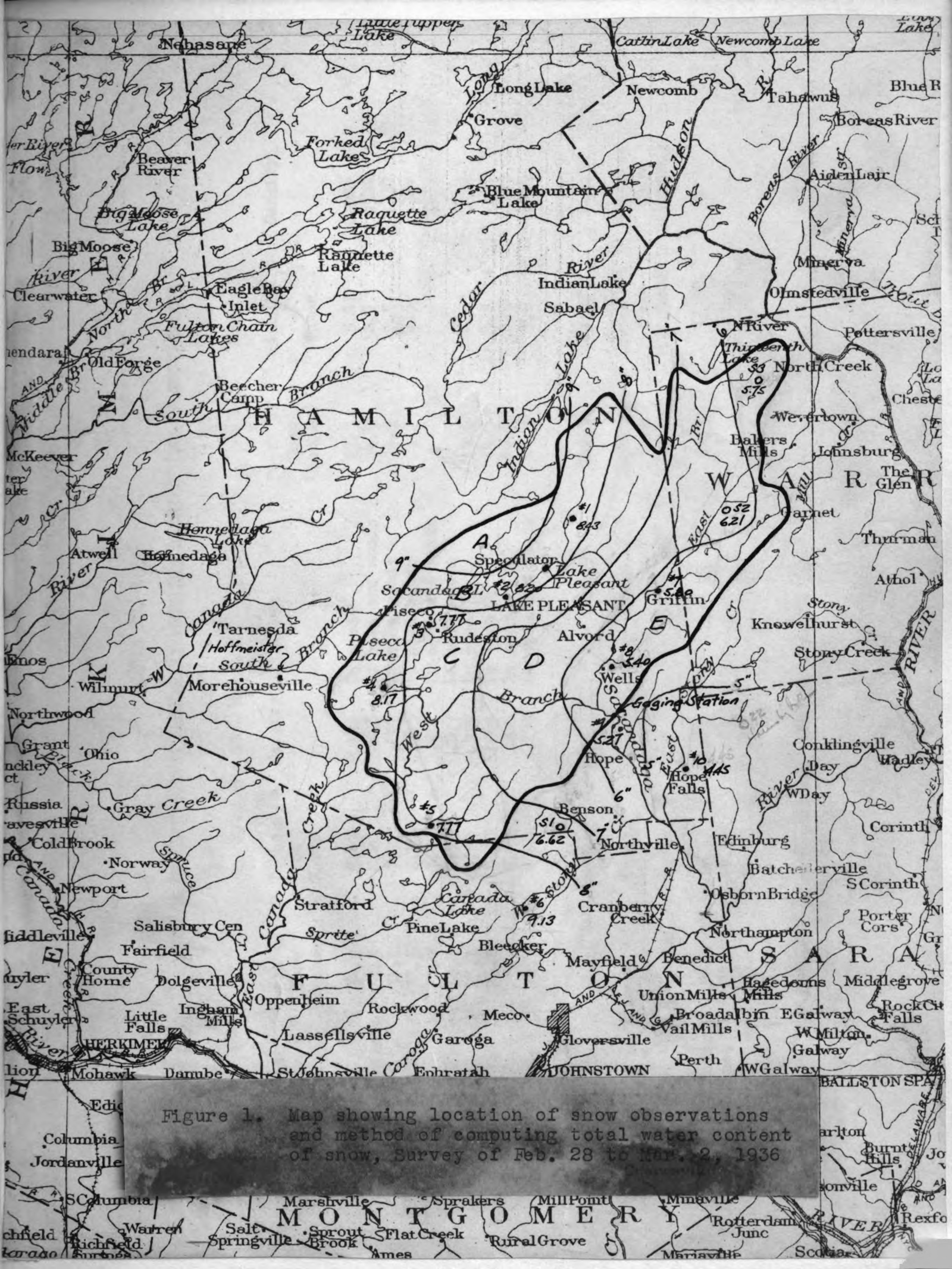


Figure 1. Map showing location of snow observations and method of computing total water content of snow, Survey of Feb. 28 to Mar. 2, 1936

TABLE NO. 1

RESULTS OF SNOW SURVEY DETERMINATIONS AND OBSERVATIONS OF SNOW-STAKES

Survey Courses		February 28 - March 2				March 17		
No.	Location	Depth of Snow (Inches)	Inches of Water	Density	Notes	Depth of Snow (Inches)	Inches of Water	Density
1	Elm Lake	34.2	8.43	0.246	In woods	23.3	6.67	0.286
2	Lake Pleasant	33.3	8.20	.246	In open and woods	24.0	8.2	.341
3	Piseco	31.2	7.77	.249	In open woods	28.8	9.5	.330
4	Morgans Mills	33.3	8.17	.245	In hard woods	23.7	7.5	.316
5	Arietta	31.0	7.77	.251	In open and woods			
6	Peters Corners	33.0	9.13	.277	In hard woods			
7	Griffin	25.3	5.80	.229	In open	13.0	4.67	.359
8	Wells	25.8	5.40	.209	In open	14.3	5.8	.405
9	Hope	25.2	5.27	.209	In open	14.3	5.5	.385
10	Hope Falls	22.5	4.45	.198	In open and woods	14.3	5.8	.405

Snow Stakes		March 2			Mar.9	Mar.16	Mar.23	Mar.30
No.	Location	Depth of Snow (Inches)	Inches of Water	Density	Depth of Snow (Inches)	Depth of Snow (Inches)	Depth of Snow (Inches)	Depth of Snow (Inches)
S1	Benson Center	26.5	*6.62	*0.25	23	18.5	1	0
S2	Barton Mines	27	#6.21	# .23		12		
S3	Oregon	24	#5.75	# .23	20			

* Computed from #6 and one other not listed
\# Computed from #7

mean of the limiting depths, for example, area D between the 6 inch and 7 inch lines was presumed to have a mean depth of 6.5 inches.

Determination of Water in Snow on March 2, 1936:

No.	Area in Sq. In.		Mean Depth in Inches		
A	0.37	x	9.5	=	3.515
B	1.64	x	8.5	=	13.940
C	2.19	x	7.5	=	16.425
D	2.26	x	6.5	=	14.690
E	1.49	x	5.7	=	8.493
Total	7.95				57.063

$$\text{Mean depth} = \frac{57.063}{7.95} = 7.18 \text{ inches of water}$$

The mean of the depths of water at the ten survey courses gives 7.04 inches. This close agreement would indicate that with well distributed courses as is the case here, the isohyetal method of computation is an unnecessary refinement.

PRECIPITATION

The records of precipitation at four stations in or near the drainage basin of the Sacandaga River above Hope, New York, were used. The records at Speculator and North Creek were furnished by the New York Power and Light Corporation; those at Hope and Hoffmeister are regular Weather Bureau cooperative stations and the records are published in Climatological Data. Each of the precipitation stations is equipped with a standard Weather Bureau non-recording gage operated, supposedly, according to the standard Weather Bureau instructions.[1]

The gages are of the standard type consisting of a round metal can over which is mounted a funnel shaped top about eight inches in diameter with a sharp vertical edge. The rain falls on or into the funnel and runs into the can. The diameters of the can and funnel are such that one inch of rain will give a depth of ten inches in the can. The depth of water in the can is determined with a measuring stick which indicates to the nearest one-hundredth of an inch the amount of rain. An outer can of about the same diameter as the funnel is provided as an overflow tank and support for the funnel. The gage should be visited each day, the depth of rainfall measured, the can emptied, and the gage again placed in position. The gage is supposed to be visited late in the afternoon each day. The rainfall measured at this time is given as the precipitation for the day but actually is the precipitation occurring in the past twenty-four hours.

1. Instructions for Cooperative Observers, U.S.Dept. of Agriculture, 1927

Gages of this type as generally operated give no information on the intensity or duration of the storm. Frequently gages are read at some other time, especially in the morning. Often discrepancies in the time of occurrence of a rain at more than one station are due to this cause. It is evident from the comparison of precipitation and run-off that the four stations here used were visited in the morning. In Figure 3 where precipitation is plotted on the day on which it was recorded, the precipitation shown on March 28 must have occurred shortly after the gage was visited on March 27. The same is shown but less noticeably on March 12, 17, and 18. However, this study is concerned mainly with the amount of precipitation rather than the time of occurrence, so no adjustment in time has been made.

The four records were combined into a composite record of the average rainfall over the area. The four stations were located on a map (see Figure 2) and connected by straight lines. At the mid-points of each of these lines perpendiculars were erected to divide the basin into four portions. It is presumed that the precipitation recorded at a station prevailed over the area adjacent to the station. Each partial area was planimetered to determine what portion of the total area it provided. The four records were listed for each day and each multiplied by its percentage of the total area. The four partials thus obtained were then added to give the composite record.

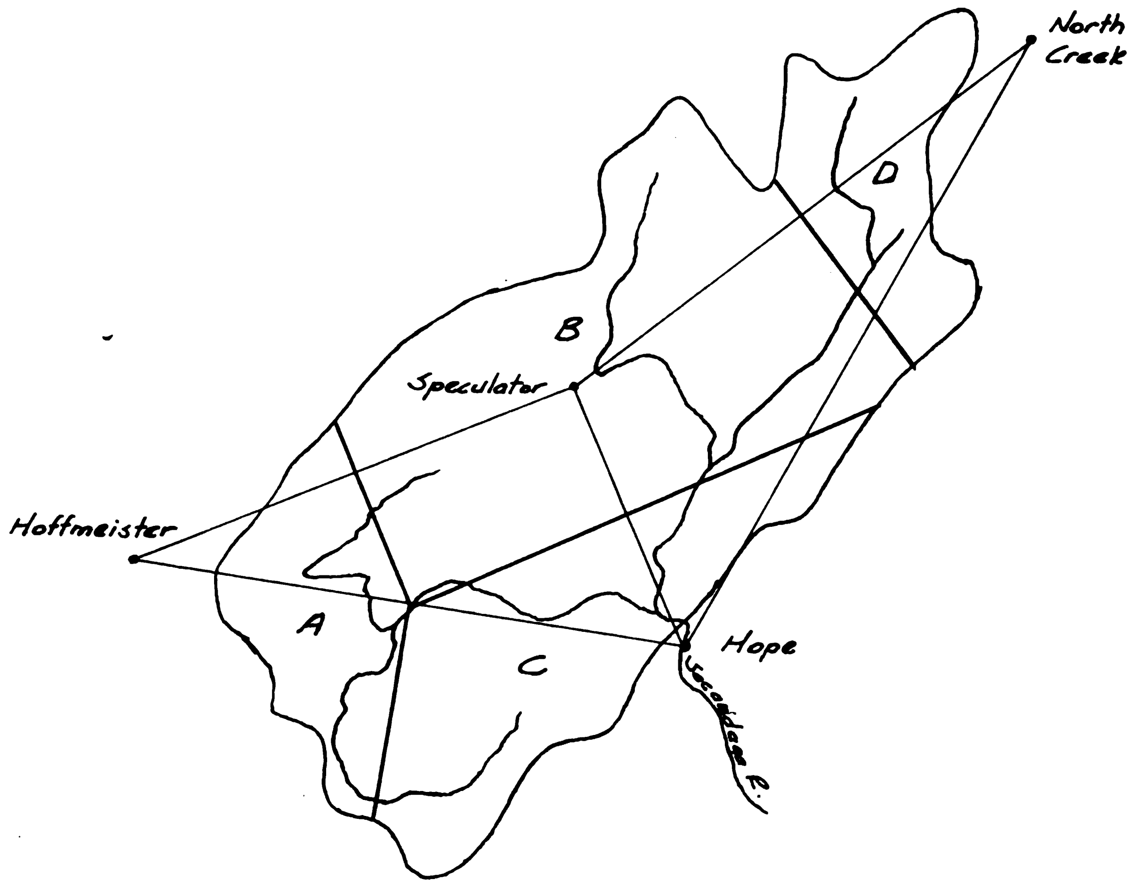


FIGURE 2. MAP SHOWING LOCATION OF PRECIPITATION STATIONS AND METHOD OF WEIGHTING PRECIPITATION DATA.

TABLE NO. 2

CUMULATIVE PRECIPITATION IN THE SACANDAGA RIVER BASIN ABOVE HOPE, 1936

	Hope		Hoffmeister		Speculator		North Creek		Total
	Obs'd	20%	Obs'd	15%	Obs'd	51%	Obs'd	14%	100%
Mar. 1	.06	.012	0	0	0	0	0	0	.012
2	.06	.012	0	0	0	0	0	0	.012
3	.39	.078	.38	.057	.43	.219	.15	.021	.375
4	.49	.098		.057		.219		.021	.395
5		.098		.057		.219		.021	.395
6		.098		.057		.219		.021	.395
7		.098		.057		.219		.021	.395
8	.49	.098		.057		.219		.021	.395
9	.83	.166	.68	.102		.219	.23	.032	.519
10	1.93	.386		.102		.219		.032	.739
11		.386		.102		.219		.032	.739
12	3.06	.612	1.43	.214	1.66	.847	1.03	.144	1.817
13	3.26	.652	1.79	.268		.847	1.33	.186	1.953
14	3.52	.704	2.19	.328	1.98	1.010	1.43	.200	2.242
15	3.57	.714		.328		1.010		.200	2.252
16	3.67	.734	2.63	.394	2.20	1.122	1.55	.217	2.467
17	4.77	.854	3.39	.508	3.45	1.760	2.57	.360	3.482
18	5.79	1.158	4.15	.622	4.75	2.422	3.57	.500	4.702
19	6.18	1.236	4.24	.636	5.17	2.637	4.13	.578	5.087
20	6.40	1.280	4.30	.645		2.637	4.46	.624	5.186
21	6.51	1.302	4.61	.692	5.67	2.892	4.54	.636	5.522
22	6.81	1.362		.692		2.892	4.99	.685	5.631
23		1.362	4.68	.702		2.892		.685	5.641
24		1.362		.702		2.892		.685	5.641
25	7.10	1.420	4.93	.740	5.92	3.019	5.29	.741	5.920
26		1.420		.740		3.019	6.02	.843	6.022
27	7.20	1.440	5.70	.855		3.019		.843	6.157
28	8.44	1.688	6.11	.916	6.77	3.453		.843	6.900
29		1.688		.916		3.453		.843	6.900
30		1.688		.916		3.453		.843	6.900
31	8.65	1.730	6.58	1.087	6.77	3.453	6.22	.871	7.141

TABLE NO. 2

CUMULATIVE PRECIPITATION IN THE SACANDAGA RIVER BASIN ABOVE HOPE, 1936

	Hope		Hoffmeister		Speculator		North Creek		Total
	Obs'd	20%	Obs'd	15%	Obs'd	51%	Obs'd	14%	100%
Mar. 1	.06	.012	0	0	0	0	0	0	.012
2	.06	.012	0	0	0	0	0	0	.012
3	.39	.078	.38	.057	.43	.219	.15	.021	.375
4	.49	.098		.057		.219		.021	.395
5		.098		.057		.219		.021	.395
6		.098		.057		.219		.021	.395
7		.098		.057		.219		.021	.395
8	.49	.098		.057		.219		.021	.395
9	.83	.166	.68	.102		.219	.23	.032	.519
10	1.93	.386		.102		.219		.032	.739
11		.386		.102		.219		.032	.739
12	3.06	.612	1.43	.214	1.66	.847	1.03	.144	1.817
13	3.26	.652	1.79	.268		.847	1.33	.186	1.953
14	3.52	.704	2.19	.328	1.98	1.010	1.43	.200	2.242
15	3.57	.714		.328		1.010		.200	2.252
16	3.67	.734	2.63	.394	2.20	1.122	1.55	.217	2.467
17	4.77	.854	3.39	.508	3.45	1.760	2.57	.360	3.482
18	5.79	1.158	4.15	.622	4.75	2.422	3.57	.500	4.702
19	6.18	1.236	4.24	.636	5.17	2.637	4.13	.578	5.087
20	6.40	1.280	4.30	.645		2.637	4.46	.624	5.186
21	6.51	1.302	4.61	.692	5.67	2.892	4.54	.636	5.522
22	6.81	1.362		.692		2.892	4.99	.685	5.631
23		1.362	4.68	.702		2.892		.685	5.641
24		1.362		.702		2.892		.685	5.641
25	7.10	1.420	4.93	.740	5.92	3.019	5.29	.741	5.920
26		1.420		.740		3.019	6.02	.843	6.022
27	7.20	1.440	5.70	.855		3.019		.843	6.157
28	8.44	1.688	6.11	.916	6.77	3.453		.843	6.900
29		1.688		.916		3.453		.843	6.900
30		1.688		.916		3.453		.843	6.900
31	8.65	1.730	6.58	1.087	6.77	3.453	6.22	.871	7.141

TABLE NO. 2 (Continued)

CUMULATIVE PRECIPITATION IN THE SACANDAGA RIVER BASIN ABOVE HOPE, 1936

	Hope		Hoffmeister		Speculator	North Creek		Total
	Obs'd	53%	Obs'd	23%		Obs'd	24%	100%
Apr. 1	0	0	0	0	Not used	0	0	7.141
2	.13	.069	.22	.051		.46	.110	7.371
3	.85	.450	.67	.154			.110	7.855
4		.450	.74	.170			.110	7.871
5		.450		.170			.110	7.871
6	2.63	1.394	2.57	.591		1.48	.355	9.481
7	2.93	1.553	2.62	.603		1.73	.415	9.712
8	3.36	1.781	3.05	.702		1.95	.468	10.092
9		1.781		.702			.468	10.092
10	3.45	1.828	3.14	.722		2.12	.509	10.200
11	3.60	1.908	3.39	.780		2.36	.566	10.395
12	3.79	2.009	3.57	.821		2.73	.655	10.626
13	3.86	2.046		.821		2.86	.686	10.694
14		2.046		.821			.686	10.694
15	4.03	2.136	3.73	.858		3.02	.725	10.860
16	4.34	2.300	4.24	.975		3.38	.811	11.227
17		2.300	4.34	.998			.811	11.250
18		2.300	4.47	1.028			.811	11.280
19		2.300		1.028			.811	11.280
20		2.300		1.028			.811	11.280
21	4.53	2.401	5.03	1.157		3.53	.847	11.546
22	4.63	2.454		1.157		3.67	.881	11.633
23		2.454		1.157			.881	11.633
24		2.454		1.157			.881	11.633
25		2.454		1.157			.881	11.633
26	4.67	2.475		1.157			.881	11.654
27		2.475		1.157			.881	11.654
28		2.475		1.157			.881	11.654
29		2.475	5.15	1.184		3.71	.890	11.690
30	4.85	2.570	5.66	1.302		4.01	.962	11.975

TABLE NO. 2 (Continued)

CUMULATIVE PRECIPITATION IN THE SACANDAGA RIVER BASIN ABOVE HOPE, 1936

		Hope		Hoffmeister		Speculator		North Creek		Total
		Obs'd	20%	Obs'd	15%	Obs'd	51%	Obs'd	14%	100%
May	1	0	0	0	0	0	0	0	0	11.975
	2	.10	.020	.02	.003	.19	.097	.78	.109	12.204
	3	.79	.158	1.81	.272	.91	.464	1.08	.151	13.020
	4		.158		.272		.464		.151	13.020
	5		.158		.272		.464		.151	13.020
	6	.82	.164		.272		.464		.151	13.026
	7	1.01	.202	2.08	.312		.464	1.25	.175	13.128
	8		.202		.312		.464		.175	13.128
	9		.202		.312	1.41	.719		.175	13.383
	10	2.07	.414	2.18	.327		.719		.175	13.610
	11		.414		.327		.719	1.85	.259	13.694
	12		.414		.327	1.57	.801	2.25	.315	13.832
	13	2.33	.466	2.40	.360	2.57	1.311	2.41	.337	14.449
	14	2.45	.490	3.30	.495		1.311	2.72	.381	14.652
	15		.490		.495		1.311		.381	14.652
	16	2.59	.518	3.50	.525		1.311	2.87	.402	14.731
	17		.518		.525		1.311	2.95	.413	14.742
	18		.518		.525		1.311	3.01	.421	14.750
	19	2.69	.538	4.23	.634		1.311		.421	14.879
	20	2.99	.598	4.61	.692	3.30	1.683	3.41	.477	15.425
	21		.598		.692		1.683		.477	15.425
	22		.598		.692		1.683		.477	15.425
	23		.598		.692	3.38	1.724		.477	15.466
	24		.598		.692		1.724		.477	15.466
	25		.598	4.64	.696		1.724		.477	15.470
	26		.598		.696		1.724		.477	15.470
	27	3.02	.604	4.79	.718		1.724		.477	15.498
	28	3.17	.634		.718	3.60	1.836	3.77	.528	15.691
	29		.634	4.82	.723		1.836		.528	15.696
	30	3.21	.642	4.87	.730		1.836		.528	15.711
	31		.642		.730		1.836		.528	15.711

The record at Hoffmeister for April appears inconsistent with the other records. Evidently, the stations was not visited each day and the total rainfall for several days given when it was visited. The monthly total from comparison with others also seems too low. After some investigation, it was decided to disregard the Hoffmeister record entirely during April using only the Hope, Speculator, and North Creek records in the same manner as all four were used during March and May. Precipitation records are given in Table 2.

TEMPERATURE

Few temperature stations are equipped with recording thermometer equipment, most being supplied with two thermometers, one which indicates the maximum and the other the minimum temperature which has occurred since the thermometers were set. They are commonly installed in the vicinity of a rain gage and are visited coincidently with it.

At Conklingville, 17 miles west of the Hope gaging station, the Hudson River Regulating District maintains a recording thermometer or thermograph. This instrument has a drum which is rotated by a spring driven clock and to which a paper chart is attached. As the drum revolves a pen actuated by the thermometer unit traces a continuous record of the temperature. The thermograph is housed in a standard Cotton-region shelter.

The temperature at Conklingville is fairly representative of that prevailing over the basin above Hope but may be a trifle warmer. Being the only recorder record near the area being studied it was used directly. No thermometers are installed at the four precipitation stations. A continuous record or frequent readings are necessary to any study which required data on the duration of certain temperatures as an ordinary thermometer station gives only the extremes.

From the thermograph charts the mean temperature for each two hour period was tabulated. For each day the total degree hours above 32° F. (degrees above 32° x duration in hours, for example, a temperature of 35° over a period of 4 hours = (35-32) x 4 = 12 degree hours) were computed from the tabulation of temperature.

Robert E. Horton has computed[1] that to melt one inch of congealed water would require 14.4 inches of rain at 42° F. It has also been determined by Horton[2] and George[3] that one degree day C will melt 0.16 inches of ice or one degree day F will melt 0.09 inches of ice. Equating these values it is found that the

1 The Melting of Snow, Monthly Weather Review, December, 1915

2 Transactions of the American Geophysical Union, Section of Hydrology, 1932.

3 Change in Density of Snow Cover with Melting, Monthly Weather Review, August, 1929

TABLE NO. 3

RECORD OF TEMPERATURE AT CONKLINGVILLE, NEW YORK, 1936

Feb.	Mean temperature for two hour periods M 2 4 6 8 10 N 2 4 6 8 10 M												Mean for day	Deg.Hrs. above 32	Rainfall Equiv. (Deg.Hrs.)	Total for day	Total
1																	
2																	
3																	
4	11	12	12	13	15	17	20	23	26	29	26	24	19.0				
5	22	20	17	16	15	16	15	13	8	5	4	3	12.8				
6	2	2	0	0	2	8	12	12	10	7	5	2	5.2				
7	1	2	1	2	6	11	15	15	9	7	4	-2	5.9				
8	-7	-10	-12	-13	-7	10	17	17	14	7	3	3	1.8				
9	4	5	5	14	16	18	20	21	20	19	12	9	13.6				
10	-1	-7	-6	1	1	5	9	9	5	4	5	4	2.4				
11	3	0	2	4	8	14	16	16	14	13	12	11	9.4				
12	11	8	4	4	7	16	18	17	15	11	10	10	10.9				
13	8	0	-2	-1	3	12	20	17	15	13	12	11	9.0				
14	12	12	13	14	15	19	24	26	26	25	24	25	19.6				
15	25	25	26	26	29	31	34	35	33	22	16	12	26.2				
16	6	4	2	1	9	23	31	35	37	36	34	32	20.8	12			12
17	31	31	31	32	32	34	32	31	27	26	26	27	30.0	4			16
18	29	30	30	28	22	19	17	15	7	2	1	-1	16.6				
19	-2	-3	-6	-7	-2	5	9	8	6	3	-1	-3	.6				
20	-7	-8	-14	-17	-13	9	16	18	14	5	-1	-6	.3				
21	-10	-13	-15	-17	-12	5	23	25	20	9	1	-5	.9				
22	-8	-10	-14	-17	-9	10	24	26	23	17	7	5	4.5				
23	1	-5	-8	-9	5	18	25	29	25	13	5	1	8.3				
24	2	6	5	5	13	26	27	27	29	30	31	32	19.4				
25	32	32	32	32	33	35	35	36	35	37	40	40	34.9	70			86
26	39	35	32	33	32	36	40	39	38	36	33	32	35.4	82			168
27	32	37	39	35	33	34	36	38	36	35	30	26	34.2	70			238
28	25	24	21	18	18	21	22	23	21	17	16	13	19.9				
29	7	3	1	0	5	19	25	26	27	27	27	27	16.2				

TABLE NO. 3

RECORD OF TEMPERATURE AT CONKLINGSVILLE, NEW YORK, 1936

Mar.	Mean temperature for two hour periods												Mean for day	Deg.Hrs. above 32	Rainfall Equiv. (Deg.Hrs.)	Total for day	Total
	M	2	4	6	8	10	N	2	4	6	8	10 M					
1	24	18	14	10	14	19	24	26	26	18	12	10	17.9				
2	4	-1	-3	-6	8	25	29	31	29	27	26	26	16.2				
3	25	24	24	26	28	32	35	34	33	31	30	29	29.2	12		12	
4	27	24	22	23	28	40	44	46	43	38	42	38	34.6	134		134	
5	35	34	32	31	28	35	32	32	31	29	28	27	31.2	16		16	
6	24	20	18	13	15	18	22	24	23	16	13	11	18.1				
7	7	2	-2	-3	5	20	26	26	26	18	12	7	12.0	4		4	
8	5	2	0	0	13	27	30	33	33	30	30	30	19.4				
9	30	30	30	32	33	34	36	36	35	34	34	34	33.2	40	2	42	446
10	33	33	33	33	35	41	45	48	45	37	33	34	37.5	132	4	136	582
11	35	35	36	36	39	42	44	46	46	45	44	41	40.8	210		210	792
12	41	44	45	41	39	38	41	40	36	34	34	33	38.8	164	20	184	976
13	32	31	31	30	29	31	32	32	30	30	28	25	30.1				
14	25	26	27	27	28	29	31	32	33	29	27	28	28.5	2		2	978
15	29	29	27	26	33	40	46	51	47	44	42	38	37.7	170		170	1148
16	36	36	36	36	38	38	38	38	38	38	38	38	37.3	128	4	132	1280
17	36	35	35	35	37	42	49	49	50	48	47	47	42.5	252	19	271	1551
18	48	48	48	49	48	47	48	50	49	43	47	44	47.4	372	22	394	1945
19	42	47	41	40	43	48	50	46	42	38	36	35	42.3	246	7	253	2198
20	34	33	33	34	35	37	40	46	48	39	35	35	37.4	130	2	132	2330
21	34	37	38	39	41	40	43	45	44	40	37	39	39.8	186	6	192	2522
22	37	35	35	36	36	37	37	36	40	39	38	37	36.9	118	2	120	2642
23	35	30	31	33	44	50	52	53	50	44	40	38	41.7	242		242	2884
24	37	37	36	38	48	57	61	58	54	51	45	45	47.2	366		366	3250
25	43	42	40	39	42	48	58	59	57	49	46	40	46.9	358	5	363	3613
26	34	30	28	30	39	48	54	57	57	44	35	32	40.7	244	2	246	3859
27	31	30	32	40	41	42	44	45	48	47	45	44	40.8	216	2	218	4077
28	40	39	35	36	42	44	44	44	44	40	38	38	40.3	200	14	214	4291
29	37	30	28	29	38	49	55	59	60	54	51	42	44.3	314		314	4605
30	38	42	38	38	47	59	64	63	61	52	47	47	49.7	424		424	5029
31	45	43	42	45	38	37	37	35	34	31	31	30	37.3	136	4	140	5169

TABLE NO. 3

RECORD OF TEMPERATURE AT CONKLINGSVILLE, NEW YORK, 1936

Apr.	Mean temperature for two hour periods M	2	4	6	8	10	N	2	4	6	8	10	M	Mean for day	Deg.Hrs. above 32	Rainfall Equiv. (Deg.Hrs.)	Total for day	Total
1	29	26	25	25	30	32	36	39	36	34	33	32	31.4	32		32	5201
2	30	30	31	31	32	32	33	34	34	33	33	34	32.2	18	4	22	5223
3	34	35	34	32	32	32	32	32	30	28	27	26	31.2	14	9	23	5246
4	25	25	25	25	27	31	35	37	38	35	32	30	30.4	34	1	35	5281
5	30	30	29	30	34	39	45	46	44	43	42	39	37.6	152		152	5433
6	37	39	43	49	52	52	51	49	44	40	39	38	44.4	298	24	322	5755
7	37	35	32	33	37	39	35	33	32	33	34	32	34.3	56	5	61	5816
8	31	30	30	31	32	35	38	40	36	31	30	28	32.7	42	3	45	5861
9	26	25	26	29	34	41	44	46	45	43	40	36	36.2	146		146	6007
10							38						38	144	2	146	6153
11							39						39	168	4	172	6325
12							38						38	144		144	6469
13							41						41	216		216	6685
14	37	33	31	36	44	49	52	53	50	45	39	39	42.3	250		250	6935
15							44						44	288	2	290	7225
16							39						39	168	4	172	7397
17							37						37	120		120	7517
18							40						40	192		192	7709
19	35	31	37	40	42	43	42	42	42	40	34	33	34.9	156		156	7865
20	32	33	34	37	41	45	51	54	53	50	48	45	43.6	278		278	8143
21							43						43	273	5	268	8416
22							35						35	73	1	72	8489
23	28	29	28	34	38	44	48	50	48	44	41	40	39.3	198		198	8687
24	38	36	33	35	36	38	41	43	44	38	32	29	36.9	124		124	8811
25	27	25	25	31	40	43	47	50	52	46	44	41	39.2	214		214	9025
26	41	39	40	42	48	50	49	48	46	39	35	31	42.3	250		250	9275
27	29	28	27	33	41	45	55	58	60	58	56	54	45.3	344		344	9619
28							52						52	480		480	10099
29							60						60	672		672	10771
30							60						60	676	4	672	11447

melting of one inch of ice = 269 degree hours = 14.4 inches of rain at 42° or one inch of rain = 18.4 degree hours F.

This equation was used to convert the precipitation into degree hours which were then added to the degree hours computed from the temperature records to correct for the melting effect of the precipitation. It is realized that this figure would not be correct for all days as much of the precipitation occurred at temperatures other than 42°. As the degree hour equivalent of the precipitation is very small in relation to the temperature alone (183 against 11,264) no serious error is incurred and it does seem advisable to take some account of the melting effect of the precipitation which occurred during the melting period.

RUN-OFF

The record of discharge as determined at the gaging station operated by the United States Geological Survey on the Sacandaga River near Hope, New York, has been used to furnish the run-off data. The station is located $1\frac{1}{2}$ miles below the junction of the east and west branches of the Sacandaga River and $4\frac{1}{2}$ miles above Hope, in Hamilton County.

The gaging station is a modern first-class installation. A concrete stilling well is surmounted by a timber shelter wherein is housed a weekly water-stage recorder. This station is visited daily by a reliable observer who checks the instrument and telephones readings to the engineers of the Hudson River Regulating District for use in the operation of the Conklingville Dam. Daily visits to a recording gage are extraordinary as these instruments are capable of operating one week or several months, depending upon the type of recorder, without attention. Medium and high water current-meter measurements are made from a cable structure at the gage. Low water measurements are made by wading near the cable. The channel and control are stable, being composed of large boulders and gravel. Although measuring conditions are not of the best at high stages owing to fast and turbulent velocities, all of the high water measurements made over a period of several years plot consistently and define a well shaped stage-discharge rating curve. The records of discharge determined at this station are believed to be very good.

The mean-daily discharges were reduced to their equivalent run-off in inches on the following basis:

$$\frac{Q \text{ (mean daily discharge in C.F.S.)} \times 86{,}400 \text{ (sec. per day)} \times 12}{5280^2 \text{ (square feet in one sq. mi.)} \times 491 \text{ (drainage area in sq. mi.)}}$$

$= R$ (run-off in inches)

or $R = .0000757 \times Q$

By application of the rating table the original gage-height record

TABLE NO. 4

DAILY DISCHARGE, RUN-OFF, AND CUMULATIVE RUN-OFF OF SACANDAGA RIVER NEAR HOPE, N.Y.

	March			April		
Date	Discharge (C.F.S.)	Run-off (Inches)	Total Run-off (Inches)	Discharge (C.F.S.)	Run-off (Inches)	Total Run-off (Inches)
1	320	0.024	0.024	4970	0.376	12.946
2	260	.020	.044	4200	.318	13.264
3	260	.020	.064	4080	.309	13.573
4	260	.020	.084	3340	.253	13.826
5	360	.027	.111	2960	.224	14.050
6	380	.029	.140	8020	.607	14.657
7	380	.029	.169	7630	.578	15.235
8	420	.032	.201	5250	.397	15.632
9	500	.038	.239	4080	.309	15.941
10	700	.053	.292	3540	.268	16.209
11	850	.064	.356	3340	.253	16.462
12	6,150	.466	.822	3540	.268	16.730
13	8,420	.637	1.459	3240	.245	16.975
14	5,010	.379	1.838	2960	.224	17.199
15	3,700	.280	2.118	2960	.224	17.423
16	3,540	.268	2.386	3150	.238	17.661
17	7,840	.593	2.979	3060	.232	17.893
18	19,400	1.469	4.448	2690	.204	18.097
19	15,400	1.166	5.614	2350	.178	18.275
20	11,800	.893	6.507	2110	.160	18.435
21	8,720	.660	7.167	2190	.166	18.601
22	7,740	.586	7.753	2190	.166	18.767
23	5,530	.419	8.172	1960	.148	18.915
24	5,250	.397	8.569	1780	.135	19.050
25	7,450	.564	9.133	1600	.121	19.171
26	7,500	.568	9.701	1500	.114	19.285
27	9,000	.681	10.382	1400	.106	19.391
28	9,620	.728	11.110	1300	.098	19.489
29	7,050	.534	11.644	1260	.095	19.584
30	6,120	.463	12.107	1390	.105	19.689
31	6,120	.463	12.570			

TABLE NO. 4 (Continued)

DAILY DISCHARGE, RUN-OFF, AND CUMULATIVE RUN-OFF OF SACANDAGA RIVER NEAR HOPE, N. Y.

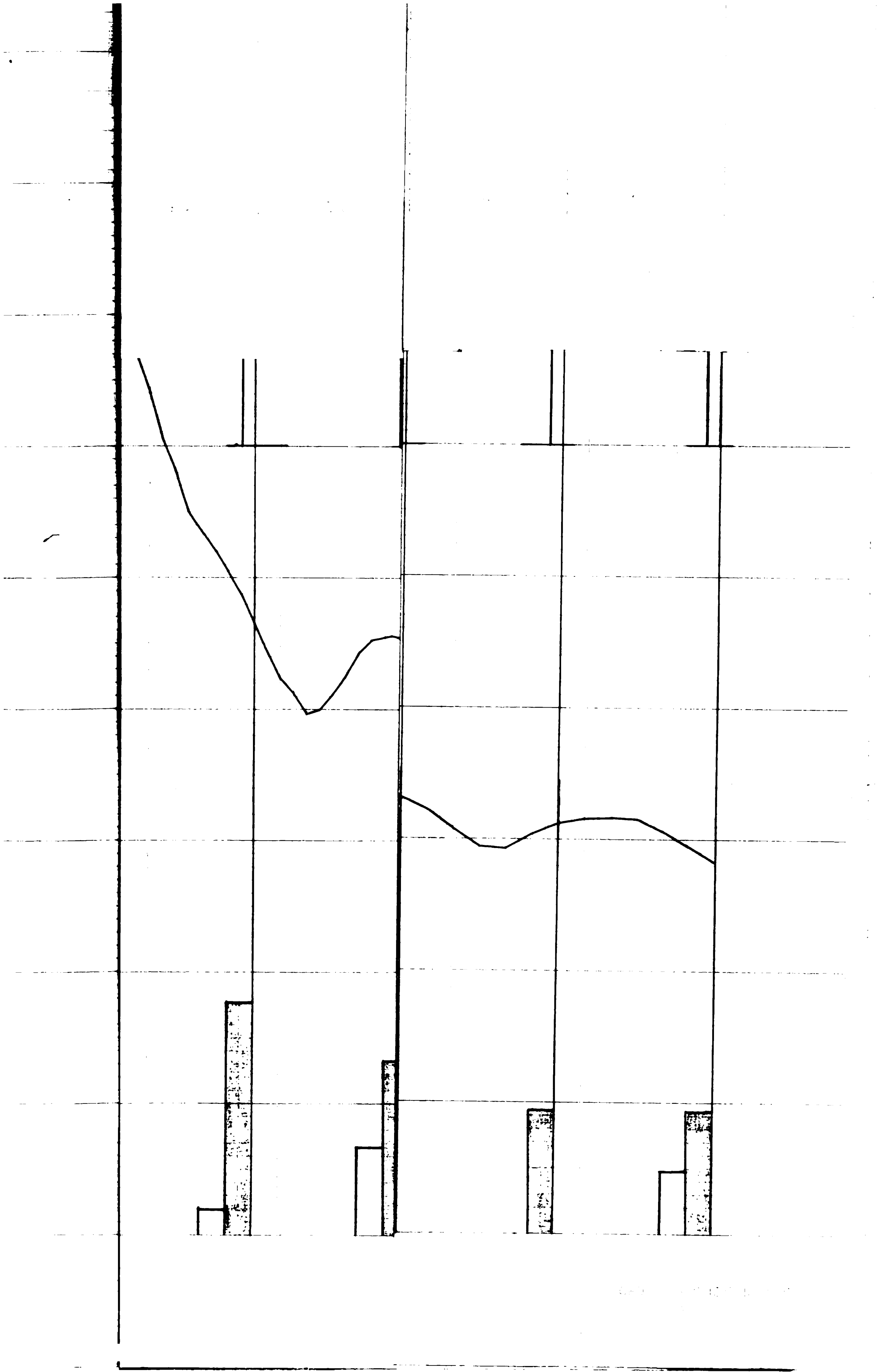
Date	May Discharge (C.F.S.)	May Run-off (Inches)	May Total Run-off (Inches	June Discharge (C.F.S.)	June Run-off (Inches)	June Total Run-off (Inches)
1	1430	0.108	19.797	461	0.035	22.868
2	1480	.112	19.909	420	.032	22.900
3	2430	.184	20.093	382	.029	22.929
4	2430	.184	20.277	340	.026	22.955
5	2040	.154	20.431	306	.023	22.978
6	1780	.135	20.566	284	.021	22.999
7	1630	.123	20.689	274	.021	23.020
8	1460	.111	20.800	274	.021	23.041
9	1310	.099	20.899	274	.021	23.062
10	1490	.113	21.012	248	.019	23.081
11	1360	.103	21.115			
12	1960	.148	21.265			
13	1780	.135	21.398			
14	2190	.166	21.564			
15	1810	.135	21.699			
16	1570	.119	21.818			
17	1360	.103	21.921			
18	1220	.092	22.013			
19	1160	.088	22.101			
20	1390	.105	22.206			
21	1270	.096	22.302			
22	1150	.087	22.389			
23	1010	.076	22.465			
24	880	.067	22.532			
25	782	.059	22.591			
26	692	.052	22.643			
27	632	.048	22.691			
28	616	.047	22.738			
29	534	.040	22.778			
30	280	.021	22.799			
31	447	.034	22.833			

on the recorder chart was transposed into a hydrograph of discharge in second feet which is shown in Figure 3.

In any study of run-off and its related factors the run-off data if collected at a good recording gage station is more accurate than the data on any of the other factors. Stream-flow records are basically a measurement of the entire quantity of water passing the gage. All other data are dependent upon sampling and some system of averaging. For example, four rain gages have been used to determine the rainfall quantities. The catch of each rain gage is liable to error owing to location, position, surroundings, wind, etc. The method of obtaining an average for the total area from the four records is based largely on assumption. Yet four rain gages in an area of about 500 square miles is a much higher gage population than is often found. In like manner snow surveys, temperature records (to a lesser degree perhaps) soil temperatures, ground water levels, relative humidity, and others are subject to variation. Of the data available it is quite evident that stream flow presents the most reliable record.

ANALYSIS AND CORRELATION OF DATA

The data which have already been presented were all gathered and compiled independently of each other and are now to be combined, compared, and investigated together in an effort to



learn some of the features of their inter-relationship.

The coordination of the separate data is graphically shown in Figure 3. Here in a general way the whole process of spring run-off is displayed. Run-off is a very small quantity until the rain of March 12, following which it increases very rapidly. After the high flow occasioned by the heavy rain of March 17, 18, the run-off decreases rather slowly. On several days, particularly March 23, 25, 29, and 30, when the amount of degree hours above 32° is large the discharge hydrograph shows a hump due to increased melting. As most of the melting occurred during March this graph is carried only through that month.

February was a cold month with the temperature above freezing for only a very short time toward the end of the month, and then not above 40°. The total accumulated temperature above 32° during February was 238 degree hours. This gave an opportunity for the temperature of the snow cover over the area to be lowered to well below 32° and also to keep the snow in a relatively light and uniform condition. The snow survey of February 29 to March 2 indicates the presence of a mean of 7.18 inches of water stored in the snow. The mean density at this time was 0.236 inches of water per inch of snow. The total degree hours above freezing remained at 238.

On March 17 another snow survey was made at eight of the courses. Using only the same eight courses for the survey on March 2 the average depth of water was 6.69 inches in snow having a density of 0.229; while on March 17 there was an average of 6.70 inches of water in snow having a density of 0.353. By the time of the second survey, the total degree hours above freezing had risen to about 1400, a gain of about 1192. Between the surveys 3.47 inches of precipitation (probably .65 inches was in the form of snow) had fallen. It is apparent that very little melting had yet taken place, evidently an amount equal to the snowfall between surveys or 0.65 inch. The density however had increased about 54%. Practically all of the rain evidently had percolated down through the snow and had run off. The snow had been settled and packed by the rain and by the warm temperatures but not enough heat had yet been transmitted to the snow to promote active melting. In Figure 4 are plotted, cumulatively, run-off, precipitation, and run-off minus precipitation. During the melting period the run-off minus precipitation represents the water coming from the melting snow. This is a minus quantity until March 19, owing partly to the precipitation on March 3 being snow. Previous to March 19 the snow cover was being warmed but very little melting was taking place. It is notable that the precipitation appeared as run-off with very little delay.

On April 29, the run-off minus precipitation curve reached its maximum of 7.89 inches. This value exceeds the 7.18 inches of water determined by the snow survey of March 2 by 0.71 inches with no allowance made for losses through sublimation and evaporation.

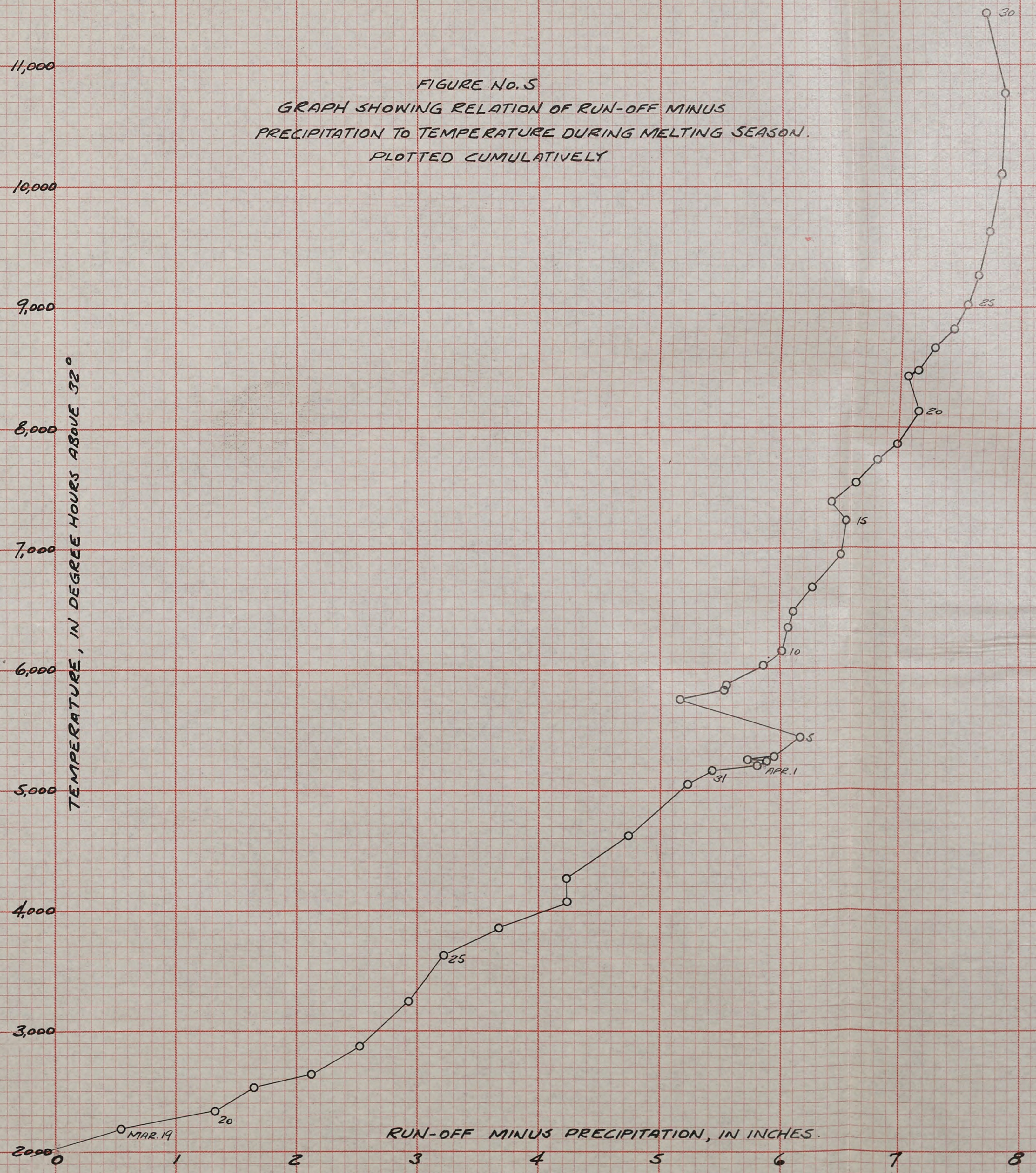
Having no data on ground water its effect on the results is unknown. If part of the spring precipitation or melting snow went into ground water storage, and it seems likely that it would, the above discrepancy should be greater than indicated. If, on the other hand, the ground water level was lowered, which is improbable, the agreement between the snow survey and the run-off minus precipitation would be closer. It seems quite certain, however, that even though ground water was high in the fall the winter flow would reduce it to a lower level than would be found on April 29. The need for records of ground water elevations in run-off studies is apparent.

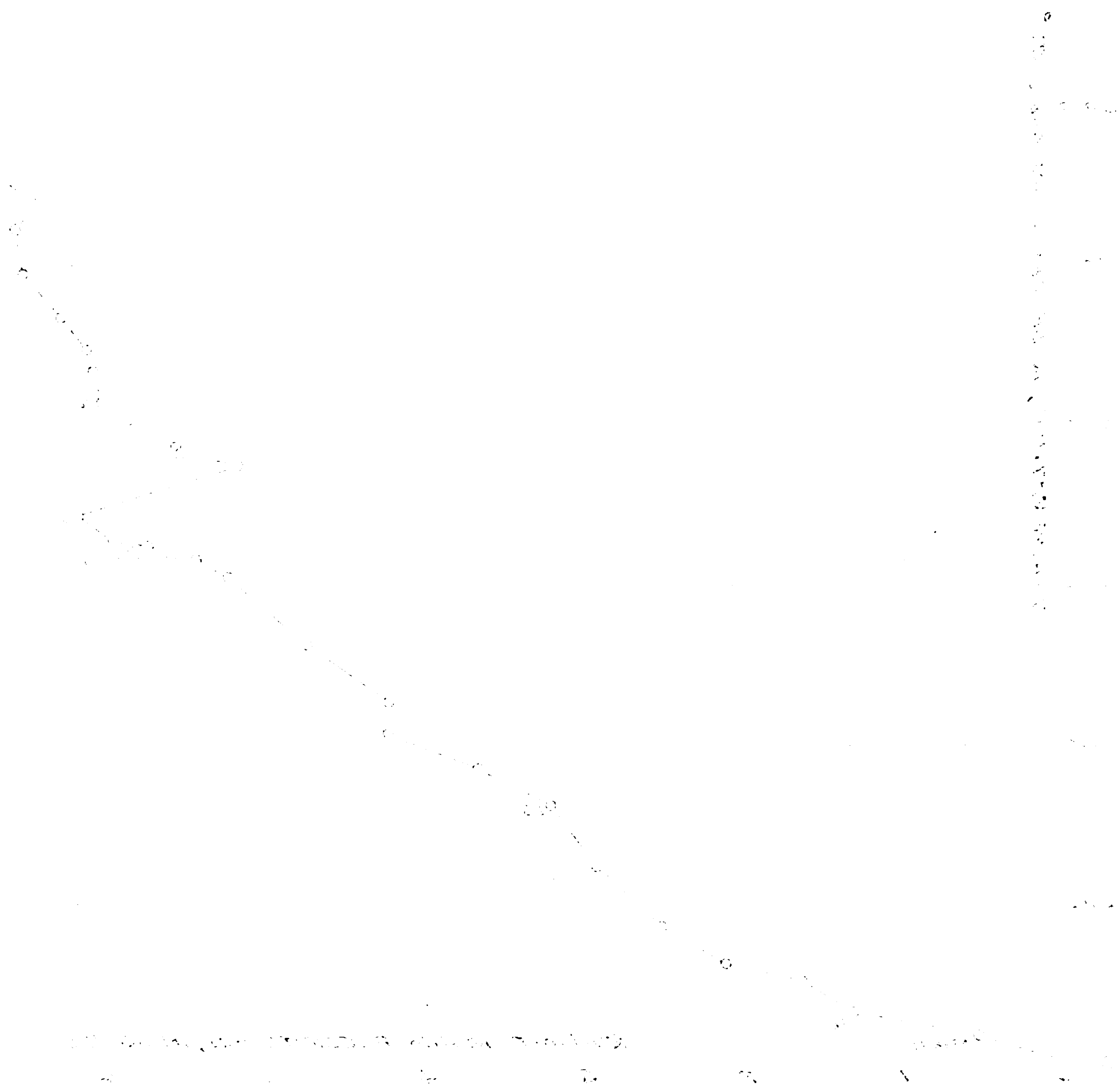
Although observations at snow stakes indicate that the snow had all melted by March 30, it is probable that some snow then remained in the woods. April 1-5, 7-8, were rather cold periods with the temperature above 32° only a few hours at a time. This makes it difficult to tell whether the flattening off of the run-off minus precipitation curve is the result of cold weather or if the snow had all been melted. It is thought that the snow was entirely gone by April 15. After that date although the run-off continued to exceed the precipitation through April 29, the slope of the run-off minus precipitation graph is more regular, indicating that the flow during this period might be due to the lowering of the water table. The rate of loss through evaporation would be increasing as the season progressed and would be supplemented by transpiration when plant growth started. During May the losses were great enough that the run-off was again exceeded by the precipitation.

For the whole period March 1 to June 10 the total run-off amounted to 23.08 inches; the total precipitation (including the 7.18 inches on the ground in snow on March 2) amounted to 22.89 inches or a run-off excess of 0.19 inches. As this leaves no allowance for evaporation and transpiration losses which might be estimated at 4 to 6 inches, it is apparent that some of the data must be in error. The greatest chance for error probably is in the amount of precipitation. If the maximum monthly precipitation values are combined a total of 26.36 inches is obtained (March, Hope, 8.65 inches; April, Hoffmeister 4.85 inches; May, Hoffmeister 4.87 inches; June 1-10, all stations 0; snow survey, 7.18 inches) which would allow only 3.28 inches for losses. Of course, there is no logical reason for using only the monthly maxima and their total has been computed only through curiosity to see what result it would give.

In plotting the cumulative run-off minus precipitation against cumulative degree hours above 32°, Figure 5, it must be remembered that run-off minus precipitation includes all run-off,

FIGURE No. 5
GRAPH SHOWING RELATION OF RUN-OFF MINUS
PRECIPITATION TO TEMPERATURE DURING MELTING SEASON.
PLOTTED CUMULATIVELY





both that from the surface and that from ground water. During periods of no precipitation the flow from ground water will cause the run-off minus precipitation quantity to increase in the same fashion as will melting snow. The need for ground water data is again made evident. At the lower end of this graph the ground water level probably stayed nearly constant so that this portion of the graph is a good indication of the rate of melting. The plotting of April 1-4, 7-8, indicates that snow remained then and that the water table was not being lowered. Using the slope of the curve March 18-22 a rate of 2.57 inches per 700 degree hours which is equal to 0.00367 inches per degree hour, or 0.089 inches per degree day. This compares favorably with the values of 0.090 and 0.089, respectively, determined by Horton[1] and Clyde[2]. The upper end of the graph is complicated by flow due to lowering of the water table so that it is impossible to tell when the melting ceased. Of course, the difference between run-off and precipitation must have been supplied by melting snow but the time required for melting it is indefinite. Using April 15

1 R.E.Horton, Proceeding of American Geophysical Union, 1932

2 George D. Clyde, Change in Density of Snow Cover with Melting. Monthly Weather Review, August, 1929

as the date upon which the melting of the snow was completed would mean that 7200 degree hours had been required. No satisfactory explanation for the inconsistent plotting of the period April 5-10 has been derived.

It appears that the high flow of March 18 was due almost entirely to rain. Evidently, active melting did not produce run-off until March 19. Had more warm weather preceded the rains of March 17 and 18, the flood flow would undoubtedly have been much greater. It is conceivable that under certain extreme conditions practically all of the snow could be melted within a very few days, possibly accompanied by rain with extreme flood conditions resulting. All of the graphs in which the precipitation data were used are step-like in shape and not smooth. As the run-off from a certain rain does not occur simultaneously with the rain the run-off minus precipitation graph shows some reverses. This lag in run-off is somewhat compensated for by the nature of the records, the run-off being computed on a mid-night to mid-night basis while the precipitation was determined presumably on a late afternoon to late afternoon basis.

A plotting of precipitation as ordinate against run-off as abscissa (Figure 6) shows the run-off and precipitation to be about equal until March 18. From there on to April 29 run-off exceeds precipitation but gradually approaches it. After

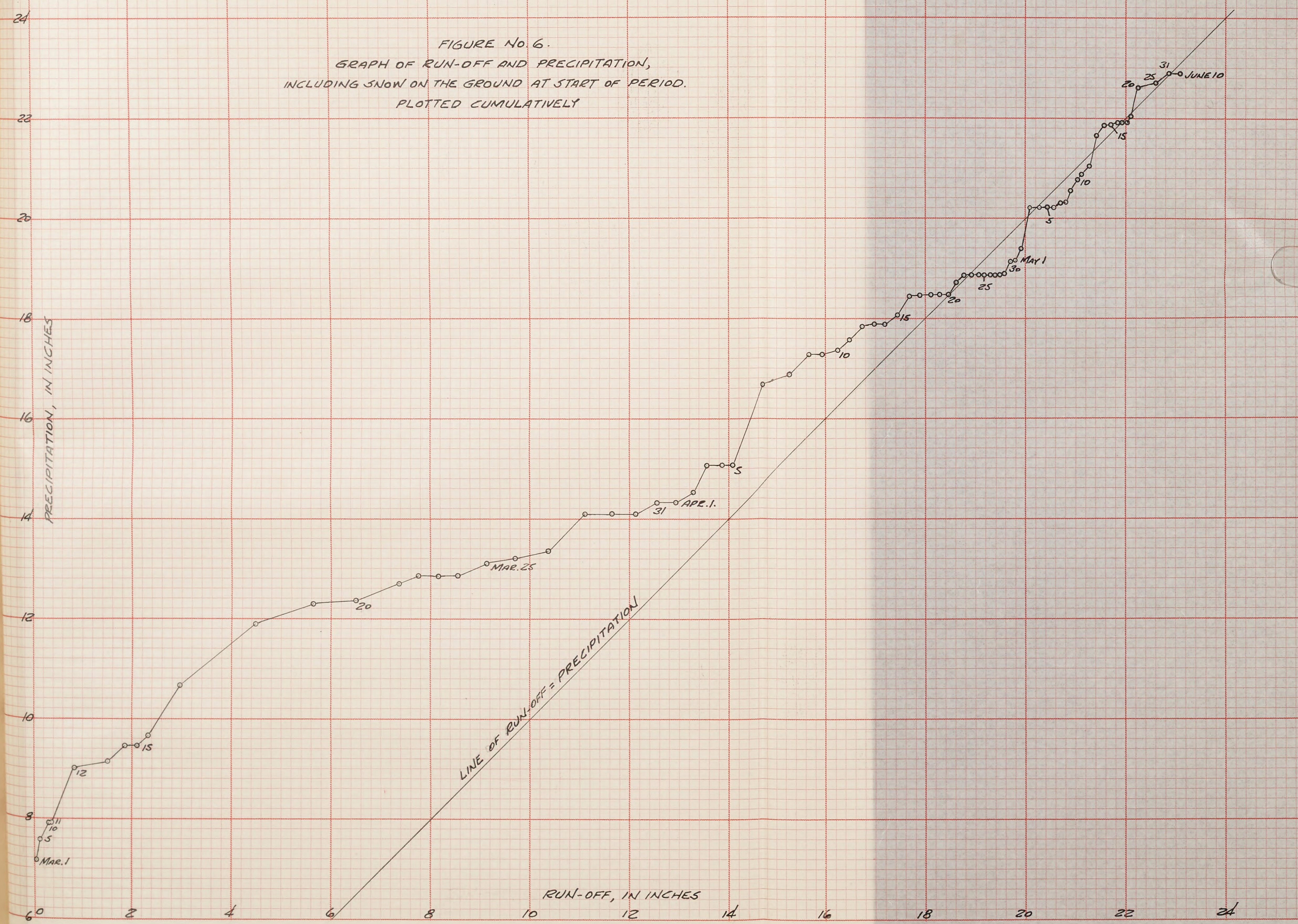
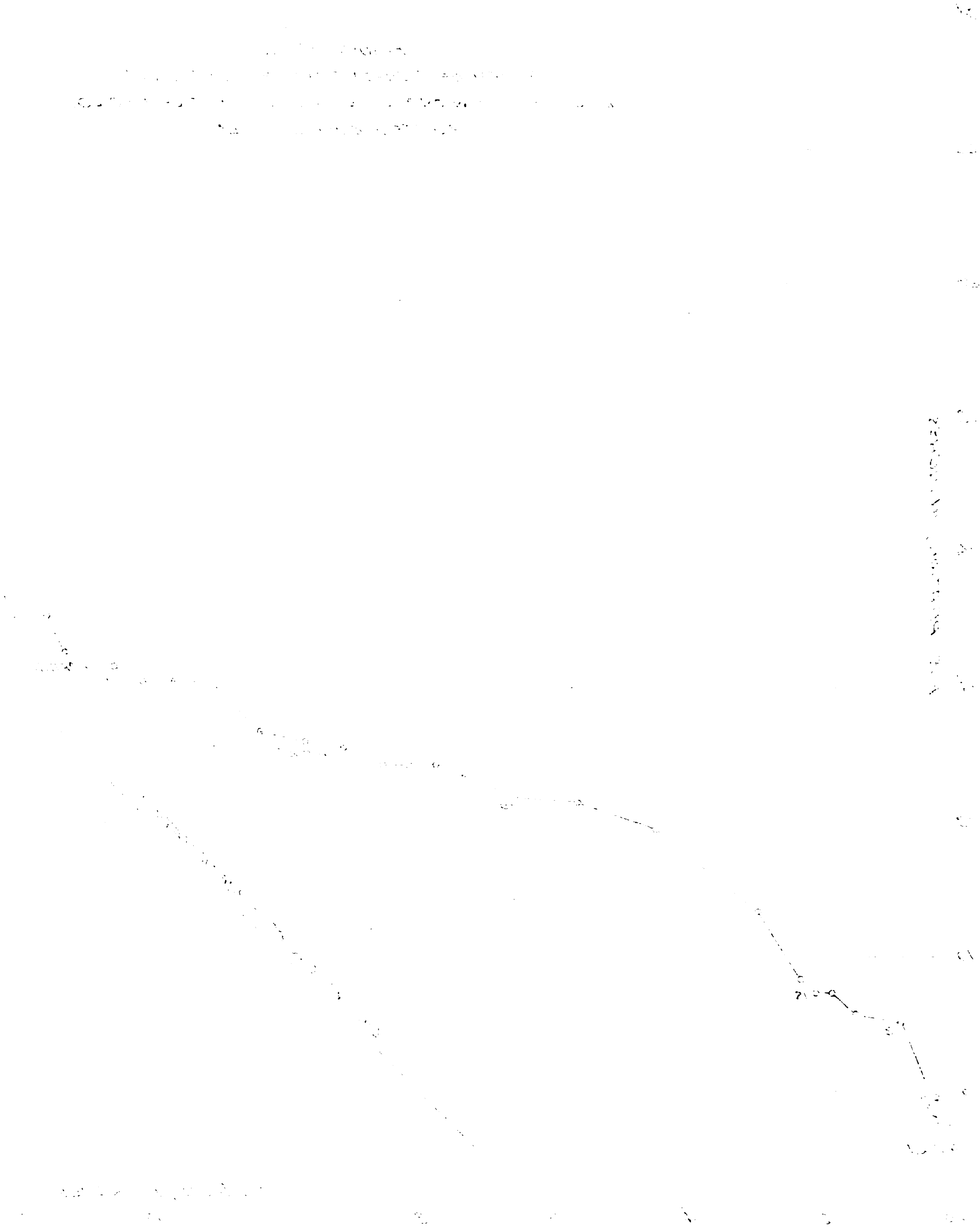


FIGURE NO. 6.
GRAPH OF RUN-OFF AND PRECIPITATION,
INCLUDING SNOW ON THE GROUND AT START OF PERIOD.
PLOTTED CUMULATIVELY
PRECIPITATION, IN INCHES
RUN-OFF, IN INCHES
LINE OF RUN-OFF = PRECIPITATION
MAR. 1
5
10
11
12
15
20
MAR. 25
31
APR. 1
5
10
15
20
25
30
MAY 1
5
10
15
20
25
31
JUNE 10
0
2
4
6
8
10
12
14
16
18
20
22
24



April 29, precipitation for the most part exceeds the run-off. This plotting is merely a different method of showing the same effects as are shown in Figure 4.

This study has dealt with temperature alone, except as corrected for the melting effect of precipitation, as the melting agent with no attempt made to give consideration to direct insolation, or solar radiation. It has been the author's observation that in unwooded and exposed areas insolation is an important factor in melting. Frequently with the temperature as low as 25° melting has been noted where the sun's rays fall directly and nearly vertically on the snow surface. Such melting, however, produces little run-off as the released water will be again congealed if and when it reaches a shaded area. As the melting rate is low much of the water will be held in the snow by capillary action or enter the ground by infiltration. Also melting of this type is of an intermittent nature occurring only near mid-day when the sun's rays strike the snow surface nearly vertically. The area herein studied is largely wooded which fact would minimize the effect of direct insolation except in so far as it affected the temperature of the air and to this extent was considered in the temperature records.

CONCLUSIONS

This study has covered only a relatively small area during one melting season. Although the results definitely apply to the Sacandaga River Basin, the study is not considered sufficiently comprehensive to justify the statement of definite principles, which would be applicable generally in other localities. Some of the more evident, and probably general, tendencies are summarized as follows:

1. Little melting of snow occurs until the snow cover throughout its depth has reached a rather unstable condition through the absorption of heat such that the addition of a little more heat will cause much of the snow in its unstable condition to be converted into water.

2. Rain falling on the snow cover appears very quickly as run-off if enough warm weather, sufficient to warm the snow blanket so that the rain will not be congealed in the snow, has preceded the precipitation.

3. The amount of run-off exceeded the amount of water available as observed by the snow surveys and the precipitation records. This indicates that the records of rainfall, as collected in scattered gages of the type in general use, give results which are too low. The results of the snow survey are considered of higher accuracy than the rainfall records.

4. Records of the fluctuations of the ground-water table are necessary to any complete study of precipitation and run-off.

5. After melting of snow has started it proceeds at a rate of 0.09 inches per degree day F. above 32°. About 2000 degree hours or 83.3 degree days were necessary to promote active melting.

6. Warm temperatures are much more potent than is rainfall as a melting agent.

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