# TIME TRENDS IN SPRING RUNOFF
# from the
# OTTAWA RIVER BASIN

A Progress Report by A. Coulson and G. M. MacNabb[1]

## INTRODUCTION

The Water Resources Branch, in connection with the regulation of the St. Lawrence River, devised a method of forecasting the weekly flow of the Ottawa River. As these studies progressed it became apparent that the April flow of the Ottawa River in recent years was a higher proportion of the annual flow than it had been in previous years, in spite of the storage that has been progressively added over the years to catch the spring runoff. This paper presents the progress made to date in determining the reason for this phenomenon.

Further investigations of the phenomenon will be made under the direction of the Ottawa River Engineering Board, which was established in 1962 by the governments of Canada, Quebec and Ontario for the purpose of studying the existing and potential regulation of the Ottawa River basin.

## OTTAWA RIVER BASIN

A short description of the topography, runoff and storage development of the Ottawa River basin follows as background material for the study. A map of the basin is given on Figure 1.

### Topography

There are two distinct types of topography drained by the river: the relatively flat country south of the lower reaches of the stream; and the low timbered mountains of the Laurentian formation in the remainder of the basin.

The Ottawa River is the principal tributary of the St. Lawrence River. It rises in Capimitchigama Lake and flows for 700 miles, first westerly then generally southeasterly, to enter the St. Lawrence River at the Island of Montreal. The area drained is some 57,000 square miles. Some idea of the relative size of the river may be had by comparison with two other major Canadian rivers, the Fraser and the Columbia. The Fraser River is somewhat larger than the Ottawa River, having a length of 850 miles and a drainage area of 89,000 square miles, while the Columbia River in Canada is smaller, with a length of 465 miles and a drainage area of 34,000 square miles.

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FIGURE 1 OTTAWA RIVER DRAINAGE BASIN

## Runoff

The mean flow of the Ottawa River at its mouth is 70,000 cfs, representing about one-half of the annual precipitation. The maximum recorded daily flow of the river is 326,000 cfs. These figures compare to the mean flow of about 67,000 cfs for the Columbia River in Canada and 93,000 cfs for the Fraser River; both these rivers have peak flows somewhat greater than half a million cubic feet per second.

The runoff in the Ottawa River drainage varies from about 2 cfs per square mile in the Laurentian slopes near the eastern boundary to less than 1 cfs per square mile from the area south and west of Ottawa. Most of the area has runoff of about $1\frac{1}{4}$ to $1\frac{1}{2}$ cfs per square mile.

More than one-half of the annual runoff occurs in April, May and June. A typical discharge hydrograph is shown on Figure 2. The peak flow occurs in April or May from snowmelt and rainfall runoff from the northern part of the basin, although high stages occur earlier from snowmelt runoff from the lower basin.

The rainfall over the basin is generally between 20 to 30 inches annually, while the average annual snowfall is about 80 to 100 inches.

## Development of Storage

The storage capacity available in the basin to regulate the runoff has increased steadily during the past half century. Before 1910 the storage volume was negligible, but during the period 1911 to 1914 the Quinze - Simard and Timiskaming reservoirs were constructed on the main stem and Kipawa reservoir on a tributary of Lake Timiskaming. The combined capacity of these reservoirs is 2.7 million acre-feet,

The next major storage developments were the Baskatong and Cabonga reservoirs in the upper reaches of the Gatineau River which were completed between 1927 and 1929. The combined 3.2 million acre-feet of live storage in these reservoirs provides almost complete regulation of the previously erratic flow of the river which had ranged between 2,000 and 76,000 cfs at its mouth.

The Dozois reservoir, completed in 1948 in the upper reaches of the Ottawa River above Lake Quinze, was the last major storage development in the basin. This reservoir has a capacity of 1.5 million acre-feet of storage, but it can only be completely filled in about 60 per cent of the freshet periods.

Other reservoirs of importance in the basin are Cedar Rapids, Mitchinameous and Kiamika constructed on the Lievre River in 1930, 1942 and 1954 respectively, and the Bark Lake storage on the Madawaska River. The Lievre River storage totals 1.3 million acre-feet and the Bark Lake reservoir contains 302,000 acre-feet.

These reservoirs and other minor ones in the basin provide a total of 11 million acre-feet of live storage.

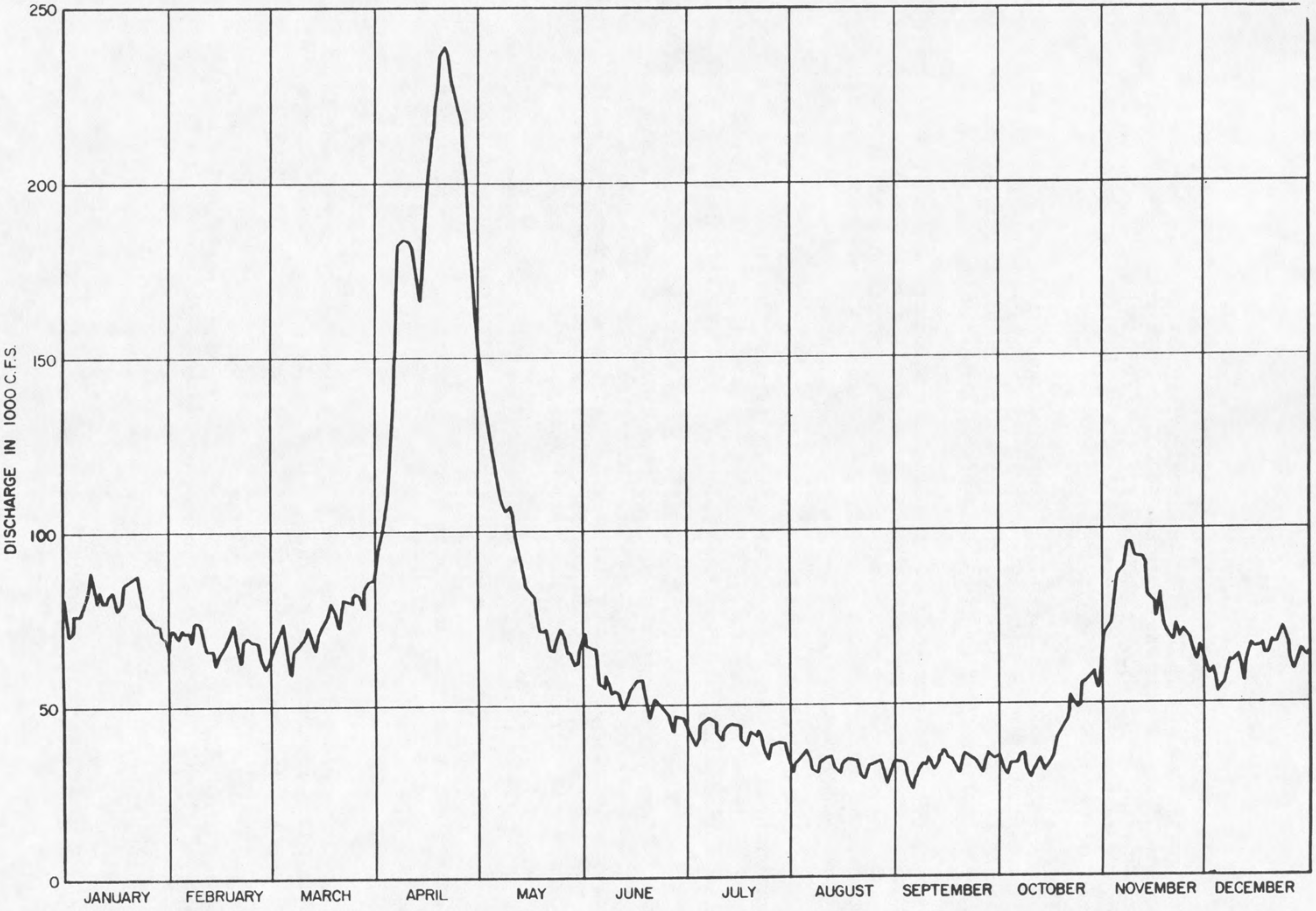


FIGURE 2 - DISCHARGE HYDROGRAPH OF OTTAWA RIVER AT GRENVILLE - 1955

## EFFECT OF STORAGE ON FLOW AT GRENVILLE

This large amount of storage, with capacity equal to about 20 per cent of the mean annual runoff, obviously has a considerable effect on the flow of the river. One of the first steps in a study of the existing and potential regulation of the waters of the Ottawa River basin is, therefore, to determine the magnitude of this effect on the natural flow.

Initially duration curves were prepared in terms of the mean monthly flow at Grenville expressed as a percentage of the total annual flow. Curves were drawn for the periods 1882 to 1910 (no major storage), 1915 to 1925 (after development of Quinze, Timiskaming and Kipawa storage), 1930 to 1940 (after development of Gatineau River storage) and 1949 to 1959 (after development of Dozois storage). Examples of these curves for the months of February, April and June are shown on Figure 3.

The duration curves show that, since 1910, increasing proportions of the runoff have been retained in the reservoirs during May and June for release during autumn and winter months. Expressed as percentages of yearly mean flow, May and June flows have been reduced to about half of their values under natural runoff conditions while the low winter flows have been more than doubled.

This is about what would be expected. However, the fly in the ointment is April. For this month the duration curves show that the flow during 1949 to 1959 was as high a percentage as during 1915 to 1925 and higher than during 1930 to 1940, which was in turn higher than during 1882 to 1910. This is in spite of the fact that a considerable amount of storage has been available in recent years to capture the high flows during April.

Records of storage content data show that all reservoirs are normally filling during April. Also, Lake Timiskaming and Lake Quinze must be filling at a rate at least equal to their pre-project rate as the discharge capacity of their outlet structures is limited by upstream river controls at low stages. Releases from storage in upstream reservoirs in late March would have a tendency to increase the April discharge at Grenville, but these releases are not great and would be substantially modified by voluntary or involuntary storage further downstream in the basin. Therefore, it seems that storage operation is not the reason for the increase in the proportion of runoff occurring during April in recent years.

## TIME TREND IN RUNOFF

In an effort to better understand the increase in the proportion of the annual runoff occurring in April, the flow at Grenville in this month has been calculated as a percentage of the total April to June runoff. These percentages of the spring runoff occurring in April are plotted at the top of Figure 4. Below this is plotted the 10-year moving mean of these same percentages. Both curves clearly illustrate the general trend over the past 90 years of increased runoff contribution in April. They also show that the increase over the last 10 to 15 years is possibly more pronounced than the general trend.

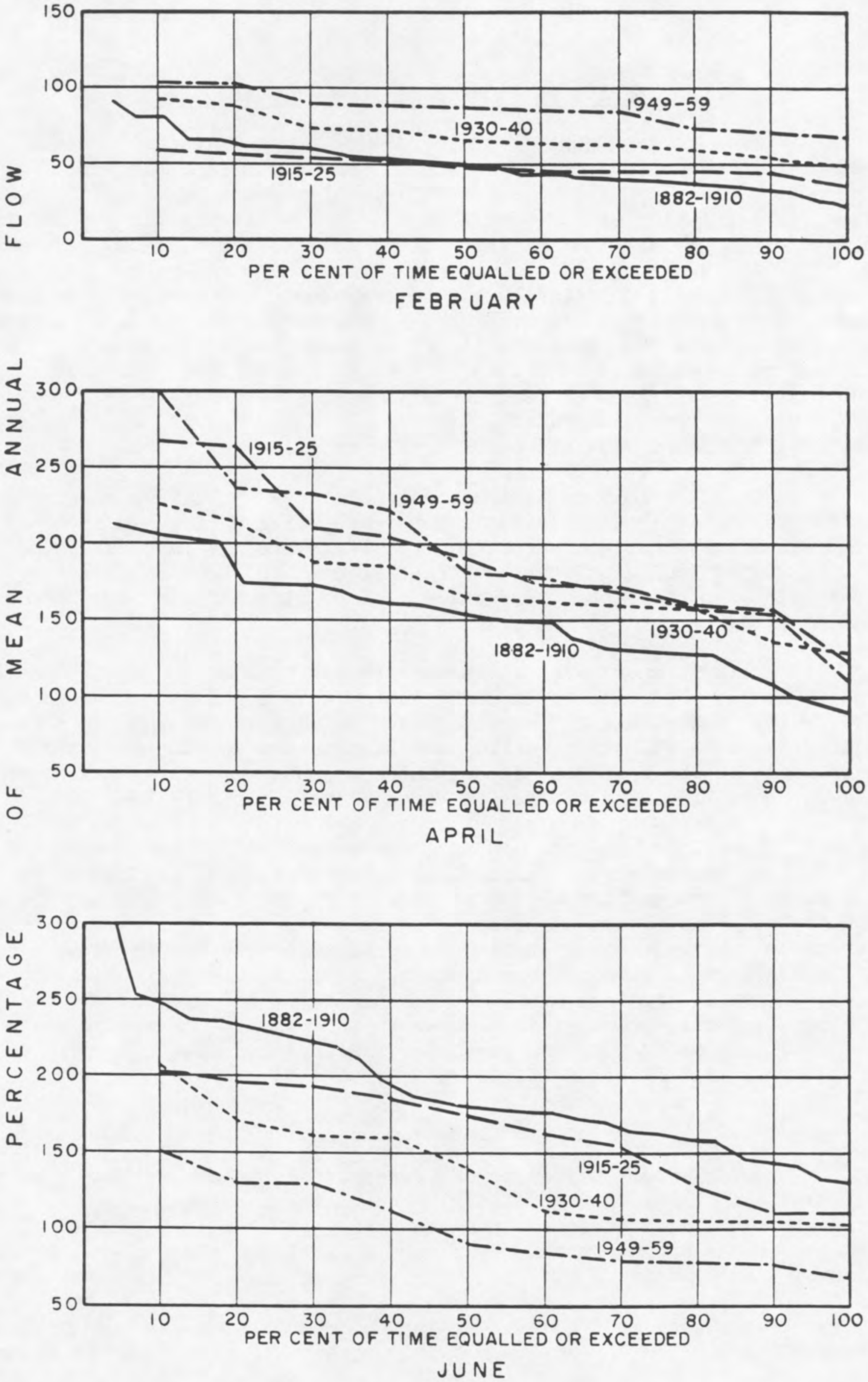


FIGURE 3-OTTAWA RIVER AT GRENVILLE DURATION CURVES OF MEAN MONTHLY FLOW AS A PERCENTAGE OF MEAN ANNUAL FLOW

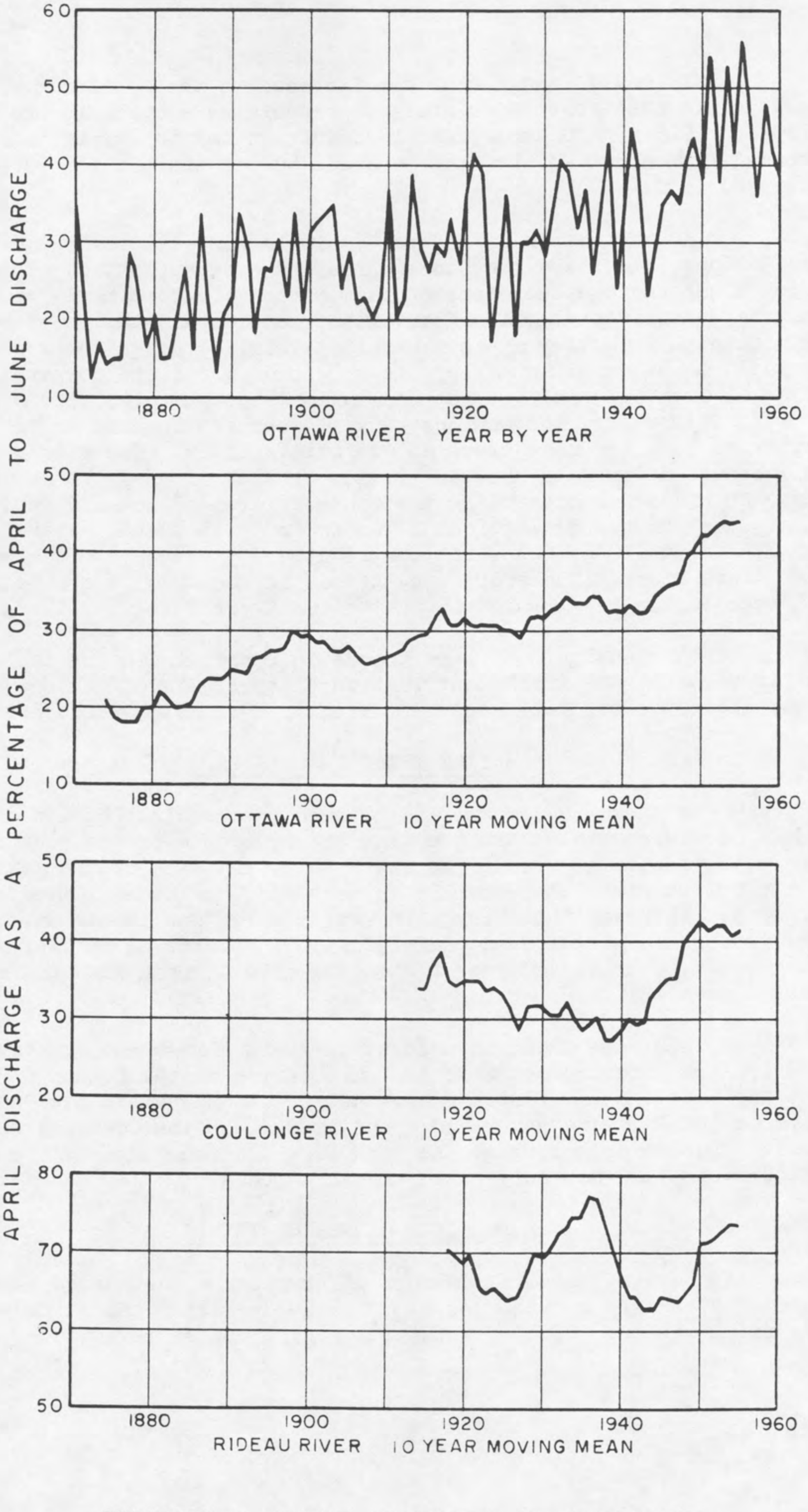


FIGURE 4 - TIME TRENDS IN RUNOFF

It would appear that the increase in the April runoff was occurring well before the first major storage projects were built in the basin between 1910 and 1915. Altogether, April's contribution to spring runoff has increased from about 20 per cent to about 40 per cent in the 90 years between 1870 and 1960.

At the bottom of Figure 4, similar 10-year moving mean curves for the Coulonge River and the Rideau River have been plotted. These streams were chosen because the minor storage effects on them have remained constant, they have comparatively long periods of record, and they represent northern and southern tributary areas. Unfortunately, although their records are long compared to other tributaries, their records are short compared to the Ottawa River at Grenville and are not really long enough to confirm or deny the trend in runoff. However, the Coulonge River, representing the northern area, does appear to have the same trend as the Ottawa River. The Rideau River is not well enough defined to show any trend, or lack of one. It should be noted that the Rideau, representing the southern area of low and early runoff, has a very much higher proportion of runoff in April than does the rest of the basin, and its runoff does not contribute very greatly to the peak flood on the Ottawa River. Therefore, any trends in runoff of the Rideau River would not necessarily be mirrored in the Ottawa River itself.

This analysis of time trends in runoff indicates the possibility that the increase in the April contribution of spring runoff is not restricted to controlled streams, but rather is occurring generally throughout the basin.

## TIME TREND IN PEAK FLOW

As there is a significant trend in the distribution of the spring runoff, it is possible that the time of occurrence of the peak flow is also undergoing a similar trend. To check this, the date of the maximum discharge of the Ottawa River at Grenville in each year has been plotted at the top of Figure 5. Although there is quite a wide variation in the date from year to year, the graph shows quite plainly a trend towards an earlier peak in the later years. Over the 80-year period the date of peak flow had advanced by about 3 weeks.

This same trend is evident on the Coulonge and Petawawa Rivers, both of which are uncontrolled streams. The curves at the bottom of Figure 5 show that the date of peak flow has advanced by about 3 weeks over a period of 38 years on the Petawawa River and about 10 days on the Coulonge River in 31 years. Thus it appears that the peak flow is occurring earlier in all parts of the basin, and not only on regulated streams.

## POSSIBLE CAUSES OF TRENDS

There are several factors which must be considered as possible causes of these trends in spring runoff. Storage operation has already been ruled out as a major reason. Other possibilities will now be reviewed.

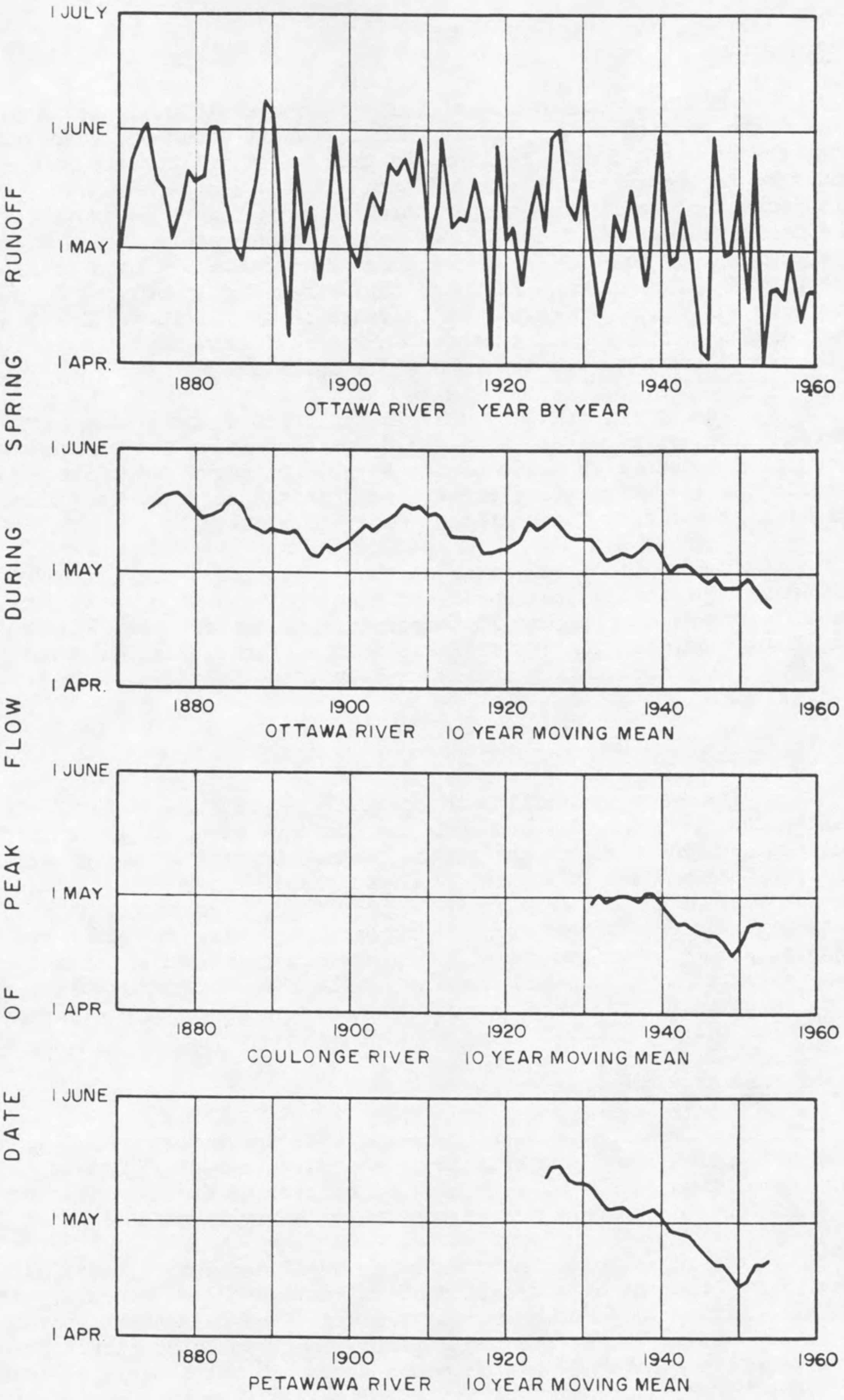


FIGURE 5 - TIME TREND IN DATE OF PEAK FLOW

### Temperature

The most obvious possibility is temperature. If April temperatures are getting progressively warmer then it would be reasonable to assume that the snow would melt earlier and thus the April contribution to runoff would be increased and the date of peak flow would be advanced. The duration curves of April mean temperature shown on Figure 6 for three points in the drainage basin do indeed show that the temperature of a median April in the period 1950 to 1959 is warmer than the temperature of a median April in the period 1915 to 1960. Although this rise is only between 0.75° and 2°, it could be sufficient to cause the increase in April flows. The graphs of 10-year moving mean temperature shown on Figure 7 show that the same change in temperature has occurred over the whole basin.

The graphs of the trends in April flow, April temperature and date of peak flow are repeated in Figure 8. A comparison between these curves shows that a change in slope of the April flow curve coincides with a change in slope of the temperature curve, and that the curve of peak flow dates is practically a mirror image of the temperature curve.

Therefore, it is apparent that temperature plays a major part in the April contribution to runoff and also in the date of peak flow. However. while there was an increase in temperature from about the mid-1920's, the temperature before then was as high, if not higher, than at present. Therefore, it would seem that temperature is not the only factor in the trend in April flows.

### Precipitation

The next possibility to consider is precipitation. If the precipitation during April, May and June has the same trend as the runoff, then this could be a major cause of the runoff trend. Precipitation records are available for Ottawa since 1890, and at first glance the curves plotted from these data at the top of Figure 9 and 10 appear to confirm that the trend in precipitation is similar to the trend in runoff. However, the other curves on these figures, plotted from records at Maniwaki and Timiskaming, show that this trend does not exist over the whole basin. While this does not exclude precipitation as a factor in the trend of runoff, it does appear doubtful that precipitation is a major factor.

### Travel Time of Flood Waves

The creation of long, deep pools in the river channel by storage and power developments will materially increase the speed with which a flood wave will travel down river. This would, of course, advance the date of peak flow and also tend to increase the percentage of early runoff.

The relation of the trends in runoff and date of peak flow to the dates of development of storage is shown in Figure 11. There appears to be some association between the noted trends and the dates when storage increased the river depths. Also, the Des Joachims and Otto Holden power developments, completed in the early 1950's deepened almost 90 miles of river channel. This may account for a good part of the increased April runoff contribution noted in the past 10 to 15 years.

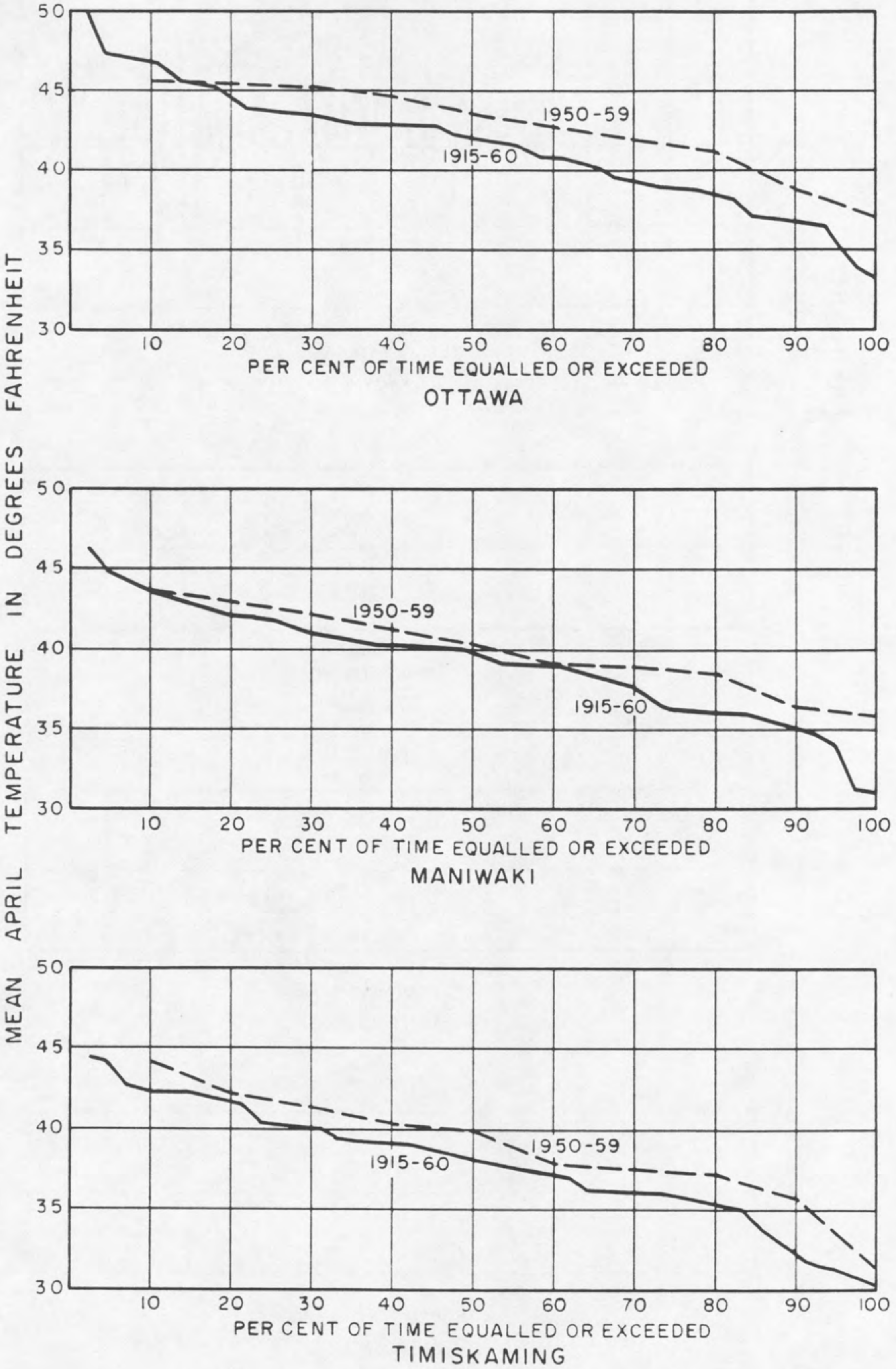
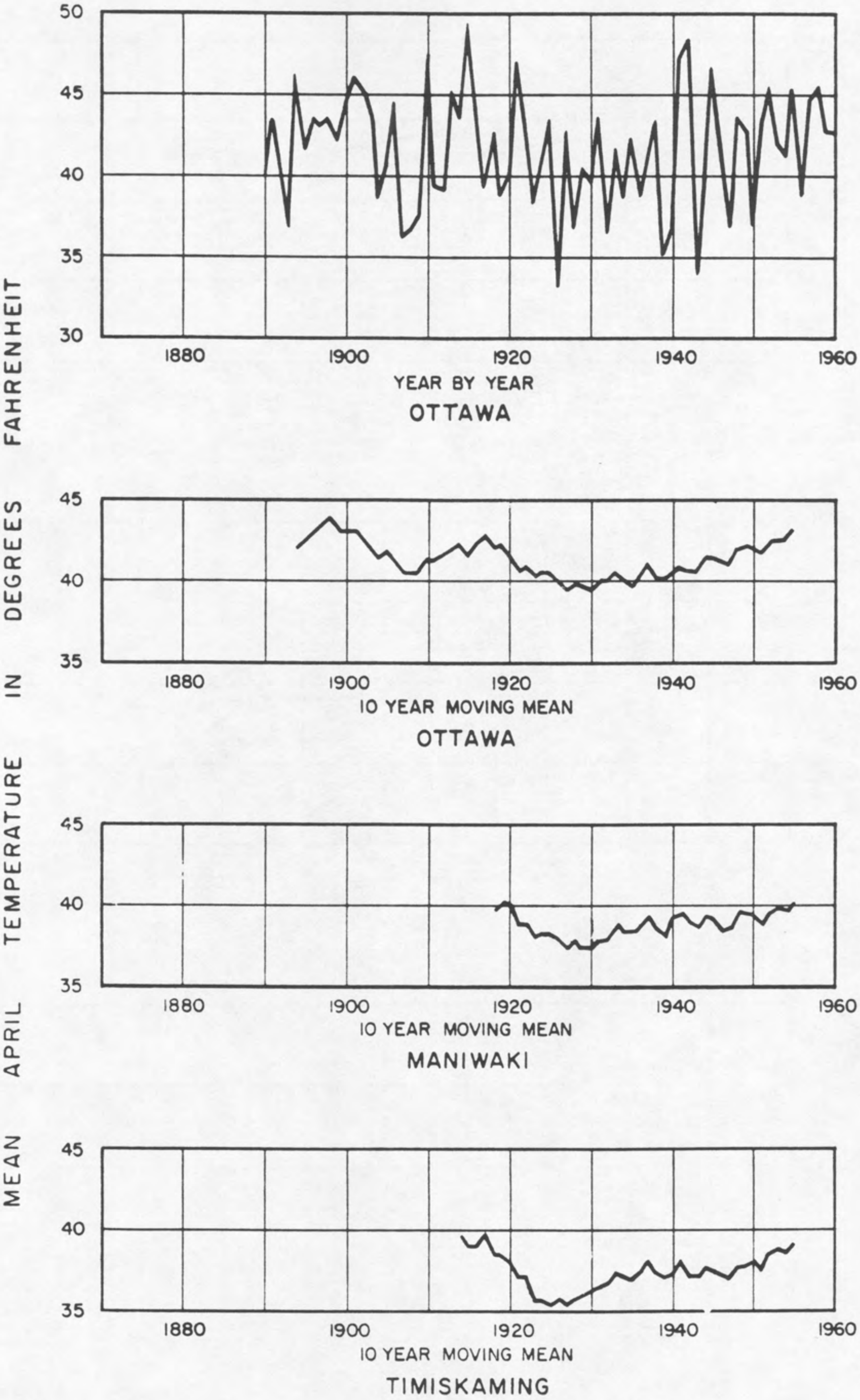


FIGURE 6 - DURATION CURVES OF MEAN TEMPERATURE FOR APRIL



YEAR BY YEAR
OTTAWA

10 YEAR MOVING MEAN
OTTAWA

10 YEAR MOVING MEAN
MANIWAKI

10 YEAR MOVING MEAN
TIMISKAMING

FIGURE 7 – TIME TREND IN APRIL TEMPERATURE

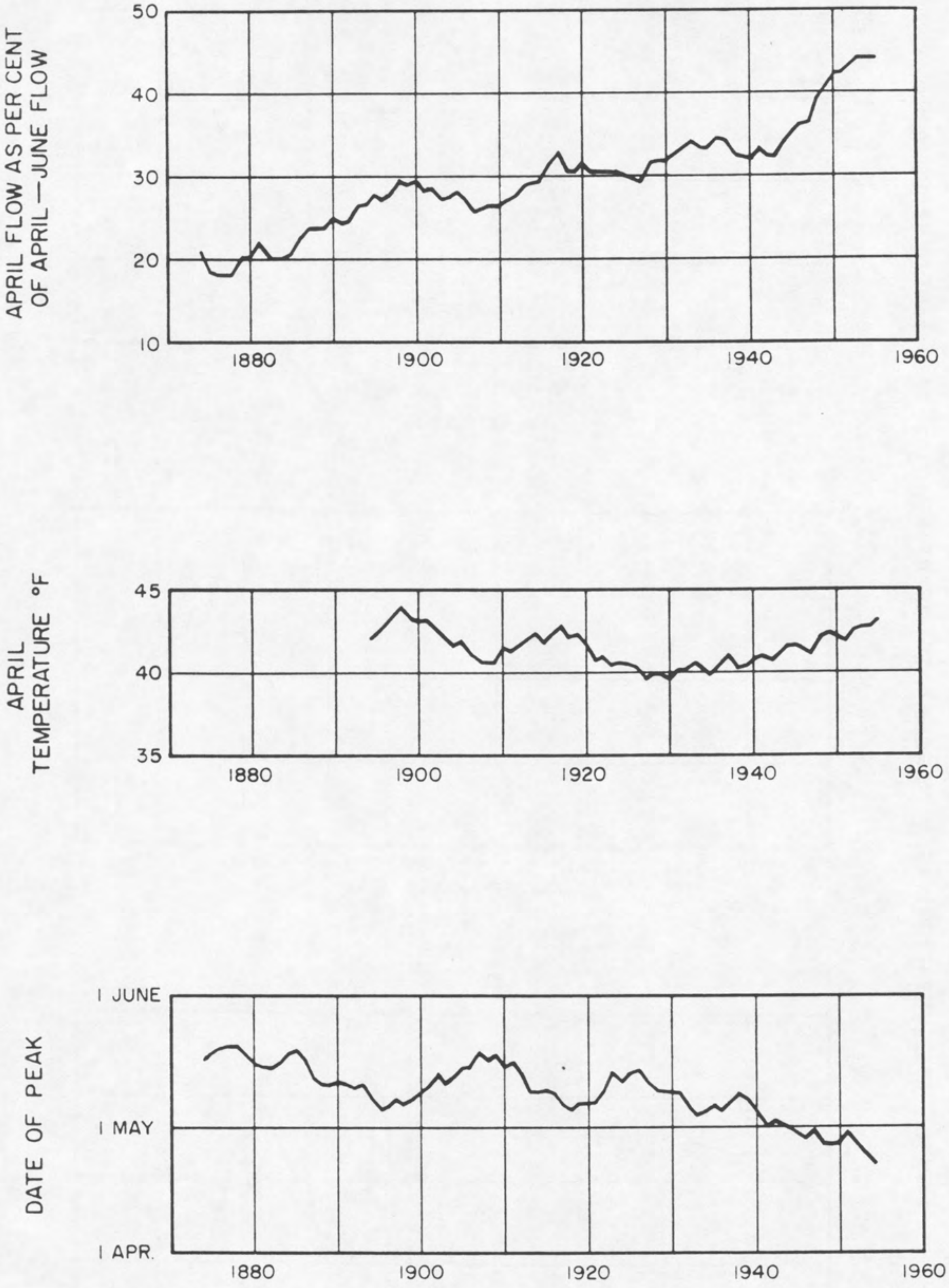
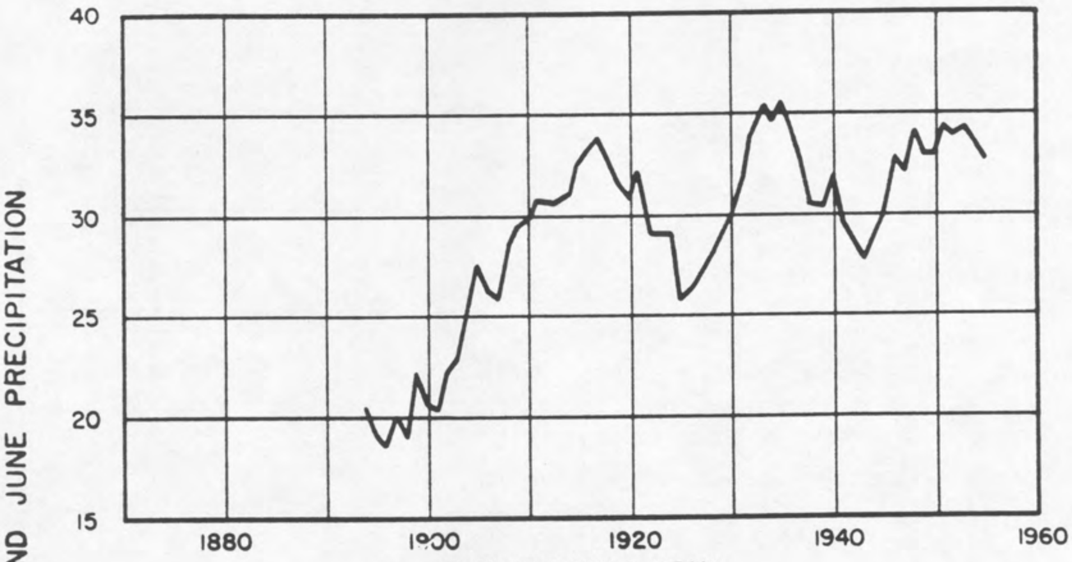
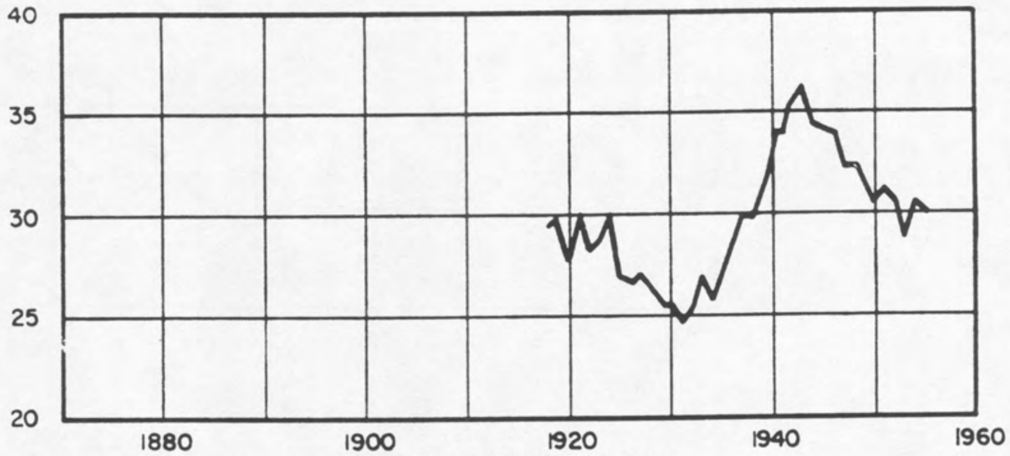


FIGURE 8 — RELATION BETWEEN TRENDS IN APRIL FLOW, APRIL TEMPERATURE AND DATE OF PEAK FLOW



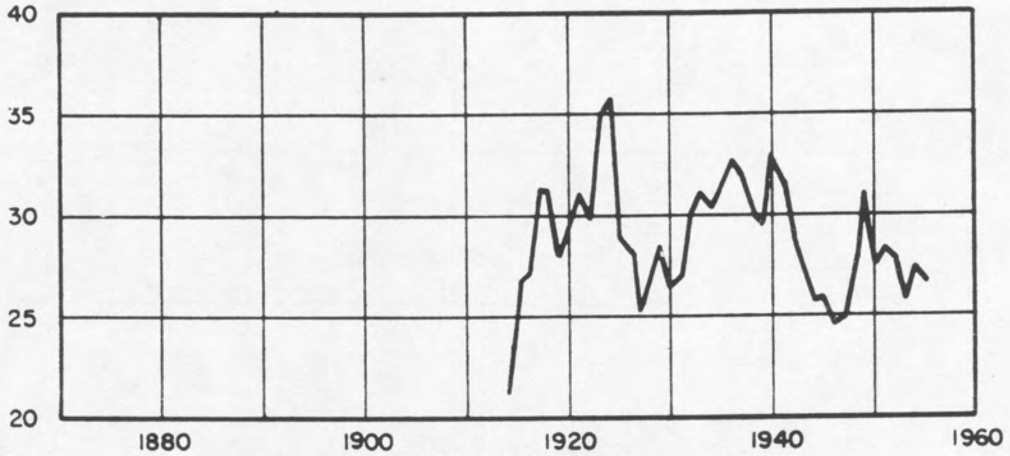
10 YEAR MOVING MEAN

OTTAWA



10 YEAR MOVING MEAN

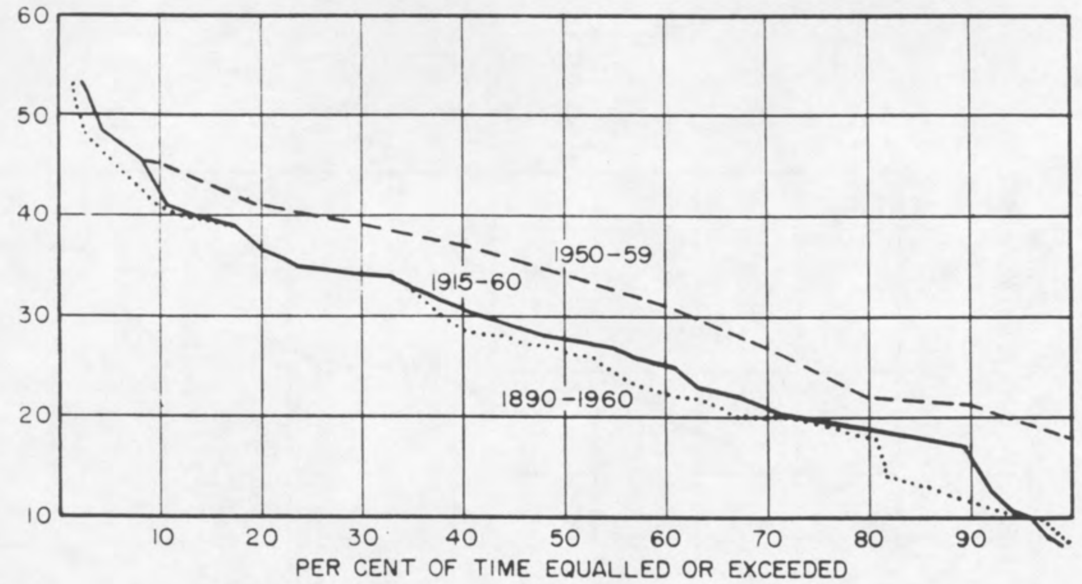
MANIWAKI



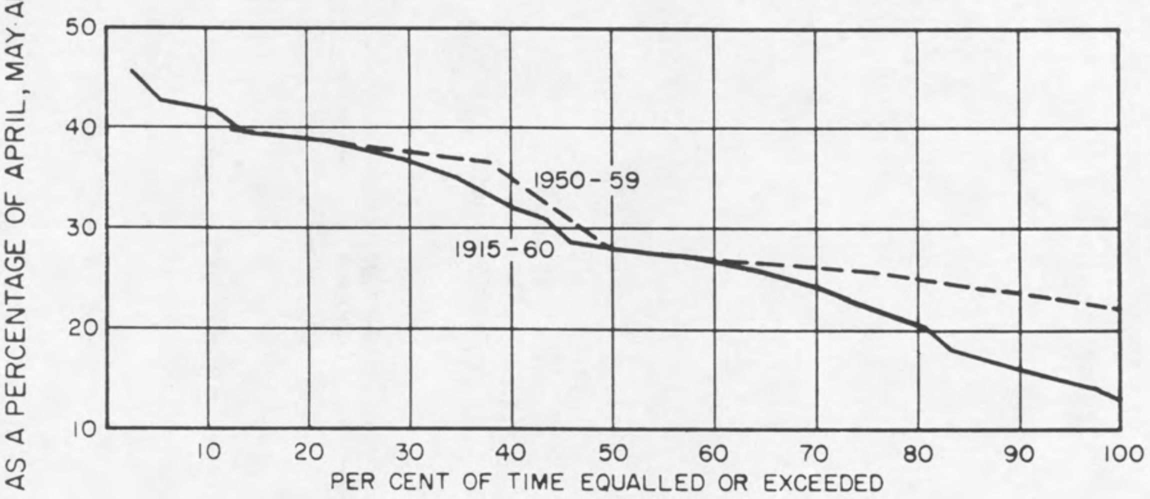
10 YEAR MOVING MEAN

TIMISKAMING

FIGURE 9 – TIME TREND IN PRECIPITATION



OTTAWA



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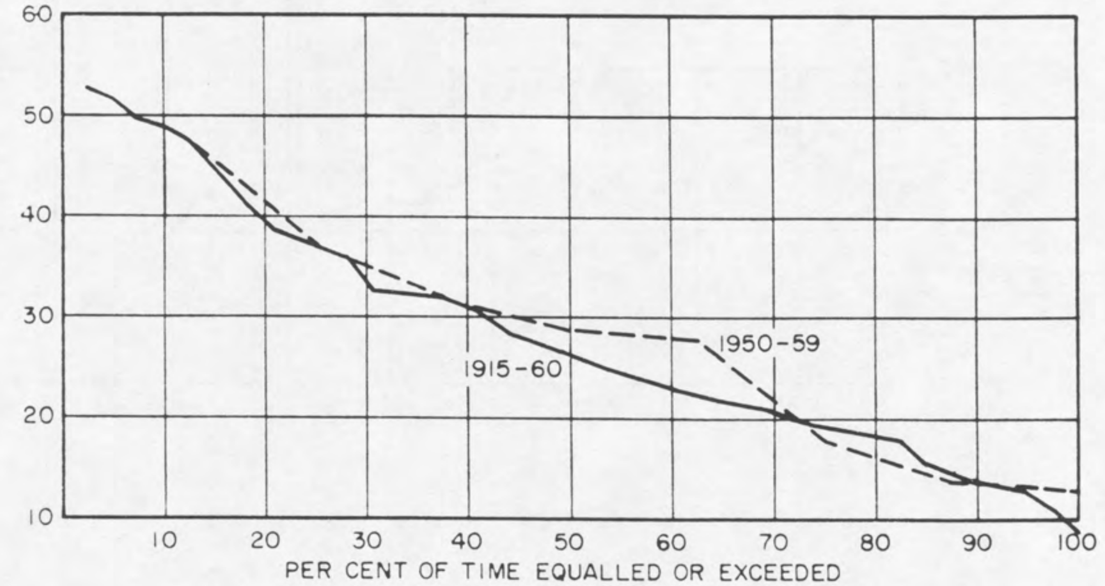
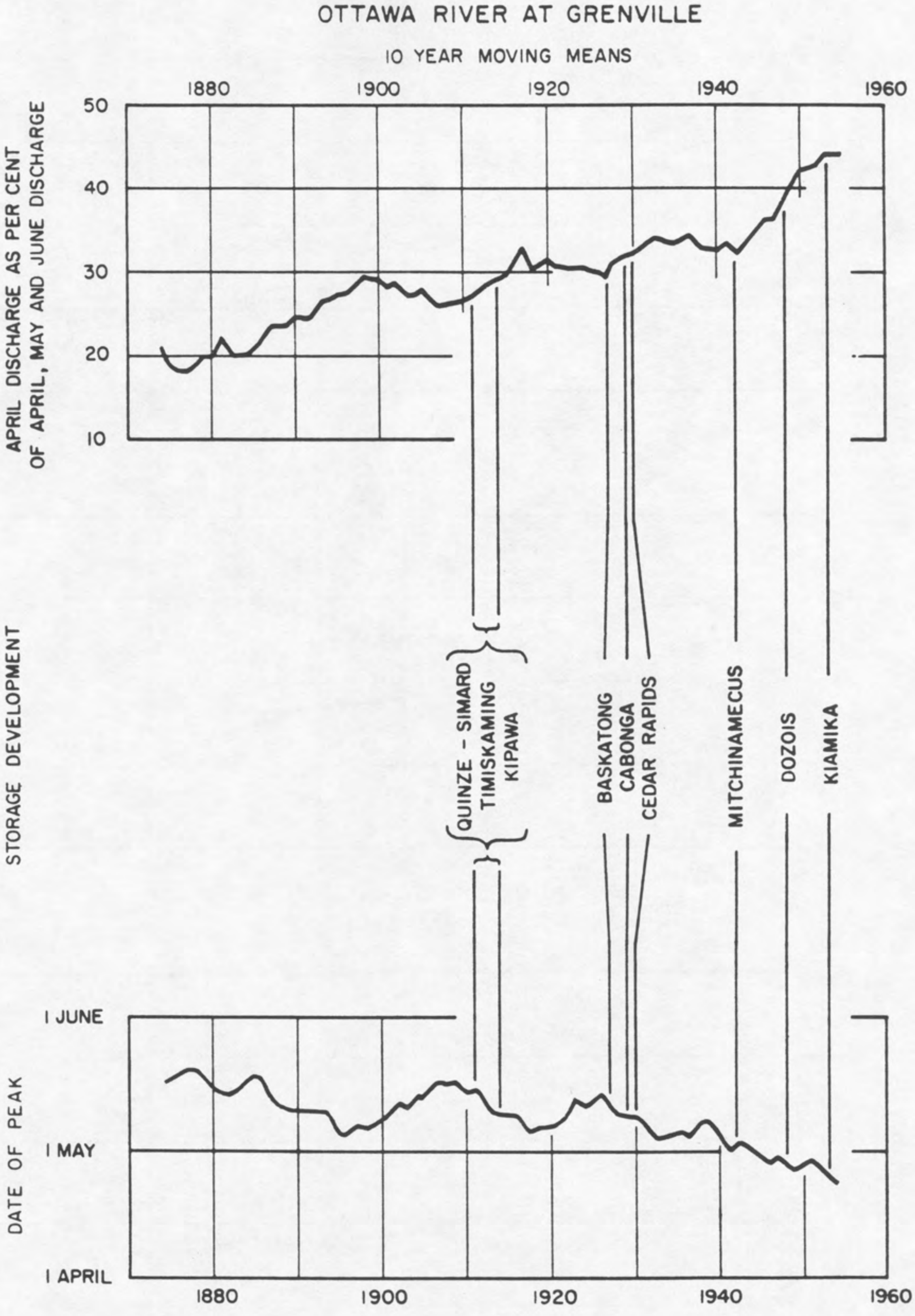


TIMISKAMING

FIGURE 10 — DURATION CURVES OF APRIL PRECIPITATION AS A PERCENTAGE OF APRIL, MAY AND JUNE PRECIPITATION


OTTAWA RIVER AT GRENVILLE

10 YEAR MOVING MEANS

FIGURE 11 – TRENDS IN RUNOFF AND DATE OF PEAK FLOW RELATED TO DEVELOPMENT OF STORAGE

No analysis has yet been done to determine the change in travel time due to increased depths, but it may well be that this is a significant factor in the change in spring runoff pattern. However, it does not explain the rise in April contribution before 1910.

### Deforestation

Logging has been the main industry in the Ottawa River basin for well over a hundred years. It has been difficult to obtain information on the logging which has taken place, other than the general belief that cutting was indiscriminate during the 1800's and has become more and more selective since 1900. It may be that the complete cutting over of large areas advanced the runoff during the 1800's and that this trend would have flattened out if the river had been left in its natural state.

## SUMMARY

The only conclusion that can be made at present is that there has been a trend for the runoff to occur earlier each year. The reasons for this have not yet been shown conclusively, but it appears that temperature changes and the increased speed of the flood wave with the increased depth due to power and storage developments are two major causes.

With the completion of the Carillon power plant the river will be almost completely developed and the trend in runoff should ease up. However, temperature will still have its effect, and future trends in temperature will bring corresponding trends in runoff. As yet, the magnitude and direction of future temperature variations defy forecast.

# TRENDS IN SPRING RUNOFF

Discussion by James Woodside, Gatineau Power Company, Ottawa, Canada

An attempt has been made to study this problem with reference to the Gatineau River drainage area, of about 9100 sq miles to Paugan. Good runoff records are available since October 1911.

Baskatong storage reservoir was completed in time to hold the spring runoff in 1927 and Cabonga reservoir was completed in the spring of 1929. Since then no further storage has been developed.

| 5-Year Period | Paugen Runoff BCF | | Percent April / Apr.& May & June | Beginning of Spring Freshet | Date of Peak Runoff |
|---|---|---|---|---|---|
| | April | April May June | | | |
| 1912-16 | 235.0 | 888.5 | 26.5 | April 8 | May 9 |
| 1917-21 | 284.0 | 948.3 | 30.1 | Mar. 27 | 10 |
| 1922-26 | 244.3 | 1051.4 | 23.2 | April 11 | 14 |
| 1927-31 | 297.5 | 1024.6 | 29.0 | Mar. 30 | 3 |
| 1932-36 | 351.1 | 1076.8 | 32.6 | April 5 | May 2 |
| 1937-41 | 321.5 | 969.0 | 33.2 | " 11 | " 2 |
| 1942-46 | 292.7 | 897.5 | 32.6 | " 4 | " 7 |
| 1947-51 | 450.2 | 1165.5 | 38.7 | " 1 | Apr.25 |
| 1952-56 | 433.2 | 965.7 | 44.8 | " 4 | May 1 |
| 1957-61 | 333.7 | 846.8 | 39.3 | " 10 | Apr.30 |

It is evident from the above tabulation that there is an apparent change in the April runoff (expressed as a percentage of the total Spring runoff) due to the installation of storage reservoirs. Two reasons can be given for this:-

(1) In computing runoff with storage in existance, no allowance has been made for the time that would be required for the flood water to travel from the sites of the reservoirs to Paugan, where the total river discharge is measured.

(2) No allowance has been made for the natural storage which existed in Baskatong and Cabonga Lakes. This natural storage would have the effect of decreasing the runoff during rising stage and increasing it during falling stage.

Coming to the period of 30 years, 1932 to 1961, inclusive, during which the storage reservoirs were fully operative, it is found that the April runoff, compared to the total, remained at a constant figure of about 33% for the first fifteen years. The remaining fifteen years averaged about 41%. Three of these years showed very high percentage.

1951 - 57.8%
1953 - 62.4%
1955 - 57.4%

In 1951 and 1953, the freshet was unusually early and in all three the precipitation in May was much below normal. Nevertheless, there seems to be a tendency during the last fifteen years for the April runoff to be a higher proportion than in previous years.

It will be seen from the tabulation, that little or no change has occurred in the last fifty years in the date of commencement of the spring freshet. During the past thirty years no trend is evident in the date of the peak runoff. The installation of storage caused an apparent advance in the date of about one week, for the reasons previously referred to.

Other factors which could affect the April percentage of runoff would include:-

(1) Water content of snow on the area at the end of the winter.

(2) Distribution of temperatures during the spring month.

(3) Distribution of rainfall during the spring month.

No study has been made of these factors on the Gatineau area.