

SNOWMELT AND RAINFALL FLOODS

SAINT JOHN RIVER BASIN

MAY, 1961

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May, 1961 in the Saint John River Basin was a highly unusual month and distinct in the recorded runoff records of the river. Meteorological records for the preceding months of March and April were also very unusual and many records were set. These factors all melded together produced two major floods within two weeks, each occurring independently. The first flood was almost totally a snowmelt runoff; the second was triggered by torrential rains falling on residual snow, lying within the forest cover.

Each flood was of major, and in some areas, record proportions in its own right. Had they occurred together, the resulting flood would have been disastrous. We hope to indicate the magnitude of this theoretical (and possible) flood.

In order to set the scene for those of you who are unfamiliar with our large and scenically beautiful river, sometimes called the "Rhine of America", a short description of it would be in order.

The river rises in the Appalachian Mountains in Maine, in Little Saint John Pond. It flows 435 miles and falls 1578 feet to its mouth at Saint John, New Brunswick, through the World Famous Reversing Falls, emptying into the Bay of Fundy (of Passamaquoddy Tidal Power fame). It is an International Boundary River and this becomes apparent on examination of a map. The river forms the International Boundary between Maine on the United States side, and Quebec and New Brunswick on the Canadian side for some 132 miles.

The drainage area of the river at its mouth is some 21,300 square miles. Of this area, 7,600 square miles or about 35% is in Maine, 2,750 square miles lies in Quebec Province, and the remaining 10,950 square miles, or about 52% is in New Brunswick.

Numerous lakes, both large and small, exist in the headwaters. The levels of some lakes are controlled for log driving purposes. One large area of some 250 square miles in the headwaters of the Allagash

at Chamberlain Lake, naturally draining into the Saint John River, now drains into the Penobscot River; a dam and the digging of the Telos Canal made this possible. Another section, which we are told only operates at high water, is at Saint John Pond and again drains into the Penobscot River.

The Saint John River was an important transportation route in the early days of New Brunswick and Maine. As a result, about half the population of New Brunswick live in or near the river valley. This pattern is also borne out in Northern Maine, along the international reach.

The Aroostook River (of potato fame) is the largest tributary in Maine, closely followed by the Allagash. The Tobique River, and the Madawaska are the largest on the Canadian side. More will be said later regarding the Aroostook and Tobique Rivers.

The power potential is largely undeveloped. Although New Brunswick now has plants at Grand Falls, Tobique and Beechwood, with much smaller units on the Madawaska at Edmundston and Green River, the latter are not part of the New Brunswick Electric Power Commission system. Maine Public Service owns a plant at Tinker in New Brunswick, which develops power for the potato area of the Aroostook Valley. A third unit is presently being installed at Beechwood bringing its capacity to 150,000 H.P. A redevelopment of Grand Falls to about five times its present capacity of 60,000 H.P. is feasible and likely in the future. Still to be developed by Maine is the Rankine Rapids or alternate Big Rapids-Lincoln School development with 540,000 H.P. In New Brunswick, untouched as yet, is the Morrill site with 148,000 H.P., and an entirely new site ten miles above Fredericton at Mactaquac, which rivals Rankine Rapids in size and potential, is presently in the planning stage; the installed capacity of this will be in the order of 650,000 H.P.

The climatology of the basin is classed as humid continental rather than maritime, with long cold winters, cool summers, and usually the absence of dry seasons (they do occur though).

Extremes of temperature are not uncommon. Minimum temperature of  $-30^{\circ}$  are relatively numerous, with  $-52^{\circ}$  having been recorded. Maximum temperatures of  $90^{\circ}$  are a usual occurrence in summer, with  $100^{\circ}$  having been reached occasionally. Frost-free days vary from 140 days near the Bay of Fundy to about 100 days further inland.

Precipitation varies from about 36 inches annually at Edmundston in the northwest to about 47 inches at Saint John in the south. Usually New Brunswick can be relied upon for more snowfall than most other areas of Canada, with 100 to 140 inches expected annually in the north, and 70 to 80 inches usually in the south. The snowpack rises from 20 inches near the Fundy coast to about 40 inches in the headwaters.

As is the pattern in North America, the river is carrying a heavy pollution load. With the advent of man, cities and towns have sprung up and the usual industries. The river has become so polluted that it will soon reach dangerous, if not disastrous proportions if not checked. A slow but steady rise of public opinion on both sides of the border is beginning to make itself felt. We hope that within a few years the now polluted water will soon be restored to its original clean, clear condition. We will then have a beautiful river again on both sides of the border.

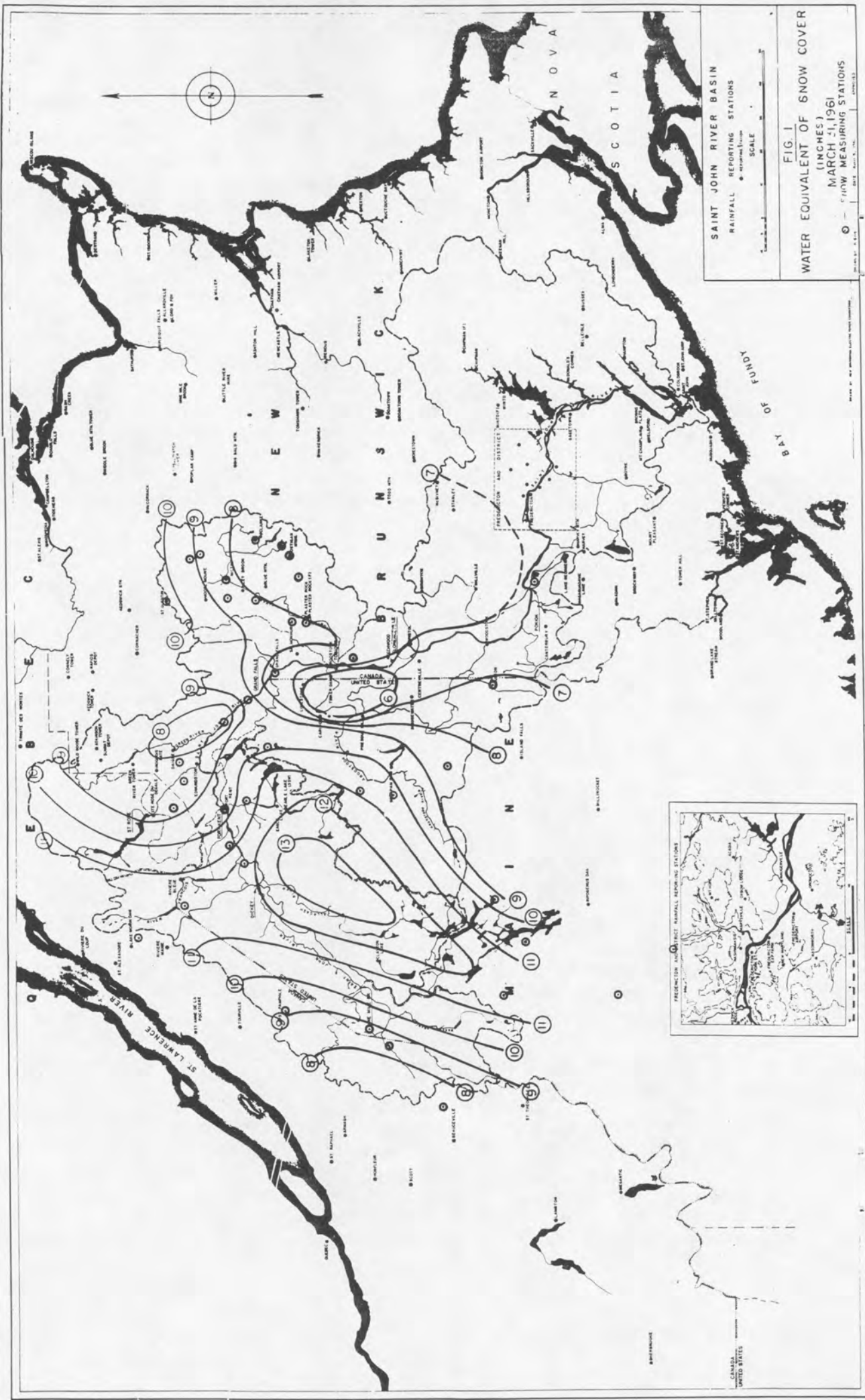
The river in its headwaters is largely unsettled and quite heavily forested. It is a great timber producing area in the form of lumber and pulpwood. This means that a heavy cover of hardwoods and conifers, combined with the terrain, tend to slow down the snowmelt. While floods have occurred due to snowmelt, it was not until May, 1961 that we had a major flood caused by nearly a pure snowmelt. This is one of the events we intend to try to explore and demonstrate by the degree-day method and other correlations we have to present.

Snow measurements in most areas in New Brunswick cease about the end of March due to breakup of roads. An arbitrary date of March 25th is the latest date one can plan on reaching remote areas by road.

Last year was no exception and yet a river breakup was not reached until April 29th. Daily records of the breakup date in the river since 1825 at Fredericton show the mean breakup date to be April 17th; March 28th being the earliest; and May 7th the latest. The open season averages about 225 days with 265 days being the maximum and 192 days the minimum.

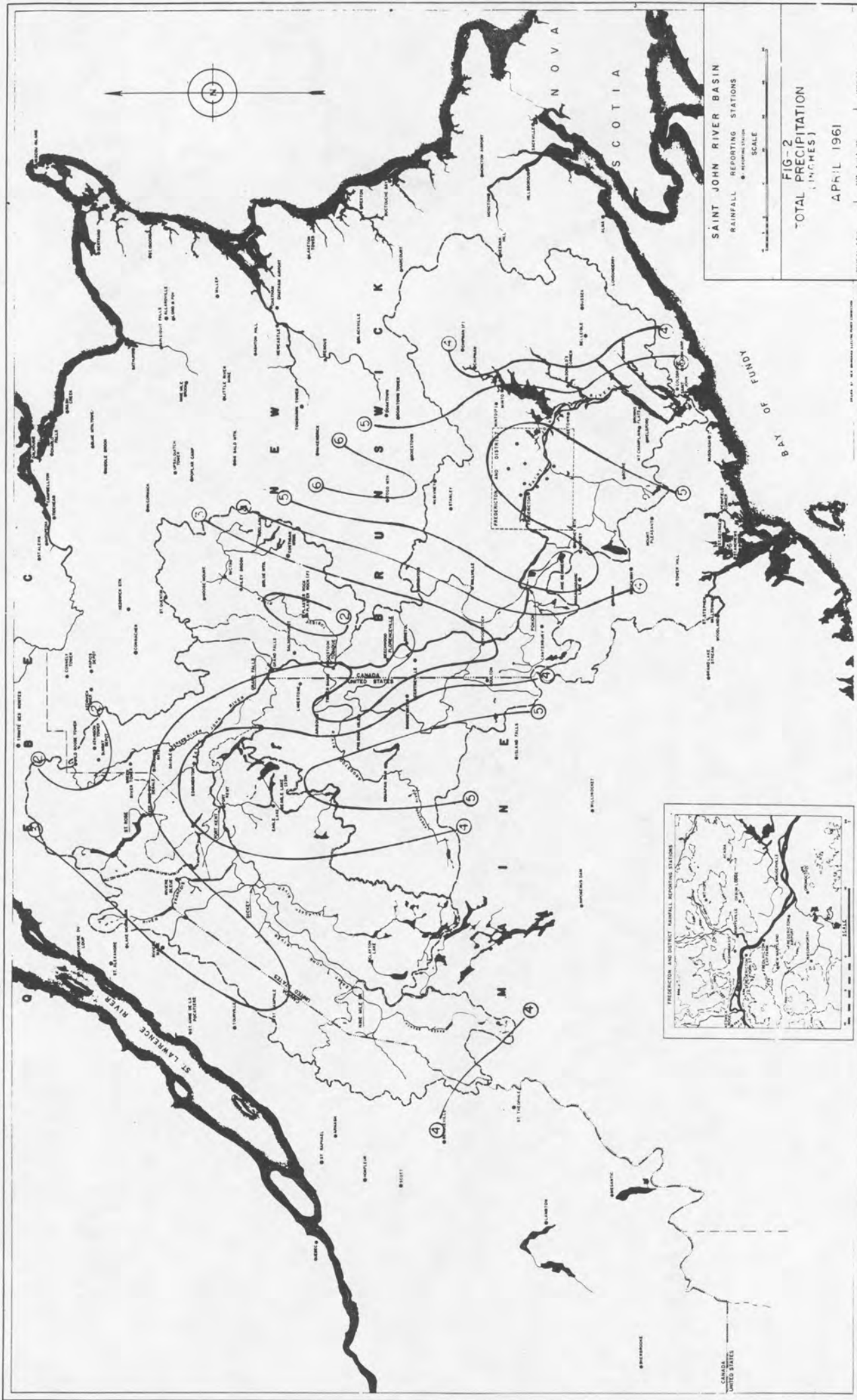
There was little evidence by March 31st of significant increases in river flows. With the exception of the lower part of the basin, the precipitation was almost entirely snow. Edmundston, chosen as the index station for the part of the basin under investigation, reported only 0.21 inches of rain. From snow course measurements taken during March, an analysis of water equivalent of the snowpack has been computed for March 31st (Fig. 1). A concentration of 13 inches was located between the Allagash and the Fish River tributaries with rapid depletion down stream. Significantly more snow lay in the Arcoostook Basin than the Tobique with the former containing an average of 10.1 inches water equivalent, the latter 8.4 inches. This difference was to be magnified during April with predictable relative behavior of the stream flows in these two sub-basins.

It is significant to note the influence of forest cover on the snowpack in the basin. By the end of March, Caribou reported a water equivalent of 5.9 inches, while nearby snow course measurement gave computed depths of 9 to 10 inches. Snow measurements taken in the open, in the Upper Saint John Valley, must be treated as quite unrepresentative of the basin as a whole. The Province of New Brunswick is 87% forest covered,



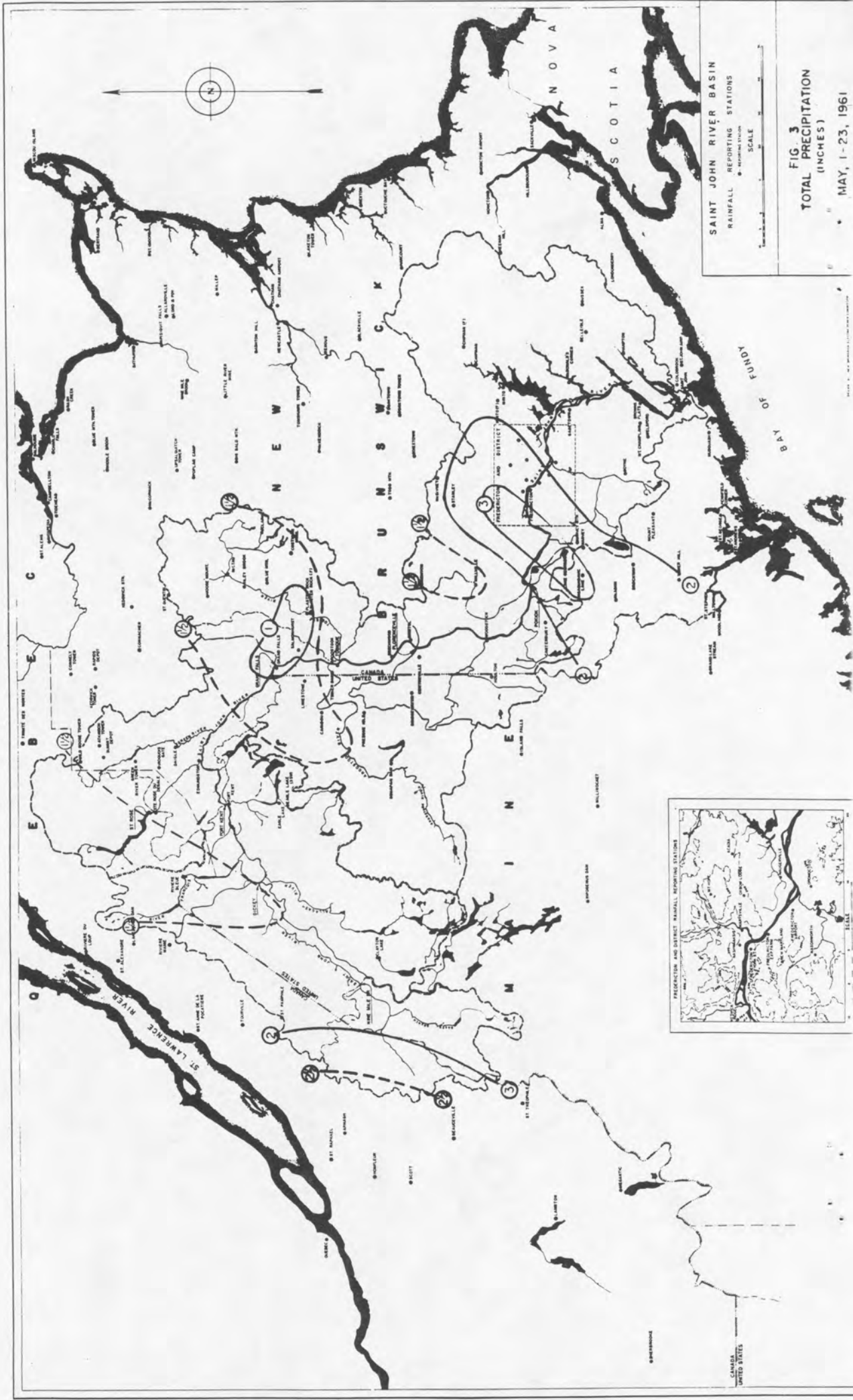
**FIG. 1**  
**SAINT JOHN RIVER BASIN**  
 RAINFALL REPORTING STATIONS  
 WATER EQUIVALENT OF SNOW COVER  
 (INCHES)  
 MARCH 31, 1961  
 SNOW MEASURING STATIONS



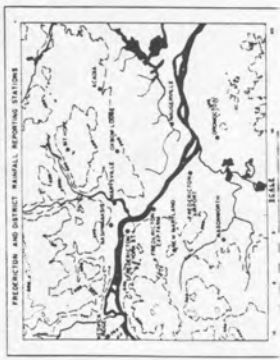


SAINT JOHN RIVER BASIN  
 RAINFALL REPORTING STATIONS  
 ● REPORTING STATION  
 SCALE  
 FIG-2  
 TOTAL PRECIPITATION  
 (INCHES)  
 APRIL 1961  
DATE: APRIL 1961





SAINT JOHN RIVER BASIN  
 RAINFALL REPORTING STATIONS  
 ● REPORTING STATION  
 ○ RAINFALL REPORTING STATION  
 SCALE  
 FIG. 3  
 TOTAL PRECIPITATION  
 (INCHES)  
 MAY, 1-23, 1961



a figure which is doubtless exceeded in the area under study.

With the warmer temperatures of April, the slow but sure progress of the melting degree-day curve was accompanied by increasing stream flows (Figs. 4 and 5), which by the end of the month were quite marked. There were a few rains, none heavy enough to produce any significant runoff, although accelerating the melt rate.

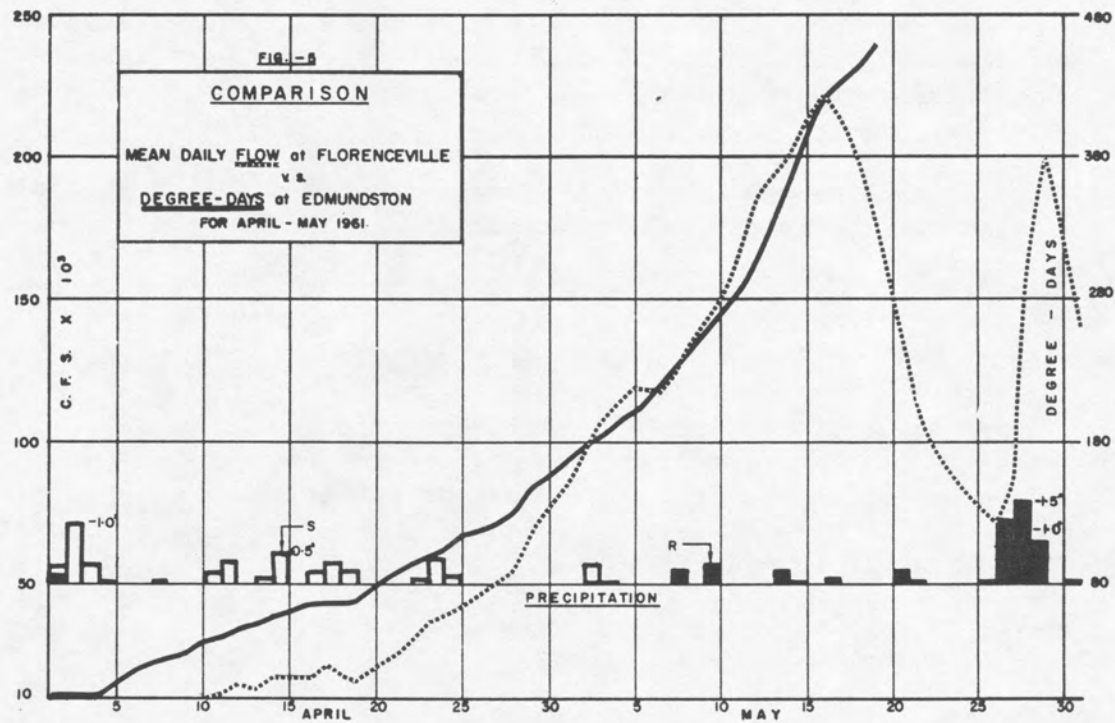
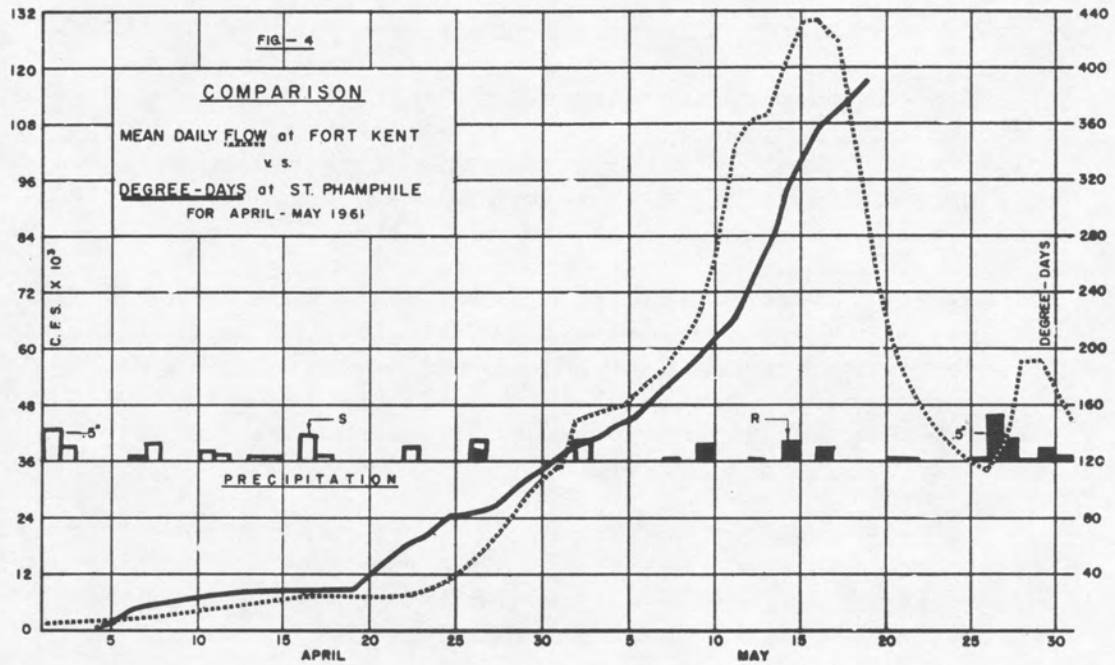
Through the first 23 days of May the lack of rainfall all over the basin was quite pronounced; computed average total precipitation was only 1.6 inches for the area drained at Florenceville and approximately 20% of this was snow. Consequently through this latter period the increase in stream flow was almost entirely due to snowmelt, with little or no direct contribution from rainfall.

The first week of May was cool, but a major change in the weather pattern occurred about May 8th, with temperatures averaging nearly 10° above the seasonal normal during the second week. The main river crested on May 17th and was in sharp decline by May 23rd.

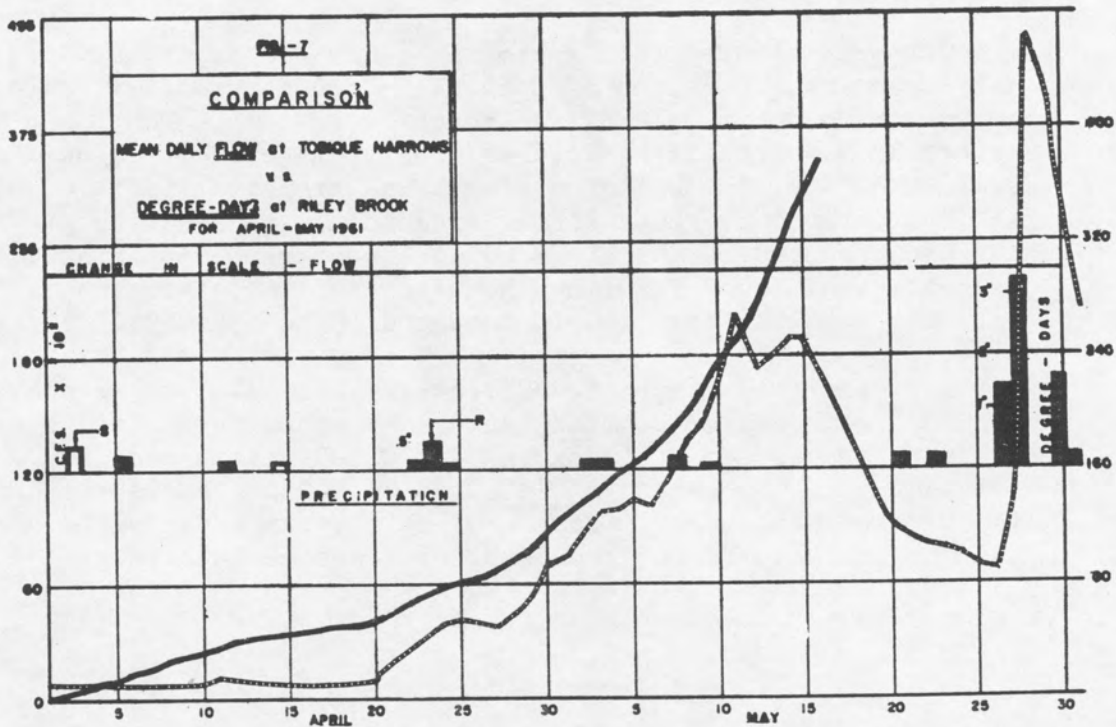
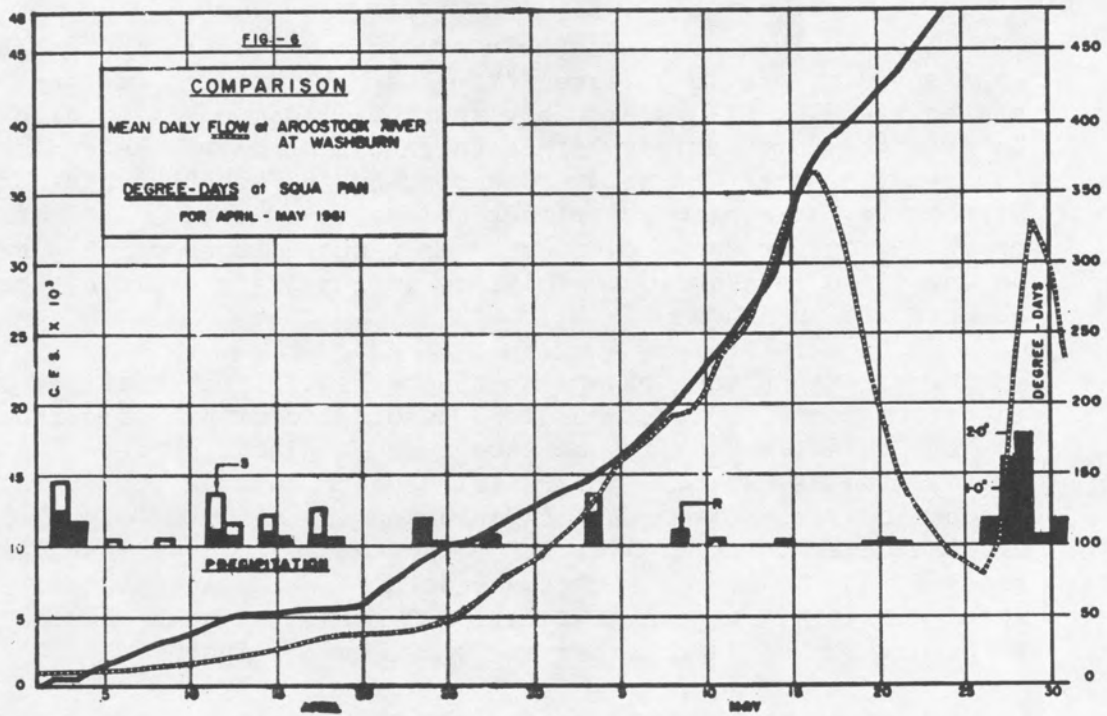
It has already been mentioned that the Aroostook and Tobique basins were accumulating different snowloads. Initial evidence of this appeared on the analysis of snow water equivalent for March 31st. An analysis for April shows that the Aroostook received 4.8 inches of additional precipitation, compared with 2.4 inches over the Tobique. With comparable melting rates and flow increases in the two basins to the end of April (Fig. 2) this left a difference in available runoff of approximately 4 inches (See Table). Consequently, the Tobique reached a snowmelt runoff peak on May 11th of 20,000 C.F.S., while the Washburn gauge did not peak until May 16th at approximately double the flow, 36,400 C.F.S. (Figs. 6 and 7).

Average degree-day factors have been computed for the following basins for two intervals--commencement of rise to April 30th and May 1st to crest,

<u>BASIN</u>	<u>INDEX STATION</u>	<u>APRIL</u> <u>D.D.FACTOR</u>	<u>MAY</u> <u>D.D.FACTOR</u>
Saint John at Fort Kent	St. Phamphile, Que.	.12	.04
Aroostook at Washburn	Squapan, Maine	.09	.05
Tobique at Tobique Narrows	Riley Brook	.11	.06
Saint John at Florenceville	Edmundston	.11	.06







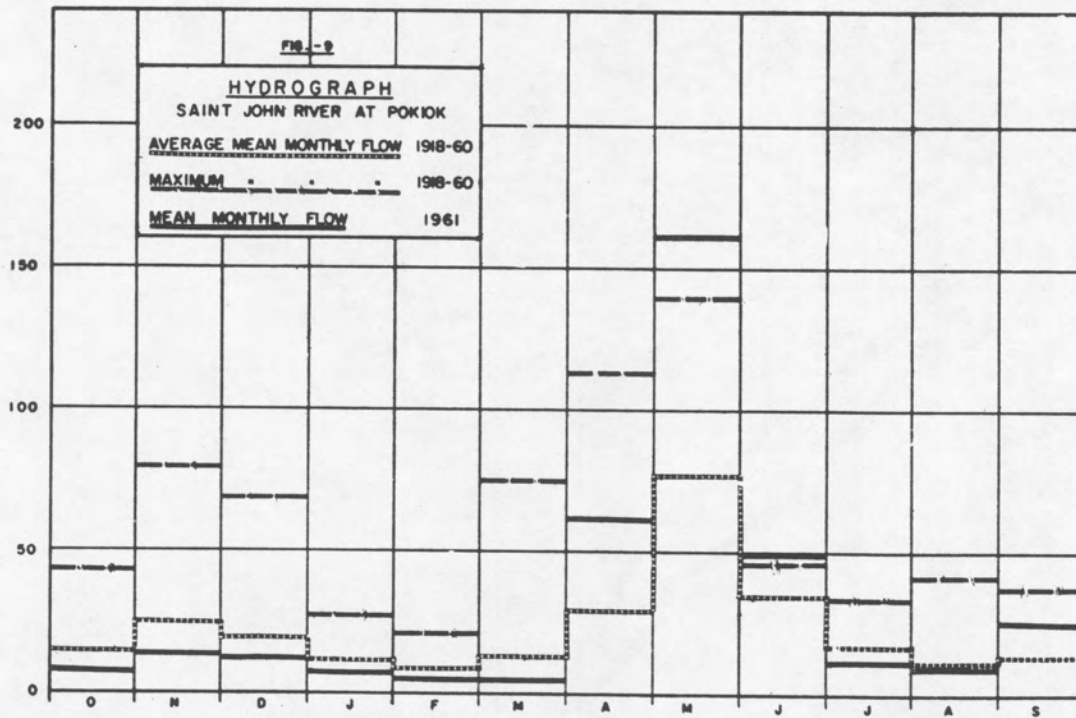
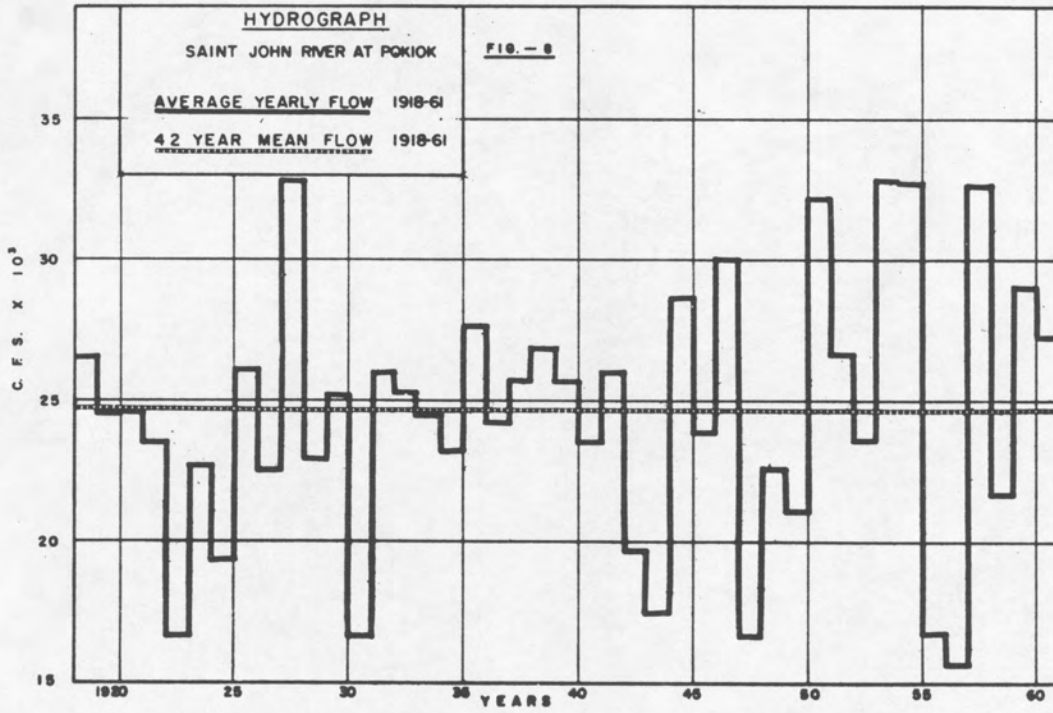
These values are reasonably consistent from basin to basin, but an apparent decrease is inferred from the May factors, contrary to the expected trend. This is probably spurious inasmuch as total basin area was used in the computations, since there was no way to determine the actual contributing area. A study conducted by the Rocky Mountain Experiment Station in the Fraser Experiment Forest found that a streamflow crest was reached when the snow cover area was reduced to about 50%, but it would be unwise to include such arbitrary values in determining the factor for an unstudied basin.

The next episode was to be the torrential rains of May 25th-28th. The storm commenced with rainfall associated with a cold front moving into New Brunswick from the northwest on May 26th, preceded by shower activity on May 25th. The crucial development was the formation of an intense coastal storm east of Nantucket on May 27th (Fig. 11), which crossed central New Brunswick from southwest to northeast. An isohyetal analysis of the storm is reproduced in Fig. 10, and Figs. 12-14 show storm analysis, depth-area-duration curves, and mass curves of rainfall, as taken from an unpublished study by Lee and Sporns.

Average basin rainfalls are shown in Table I and the resultant stream flow behavior in Figs. 4-8. Although impressive, these figures were small in comparison with those for rivers in the direct path of the storm. The Nashwaak River, a tributary of the Saint John River emptying at Fredericton received an average storm rainfall of 7.7", the bulk of it in a 24 hour period. The flood plain of this valley is populated by farms and cottages, and a main highway parallels a steep hillside, conditions which accounted for much of the flood damage toll, including the loss of two main bridges.

Transposition of this storm in both space and time would yield fantastic results, even with a cross-basin orientation. It is our intention however to do the simplest transposition in time. Continued snowmelt in the period May 16th-26th, unquestionably, materially reduced the snowpack, despite the rapidly declining flows, and graphical addition of the snowmelt hydrograph, (a gauge nearer Fredericton is used in this illustration), and that produced by the storm would therefore be optimistic in a time transposition. Even ignoring the effect of increased snowmelt rate however, the hypothetical flow is computed to be 430,000 C.F.S.

Applying this figure to a frequency analysis prepared by McCaig and Erickson from earlier records, such a hypothetical flood is estimated to have a return period of in excess of 10,000 years, and only a 10% probability of a return period of 1,000 years. Since space transposition is also within reason, maximization of this storm would yield a higher "Maximum probable flood" than earlier frequency analysis.



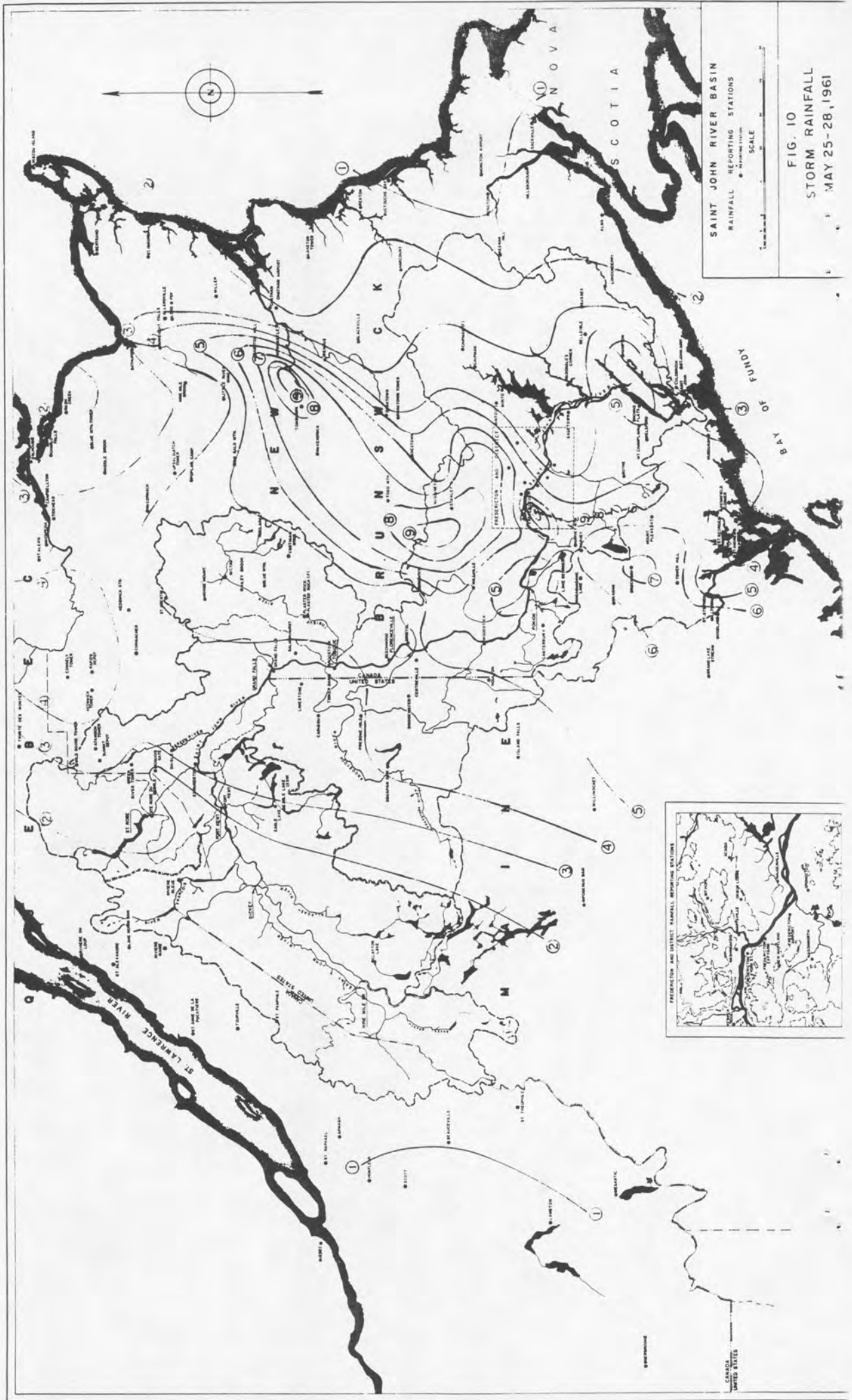


FIG. 10  
 STORM RAINFALL  
 MAY 25-28, 1961

Figure 11. After Lee and Sporns

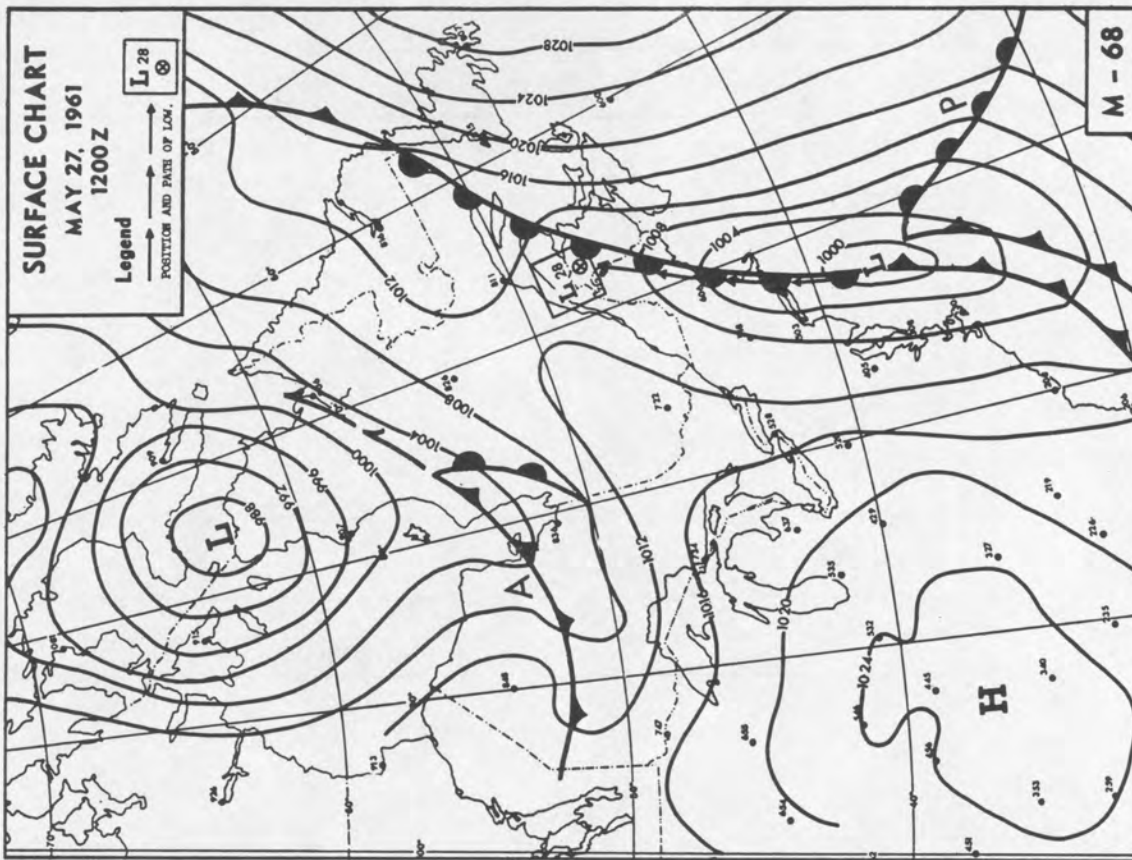


Figure 12. After Lee and Sporns

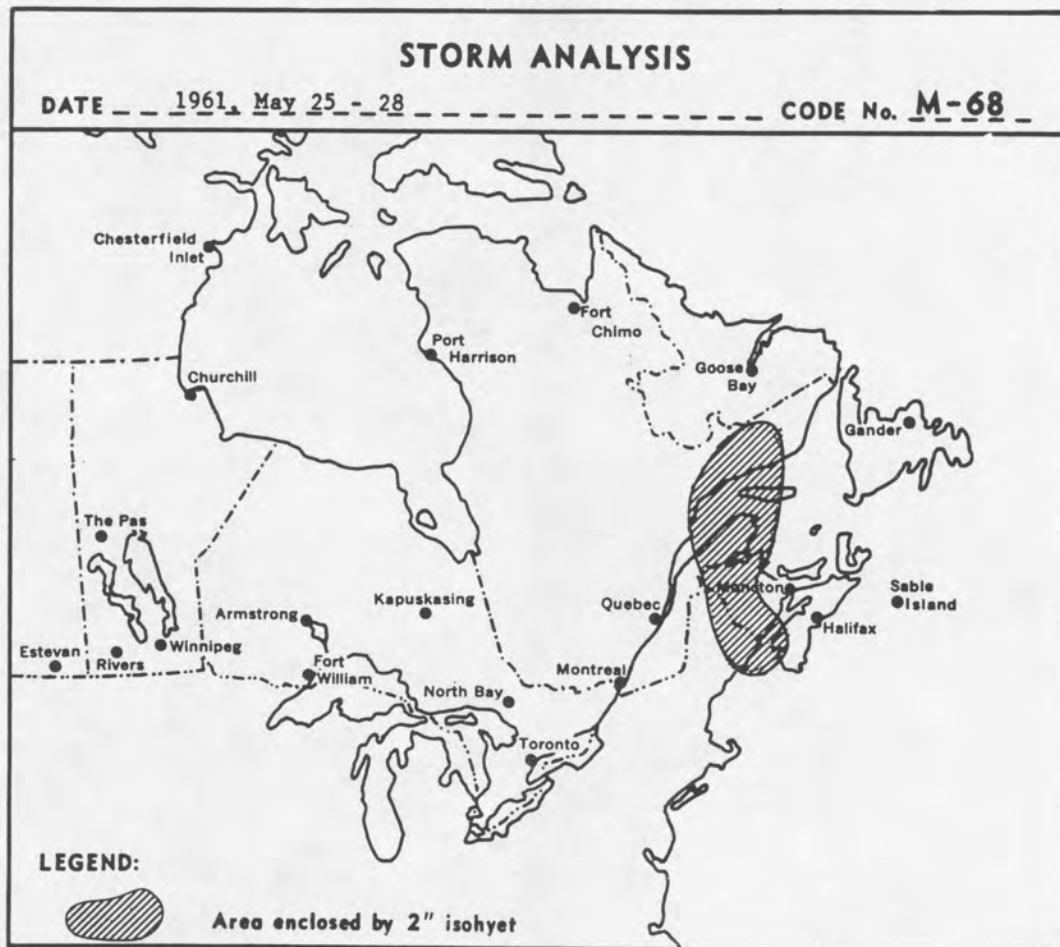


Figure 13. After Lee and Sporns

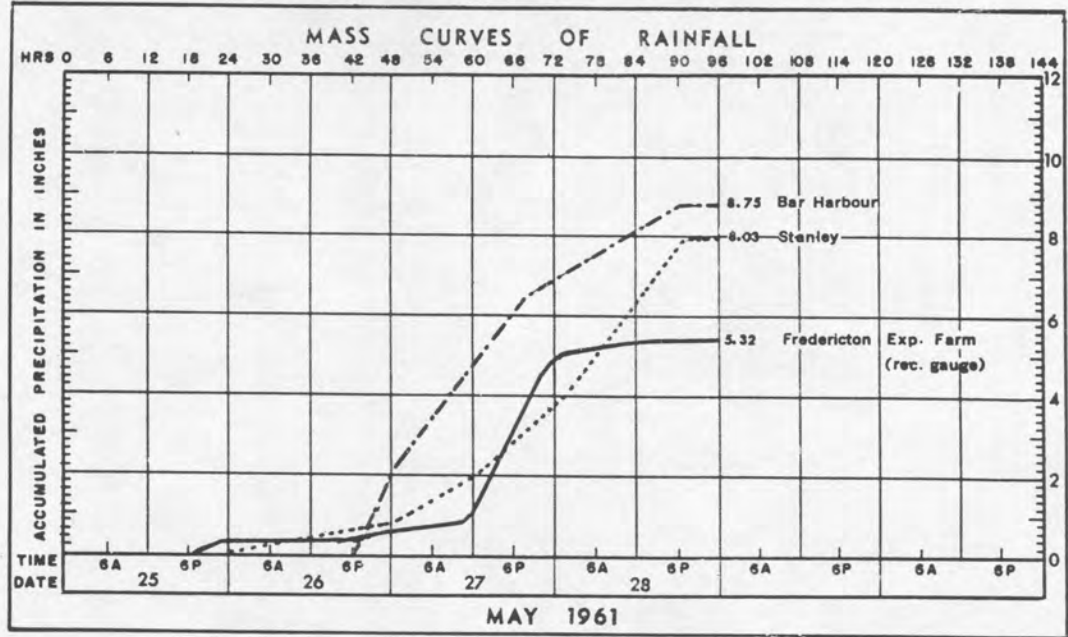


Figure 14.

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After Lee and Sporns

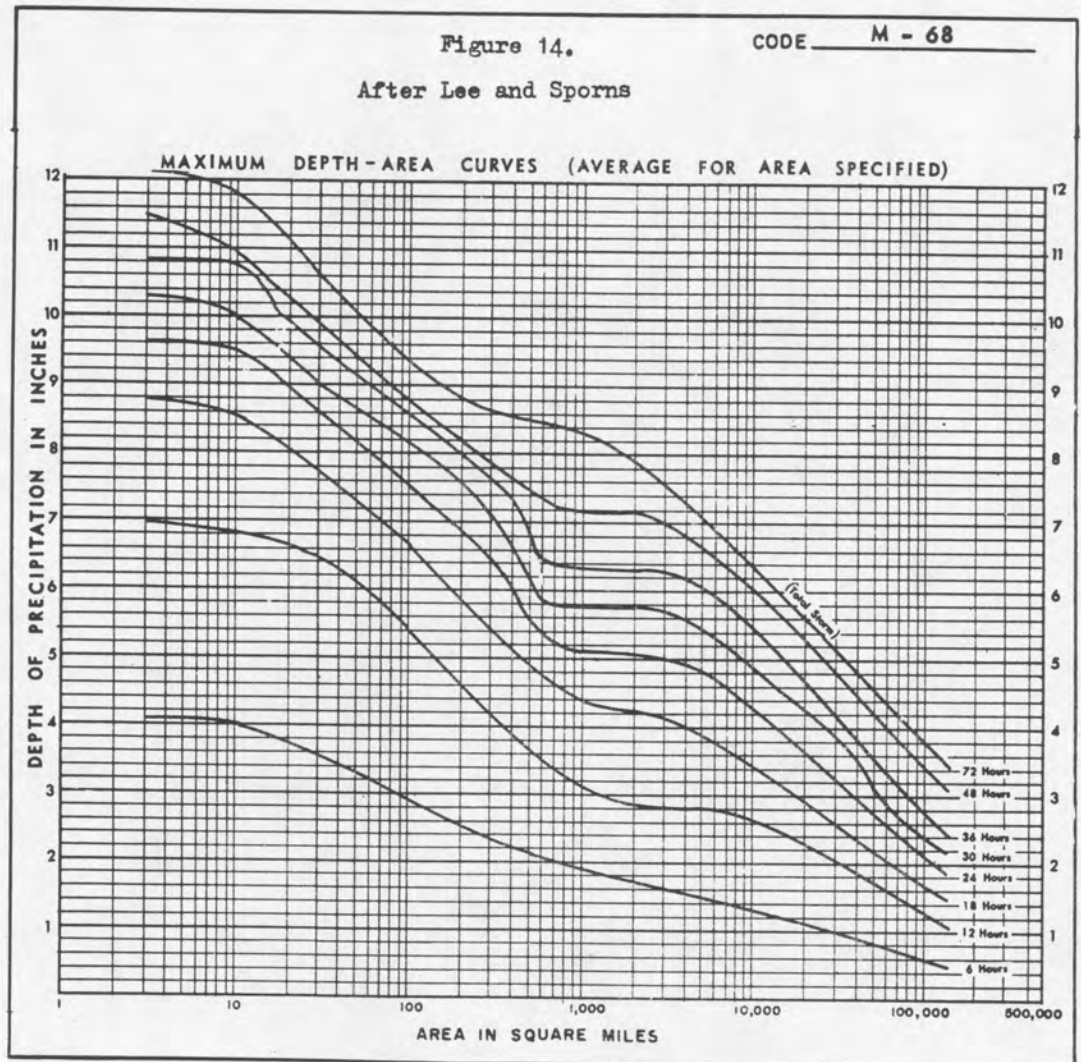


TABLE I.

	<u>SAINT JOHN</u> <u>RIVER</u> AT <u>FORT KENT</u>	<u>AROOSTOOK</u> <u>RIVER</u> AT <u>WASHBURN</u>	<u>TOBIQUE</u> <u>RIVER</u> AT <u>NARROWS</u>	<u>SAINT JOHN</u> <u>RIVER</u> AT <u>FLORENCEVILLE</u>
Water Equivalent Snowpack - MARCH 31/61	11.0"	10.1"	8.4"	9.8"
Total Precipitation APRIL 1961	3.5"	4.8"	2.4"	3.4"
Total Precipitation MAY 1-23, 1961	1.7"	1.7"	1.2"	1.6"
First Creast (C.F.S.) (Mean Daily)	130,000	36,400	20,100	220,000
Storm Rainfall MAY 25-28, 1961	1.8"	3.3"	4.6"	2.8"
Second Crest (C.F.S.)	57,800	33,000	47,500	199,000

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## REFERENCES

- Garstka, W. U., Love, L. D., Goodell, B. C., and F. A. Bertle.  
1958. Factors Affecting Snowmelt and Streamflow, Report on 1946-53 Co-Operative Snow Investigations at Fraser Experiment Forest U.S.D.A. and Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Lee, R., and U. Sporns.

1962. A Study of Exceptional Rainfall in the Saint John River Basin in New Brunswick from May 25-28, 1961. Meteorological Branch, Canada Department of Transport, Tec. Circ. (Unpub).

Linsley, R. K. (Jr.), Kohler, M. A., and J. L. H. Paulhus.

1949. Applied Hydrology. McGraw-Hill.

McCaig, I. W., and O. M. Erickson.

1959. Spillway Capacity and Flood Flows. First Canadian Hydrology Symposium, N.R.C.