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Environment Canada
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Inland Waters Directorate
Western and Northern Region

THE RED RIVER FLOOD OF 1979

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November 1981

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FOREWORD

Floods, their causes and effects, are an ever increasing water management concern, particularly in the Red River Valley. Inhabitants of the valley prospered for several decades thankful for the waters of the Red River. In 1950 a disastrous flood occurred, inundating sections of the City of Winnipeg and several upstream towns and villages in both Canada and the United States. Wisely, man responded with protective and mitigative works in the ensuing years but few expected to see a repeat of flooding as soon as 1979.

Thus, the report, "The Red River Flood of 1979", was prepared*; keeping in mind the relatively unique event that necessitated it; recognizing the need to document more than the bare causes and effects, and lastly; wishing, through rudimentary analyses and descriptive material, to relate to the layman, engineer and manager alike, sufficient information to allow an appreciation of this complex water management problem.

Dale Kimmett, P. Eng.

*In July of 1980 a few copies of this report were prepared for distribution for review purposes. Many of the valuable comments and suggested revisions that were made have been incorporated into this edition. Also, this version has been published in both official languages with the intent of giving it as wide a distribution as practical both within the government and to the public.

On peut se procurer la version française de la présente publication.

ACKNOWLEDGEMENTS

This report was produced only through the efforts of many persons from a variety of government agencies.

The river flows and stages in Manitoba were measured and computed by the field personnel of Water Survey of Canada under the direction of the Hydrometric Surveys Engineer in Winnipeg, Mr. Jim Way. The field personnel were Messrs. Daigneault, Sawatzky, Lokits, Anderson, Helfrick, McLaurin, McCulloch, Hescott, Larsen, Happychuk, Engstrom, Solmundson, Milani, and Thorne.

The flow data and other information on the rivers in the United States were obtained from the offices of the Water Resources Division of United States Geological Survey in Grand Rapids, Minnesota; Grand Forks, North Dakota and Bismark, North Dakota. The U.S. Army Corps of Engineers Water Control unit in St. Paul, Minnesota provided information and data on reservoir storage. The Water Resources Branch of Manitoba's Department of Mines, Resources and Environmental Management contributed material, from discharge measurements to natural flow calculation, and provided valuable comments on various segments of the report.

The meteorological data was provided by the Winnipeg office of the Atmospheric Environment Service (AES) of Environment Canada and by the National Oceanic and Atmospheric Administration (NOAA) in the United States. AES also obtained and made available for the flood delineation, the Side Looking Airborne Radar imagery. Mr. Mark Hacksley, with Scientific Services of AES, contributed to the report the thorough summary of the meteorological conditions pertaining to the flood.

The entire staff of the Winnipeg office of Water Survey of Canada contributed to the production of this flood report and significant contributions were made by several persons. Mr. Dale Kimmett initiated the report and provided guidance throughout. Mr. Russ Hinds drafted the figures and gathered and plotted the river and weather data and several typists worked on the word processor to type the various drafts of the report.

METRIC UNITS

On January 1, 1980 the data dissemination services of Water Survey of Canada converted to the International System of Units which is more commonly referred to as the Metric System. This report is one of the first from Water Survey of Canada to be entirely in metric and as most readers are not completely familiar with metric, the units that are used in this report are described and converted to Imperial units here.

The metre is the basic unit of length in the metric system. It is roughly equivalent to the yard and as such the metre is used for measuring short distances over land or the size of large objects. The metre is also the unit of measure for the water level or stage of rivers and lakes. The kilometre, which is 1000 or 10^3 metres, is used to measure land distances and has replaced the mile on maps and road signs. The square kilometre replaces the square mile as the measure of drainage area. The metric equivalent to the acre is the hectare. The hectare is 10 000 m^2.

Short lengths, formerly measured in inches and fractions of an inch, are generally measured in centimetres, of which there are one hundred in a metre, or millimetres, of which there are one thousand in a metre. Rainfall is measured in millimetres and snowfall in centimetres and with the standard density of new fallen snow being 0.10, one centimetre of snow is convertible to one millimetre of water.

Temperature, along with the other weather information, has been released by the Atmospheric Environment Service Weather Offices in the metric units for the past few years. Celsius temperatures should be familiar to most persons with 20°C as a room temperature and 0°C as the freezing point.

River discharge, or volume rate of flow, is now measured in cubic metres per second. There are just over 35 cubic feet per second for every cubic metre per second. The cubic metre contains 1000 of the now familiar litres.

The metric system is very easy to work with when using the derived secondary units. The cubic decametre was adopted by Water Survey of Canada as the measure of runoff volume and reservoir volume. As a volume, the cubic decametre is a cube 10 metres to a side. It is also the volume of one millimetre of rain over one square kilometre or the total volume of one cubic metre per second flowing for 1000 seconds. The acre foot, which the cubic decametre replaces, represented one inch of rain over 0.01875 of a square mile or 1 cubic foot per second flowing for 43560 seconds.

The slope of a land surface or a river reach was formerly expressed as, for example, 1/2 foot per mile or 0.0095%. In metric it can be expressed as 0.095 m/km or 0.0095%.

The metric system brings with it a special system of notation. Dates and/or times, when written solely in numbers, are in descending order with spaces or hyphens separating year, month, and day and colons separating hours, minutes, and seconds. Spaces every three digits are used instead of comas for spacing in large numbers and the metric units are abbreviated to symbols without periods.

METRIC UNITS

NAME	SYMBOL	EQUIVALENT IMPERIAL MEASUREMENT
metre	m	3.2808 feet
centimetre	cm	0.39370 inch
millimetre	mm	0.03937 inch
kilometre	km	0.62137 mile
square kilometre	km^2	0.38610 square mile
hectare	ha	2.4710 acres
cubic metre per second	m^3/s	35.315 cubic feet per second
degrees celsius	°C	5/9 (Degrees Fahrenheit -32)
cubic decametre	dam^3	0.8107 acre foot

ABSTRACT

The 1979 spring flood event of the Red River which disrupted thousands of people and did many millions of dollars damage is documented and analyzed in this report. The basin of the Red River (known in the U.S. as Red River of the North) covers 124 000 km^2 (exclusive of the Assiniboine River basin) in Manitoba, North Dakota, South Dakota, and Minnesota. The geography and flooding history of the area is summarized. The event of 1979 is documented with a map of the extent of flooding from the Red River in Manitoba and with the records of 36 hydrometric and 6 weather stations in Canada and the United States of America. The data from the similar major flood of 1950 is presented for comparison. The meteorological conditions, the events of the flood, the hydrometric data collection techniques, and the use of the major reservoirs and diversions are described. The effects of man-made channels, runoff timing, and the degree day accumulations on floods are discussed.

The peak daily discharge of the Red River at Emerson, Manitoba, on the Canada/U.S. border, was 2620 m^3/s and from Emerson to Winnipeg, Manitoba, 650 km^2 were inundated by the river. A similar but unmeasured amount of land was flooded by the tributaries. As there were three historic floods since 1826 that were higher than both the 1950 and 1979 floods, a return period of approximately 30 years is indicated. The 1979 flood was due to a late and sudden snowmelt, with prebreakup snow accumulation and post breakup rainfall being approximately twice the normal. Runoff ratios for the 8 sub-basins ranged from 0.12 to 0.40; the variance due to differences in physiography and reservoir storage. Without reservoirs and diversions, especially the Red River Floodway, the flood level in Winnipeg could have been 9.20 m, (City Datum) just 0.036 m below the disastrous 1950 flood level instead of the non-damaging 5.837 m that actually occurred.

RÉSUMÉ

Ce rapport est une analyse des données recueillies sur l'inondation désastreus de la rivière Rouge qui a perturbé la vie de milliers de personnes et a entraîné des millions de dollars de ravages au printemps de 1979. Le bassin de la rivière Rouge (connu aux E.-U. sous le nom de rivière Rouge du Nord) couvre 124 000 km^2 (à l'exclusion du bassin de la rivière Assiniboine) au Manitoba, au Dakota du Nord, au Dakota du Sud et au Minnesota. Le rapport résume la géographie de la région et l'histoire des inondations qui s'y sont produites. Il contient une carte indiquant l'étendue du débordement de la rivière Rouge au Manitoba en 1979 ainsi que les relevés faits dans 36 stations hydrométriques et 6 stations météorologiques du Canada et des Etats-Unis d'Amérique. Aux fins de comparaison, on a inclus les données sur l'inondation, également catastrophique, de 1950. On décrit les conditions météorologiques, la progression du gonflement des eaux, les techniques de collecte de données et l'utilisation des réservoirs et des canaux de dérivation les plus importants. On fait état aussi des résultants, sur les innodations, des canaux artificiels, du coefficient d'écoulement et du degré d'accumulations quotidiennes.

Le débit de point quotidien de la rivière Rouge à Emerson (Manitoba), petite ville située à la frontière Canada-E.-U., atteignait 2620 m^3/s, et d'Emerson à Winnipeg (Manitoba), les eaux de la rivière inondaient une étendue de 650 km^2. Les eaux des affluents débordaient également sur une superficie qui, bien qu'on ne l'ait pas mesurée, était tout aussi considérable. Puisque, depuis 1826, l'on compte trois crues historiques plus grandes que celles de 1950 et de 1979, on estime un retour périodique de grande crue d'environ 30 ans. L'inondation de 1979 a été provoquée par une fonte des neiges tardive et brusque, et des chutes de neige et de pluie, précédant et suivant respectivement la débâcle, qui étaient deux fois plus abondantes que la normale. Les coefficients d/écoulement mesurés aux 8 sous-bassins variaient de 0.12 à 0.40, les différences étant attribuées à la géomorphologie de chauqe endroit et à la capacité d'entreposage des réservoirs. Sans la création de réservoirs et de canaux de dérivation, surtout celui de la rivière Rouge, la niveau des eaux à Winnipeg aurait atteint 9.20 m (plan de référence pour la Ville), soit exactement 0.036 m de moins que celui de l'inondation désastreuse de 1950; grâce à ces ouvrages de protection, la crue maximale ne s'est élevée qu'à 5.837 m, et l'on a pu éviter de graves effets destructeurs.

TABLE OF CONTENTS

LIST OF TABLES

Table

LIST OF FIGURES

Figure

LIST OF PHOTOGRAPHS

Photograph

1.0 THE RED RIVER BASIN

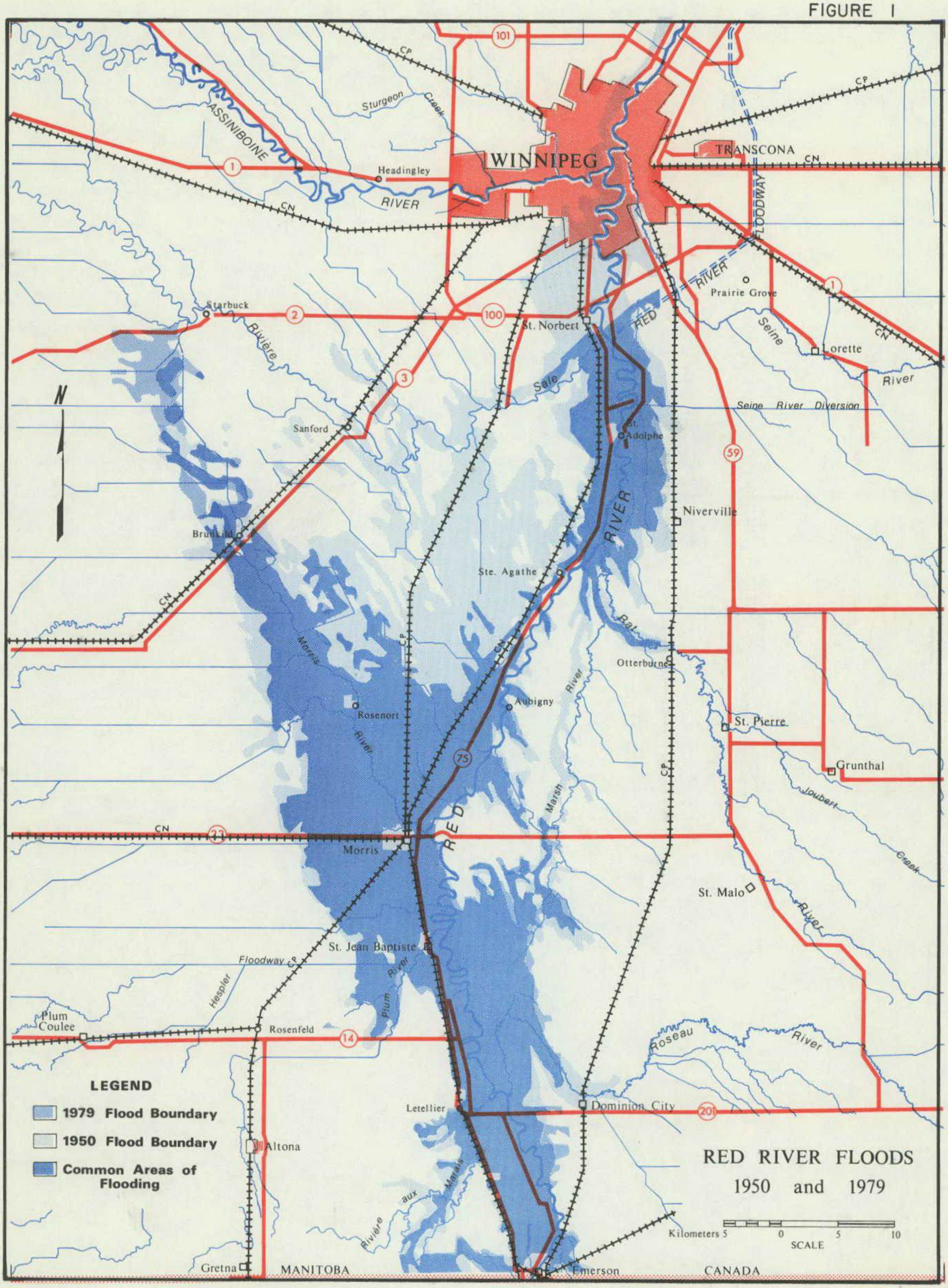
The entire Red River watershed to Lake Winnipeg encompasses 290 000 km^2 of land surface and is rather easily divided into the two main segments - the Assiniboine River basin to the west, which is 153 000 km^2, and the Red River basin south of the confluence at Winnipeg, with a surface area of 124 000 km^2. The latter area includes the Devil's Lake sub-basin of 10 000 km^2 in North Dakota which is considered to be non-contributing but is generally included in calculations of gross Red River drainage area. The two major segments drain distinctly different physiographic regions. Also, they differ in precipitation totals and in its annual distribution. For these reasons the hydrologic characteristics of the two areas are quite different. The Red River basin generally exhibits greater basin yields and tends to generate catastrophic spring floods more frequently than the Assiniboine basin. Fortunately the large flood events from the two basins have not coincided in recent times.

Except for some considerations in the natural flow calculations for the Assiniboine River as it affects Winnipeg, this report deals exclusively with spring floods within the Red River basin south from Winnipeg as shown in Figures 1 and 2.

1.1 Physiography

Topographically this basin can be visualized as a huge soup plate, tilted very slightly to the north and with the northern rim broken off. The wide rim of the basin is irregular, consisting of morainic glacial deposits and the beach materials of Lake Agassiz. From the rim of the basin there is a drop of 100 to 200 metres to the central plain. This plain slopes towards the Red River which is located along the north-south axis of the basin. This side-slope is approximately 0.35 metres per kilometre (0.00035). The tilt of the central plain, and the Red River, to the north is slight, dropping only 0.1 m/km (0.0001).

FIGURE I



RED RIVER FLOODS
1950 and 1979

The surface materials and topography of the basin were formed during the later phases of the Wisconsin glaciation, 13 000 to 10 000 years B.P. (Before Present).

The general low relief of the basin was created by the advance of the glaciers. During the retreat of the glaciers, the materials deposited were reworked and sorted by Lake Agassiz during its 3000 years of existence to form gravel and sand beaches at its margin and thick lacustrine clay deposits on its bed. The relic lake bed extends from Wahpeton to Winnipeg (400 km) and is tens of kilometres wide. Its extreme flatness is its dominant feature. A more featureless plain is not to be found anywhere. Because of its high clay content, infiltration rates are generally too slow to modify runoff events caused by rapid snowmelt in spring or by severe thunderstorms in summer. In the west and the south of the basin local relief becomes more evident, typical of terrain of glacial origin. Numerous pothole lakes dot the landscape and poorly integrated drainage systems prevail. Prairie grassland is the dominant natural vegetation and black Prairie soils are the main soil class. In the northeastern margin step-like rises in topography have their origin in Lake Agassiz shoreline structures and the vegetation mostly consists of coniferous forests and bog vegetation.

In the hydraulic view, the low relief and modest slopes dictate a low energy river system with little ability to erode streambeds. Knickpoints of resistant till or bedrock further inhibit downcutting. One such knickpoint at Lister's Rapids just below Winnipeg regulates the shape of the river channel in the Winnipeg reach. The lacustrine clay soils found along the main stem from Wahpeton to Winnipeg give rise to a fairly well developed system of river meanders such that 800 km of river channel traverse the airmile distance of 400 km between the two towns. Channel capacities for both the main stem and its tributaries are generally of insufficient size to accommodate flood flows. Man-made features on the wide flood plain such as rail and road embankments, dykes, and ditches exert a powerful influence on the severity and pattern of inundation wherever overbank flooding occurs.

1.2 Population Distribution

The Red River basin is home to approximately 750 000 people, most of whom are found in its three main cities - Winnipeg, Fargo-Moorehead, and Grand Forks. Rural population density, which includes all other towns, is rather evenly distributed at an average density of five persons per square kilometre. The population centres and the principal rivers are shown in Figure 2.

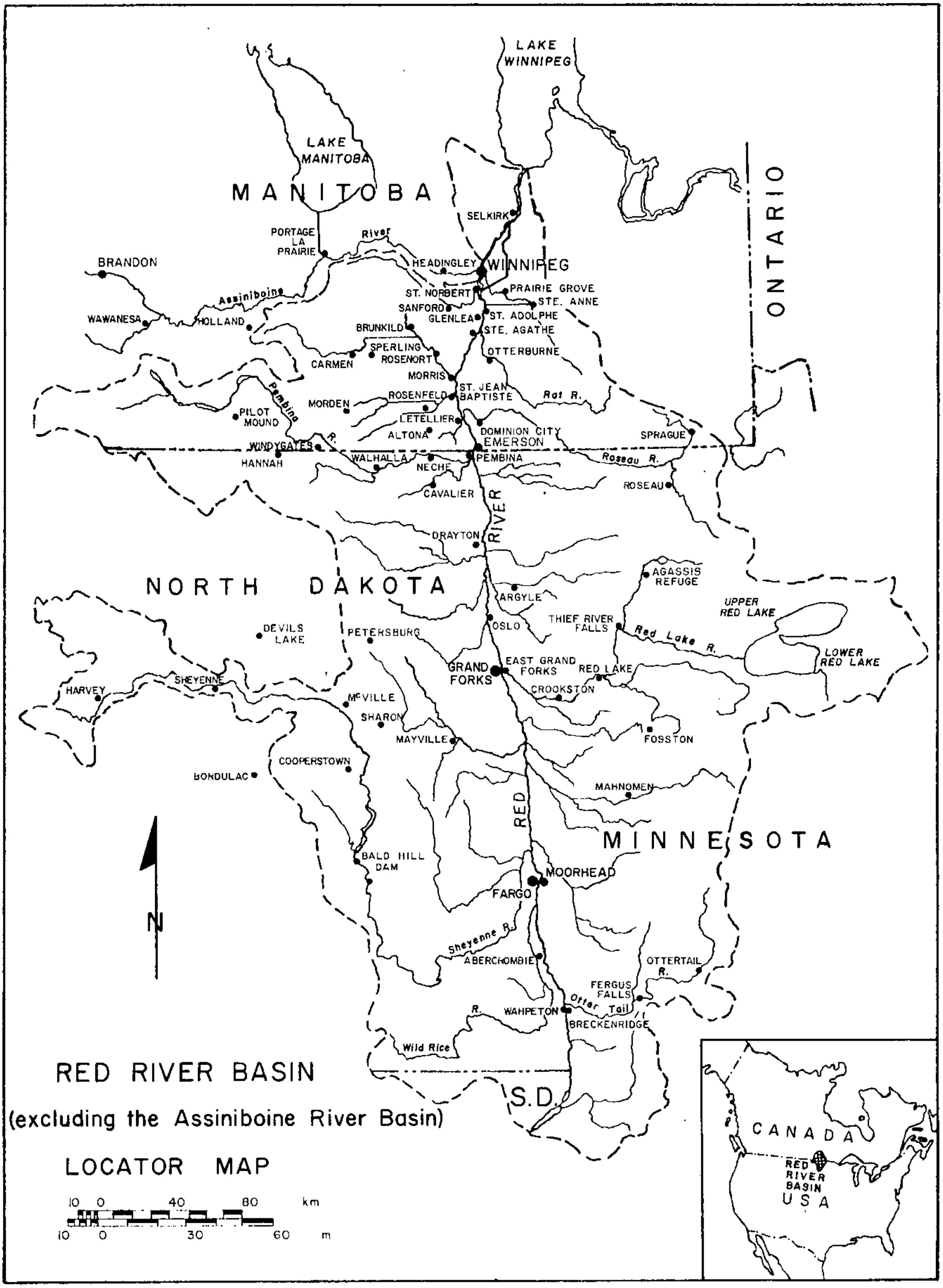
1.3 Climate

Espenshade and Morrison's (1974) modified climatic classification system places the Red River basin in a class defined as humid continental. On average, Red River mean monthly basin temperatures range from -15°C to +20°C with a spread in extreme values of 70°C. Annual totals of precipitation approximate 500 mm and precipitation events occur in every month with summer monthly means roughly two times those of winter months. The winter snows remain to generate runoff in the spring. On average, summertime convective thunderstorms do not keep up with evapotranspiration losses. For these reasons most of the annual river flow occurs in April and May. On the Red River at Emerson, for example, the sum of April-May flows is generally one-half of the total annual mean flow. On occasion intense thundershower activities, especially in the southern portions of the basin, have generated high runoff events.

1.4 History of Flooding

A history of flooding in the Red River valley is firmly embedded in the folklore of the region. Although no written documentation of floods in the 18th century exists, three references to floods in 1776, 1790 and in 1809 are found in the writings of Alexander Ross in the 1850's. The description of the 1776 flood is attributed to a Mr. Nolin, who sailed over the flooded lands from Red Lake River to the colony of

FIGURE 2



RED RIVER BASIN
(excluding the Assiniboine River Basin)
LOCATOR MAP

Red River (Winnipeg). Ross states that this flood was bigger than the flood of 1826, the largest flood for which quantitative stage data exists. The floods of 1852 and 1861 have also been quantified. Since 1875, records of water levels have been obtained at Winnipeg and floods have been documented more precisely.

The following table is a summary of the historic floods.

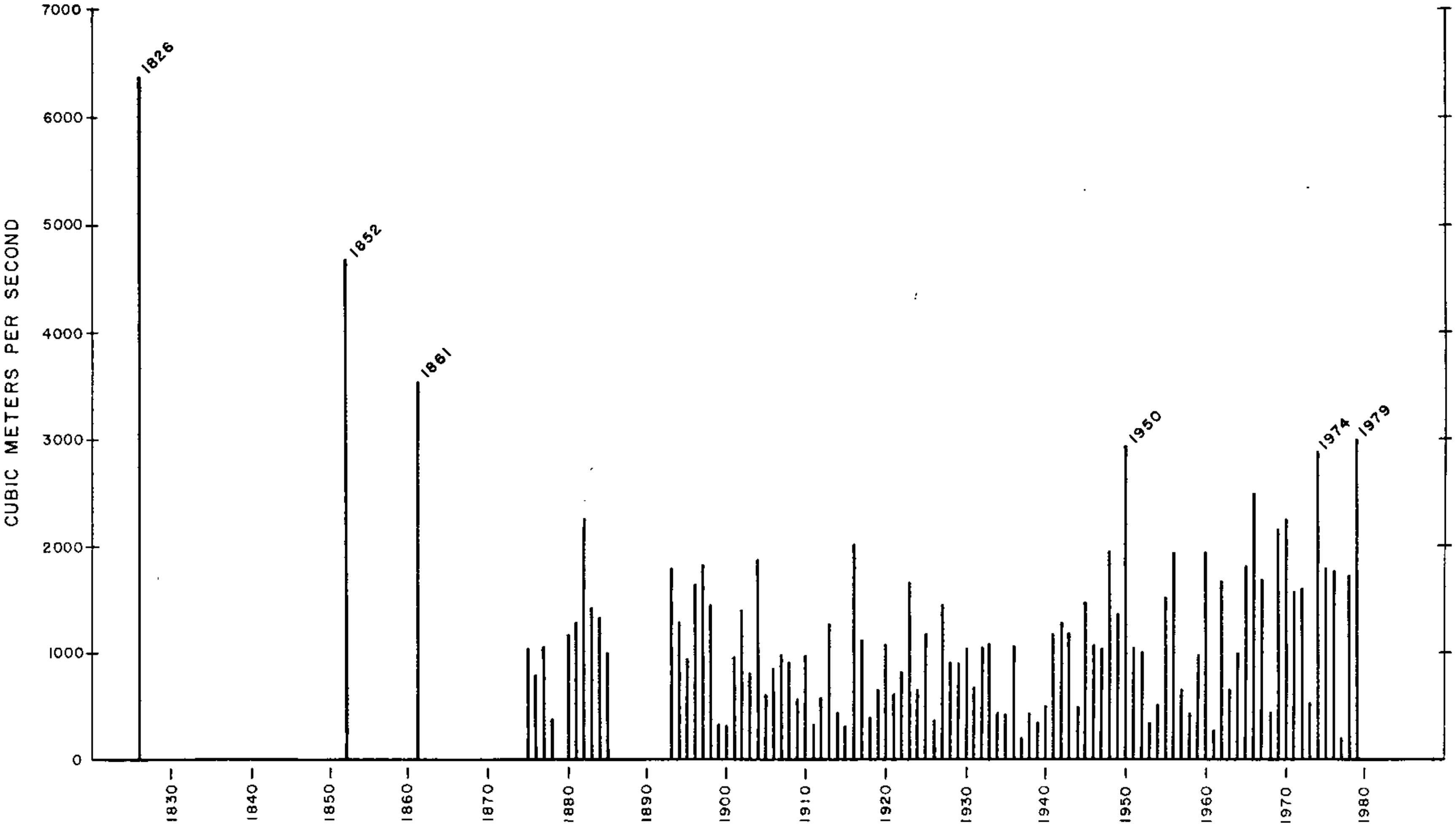
Historic Floods - Red River at Winnipeg

Year	Water Level*	Discharge
1826	11.25 m	6370 m^3/s
1852	10.64 m	4670 m^3/s
1861	10.03 m	3540 m^3/s
1950	9.43 m	2930 m^3/s
1966	8.25 m	2490 m^3/s
1882	7.93 m	2260 m^3/s

* City datum

For interested readers, a comprehensive summary of historical flood events can be found in Clark (1950), in Appendix B of the "Report on Investigations into Measures for the Reduction of the Flood Hazards in the Greater Winnipeg Area" (1953), and in Morton (1957).

Clark shows annual flood maxima at Winnipeg in chronological order in his report as an illustration. This has been updated and is shown here as Figure 3. The flood maxima shown for the last decade are projected natural flow peaks calculated by the provincial Water Resources Branch and take into account the operation of the Shellmouth Reservoir, the Portage (Assiniboine River) Diversion and the Red River Floodway.



RED RIVER SPRING PEAK FLOWS AT WINNIPEG

NOTE 1 : For period 1969-79, computed natural flows as computed by WRD, Manitoba

NOTE 2 : For period prior to 1913, data from Red River Basin Investigations, Appendix D

FIGURE 3

2.0 THE SPRING FLOOD OF 1979

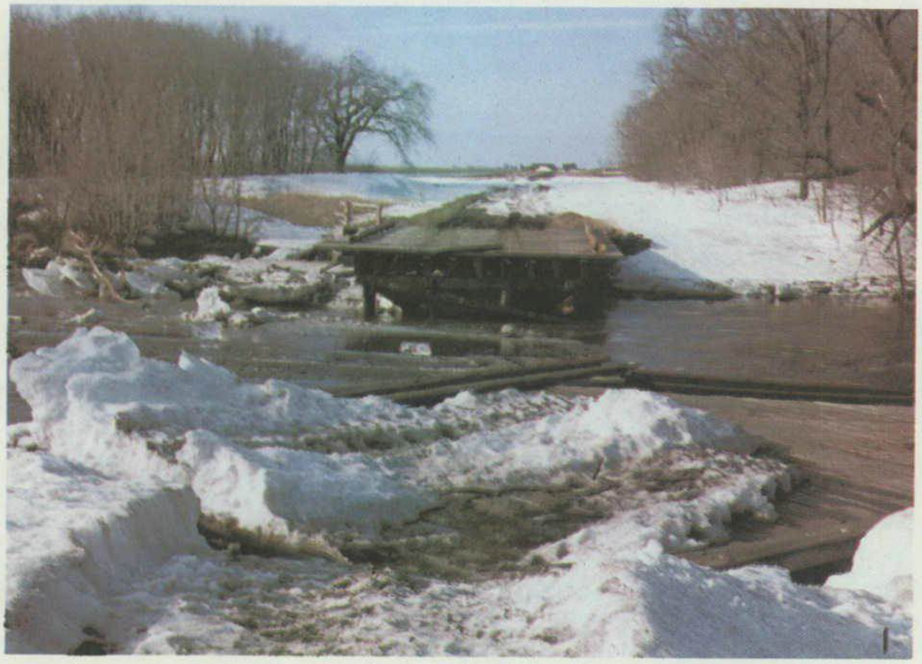
Periodic flooding in a river basin can generally be attributed to two principal causes. The first, predominantly static, is dictated by elements of physical basin properties. The physiography of the Red River basin, described earlier, can be inferred to be of a class susceptible to flooding. Low slopes, badly integrated drainage networks, low channel capacities and the extensive, extremely flat flood plain all contribute to the likelihood of flooding. Clark (1950) indicates the channel capacity at Emerson to be 1080 m^3/s, for example, and this flow value is estimated to be exceeded every five years on average.

The second, predominantly dynamic, cause of flooding in the Red River valley relates to meteorological factors, both the antecedent conditions and those concurrent with the spring snow-melt. A detailed analysis of the meteorological background to the 1979 flood has been done by H.M. Hacksley, climatologist, of the AES, Winnipeg office and is included in this report as Appendix 1. The salient features of the analysis show that two of the features thought by Clark (1950) to be necessary prerequisities to a major flood on the Red River were not present for this flood. (1) Antecedent moisture conditions in the fall of 1978 were much below normal. (2) The fall weather remained warm and dry until the first heavy snowfall on November 12 and 13. The factors which probably contributed most to the flood were: (1) The heavy precipitation events of the late winter, especially in the U.S. portions of the basin, and the continuation of these events into late April and early May; and (2) The colder-than-normal temperatures of the 1978/79 winter with a subsequent delay of spring melt until mid-April.

Excessive precipitation and a late, sudden melt led up to the catastrophic 1979 flood event. (Subsequent sections of this report will deal with these points in more detail.) Because these conditions were so dynamic, accurate flood forecasts were exceedingly difficult to achieve and upward revisions were frequent as the flood event unfolded.

FLOOD DAMAGE

Bridge over Boyne River below Carman April 23



Water draining from west at Hwy. 75 to Red River May 24

2.1 Chronology of the Flood

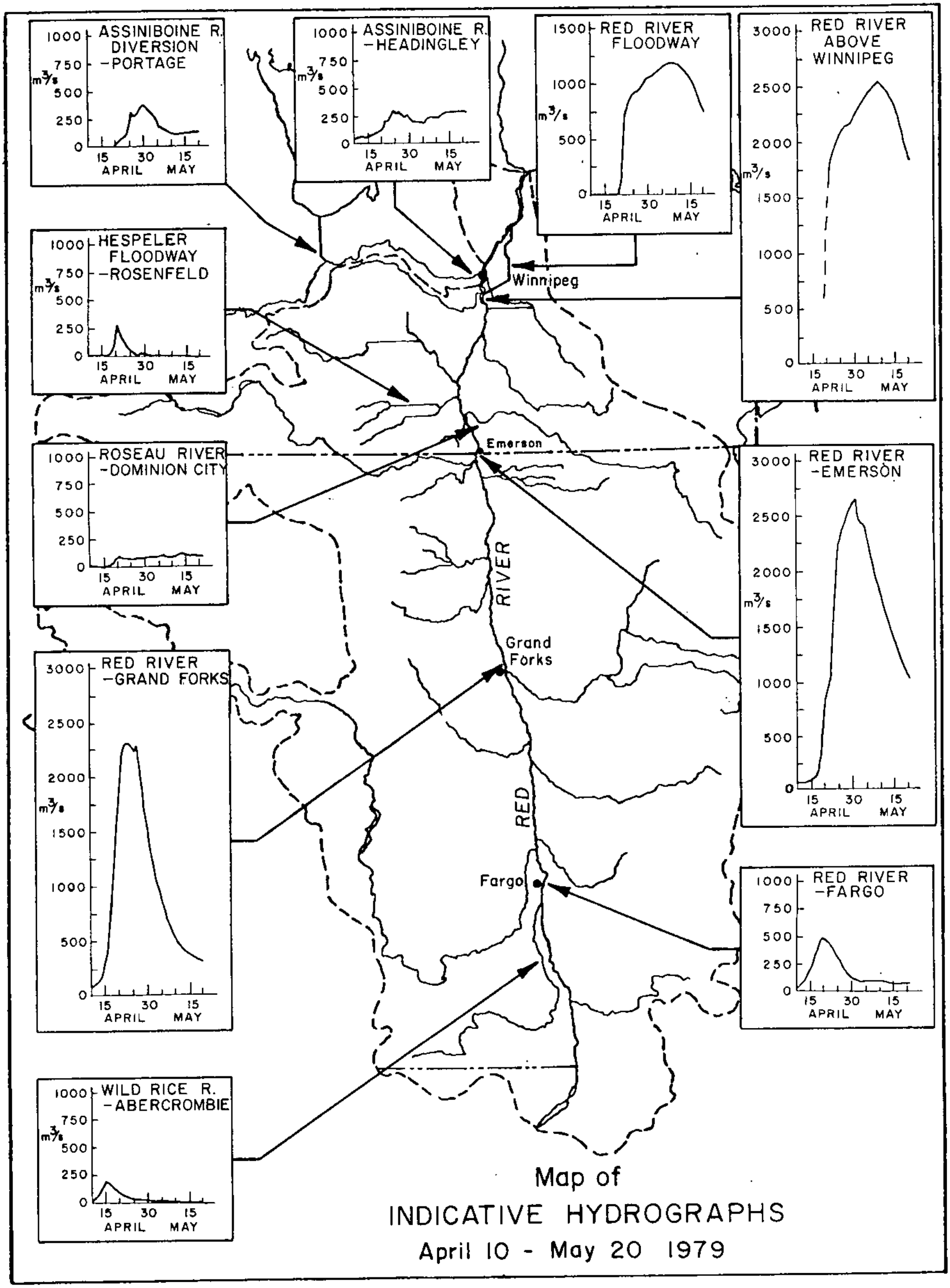
South of Grand Forks, N.D., rivers began their spring rise on April 11 and reached their peak one week later (Figure 4). In the late afternoon of April 18, the Manitoba tributaries of the Red River began their sudden rise. In this period daily temperature maxima ranged between 5°C and 10°C while night-time temperatures remained above freezing. A sudden snow-melt resulted. By April 20, Manitoba tributaries reached new peak levels in many cases. Serious flooding at a level a few feet below the 1950 levels was now predicted for the main stem of the Red River north from Emerson.

Bankfull channel capacities in the Manitoba tributaries were exceeded everywhere on the plain and hundreds of homes in the communities of Altona, Morden, Carman, Brunkild and low-lying areas in metropolitan Winnipeg were flooded. Overland flow was common southwest of Winnipeg and these waters isolated many farm homes (Photograph 5). Many farms and homes sustained flood damage in this phase of the flood.

On April 23, the Red River at Grand Forks attained a peak one metre higher than in 1950 and was very close to the all time peak of 1897. On this date most of the small headwater streams were well into recession but the major tributaries were still very high. A major flood of 1950 proportions along the main stem of the Red River became a distinct possibility and plans were made in Manitoba to close the ring dykes around the threatened communities of Emerson, Letellier, St. Jean, Morris, Ste. Agathe and St. Adolphe.

Very heavy rains fell during the next two days and by April 25 the Red River was expected to exceed the 1950 level. Preparatory flood fighting activity intensified in response to this prediction. Ring dykes surrounding the communities and isolated farms in the valley were raised. Premier Lyon of Manitoba announced an evacuation plan and 7000 people not actively involved in flood fighting began to leave their

FIGURE 4



Map of
INDICATIVE HYDROGRAPHS
April 10 - May 20 1979

threatened communities while road access was still possible. For the most part the evacuees stayed with friends and relatives in Winnipeg or other communities, such as Steinbach, St. Pierre and Morden, around the periphery of the Red River basin. Because of this, emergency plans to shelter large numbers of evacuees at a number of reception centres in arenas and other large buildings in Winnipeg were never fully realized. A substantial number of people remained behind in the beleaguered communities - the women to operate emergency kitchens and accommodations, and the men to patrol evacuated towns and to assist in the movement of people, livestock and grain out of the flood zones. They were aided in these tasks by several hundred members of the Canadian Armed Forces from Winnipeg and by helicopter support from the Armed Forces Base at Southport near Portage La Prairie. Overall co-ordination was the responsibility of the Emergency Measures Organization headquartered in Winnipeg.

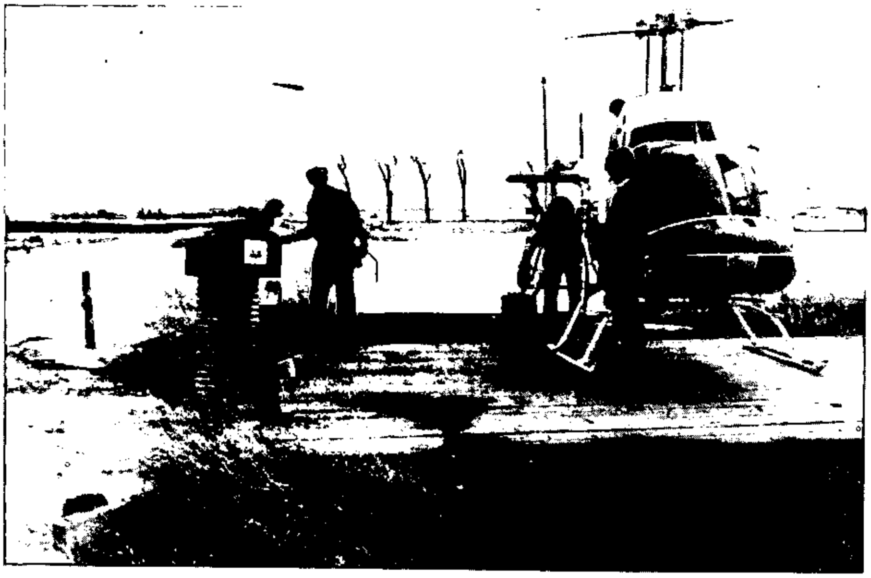
Water levels on the Red River at Emerson reached a peak* of 241.151 m on May 1, 1979, a tenth of a metre higher than the 1950 level. The peak discharge of 2620 m^3/s, however, was slightly below that of the 1950 flow. This unusual effect is thought to have been caused by the construction of ring dykes and the raising of road and rail embankments in the vicinity of Emerson since 1950. Because many of the tributaries to the Red River between Emerson and Winnipeg had receded to insignificant flows by May 1, the peak flow decreased as the flood wave progressed northward. When the peak reached St. Norbert it measured only 2500 m^3/s. Temporary storage of excess water on the broad flood plain south of Winnipeg also contributed to the marked attenuation of the maximum peak discharge.

Within the City of Winnipeg, the peak stage at the Water Survey of Canada station at the James Avenue pumping station was 5.837 m (City Datum) on May 10, 1979. This is much less than the 9.236 m peak elevation at the same location in 1950. The low stage of 1979 was due, of course, to the operation of the Red River Floodway and the Assiniboine

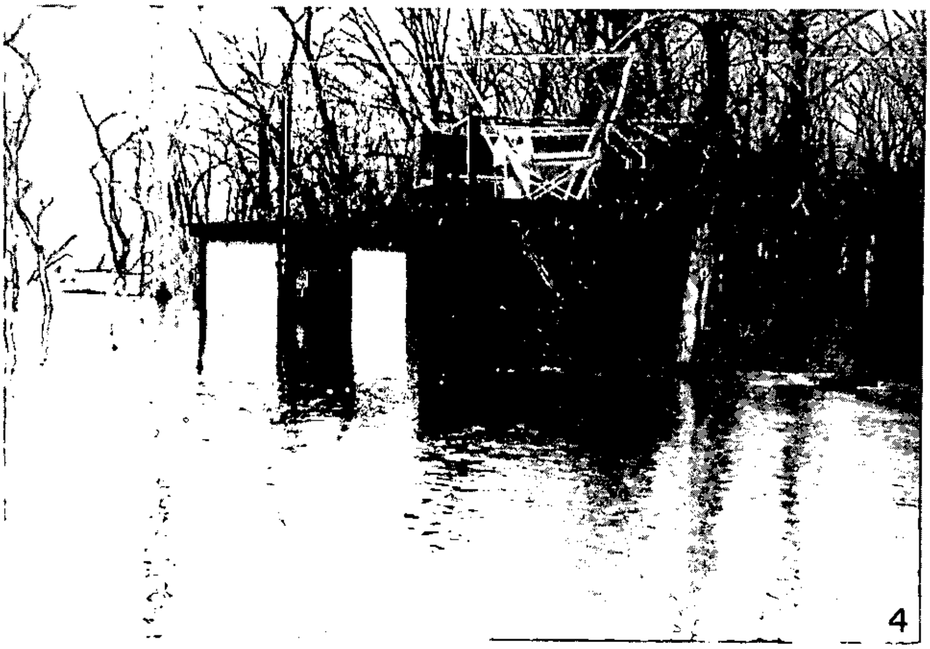
* maximum daily mean unless otherwise noted

HYDROMETRIC STATIONS

Visit to Shannon Creek near Morden April 20



Red River near Ste. Agathe, near peak



River Diversion at Portage La Prairie. The floodway, with a capacity of 1700 m^3/s, handled up to 1200 m^3/s during the 1979 flood peak and the Assiniboine Diversion, with a capacity in excess of 500 m^3/s, passed a peak of 354 m^3/s on April 30. These two major works served the City of Winnipeg exceedingly well in 1979 and the flood damages within the city were minimal.

The flood damage outside of Winnipeg was extensive. Manitoba's finance minister estimated that Manitoba's damages would likely exceed 30 million dollars. A spokesman for the U.S. Army Corps of Engineers, in a Winnipeg Free Press article on May 2, estimated the damages in the United States' portion of the basin at 72 million dollars with 3200 km^2 having been flooded.

2.2 Data Collection

2.2.1 Stream Gauging

The flow data in this report were collected in Canada by Water Survey of Canada (WSC) of the Department of the Environment and in the United States of America by the Water Resources Division of the United States Geological Survey (USGS). The data are from sites where WSC and USGS routinely operate hydrometric stations on year round or seasonal (March-October) schedules.

The data consist of continuous stage (water level), and discharge (volume rate of flow) record. The discharge data are computed from the stage record using stage discharge relationships derived from physical measurements of discharge. At most of the sites referred to in this report, the stage is recorded on a continuous strip chart (or digital punch tape in the U.S.). Water levels are sensed by a float located in a stilling well or by a servomanometer pressure-sensing gauge.

The chart record is referenced to a manually read staff gauge or wire weight gauge which in turn is referenced to a permanent bench mark. Most bench marks are in turn referenced to a sea level datum.

In the spring runoff period a WSC hydrometric technician visited each of the Canadian stations at intervals of one to three days to obtain measurements of river discharge. In the period of flow recession, the frequency of visits were reduced to weekly. The USGS staff operated on a similar schedule.

Because the melt and breakup occurred quickly, (an average of 2-3 days from start to peak), the usual data collection problems brought about by frozen recorder wells and ice jams were reduced to a minimum. The different response times of the Red River and its smaller tributaries spread the workload and enabled good hydrometric coverage during the breakup phase. The high water from the Red River did not affect the hydrometric stations situated near the mouths of the tributaries until after their own peaks has passed. Tributary discharges during the backwater period were measured frequently and the flows were relatively unaffected by rainfall events.

In general the record collected at the hydrometric stations in this report is of good quality and none of the stations required extended periods of estimation or the use of non-typical methods of computation. This was possible only through the dedicated effort of the field crews, the minimal effects of snow and ice on the stage-discharge relations and the absence of significant rains during the recession period.

The hydrometric stations used in this report were selected to describe the conditions on the Red River, on its major tributaries and on a few small headwater streams. Table 1 lists the peak daily mean discharges and Table 2 lists the flood volumes and peak stages for selected stations. For comparison purposes the data for the 1950 flood are included in the Tables. Appendix 3 contains the hydrographs for the 1979 and 1950 spring periods for the hydrometric stations and gives their locations in terms of latitude and longitude.

Daily values of discharge (or water level) for these and other stations have been published in the annual Water Survey of Canada publication "Surface Water Data, 1979 Manitoba" and the annual USGS Water Data Reports for North Dakota and Minnesota. The WSC publication, "Sediment Data for Canadian Rivers", for this flood period has also been published. The USGS flood report "Flood of April-May 1979 in the Red River of the North Basin; North Dakota and Minnesota" by Ericson, Holmen, and Latkovich is also available.

2.2.2 Flood Delineation Methods

In addition to the conventional data collected by WSC and USGS, both the Federal and Provincial Governments in Canada were most interested in delineation of the flood at maximum extent on suitable maps scales. Their interest was twofold: (1) to provide definition of flood damage in order to assess subsequent compensation claims from an independent source; and (2) to provide good imagery of the 1979 flood for follow-up hydrologic studies.

Conventionally such imagery consists of good-quality, high-level aerial photography, either in colour or black and white, and this can be supplemented by multi-spectral imagery from aircraft or satellites. Both of these methods, however, require cloud-free weather conditions and for the period, April 26 to May 11, 1979, the Red River Valley was continuously blanketed by heavy cloud. The alternative was to use radar sensors, which penetrate cloud cover.

Airborne radar sorties were flown on May 6 to obtain SLAR (Side-Looking Airborne Radar) imagery (Figure 5) and on May 12 to obtain SAR (Synthetic Aperture Radar) imagery. The May 6 sortie was flown by the Atmospheric Environment Service's Ice Reconnaisance aircraft brought in from the Atlantic coast; the May 12 sortie was flown by the CCRS (Canada Centre for Remote Sensing) aircraft under the direction of the Manitoba Water Resources Branch and the Manitoba Remote Sensing Centre

FIGURE 5

MOSAIC OF MAY 6,1979 RED RIVER VALLEY FLOOD DELINEATION USING SLAR

(MRSC). Clear weather after May 12 permitted conventional photographic coverage.

It should be noted that the map of the 1979 flood shown in this report as Figure 1 is based on the SLAR imagery obtained on May 6. Unfortunately, the high demand for the SLAR aircraft in the period April 20 to May 12 prevented multiple flights to delineate the progression of the flood northward.

TABLE 1

PEAK DISCHARGES 1979 AND 1950

HYDROMETRIC STATION	DRAINAGE AREA	1979 PEAK DAILY DISCHARGE		1950 PEAK DAILY DISCHARGE	
	km^2	date	m^3/s	date	m^3/s
RED RIVER NEAR LOCKPORT	287000	MAY 08	2780	--	--
STURGEON CREEK AT ST. JAMES	572	APR 24	63.2	--	--
ASSINIBOINE RIVER AT HEADINGLEY	153000	APR 24	270	MAY 16	281
ASSINIBOINE RIVER NEAR PORTAGE LA PRAIRIE	152000	APR 25	326	--	--
ASSINIBOINE RIVER DIVERSION NEAR PORTAGE LA PRAIRIE	--	APR 30	353	--	--
ASSINIBOINE RIVER NEAR HOLLAND	152000	APR 24	546		
SOURIS RIVER AT WAWANESA	60300	APR 27 MAY 26	103 181	MAY 11	107
ASSINIBOINE RIVER AT/NEAR BRANDON	85700	APR 27	314	APR 23 JUL 16	142 157
RED RIVER NEAR ST. NORBERT	124000	MAY 07	1310	--	--
RED RIVER FLOODWAY NEAR ST. NORBERT	--	MAY 09	1190	--	--
SEINE RIVER DIVERSION NEAR ST. ADOLPHE	--	APR 19	133	--	--
SEINE RIVER NEAR PRAIRIE GROVE	1090	APR 20	56.4	APR 21 MAY 07	53.8 80.4
LA SALLE RIVER AT SANFORD	1900	APR 26	119	--	--
RAT RIVER NEAR OTTERBURNE	1350	APR 20	42.3	MAY 06	166
RED RIVER NEAR STE. AGATHE	117000	MAY 04	2320	MAY 15-18	2550 EST.
BOYNE RIVER NEAR CARMAN	976	APR 23	119	--	--
ROSEISLE CREEK NEAR ROSEISLE	212	APR 21	34.0	--	--
HESPELER FLOODWAY NEAR ROSENFELD		APR 20	288	--	--
DEADHORSE CREEK AT MORDEN	136	APR 19	33.5	--	--
PLUM RIVER NEAR ROSENFELD	782	APR 20	197	--	--
BUFFALO LAKE CHANNEL NEAR ALTONA	448	APR 20	127	--	--
RIVIERE AUX MARAIS NEAR CHRISTIE	138	APR 19	36.4	--	--
ROSEAU RIVER NEAR DOMINION CITY	5150	MAY 13	103	MAY 06	230
SPRAGUE CREEK NEAR SPRAGUE	355	APR 22	26.5	MAY 11	36.8
RED RIVER AT EMERSON	104000	MAY 01	2620	APR 30 MAY 13	2070 2670
PEMBINA RIVER AT NECHE	8470	APR 21	263	APR 20	218
PEMBINA RIVER NEAR WINDYGATES	7510	APR 22 MAY 02	129 152	--	--
RED RIVER OF THE NORTH AT GRAND FORKS, N.D.	78000	APR 23	2290	MAY 12 APR 25	1530 1220
RED LAKE RIVER AT CROOKSTON, MN.	13700	APR 26 APR 20	600 581	MAY 07	756
SHEYENNE RIVER AT WEST FARGO, N.D.	23000	APR 21	98.5	MAY 22	79.5
RED RIVER OF THE NORTH AT FARGO, N.D.	17600	APR 19	487	MAY 12 APR 07	185 217
WILD RICE RIVER NEAR ABERCROMBIE, N.D.	5390	APR 15	167	APR 04 MAY 10	62.0 51.3

NOTE 1: THE NOTATION OF 2 PEAK VALUES INDICATES THAT THERE WERE 2 QUITE SEPARATE AND DISTINCT PEAKS.

NOTE 2: TRIBUTARY STREAMS ARE INDENTED FROM THE MAIN STEM RIVER.

TABLE 2

PEAK STAGE AND FLOOD VOLUMES - 1979 and 1950

HYDROMETRIC STATION	PEAK DAILY STAGE (m) 1979	1950	DATUM
Red River at James Ave. Pumping Station	5.837 227.599	9.236 230.999	City of Winnipeg G.S.C.
Red River Below Floodway Control Structure	229.431	-	G.S.C. 1974
Red River Above Floodway Control Structure	233.151	-	G.S.C. 1974
Red River near Ste. Agathe	235.626	235.671	G.S.C. 1953 (1928)
Morris River near Rosenort	6.740	-	Gauge Datum
Red River at Emerson	241.151	241.042	G.S.C. 1953 (1928)
Red River of the North at Grand Forks, N.D.	252.109	251.164	U.S.C.&G. 1929

	FLOOD VOLUME* (10^5 dam^3) 1979	1950
Red River Floodway near St. Norbert	29.0	-
Assiniboine River Diversion near Portage La Prairie	6.5	-
Seine River Diversion near St. Adolphe	0.6	-
Plum River near Rosenfeld	1.0	-
Red River at Emerson	62.0	92.0
Red River of the North at Grand Forks, N.D.	39.0	54.0
Red River of the North at Fargo, N.D.	8.2	6.4

NOTE * Flood volume is different from runoff volume, see Figure 8 for the distinction

3.0 ANALYSIS OF THE 1979 FLOOD

3.1 Comparison of the 1979 and 1950 Red River Floods

A scan of Table 1 shows a similarity in the 1979 and 1950 peak flows except in three areas. Firstly, the Assiniboine River upstream of the Portage Diversion, i.e. at Brandon, was considerably higher in 1979 than in 1950. However, the 1979 flows in the Assiniboine and Souris basins were well below the all time highs of the past 60 years. Secondly, flows in the American portion of the Red River basin were much higher than in 1950 and were generally equal to or greater than the all time highs of the last 50 or so years. Thirdly, Roseau River and the Rat River were considerably lower in 1979 than in 1950.

The Red River tributaries between Emerson and St. Norbert did not have hydrometric stations until the 1960's. Their peak flows of 1979 can, however, be compared to the more recent floods of 1970 and 1974. The 1979 peaks exceeded, or were very near to, the peaks of 1970 or 1974.

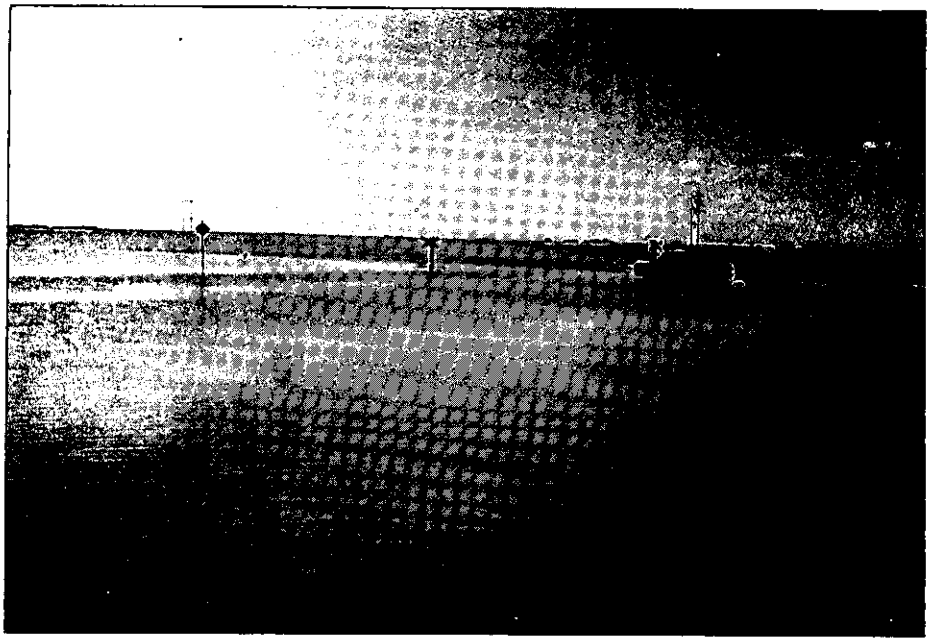
The comparisons of flow volumes for the Red River stations in Table 2 shows that although the peaks in 1979 and 1950 were similar, the 1950 flow carried much more water. This is clearly illustrated in the flow hydrographs shown in Appendix 3. The 1950 flood had two similar but separate peaks, the first composed largely of snowmelt and the second a rainfall peak approximately two weeks later, superimposed on the receding flows of the snowmelt. In 1979, the rainfall coincided with the snowmelt so that a single peak was generated on the larger rivers. Appendix 2 shows graphical comparisons of spring temperatures and precipitation data for the two years at selected stations in the Red River Basin.

As shown in Figure 1, the aerial extent of flooding by the Red River in 1979 was remarkably similar to the 1950 flooding except for the area north and west of the Red River at Ste. Agathe to the La Salle River. This area was flooded in 1950 but not in 1979. The reasons for

FLOODED LAND

Hespeler Floodway - Plum Coulee area April 20

West of Morris looking southwest early May



this are not clear but it is felt that the 1950 flooding was due to local runoff and in 1979 the local runoff had drained before the flood was delineated. The 1979 imagery (Figure 5) was obtained May 6 when the peak of the Red River was in the Morris area. The 1950 delineation was taken from R.H. Clark's 1950 flood report. It was presumably obtained from aerial photographs taken May 18-20 when the peak was in Winnipeg. Although Clark (1950) shows the Ste. Agathe-La Salle area to be inundated, the Carillon News 1950 Flood Report, published in Steinbach, Manitoba, contains a map which depicts this area as dry land.

3.2 The Water Budget

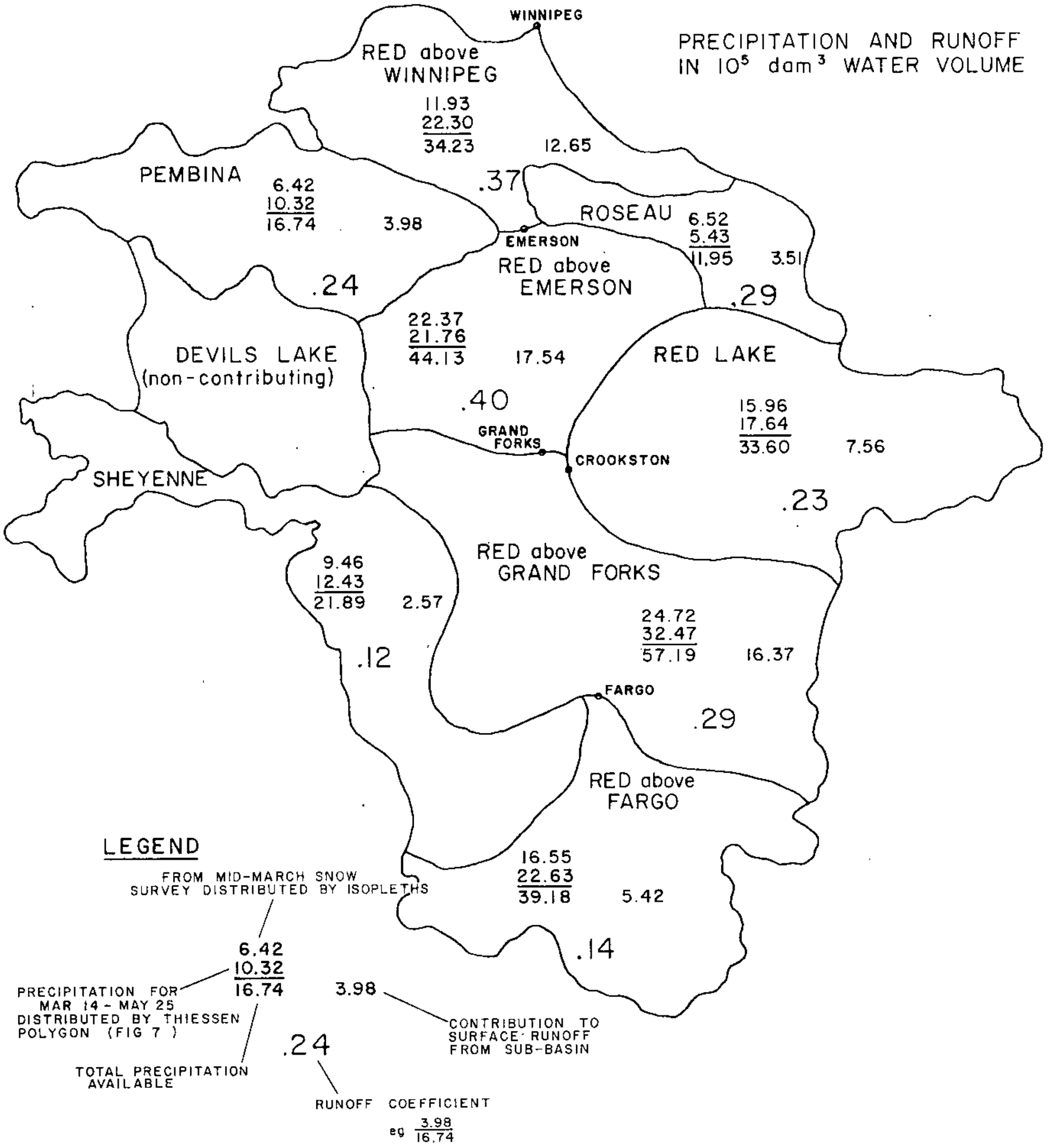
This section examines the water budget of the 1979 spring flood in the Red River basin by relating the river discharges to the snow available for melting and the spring rainfall amounts. A rather simplistic water balance calculation was made for eight sub-basins within the basin (Figure 6). These divisions are dictated by the location of the stream gauging stations. They are as follows:

Roseau River sub-basin above Dominion City
Pembina River sub-basin above Neche
Red Lake River sub-basin above Crookston
Sheyenne River sub-basin above West Fargo
Red River sub-basin above Winnipeg (and below Emerson)
Red River sub-basin above Emerson (and below Grand Forks)
Red River sub-basin above Grand Forks (and below Fargo)
Red River sub-basin above Fargo

The basin inputs were considered to be the snow water content of the snow surveys conducted on March 12 and 13, both in Canada and the United States and the precipitation (rain and snow) for the period March 14 to May 25 inclusive. The basin outputs or yields were the river discharges. Because of the cool temperatures and generally cloudy skies, evaporation was considered to be relatively insignificant.

FIGURE 6

WATER BUDGET DATA BY SUB-BASINS



For the calculation of the spatial distribution of snow water content, the point values were plotted from the results of the mid-March snow surveys and isopleths of equal water content were drawn. Areas of equal water content were then computed; multiplication of area by the respective water content depths provided water volumes available for runoff for each sub-basin. These volumes of water available in the mid-March snow pack in each sub-basin are shown on Figure 6.

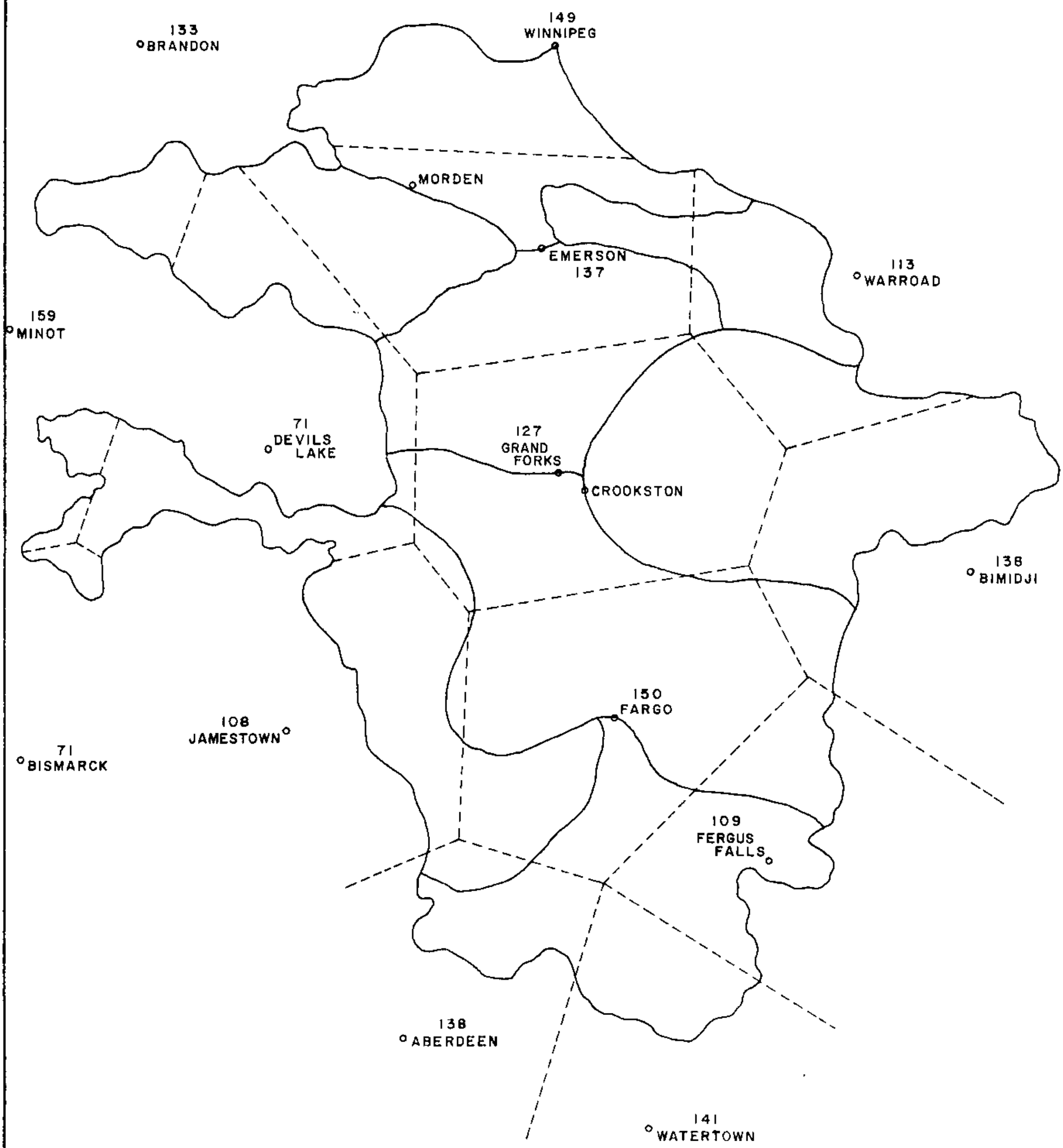
For the period March 14 to May 25, precipitation data was plotted on a sketch map (Figure 7), for Brandon, Minot, Winnipeg, Emerson, Warroad, Devil's Lake, Grand Forks, Bimidji, Bismarck, Jamestown, Fargo, Fergus Falls, Aberdeen and Watertown. Also shown on Figure 7 are the Thiessen polygons devised to distribute the point values areally. The calculated sub-basin volumes of post snow survey precipitation are also shown in Figure 6.

These two calculations represent water inputs into the Red River basin for the period antecedent to the runoff and during the spring flood and the totals are shown in Figure 6 as the Total Precipitation Available.

The basin yields were computed as runoff volumes for the eight discharge stations by hydrograph analysis. An example, Figure 8, for Red River at Emerson illustrates the distinction between the runoff volume employed here and the flood volume described in other sections. The flood volume is the total net input to the stream from all sources related to the flood event, the runoff volume is that portion of the flood volume that is from the surface runoff or quickflow sources. The area under each hydrograph taken as runoff was integrated to arrive at the volume of the sub-basins' runoff. Subtraction of upstream runoff volumes permitted the calculation of output water volumes for the sub-basin. Inputs to the sub-basins had been calculated as earlier described and thus permitted the calculation of Runoff Coefficients (surface runoff/precipitation) as shown in Figure 6.

FIGURE 7

PRECIPITATION IN mm FOR PERIOD MARCH 14 TO MAY 25

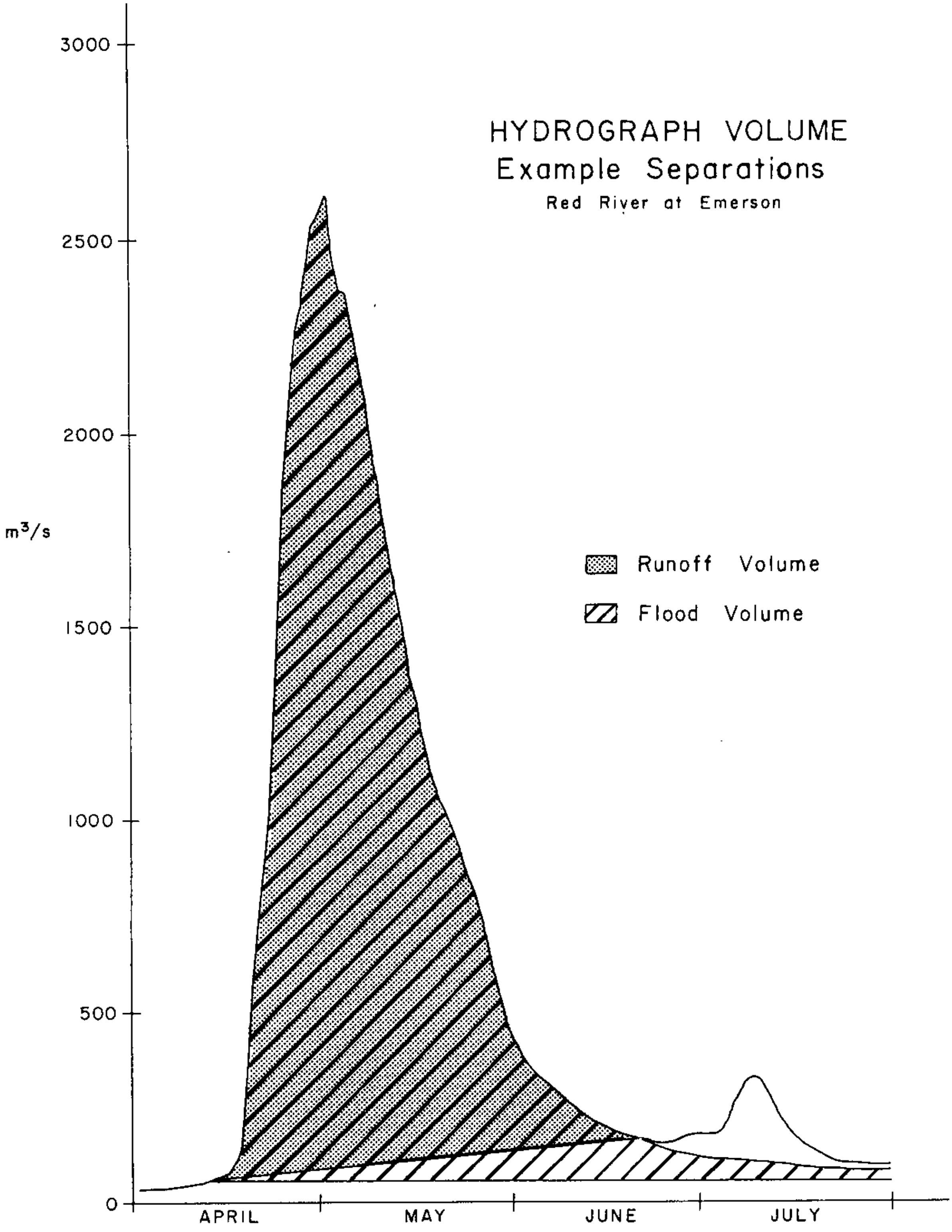


One aspect of the 1979 spring flood which deserves some discussion is the distribution of the precipitation input values. In the data presented the precipitation record is divided at mid-March. Of the eight sub-basins examined, ony the Roseau and Emerson sub-basins showed greater volumes of snow water prior to March 14 than water volumes input in the period March 14 - May 25. For example, in the Red River above Fargo sub-basin the snow water equivalent at mid-March was 16.55 x 10^5 dam^3. Thus the spring precipitation was greater than the winter's accumulated snowfall for six sub-basins. Much of the precipitation in the latter period must still have been snow but the weather records do not permit easy separation of precipitation events into snowfall or rainfall.

The differences in runoff coefficients for the sub-basins suggest that some correlation with terrain characteristics of individual sub-basins exists. The runoff coefficients may be separated into two-areas - the western portion of the basin in North and South Dakota, and the northern and eastern sub-basins in Minnesota and Manitoba. This generalization immediately points out the anomalously low value obtained in the Red Lake River basin in Minnesota. This can be explained by examination of change in storage in Red Lake. Data obtained from U.S. Corps of Engineers indicates a change in storage in Red Lake from April 10 to June 10 of 5.37 x 10^5 dam^3. This is just less than 7.56 x 10^5 dam^3 of runoff measured at Crookston in the same period. If these two values are added and considered as runoff, the runoff coefficient for Red Lake basin becomes 0.38, almost identical to the runoff coefficients derived from the two sub-basins between Grand Forks and Winnipeg on the main stem of the Red River.

The Roseau sub-basin, just to the north of the one previously discussed also shows a low runoff coefficient. In this case, the suspected reason is natural storage. Topographic maps of the sub-basin indicate that more than half of it is in swamp or marsh. Examination of the hydrograph for Roseau River near Dominion City (Appendix 3)

FIGURE 8



HYDROGRAPH VOLUME
Example Separations
Red River at Emerson

corroborates this opinion - its general shape is that of a system with extensive storage capacity.

In the two most southerly headwater sub-basins, man-made storage effects are known to have affected the basin outflow. For example, Lake Ashtabula (Bald Hill Dam) of the Sheyene showed a change in storage from April 10 to June 10 of 0.41 x 10^5 dam^3, approximately 15% of the tabulated runoff. Above Fargo, controlled storage structures at Wheaton, S.D., and on the Ottertail River in Minnesota are believed to have had significant effect on the runoff at Fargo.

When summarizing this water budget analysis, it could be stated that well over half of the water available did not become runoff and that both man-made and natural storage in the Red River above Winnipeg descreased the magnitude of the 1979 flood. These topics are further discussed in the two subsequent subsections.

3.3 The Diversions, Reservoirs and Natural Flows

3.3.1 The Red River Floodway

The floodway, which was in operation from April 20 to May 28, carried a total of 29 x 10^5 dam^3 of water around the city of Winnipeg from St. Norbert to Lockport. This represents just under one-half of the water that entered the province at Emerson via the Red River. At the peak, 1190 m^3/s of the total 2500 m^3/s went through the floodway. A discharge of 2500 m^3/s through Winnipeg would have produced a stage at the James Avenue pumping station, near downtown Winnipeg, of 8.25 m, or 2.5 m higher than that which actually occurred in 1979. This estimate does not include any inflow from the Assiniboine River.

3.3.2 The Assiniboine River Diversion

The Assiniboine River Diversion at Portage La Prairie was in operation from April 21 to June 14. It diverted 6.5 x 10^5 dam^3 from the Assiniboine River into Lake Manitoba. This represents approximately one-quarter of the Assiniboine River's 1979 flood hydrograph. Without the diversion the peak daily flow at Portage La Prairie would have been in the order of 450 m^3/s instead of the 331 m^3/s maximum daily discharge which was actually recorded.

3.3.3 The Shellmouth Reservoir

Although there are many reservoirs in Manitoba, only the Shellmouth Reservoir on the Assiniboine River near the Saskatchewan boundary is capable of storing enough flood water to have a significant effect on the main stem river discharges. From the start of runoff in mid-April to the first of June when the reservoir peaked, the level in the reservoir rose 7.2 m and 3.6 x 10^5 dam^3 of water was stored for release during the remainder of the year. This represents an average of 85 m^3/s going into storage during the one and a half months. On May 2, with a peak inflow of 270 m^3/s, all but 14 m^3/s went into storage.

3.3.4 The Red Lake Dam

There are also many reservoirs in the United States portion of the basin; the largest, by an order of magnitude, is controlled by the Red Lake Dam located at the outlet of Minnesota's Red Lakes. Although the reservoir level rose slightly less than 0.5 m from mid-April to its peak at the end of May it stored 5.7 x 10^5 dam^3 of water. In the same period the Red Lake River, which drains the Red Lake and a total of 13700 km^2, discharged 7.6 x 10^5 dam^3 into the Red River at Grand Forks - a significant portion of the 55 x 10^5 dam^3 of the flood volume recorded at Emerson.

3.3.5 Natural Flows

By adding the diverted flows and the stored volumes to the measured flow volumes, and mathematically routing these synthetic natural flows through the river system to account for the natural effects of lag and overbank storage, it is possible to estimate what the Red River's flow and level would have been in Winnipeg if the reservoirs and diversions had not been built. The Water Resources Branch of the Manitoba government estimated a natural discharge at the James Avenue site of 3000 m^3/s with a corresponding stage of 9.20 m. The 1950 peak daily was 2930 m^3/s at 9.236 m. Without the protective works, the Red River Floodway being the most important, the flooding in Winnipeg in 1979 could have been as bad as that which occurred in 1950.

The estimated natural discharge for 1979 does not consider any of the storage reservoirs in the United States, the largest being behind the Red Lake Dam previously mentioned. The volume of water that it stored represents 10 percent of the flood volume that the Red River carried into Manitoba at Emerson. The holding back of this much water by the natural attenuating effect of Red Lake, and the additional effect of the control dam at its outlet, may have caused a reduction in Red River discharges and levels downstream in Manitoba. However, without a complete routing analysis the degree of flood reduction can not be estimated.

The other aspect of natural flow computation is the effect of man's activities on the drainage behaviour of the watershed. Hydrologically, the most significant aspect of man's activity on the Lake Agassiz plain within the Red River basin has been the construction of numerous drains, especially in the western half of the basin within Manitoba. Morton (1957, p. 206) describes the inception of the Red River drainage schemes:

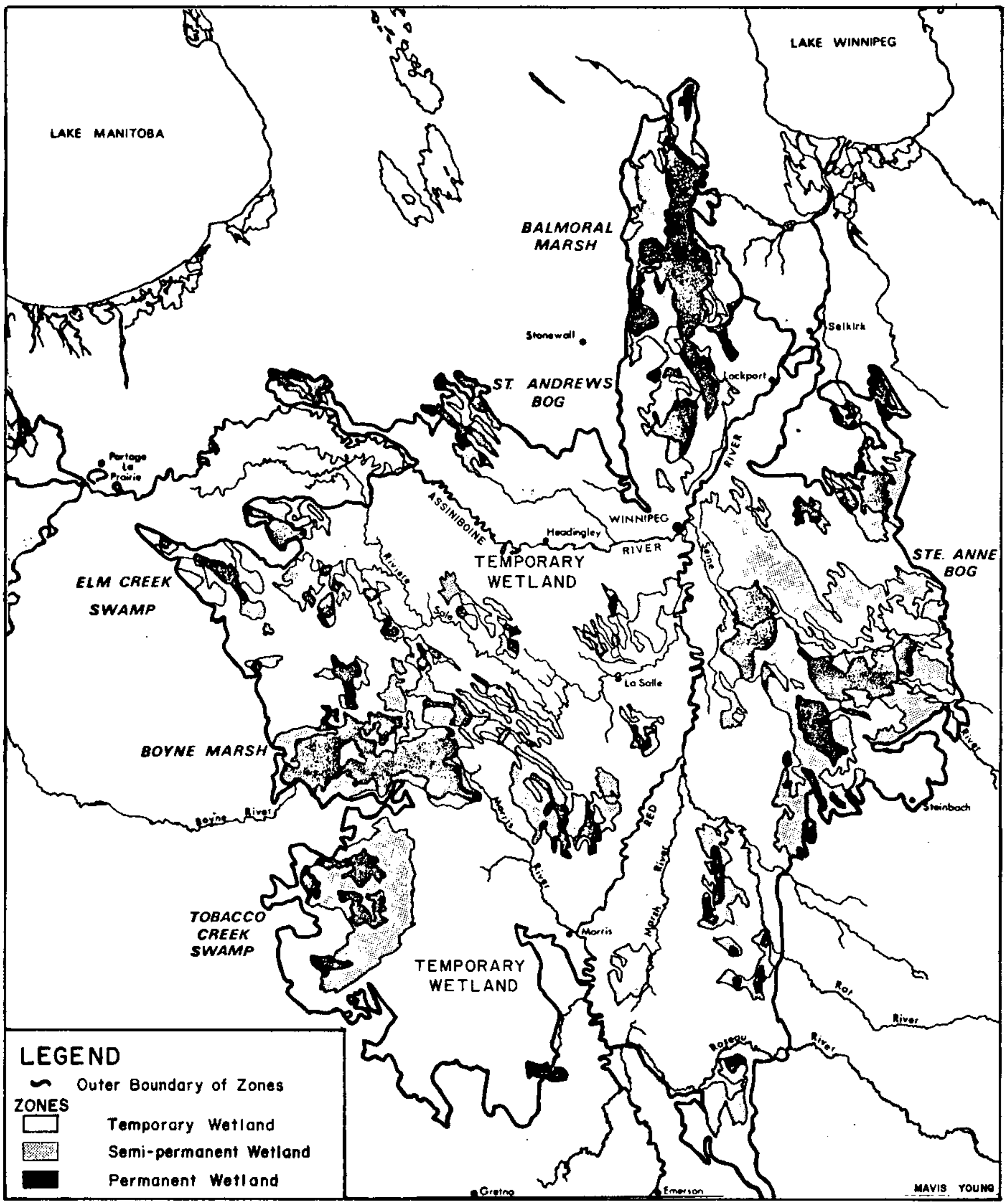
> ".....the great marshes, particularly that of the Boyne, checked the occupation of the valley lands but in 1881 the provincial government, spurred on by the wet seasons and the grant of swamp lands by the federal government, began a series of drainage schemes, the greatest of which was the Norquay Dyke to empty the Boyne marsh".

The historical floods of the 19th century occurred in natural conditions which are illustrated in Figure 9. It can be inferred that under these natural conditions, distinctly different from the present conditions, the flows which were in excess of channel capacities would go into fairly long-term retention storage in the numerous bogs and swamps. The snowmelt would likewise be retained before entering channels. The way in which melt water is routed into the main stem of the Red River has changed. Today this water transport must take much less time since a straight, clean drainage ditch is a much more efficient channel than the inadequate drainage systems of the natural state.

There is much controversy about the effect of drainage works on floods in general. While it is known that channel straightening and the drainage of wet lands increases the flood peak on the smaller watersheds by causing the water to drain off faster, the net effect over a large basin has not been conclusively demonstrated. It does appear, however, that with the drainage works making the hydrographs of their sub-basins higher, sharper, and of greater volume, that the timing of the entire basin's runoff becomes important. During the 1979 flood, with the snowmelt occurring at more or less the same time over the entire basin, (this will be documented in the following subsection), the rivers in Manitoba with extensive drainage works, notably the Plum River, were well into recession when the Red River peaked in Manitoba. The undrained rivers, notably the Roseau, were still at high flows when the Red River peaked. This can be seen by examining the hydrographs in Figure 4 or by comparing the hydrographs for the Plum River, the Roseau River and the Red River at Emerson in Appendix 3.

FIGURE 9

ORIGINAL WET PRAIRIE ZONES OF THE RED RIVER VALLEY



The hydraulically efficient drains permitted the escape of the tributary flood waters before the arrival of high water from the United States, thus preventing synchronous flood flows. On the Plum River near St. Jean for example, a peak flow in excess of 450 m^3/s (40% of channel capacity of the Red River at St. Jean) was measured* in the morning of April 20, but the peak of the Red River did not get to St. Jean until over a week later.

In comparison, the Roseau River, which still contains natural wet lands and has a larger drainage area than the Plum River, peaked at a much smaller flow (103 m^3/s) but on a much later May 13 when the Red River was higher. At Morris, the peak flow on the Morris River (approximately 170 m^3/s) occurred on April 25, but the peak occurred on the Red River near Morris a week and a half later. If the Manitoba tributaries had still been in their natural state with meandering channels and extensive wet lands, the peak of the Red River in 1979 would likely have been higher, even allowing for the increased storage of the wet lands, because of the timing of the peak flows.

If melt progressed more slowly from south to north and other antecedent conditions for a flood existed, it is entirely conceivable that local tributary runoff peaks would coincide with the arrival of the peak of the southern flood waters. If the tributary is of the natural slow-response type similar to the Roseau River where the flows in 1979 were within 80% of the peak value for three weeks, the coincidence or lack of it is of little consequence. If, however, the tributary peaks are very sharp, as the peaks of the improved basins are, the coincidence is of consequence. For example, although the Plum River is less than 2% of the Red River's drainage area the sharpness of its hydrograph meant that if its peak was coincident with the Red River's it would increase the flow of the Red River at Ste. Agathe by 5% and the level by approximately 0.1 m.

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* measurement by Manitoba Water Resources Branch

The information and analyses in this section has clearly demonstrated that the reservoirs and diversions had a significant effect in reducing the flooding, especially in Winnipeg. It also appears that in 1979 the numerous drains in the Manitoba section of the basin reduced the peak of the Red River by draining away the local runoff before the main-stem flood wave arrived. However, in some years drains which increase their sub-basin's peak discharge, can increase the main steam peaks. Indeed, given that the Red River flows north and its tributaries flow east or west into it, it is possible that a large flood out of proportion to the total snowmelt input could be created if the melt progressed northward at the same rate as the main stem peak moved north down the Red River.

3.4 Investigation of Flood Causes

The generally accepted climatological reasons for flooding on the Red River were summarized by Clark (1950, p. 14). They are as follows:

1. A very wet autumn.
2. Very severe and continued frost before the first snowfall, sealing up the marshes, lakes and saturated ground.
3. Heavy snowfall during the latter part of the winter.
4. A late and sudden spring.
5. Above normal rainfall during the breakup, over the entire drainage basin.

His research concludes that all of these conditions were found to be present in 1826, 1861 and 1950. As previously stated, they were not all present for the flood of 1979.

Let us consider the cited reasons for a Red River flood point by point as they relate to the 1979 flooding. (For a more complete analysis of the meteorological conditions refer to Appendix 1.)

3.4.1 A Wet Autumn

The period of October and early November was exceptionally mild and sunny. Precipitation values for the Red River basin were extracted from the weather record and are as follows:

Precipitation in Millimetres

	October		Nov. 1-15	
	Actual	Normal	Actual	Normal
Fargo	3.3	27.4	22.6	11.3
Grand Forks	6.9	22.2	9.4	9.9
Emerson	8.2	30.7	-	-
Winnipeg	10.2	34.9	25.5	13.4

Examination of these data show conclusively that the autumn in the Red River Valley certainly was not wet - in fact, precipitation during October was 30% of the long term normal.

3.4.2 Severe, Prolonged Frost Before First Snowfall

The weather record shows that the fall of 1978, before the first snowfall, was exceptionally warm and sunny. Thus, from AES Weekly Weather Summary, 1978 10 16, ..."Temperatures generally averaged from normal to four degrees (C) above normal during the second week of October...". On Nov. 3, the record states, ..."November 2 was the warmest on record over an area from Alberta to the Great Lakes...". On

November 8, ..."In Manitoba and Saskatchewan, after a record-breaking warm day for November 7...". This pattern was dramatically broken when a severe, early-winter storm tracked farther north than expected. The weather report dated November 14, 1978 states, "A storm moving across the north central United States spread a thick blanket of snow over the Canadian Prairies. It was the first snow of the season over southeastern Manitoba and at Winnipeg snowfall measured 18.6 cm...". This antecedent condition is exactly opposite to one that contributes to a major flood.

3.4.3 Heavy Snowfall During the Latter Part of the Winter

Examination of the mid-March snow survey data illustrates a marked dichotomy for snow water contents within the basin. Thus, unusually high snow-water contents are noted in southeastern Manitoba and northeastern Minnesota, above average values in the Fargo-Sheyenne basins and average to below average values in southwestern Manitoba and western North Dakota. The data on the precipitation for the four centres previously listed are as follows:

Precipitation (mm) - March 1 - April 16, 1979

	Actual	Percent of Normal
Fargo	98.3	211%
Grand Forks	65.5	157%
Emerson (Pembina)	89.2	226%
Winnipeg	79.3	192%

From these values it can be inferred that the pre-condition of heavy snowfall was fulfilled.

3.4.4 A Late and Sudden Spring

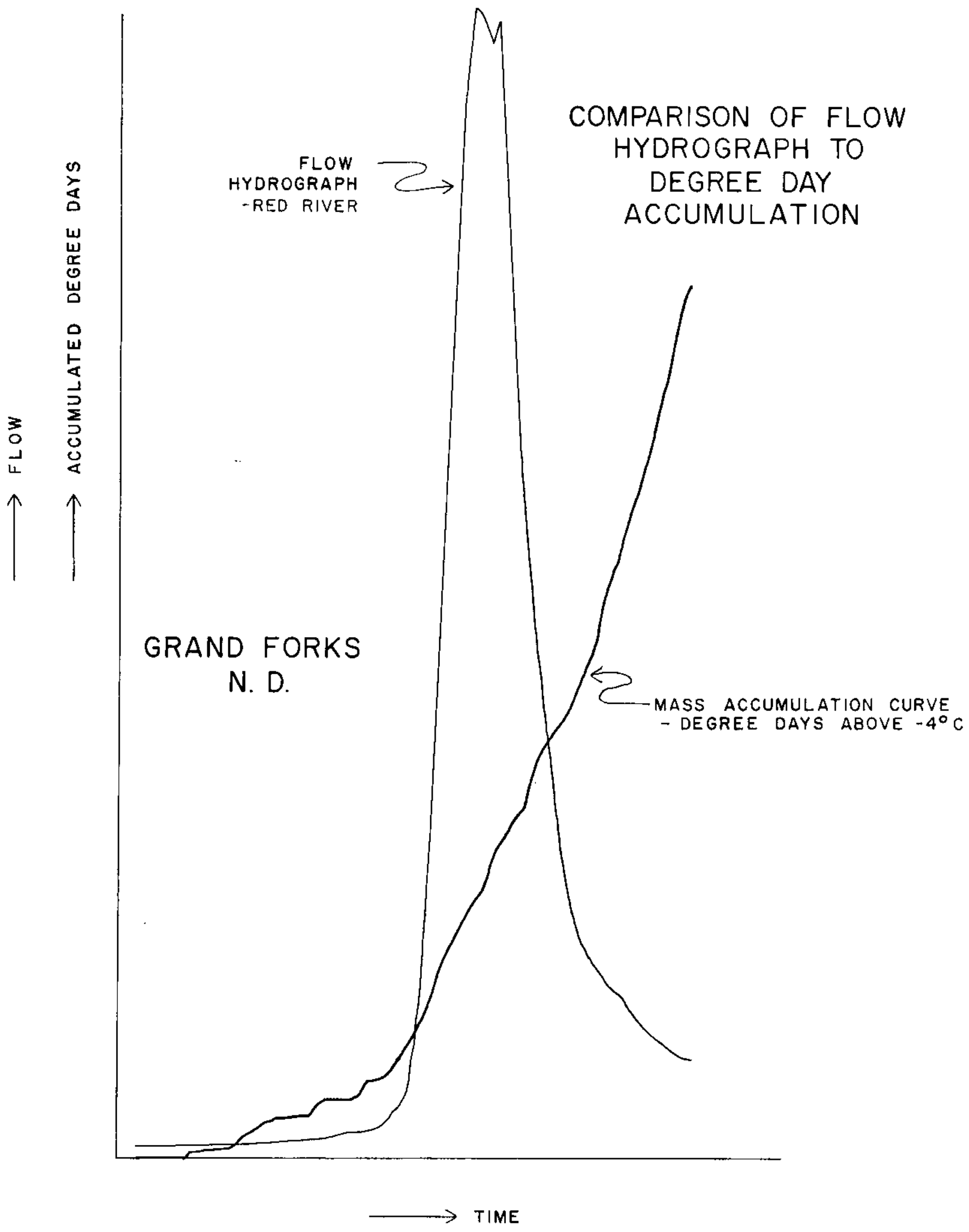
As there is no standard hydrologic definition of "spring" nor statistics regarding its normal timing, the analyses in this sub-section were required to be quite extensive.

To establish whether the spring of 1979 was late or not, first of all requires the establishment of when spring normally occurs. This could be done by examination of climatic data, e.g. the comparison of the degree day accumulations for a variety of years as in the later portion of this sub-section. However, our ultimate interest is in the spring rise of the rivers so the examination of the hydrometric record will be the primary analysis. The results of the hydrometric analysis should resemble the results of a climatic analysis as the two are related. Examination of Figure 10 suggests that the beginning of the sharp rise of a discharge hydrograph is coincident with the sharp rise of the degree day single mass curve and should therefore be coincident with the sharply increased snowmelt of "spring".

For the Red River at Emerson for the period of record 1913-1979 the mean date for "spring" as defined by the beginning of the sharp rise of the flow hydrograph is March 28. (The standard error of the estimate is ±1 day and the standard deviation is 9.4 days.) For 1979 the date identified was April 15 and was in fact, the latest spring breakup at Emerson from 1913 to 1979. Its statistical location is 1.71 standard deviations away from the mean, with about 9% probability of occurrence.

A more objective treatment examined the flow record for Pembina River at Neche from 1919 to 1979 and calculated the mean and standard deviation for three points of the spring rise for each of the years (Figure 11). The initial point was the first day that the mean daily flow was five times the February mean flow (for that year). The second point was at fifty times February's flow. (In years with zero flow in February, initial flow was generally substantial and was taken as the

FIGURE 10



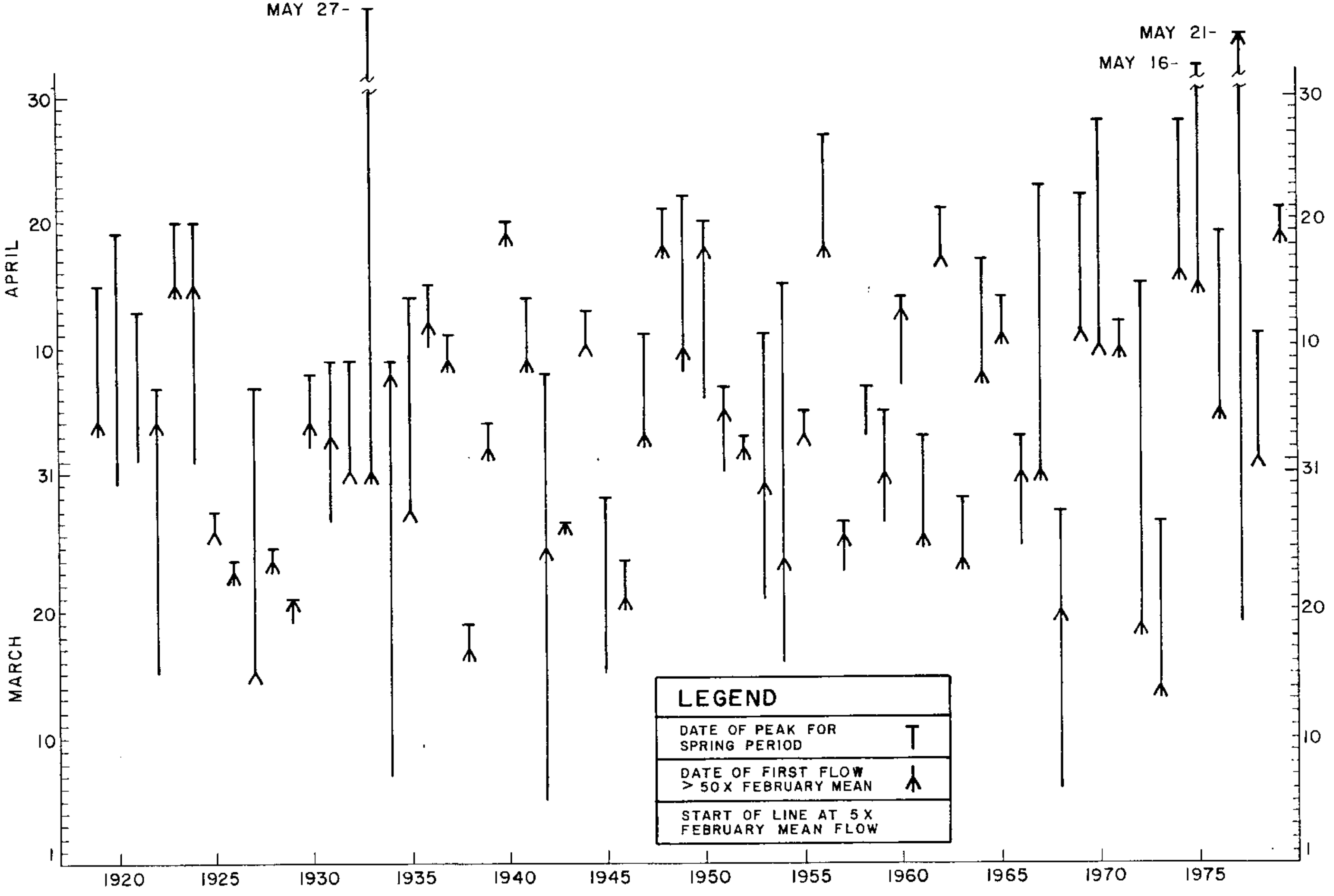
COMPARISON OF FLOW HYDROGRAPH TO DEGREE DAY ACCUMULATION first point; the second point was taken at ten times the first.) The third point was the date of the spring peak discharge. These three points gave (with standard deviations ranging from 11 to 13 days) mean dates of "spring" of March 30, April 5, or April 12 respectively. (The distribution was approximately normal with a slight skew to the right.) In the period of record, there was not a rise later than the rise of 1979, on April 18-19. By the normal distribution, there is only a 5% to 10% chance of any year being later, depending upon the choice of the first or second point being "spring".

These two analyses have demonstrated that based upon the rise in the hydrograph on two rivers, the spring of 1979 was late. It was approximately two and one-half weeks later than normal.

The suddenness of the spring of 1979 can be examined from two viewpoints. The first is the suddenness at a particular site as indicated by the rapidity of a hydrograph rise and the second is the spatial distribution of the onset of the runoff over the entire basin as indicated by the difference in the date of the peak for various rivers across the basin.

By using the data from the previous sample (Pembina River at Neche) and the interval in days between point one and point two as an indicator of the"suddenness" of spring, the sample provides a mean spread of 5.1 days, but in over one-half of the data the second point occurred on the same day or the next day as point one. This was the case in 1979 and the rate of rise, although quick, is then not unusual.

The suddenness of the snowmelt and runoff can be seen in the series of Photographs 7-10. The snow on the field in the background almost entirely disappeared between the 18th and the 20th of April and by the 22nd all but the larger drifts had melted.



DATE OF HYDROGRAPH RISE FOR PEMBINA RIVER AT NECHE 1919 TO 1979

FIGURE 11

In the second viewpoint of a sudden spring, that of the spatial distribution of the initiation of flow, a marked dissimilarity is noted in data from 1950 and that of 1979. This can be shown by comparing the dates for hydrograph rise of mainstream and tributary stations in the Red River basin for the two years or the dates of peak discharges in Table 1.

It can be seen that initiation of snowmelt from south to north was much more coincident in 1979 than it was in 1950. In 1950 Wild Rice River near Abercrombie peaked April 4 and Seine River near Prairie Grove peaked April 21, a spread of 17 days. In 1979 the dates were April 15 and April 20, a spread of only 5 days. The near coincidence of the melt through out the entire basin in 1979 as opposed to the more normal progression of the melt northwards can exert a powerful influence on the magnitude of flooding in the Red River Valley.

The lateness and suddenness of the spring of 1979 has been determined by the foregoing analysis of the hydrometric record. As was suggested previously it can also be examined from the viewpoint of the climatic data or more specifically by examining the degree day accumulations for a few selected years.

The station selected for the degree day analysis was Emerson, Manitoba. It was decided to examine temperature accumulations at Emerson for the flood years 1950 and 1979 as well as for four years in which average flows occurred. These are shown in Figure 12. The calculated degree days are above a base of -4°C. While at first glance these data appear to be rather inconclusive, closer examination reveal some interesting facts about how these single mass curves develop. For the years 1950, 1956 and 1979, the shape of the curve can be approximated by two lines. This effect is more clearly illustrated in Figure 10 in the data for Grand Forks. A similar condition was found for the Winnipeg data. For the Emerson data, the break in the slope occurs approximately at the 30 degree days level of accumulation. The time period in which accumulation to 30 degree days occurs is considered to be a priming

DEGREE DAY ACCUMULATIONS
FOR
EMERSON, MANITOBA

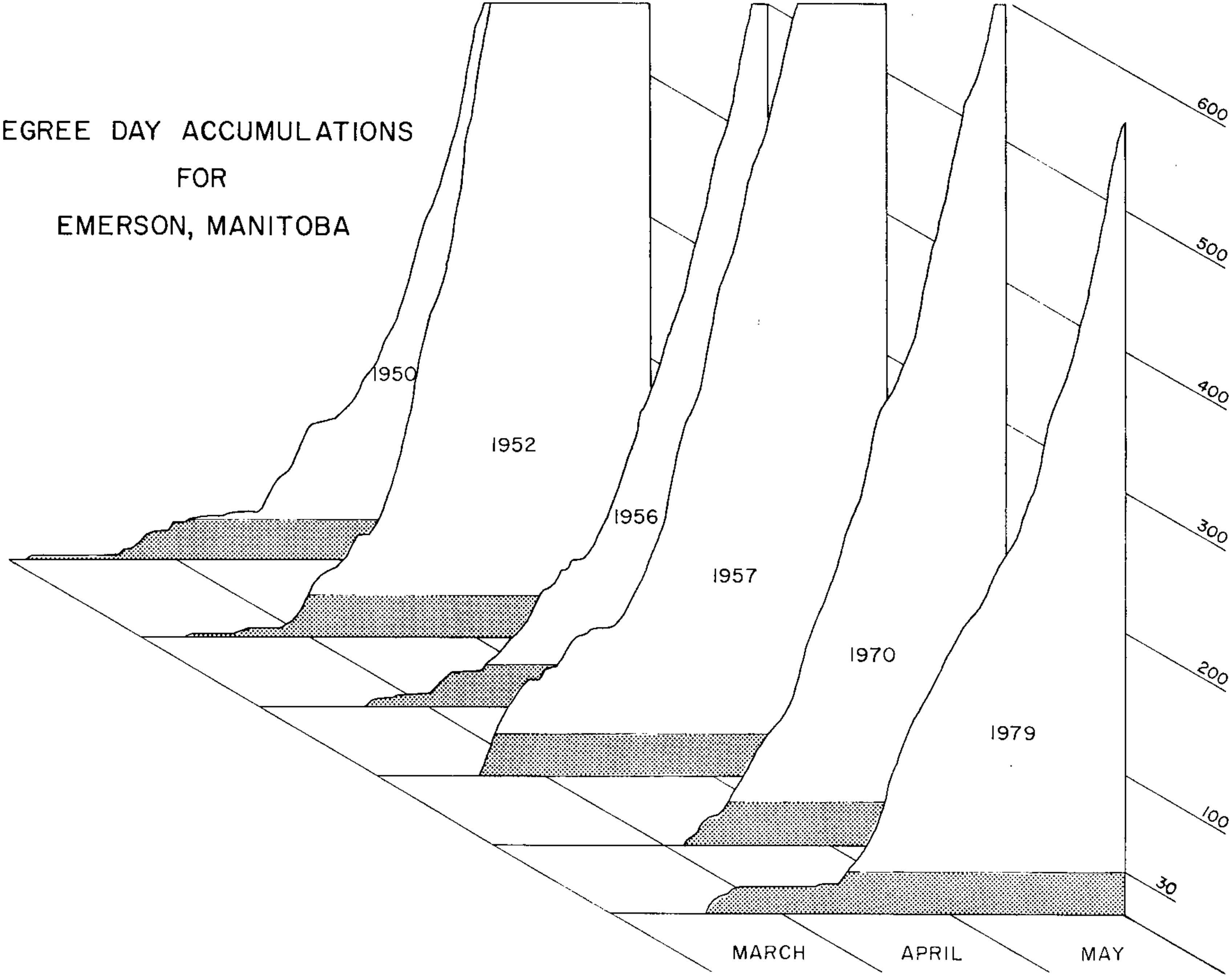


FIGURE 12

period, a period in which the snow pack becomes ripened and ready to melt but no significant runoff occurs. It then follows that when 30 degree days are exceeded a rise in flow is experienced. For the years of data shown in Figure 12 the date of the 30 degree days level and the date that the spring hydrograph began to rise are as follows:

	From Fig. 8 30 Degree Day Level	From Flow Data Start of Sharp Hydrograph Rise
1950	April 2	April 4
1952	March 30	April 1
1956	April 11	April 12
1957	March 22	March 23
1970	April 12	April 8
1979	April 12	April 14

This rather small sample suggests that an energy constant of 30 degree days as calculated for this analysis is consistent with initiation of spring runoff at Emerson.

In both of the flood years, slow, gradual accumulation of energy occurred prior to the actual snowmelt. Antecedent priming of this nature which produces a homogeneous snow pack is conducive to a rapid transformation of snow to water once the 30 degree days is exceeded. These conditions which existed in 1950 and 1979, produce a sudden spring in the hydrologic sense.

This rather long subsection has demonstrated that the fourth of Clark's five causes of flooding, "a late and sudden spring" did occur in 1979. It was one of the latest if not the latest spring in terms of initial hydrograph rise and that rise was quite fast and progressed quickly from the south to the north of the basin. It appears that a sudden spring, as defined by rapid accumulation of degree days is conducive to flood production when preceded by 30 degree days (above a base of -4°C) of priming.

3.4.5 Above Normal Rainfall During Breakup

The effects of excessive rainfall during the breakup were highly significant in both 1979 and 1950. For Winnipeg, Emerson and Fargo the data for the period of March 15 - May 22 are as follows:

	1950		1979	
Fargo	167	(N/A)	142	(78)
Emerson (Pembina)	108	(34)*	122	(60)
Winnipeg	135	(55)	132	(76)

* The values in brackets are the AES long term (up to that year) averages for the period.

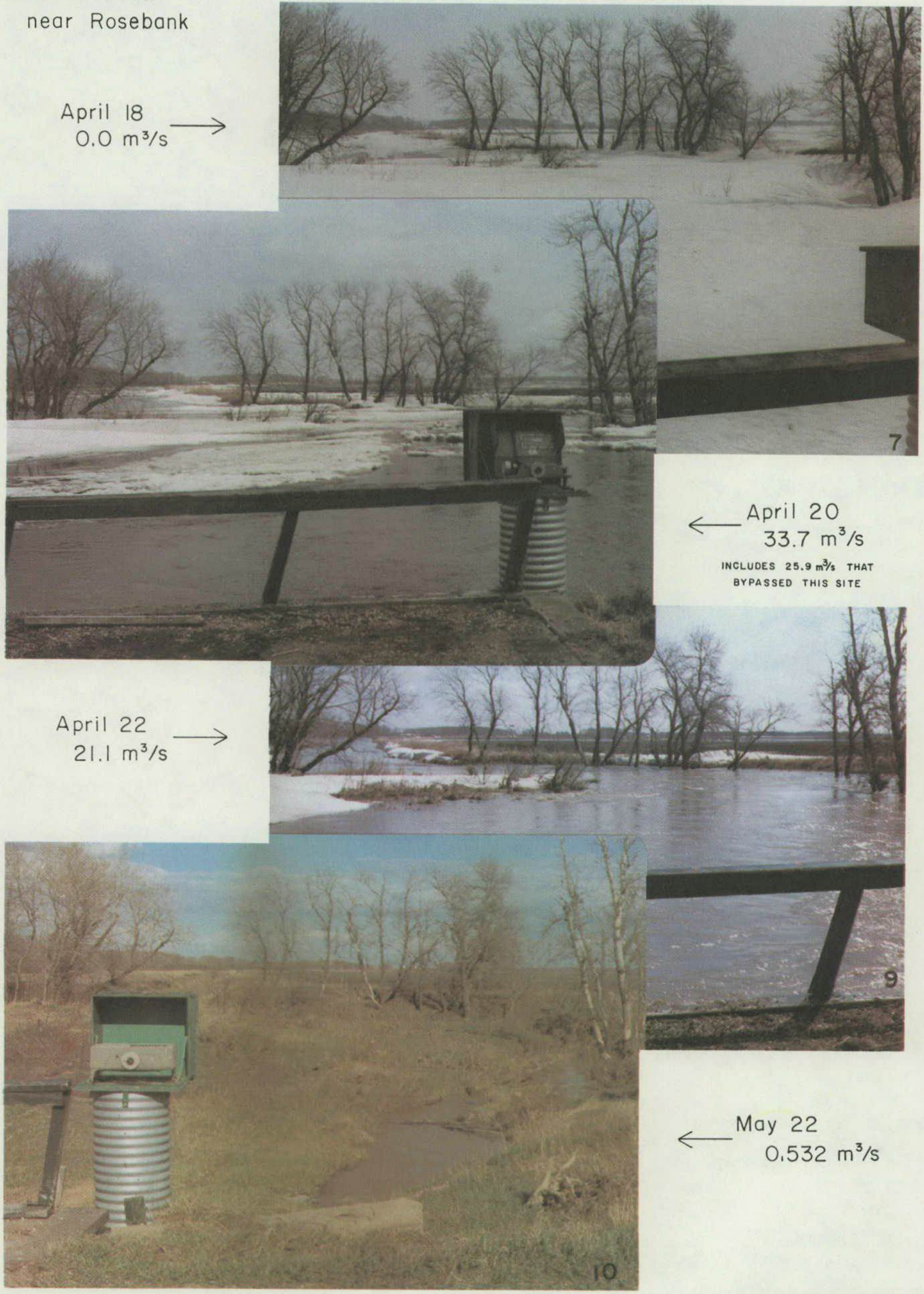
If these data are compared to the normal values shown in 1979, it can be seen that precipitation over the entire basin was roughly two times the normal values in both years.

In summary, some fairly important distinctions can be made between the flood of 1950 and 1979 based on the five causitive conditions discussed. They were all present in 1950 and Ross indicates that they were also all present in 1826 and 1852. Only three were met in 1979: a heavy snowfall; a late and sudden spring; and above normal rainfall in the spring.

PHOTOGRAPHS 7 - 10

PROGRESSION OF RUNOFF 1979

Tobacco Creek
near Rosebank



April 18
0.0 m³/s

April 20
33.7 m³/s
INCLUDES 25.9 m³/s THAT
BYPASSED THIS SITE

April 22
21.1 m³/s

May 22
0.532 m³/s

In 1979 the first two conditions, which in essence describe antecedent moisture conditons, were not present. There is no question that the runoff ratios derived earlier would have been much higher had the antecedent soil-moisture conditions been high. An equally significant difference can simply be derived from the shape of the rising limbs of the hydrographs for 1950 and 1979. In other words, the flood waters in 1979 rose to their maximum values more quickly than in 1950. Two reasons are suggested, the first is the rapid melt synchronous over the entire basin. It is put forward that the second cause is man's activity within the basin affecting the natural flows as discussed previously in Section 3.3.5.

3.5 Flood Frequency

The question asked of a flood after "how big?", is usually, "how rare?" This is answered by assigning a flood frequency to the flow that occurred. Flood frequency is expressed as a probability of the flow being met or exceeded in any one year. It is more often expressed as a return period, or the average number of years between occurrences of that flow rate. Table 3 lists flood frequencies of the 1979 peak for those stations in the Manitoba portion of the basin with peak flow record of at least ten years duration. The selection of the flood frequency distribution, either Gumbel, Log-Normal or the Three Parameter Log-Normal, was made on the basis of the coefficient of skew of the transformed data for each station.

For the 67 years of data for the Red River at Emerson and the 21 years of data at Red River at Ste. Agathe, return periods of 59 and 77 years are indicated. However, the 1950 flood for which a similar return period could be applied, has also occurred in the last 67 years at Emerson and from Figure 3 we see that five floods approximately equal to or greater than the 1979 flood have occurred in the 154 years back to the 1826 flood. Thus a return period of 35 or 30 years would appear to be more reasonable. It would also be in agreement with the frequency assigned to the 1950 flood in the "Report on Investigations into Measures for the Reduction of the Flood Hazard in the Greater Winnipeg Area", (1953).

Except for the Pembina River at Neche, the Boyne River at Carman, Hespeler Floodway near Rosenfeld and the above mentioned Red River stations, the return periods for the 1979 peak flows were calculated at less than 20 years and most of these were, in fact, less than 10 years.

The return periods that these frequency distributions produced should be considered as approximations. Only three of the half dozen or so more commonly used flood frequency distributions were considered, and the selection of which one of these three distributions to use for a site was made on the basis of only the simplest criterion - the coefficient of skew. Also the distributions give unreliable results when the return period generated is much greater than the number of years of record. This would apply, for example, to the return period of 59 years generated for Hespeler Floodway's 1979 peak on the basis of only 12 years of record.

FLOOD FREQUENCY OF 1979 PEAK DAILY FLOWS

HYDROMETRIC STATION	RETURN PERIOD YEARS	DISTRIBUTION USED	YEARS OF RECORD
Red River near Lockport	18	3 Parameter*	18
Sturgeon Creek at St. James	18	Gumbel	18
Assiniboine River at Headingley	2	3 Parameter	67
Assiniboine River near Portage La Prairie	1.4	3 Parameter	27
Assiniboine River near Holland	5	Log-Normal	19
Souris River at Wawanesa	8	Log-Normal	67**
Assiniboine River near Brandon	6	Gumbel	74
Seine River near Prairie Grove	10	Gumbel	37
La Salle River at Sanford	10	3 Parameter	21
Rat River near Otterburne	5	Log-Normal	67***
Red River at Ste. Agathe	77	3 Parameter	21
Boyne River near Carman	50	Gumbel	24
Roseisle Creek near Roseisle	9	3 Parameter	15
Hespeler Floodway near Rosenfeld	59	Gumbel	12
Roseau River near Dominion City	7	3 Parameter	40
Sprague Creek near Sprague	4	Gumbel	40
Red River at Emerson	59	Log-Normal	67
Pembina River at Neche	31	Log-Normal	76
Pembina River near Windygates	5	Log-Normal	18

Notes *3 parameter refers to 3 parameter log-normal

**4 peaks estimated to provide 67 unbroken years of record back to 1913

***9 peaks estimated to provide 67 unbroken years of record back to 1913

4.0 SUMMARY

Since the eighteenth century when the first Europeans settled the Red River Valley, the Red River has flooded the surrounding plains many times. On average, large floods of the magnitude of the 1979 flood or greater have occurred every 30 to 35 years. The prominent features of the Red River floods - the large areal extent of flooding (many kilometres wide) and the slow rise and fall of the river - are more a product of geography than climate. Glacial Lake Agassiz created the very flat plain of clay soil that forms much of the basin. This plain provides a wide expanse for the flood water to cover and allows for temporary over bank storage of the flood peak. Also, the clay soil of the plain restricts the formation of river channels to small capacities and is almost impervious to the infiltration of water.

The spring of 1979 was half a month later than usual in arriving and ended a long, cold winter in southern Manitoba. The runoff from the heavy snowpack began on April 18 in the Manitoba portion of the basin, only a week after the snowmelt began in the southern portion. The rapid snowmelt and frequent rainfalls caused severe flooding along the tributaries of the Red River. Within a week the Red River tributaries had peaked at record or near record levels and the intermittent rains continued. Warnings to Manitobans of a Red River peak similar to the flood of 1950 brought the inhabitants of the valley to action. They closed and strengthened the dykes around their homes and towns that had been built in response to earlier floods and then evacuated the area as the waters rose.

The Red River at Emerson peaked May 1, 1979 at 241.151 m and 2620 m^3/s, conditions almost identical to those of the 1950 flood. Although millions of dollars of property damage and flood fighting costs were incurred, the Red River did not inundate any of the major communities as the Red spread to cover 650 km^2 in Manitoba. When the Red River peaked in Winnipeg on May 10 the effect of the Red River

Floodway and the other diversions and reservoirs was to reduce the flooding in Winnipeg to levels which were insignificant in comparison to the catastrophic 1950 flood. The meteorological factors that caused the flood were 1) excessive precipitation of snow before the flood and of rain during the flood and 2) a sudden thaw or snowmelt. A cold winter allowed for the continual accumulation of snowfall until the melt began in April. Once the snowmelt began, the heavy rainfalls, in particular the event of April 23-24, added to the river flows to produce a single high peak on the Red River. If there had been heavy fall rains and a deep frost before the accumulation of the winter's snow, the runoff coefficients, which ranged from 0.12 to 0.40, would have been higher and the flood greater.

This report contains a number of items that are worthy of continued interest.

The degree day accumulation analysis has indicated that snowmelt runoff is initiated when 30 degree (above a -4°C base) days have accumulated. The data from the small sample in this analysis also suggests that a flood-producing melt occurs when the 30 degree days is accumulated slowly over many days. The sample size is too small however to demonstrate this conclusively. By a variety of methods the lateness and suddenness of the spring of 1979 was documented as being one of the latest ever with the runoff rising not unusually quickly but with little lag throughout the basin from south to north. What was not investigated was the relationship between a late and sudden spring and flooding. A sudden snowmelt contributes to flooding because there is less time for the water to move into the soil by infiltration or into the air by evaporation but is a late spring a contributor to flooding? If so, is it because it allows for more snow accumulation or does a late spring warm up faster or does it have more rainfall?

This report has presented some information on the effects of drainage works on the flooding but as was discussed in the Red River Basin Investigation Report of 1953 the net effect is complicated. It is known that, in general, agricultural drains remove more water from the land faster than natural systems with swamps and winding channels. However, in some years this may reduce flooding by draining off heavy late fall rains that would otherwise saturate the soil. The sharp spring hydrographs of the sub-basins with drains increase high floods if their peaks are coincident with main stem peaks or with each other. The sharp peaks can also work as they did in 1979 to reduce the Red River flooding by draining away the local flows before the main stem peak arrives. The effects of drains on runoff timing should be quantified because the timing of tributary inflows could be a significant factor in the production of floods. If the drains do have an effect on flooding they are a contributor over which man has control and also their effect must be accounted for when comparing floods from an earlier more natural time to recent floods.

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APPENDICES

APPENDIX 1

METEOROLOGICAL CONDITIONS

November 1978 to May 1979

Provided by

H.M. Hacksley

Atmospheric Environment Service
Central Region

METEOROLOGICAL CONDITIONS

I Weather Conditions Preceding the Flood - The Winter of 1978-79

Winter arrived over the Red River Basin when cold Arctic air plunged southward over southern Manitoba, November 10th and into the northern United States on the 11th. In Winnipeg maximum temperatures tumbled from over 11 degrees* on the 8th to only -3 on the 10th. In Fargo highs plummeted from 19 on the 8th to -4 on the 11th. The first significant snowfall occurred only a few days later as 18.2 cm fell in Winnipeg on the 12th and 13th creating near blizzard conditions in areas near the city. The cold continued and on November 20th Winnipeg equalled an all-time record low for that day of -31. November ended with mean temperatures throughout the basin 3 to 4 degrees below normal. Precipitation for the month was above normal in most localities (Table 1).

The Arctic air continued to dominate the basin through December with most stations once again averaging 3 to 4 degrees below normal. Precipitation was quite variable with some localities well above normal, others well below. In many places however, precipitation was close to normal. Winnipeg for example, was only 2 mm above average for December (Table 1)

An Arctic ridge dominated the weather pattern over the basin during January and February. January began very cold. On New Years Day, Pilot Mound set a new minimum temperature record of -37. Milder Pacific air broke through briefly in the third week of January. However, maximum temperatures did not rise above -3 and the Arctic air quickly became re-established over the basin. Precipitation was near or below normal for January.

February was one of the coldest in 40 years over southern Manitoba. The latter half of the month saw a little moderation due to several disturbances which moved across the prairies replacing the bitterly cold Arctic air with milder air from the Pacific. Precipitation

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* Celsius degrees

resulting from these disturbances gave totals for the month near normal over southern Manitoba. South of the border however, February totals were greater than normal, in some cases exceedingly so (Table 1). Most of this precipitation came from a major snowstorm which passed through the area February 21st to 23rd.

The weather pattern in March became more variable. The Red River Basin was affected by a series of disturbances, some moving eastward across the northern States, the remainder moving southeastward from Alberta. As a result of these disturbances precipitation totals were well above normal throughout the basin. Several locations including Fargo, received more than double their normal amounts. Winnipeg's snowfall of 38.1 cm was the greatest amount in March since 1966 and well above the normal of 21.1 cm. Winnipeg also received 8.1 mm of rain, most of which fell as freezing rain on the 19th and 20th.

Precipitation totals for the winter were well above normal in most areas of the basin (Table 2).

Mean temperatures for March were well below normal throughout the basin. However, a weather system moving across Montana did bring mild Pacific air into the area on the 16th. In Winnipeg the temperature rose to +2.4 ending a record breaking period of 127 days in which the mercury had failed to rise above the freezing mark.

II Weather Conditions During the Flood - April and May 1979

April was cool and wet. Throughout the basin temperatures for the month were 3 to 4 degrees below normal values. At Winnipeg it was the seventh consecutive month in which the mean was below normal. This made the winter of 1978-79 the second coldest of the century with an average temperature of -13.8 degrees for the period November 1 to April 30.

Precipitation in April was above normal (Table 3). Once again several localities recorded more than double their normal amounts. Altona, Manitoba more than tripled its normal value with a total of 108 mm.

April began with snow still covering most of the Red River Basin (Figure 2). The pattern aloft at 500 mb still exhibited a winter-like northwesterly flow (Figure 6a). At the surface an Arctic high dominated the area (Figure 6b), producing record breaking low temperatures. The cold spell continued for a week with records of minimums and low maximums being shattered throughout the southern prairies on the 5th.

A southerly flow gradually developed and brought milder air into the Dakotas on the 7th and into southern Manitoba on the 9th (Figure 6c). In this milder air maximum temperatures rose above freezing and never fell below zero again that winter (Figure 5). With the onset of the milder tempertures the snow cover throughout the basin began to melt.

An examination of Table 4 reveals that melt began at most stations between April 7th and 10th with the average date the 9th.* In most cases the melt was fairly rapid, lasting about 10 days (Figure 4). In Winnipeg the beginning of the melt was coincident with the beginning of maximum tempertures above zero on the 9th (Figure 3). The average date for the maximum temperture at Winnipeg to rise above freezing is March 27. This implies that the melt at Winnipeg began about two weeks later than normal.

The upper flow at 500 mb had now become southwesterly (Figure 6d). An intense low pressure system moved northward under this flow giving drizzle, rain and snow to the north central States and the southern prairies (Figure 7a). For April 11 to 14 precipitation totals of over 20 mm were quite general over the basin with totals of over 40 mm being reported at several locations [See Appendix 2].

Note * From the hydrologic viewpoint, i.e. the drainage of liquid water from the snowpack, the melt did not begin until many days later.

On the 17th and 18th of April a complex low pressure system moved northeastward from southern Idaho (Figure 7b). This system brought warm moist unstable air into the Red River Basin. The combination of temperatures in the mid-teens and showers and thundershowers quickly melted most of the snow that still remained in the basin. Precipitation totals of 10 to 20 mm were quite general throughout the area for the period April 17 to 20. However, a few stations received considerably more. Emerson, for example, received over 34 mm.

The Red River broke-up at Winnipeg on the 18th and was free of ice on the 22nd. On the 19th many of its smaller tributaries were in flood and the Red itself was beginning to rise. The weather for the next couple of weeks became critical.

On the 23rd of April a low pressure system moved into the western Dakotas from the southwest. This produced rain and drizzle over the southern half of the basin and on the 24th moved into Manitoba (Figure 7c). This rain had a significant effect upon the flood. By the 25th the system had moved into Northwestern Ontario and the rain and drizzle had changed to snow.

On the 26th a weak low moved southeastward from Saskatchewan giving some light snow and drizzle to the Dakotas. This was followed on the 28th by a low that developed in Montana, and moved eastward (Figure 7d). Varying amounts of rain and light snow fell throughout the basin on the 29th and the morning of the 30th as this system tracked eastward into Minnesota.

Precipitation amounts occurring from the series of disturbances from April 23 to 30 varied across the basin (Table 5). Many locations reported amounts in excess of 40 mm for this period with Thief River Falls, Minnesota the highest with a total of 91.9 mm. Temperatures from the 20th to 30th were generally below to near normal.

At the end of April the flood crest of the Red River has reached Emerson.

May was again cool throughout the basin. The first two weeks were especially cool, the maximum temperature at Winnipeg not rising above 8 degrees until the 12th. During this same time precipitation in southern Manitoba was above normal (Table 6). In Winnipeg at least a trace was recorded every day for the first 12 days of the month.

The first two weeks of May saw a series of disturbances track eastward across the southern prairies and northern States. On May 1 a low pressure system moved across southern Manitoba producing rainshowers ahead of it and snowflurries in its wake (Figure 8a). Cool moist Arctic air moved over the area behind this sytem and for the next few days light snowflurries occurred in many locations. On the 5th, 6th and 7th a complex low pressure system moved eastward south of the border producing widespread drizzle, rain and light snow (Figure 8b).

Snowflurries developed again in the northerly flow of cool air on the 8th. On the 9th a low pressure system moved northeastward into Minnesota giving some precipitation to the southernmost parts of the basin. The rain and snow spread northward into Manitoba on the 10th and 11th as the system moved into Northwestern Ontario (Figure 8c).

By the time a high pressure area moved over the basin on May 13 and 14th, Winnipeg has received 30.1 mm of precipitation since the first of the month, including 8.3 cm of snow, Grand Forks has received 13.5 cm and Fargo 24.1 cm. Similar amounts were recorded elsewhere in the basin.

During this time the flood crest on the Red River had continued to move northward reaching Morris on the 6th, passing St. Adolphe and finally arriving at Winnipeg on the 10th.

The unsettled weather continued in the latter half of May. Temperatures moderated to more seasonable values as disturbances from the Pacific continued moving eastward across the prairies. With the warmer temperatures, no more snowflurries were experienced and the rain became more showery in nature with the occasional thundershower.

III Summary of Significant Factors

From a meteorological point of view, the 1979 flood of the Red River was the result of a combination of several factors: firstly, the long period of intense cold which prevented melting and resulted in a continuous accumulation of winter snowfall; secondly, the heavy snowfalls south of the border in February and the above normal precipitation totals* throughout the basin in March and April; thirdly, below normal temperatures in early April resulting in a late and sudden thaw throughout the basin; and fourthly, the above normal precipitation north of the border the first two weeks in May.

The fact that the melt began at about the same time throughout the basin probably prevented a worse flood in southern Manitoba than actually occurred. Tributaries were able to peak before the crest of the Red River arrived.

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* In particular the rainfall of April 23-24.

FIGURE 1

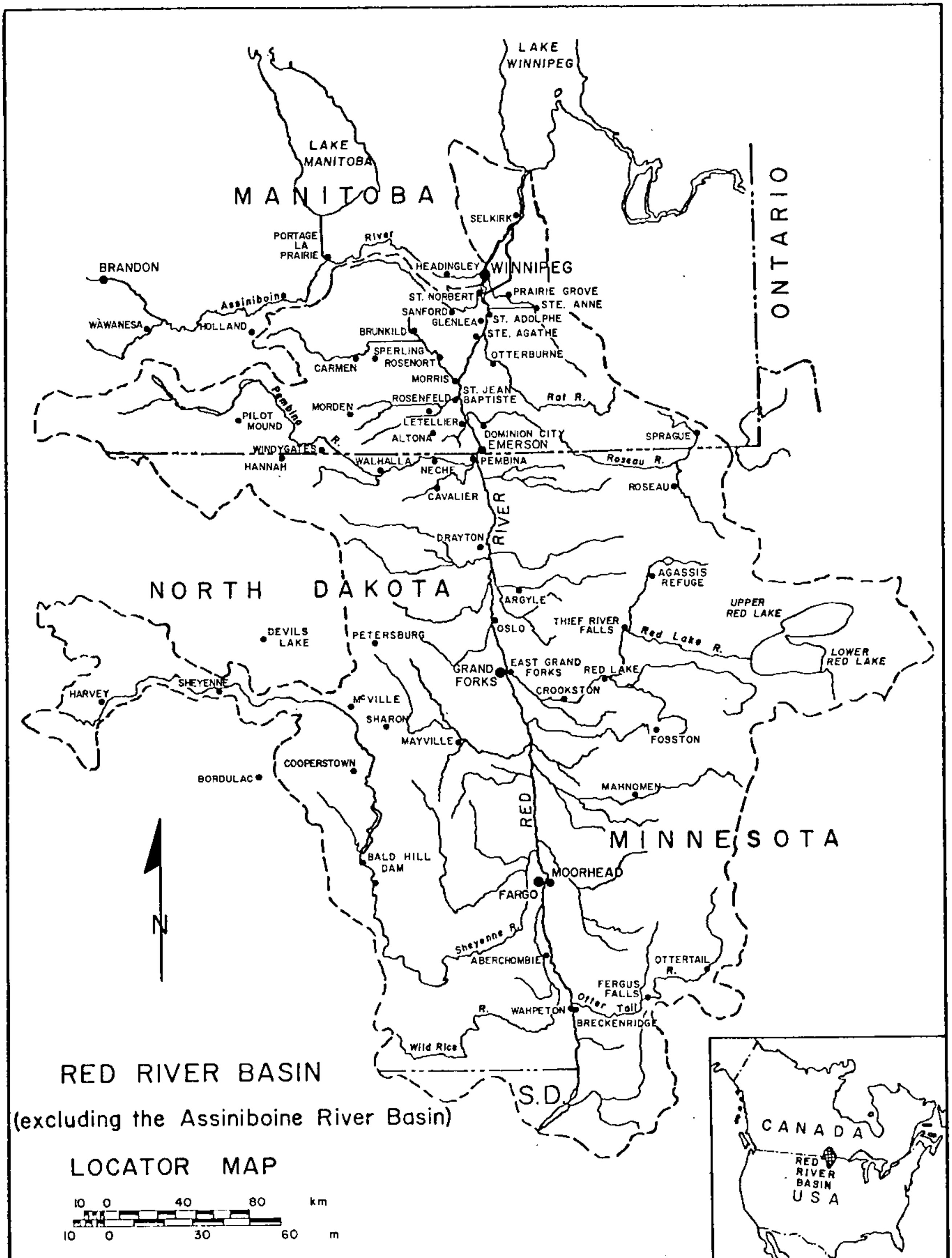
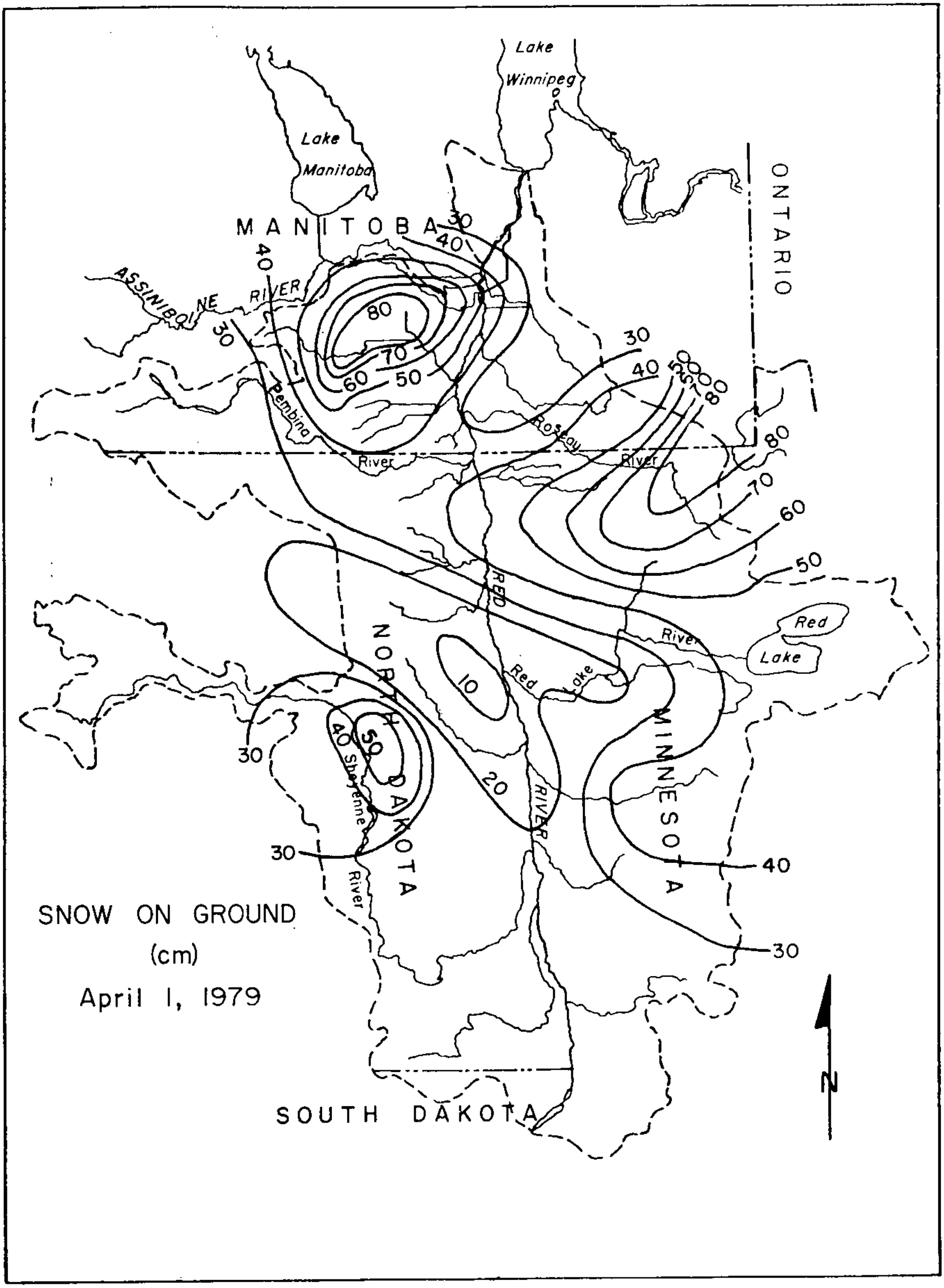

RED RIVER BASIN
(excluding the Assiniboine River Basin)
LOCATOR MAP
10 0 40 80 km
10 0 30 60 m
N
LAKE WINNIPEG
LAKE MANITOBA
MANITOBA
ONTARIO
NORTH DAKOTA
MINNESOTA
S.D.
SELKIRK
PORTAGE LA PRAIRIE
River
BRANDON
Assiniboine
WAWANESA
HOLLAND
HEADINGLEY
WINNIPEG
ST. NORBERT
PRAIRIE GROVE
STE. ANNE
SANFORD
GLENLEA
ST. ADOLPHE
BRUNKILD
STE. AGATHE
SPERLING
ROSENORT
CARMEN
OTTERBURNE
MORRIS
Pembina
MORDEN
ROSENFELD
ST. JEAN BAPTISTE
Rat R.
PILOT MOUND
LETELLIER
ALTONA
DOMINION CITY
EMERSON
SPRAGUE
WINDYGATES
R.
HANNAH
WALHALLA
PEMBINA
Roseau R.
NECHE
ROSEAU
CAVALIER
DRAYTON
RIVER
AGASSIS REFUGE
ARGYLE
UPPER RED LAKE
OSLO
THIEF RIVER FALLS
Red Lake R.
DEVILS LAKE
PETERSBURG
LOWER RED LAKE
GRAND FORKS
EAST GRAND FORKS
RED LAKE
SHEYENNE
HARVEY
CROOKSTON
McVILLE
SHARON
FOSSTON
MAYVILLE
COOPERSTOWN
BORDULAC
MAHNOMEN
RED
BALD HILL DAM
MOORHEAD
FARGO
Sheyenne R.
ABERCROMBIE
OTTERTAIL R.
FERGUS FALLS
Otter Tail
R.
WAHPETON
BRECKENRIDGE
Wild Rice
CANADA
RED RIVER BASIN
USA

FIGURE 2

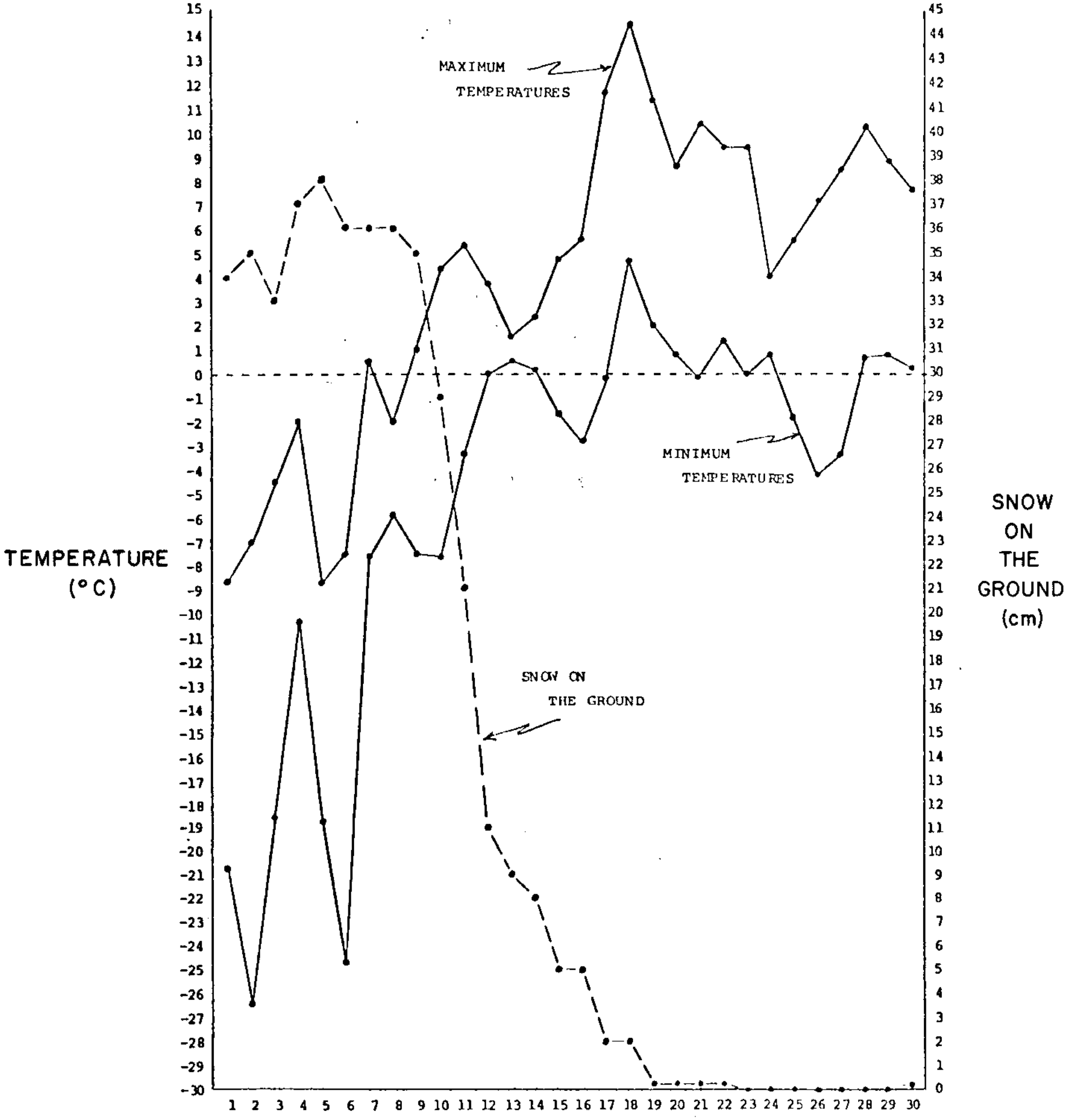


SNOW ON GROUND
(cm)
April 1, 1979

FIGURE 3

DAILY TEMPERATURE RANGE AND SNOW ON THE GROUND

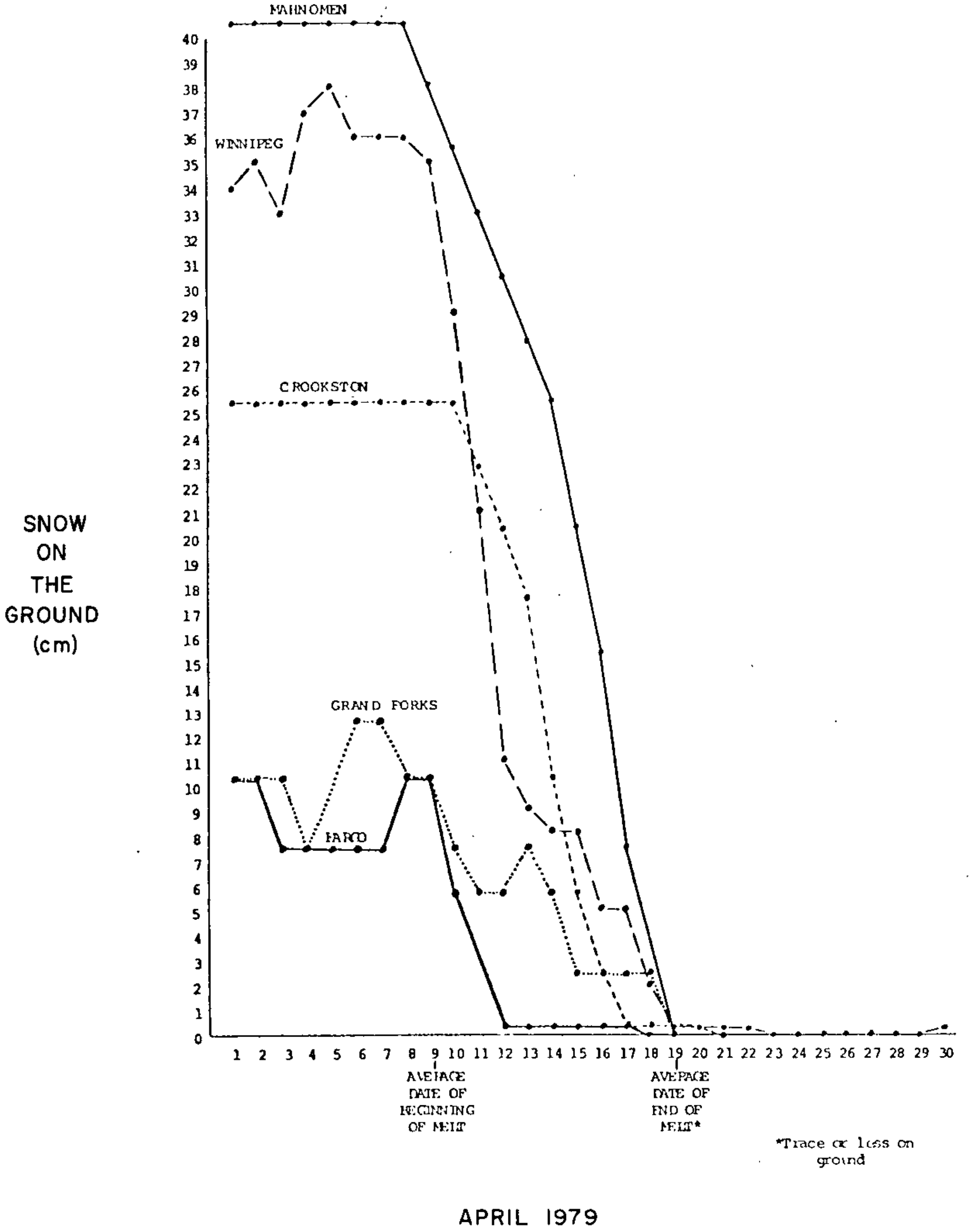
WINNIPEG



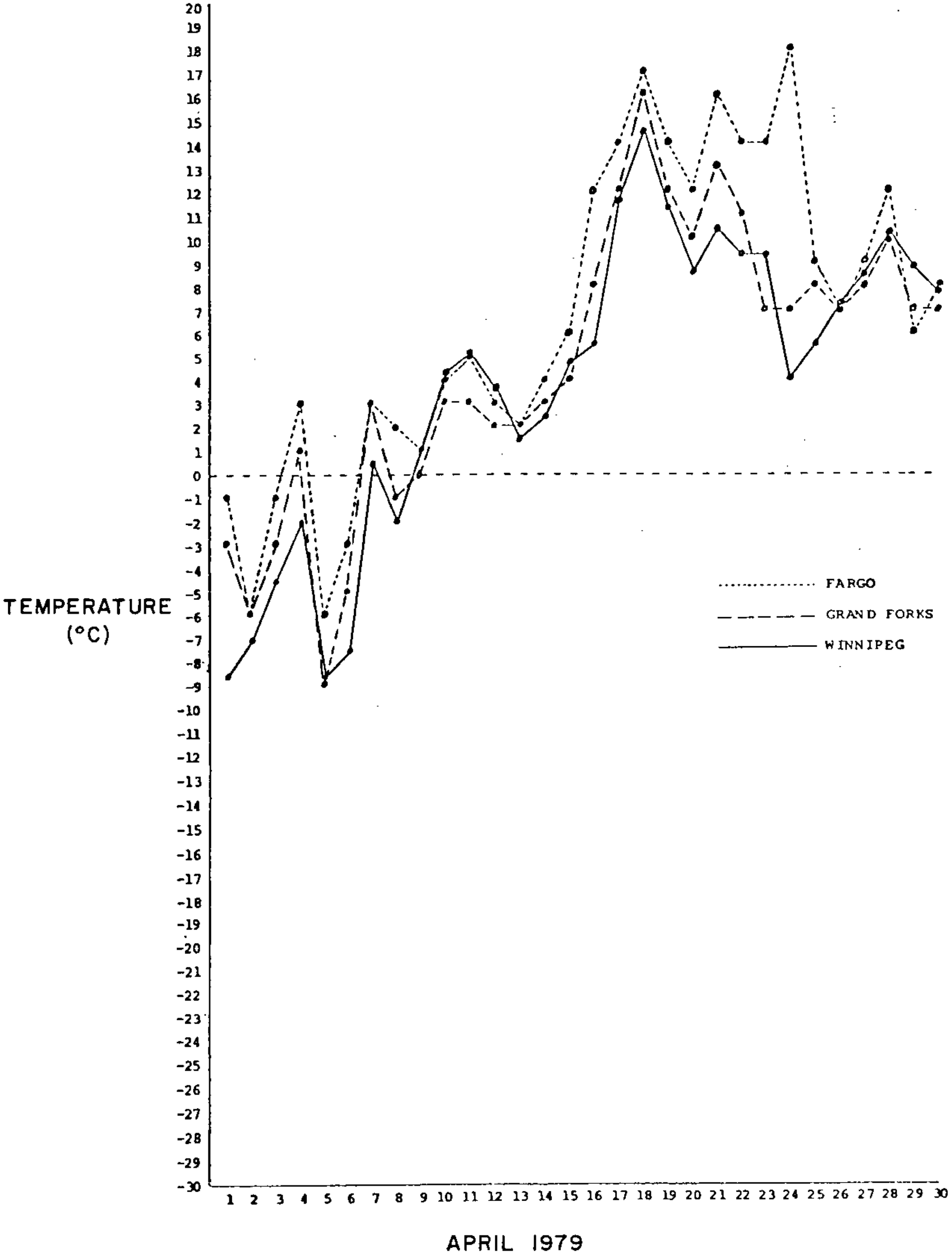
APRIL 1979

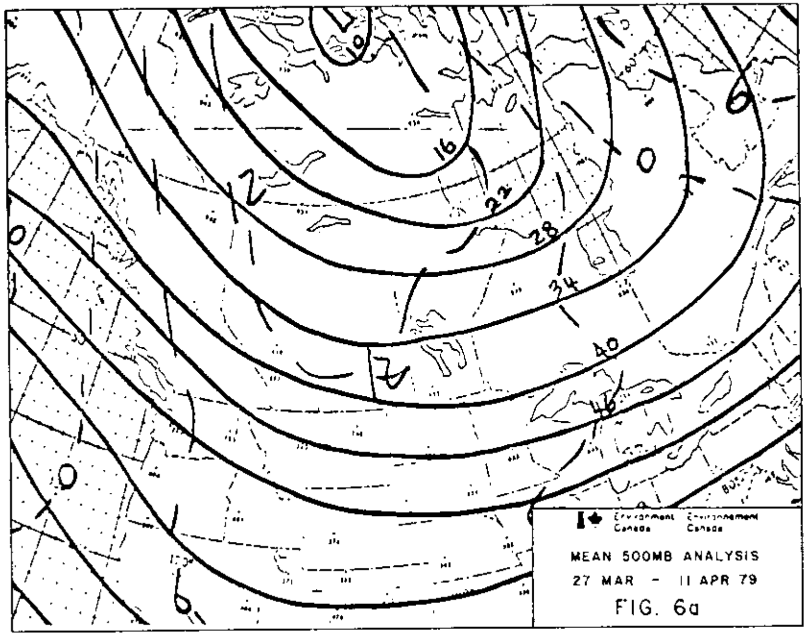
FIGURE 4

SNOW ON THE GROUND APRIL 1979



MAXIMUM TEMPERATURES APRIL 1979



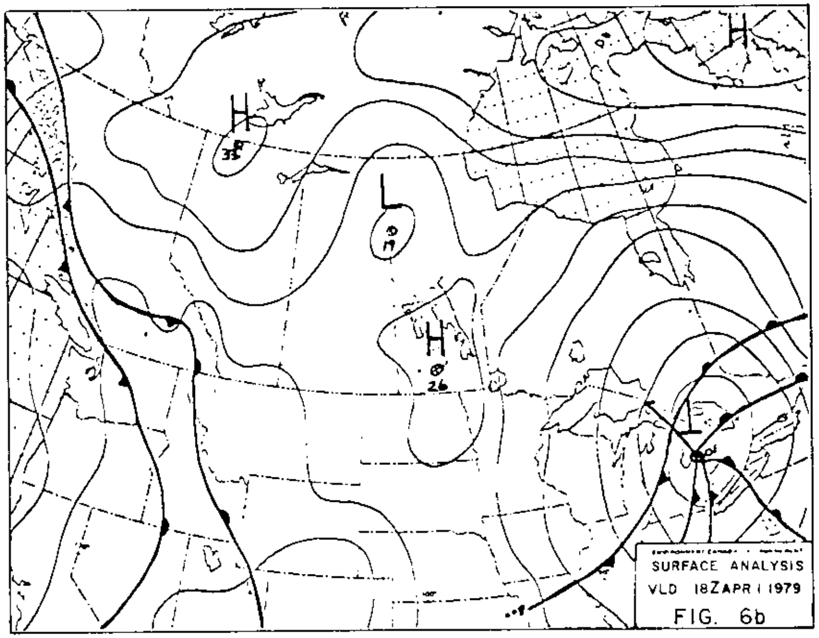


Environment Canada Environnement Canada

MEAN 500MB ANALYSIS

27 MAR - 11 APR 79

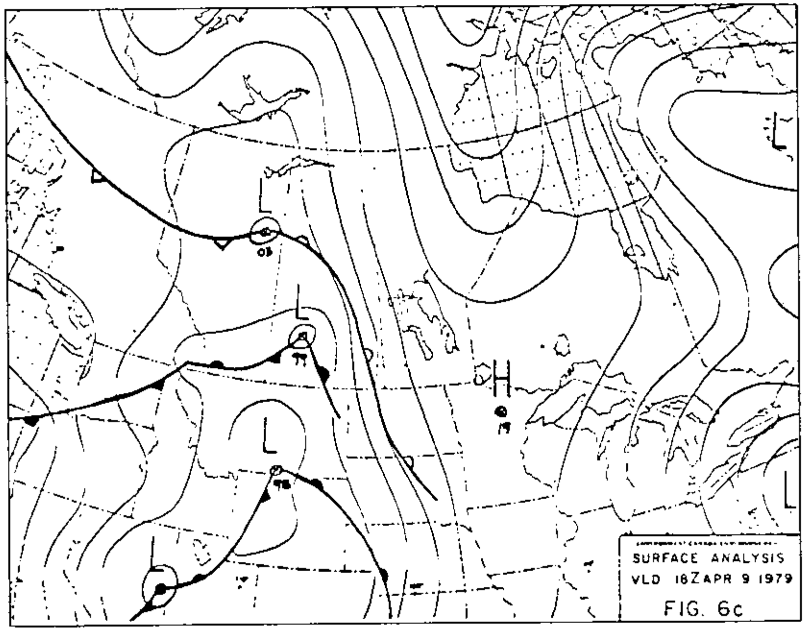
FIG. 6a



SURFACE ANALYSIS

VLD 18Z APR 1 1979

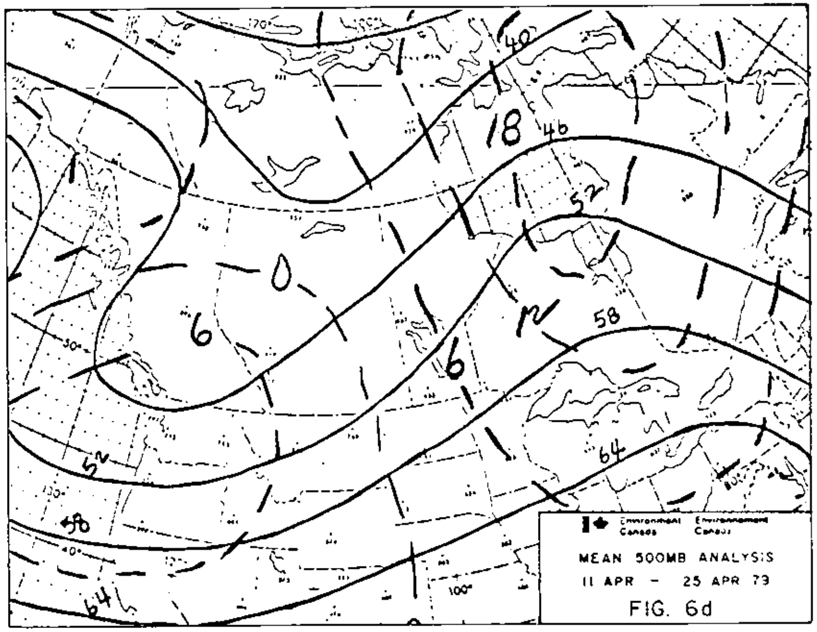
FIG. 6b



SURFACE ANALYSIS

VLD 18Z APR 9 1979

FIG. 6c



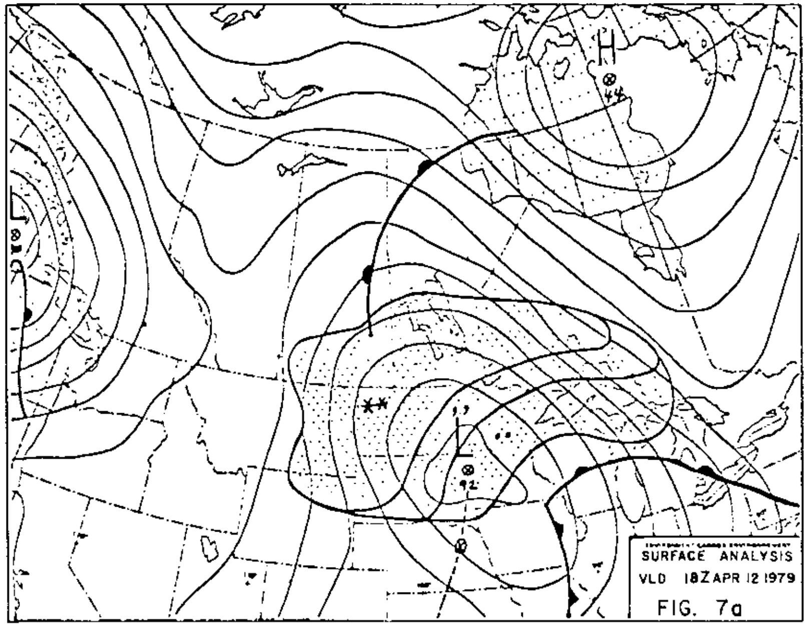
Environment Canada Environnement Canada

MEAN 500MB ANALYSIS

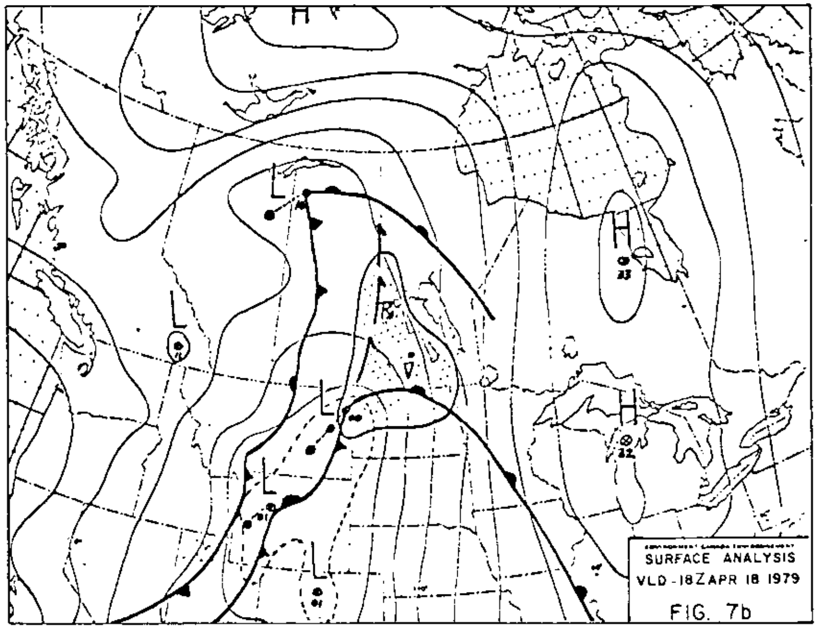
11 APR - 25 APR 79

FIG. 6d

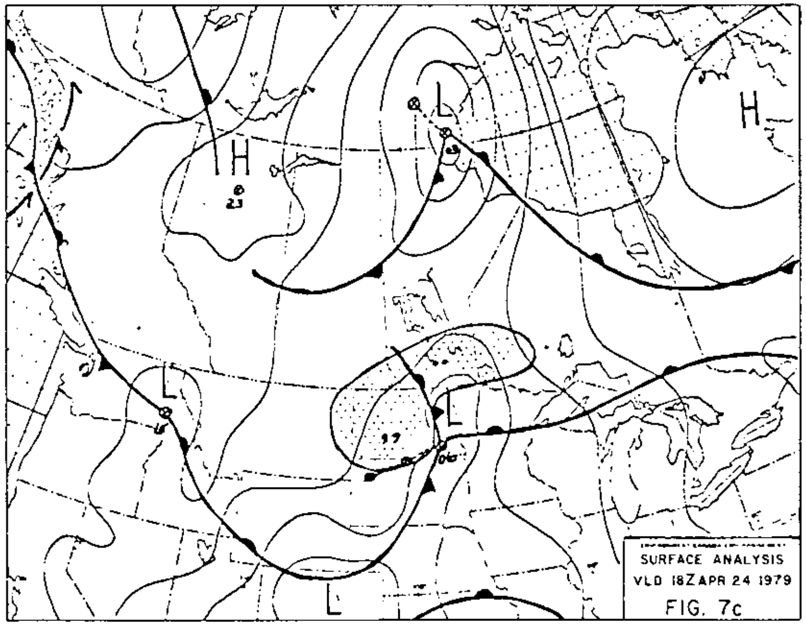
FIGURE 6



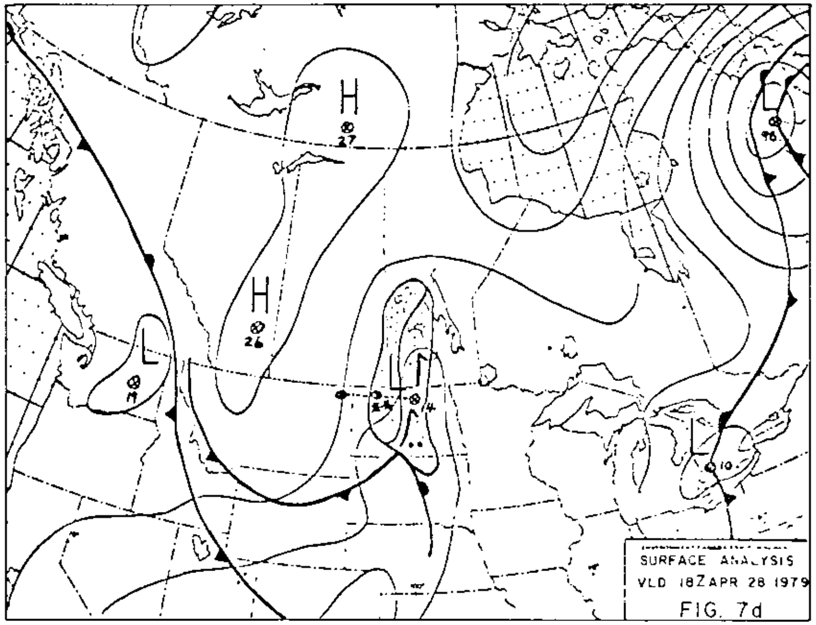
SURFACE ANALYSIS
VLD 18Z APR 12 1979
FIG. 7a



SURFACE ANALYSIS
VLD -18Z APR 18 1979
FIG. 7b



SURFACE ANALYSIS
VLD 18Z APR 24 1979
FIG. 7c



SURFACE ANALYSIS
VLD 18Z APR 28 1979
FIG. 7d

FIGURE 7

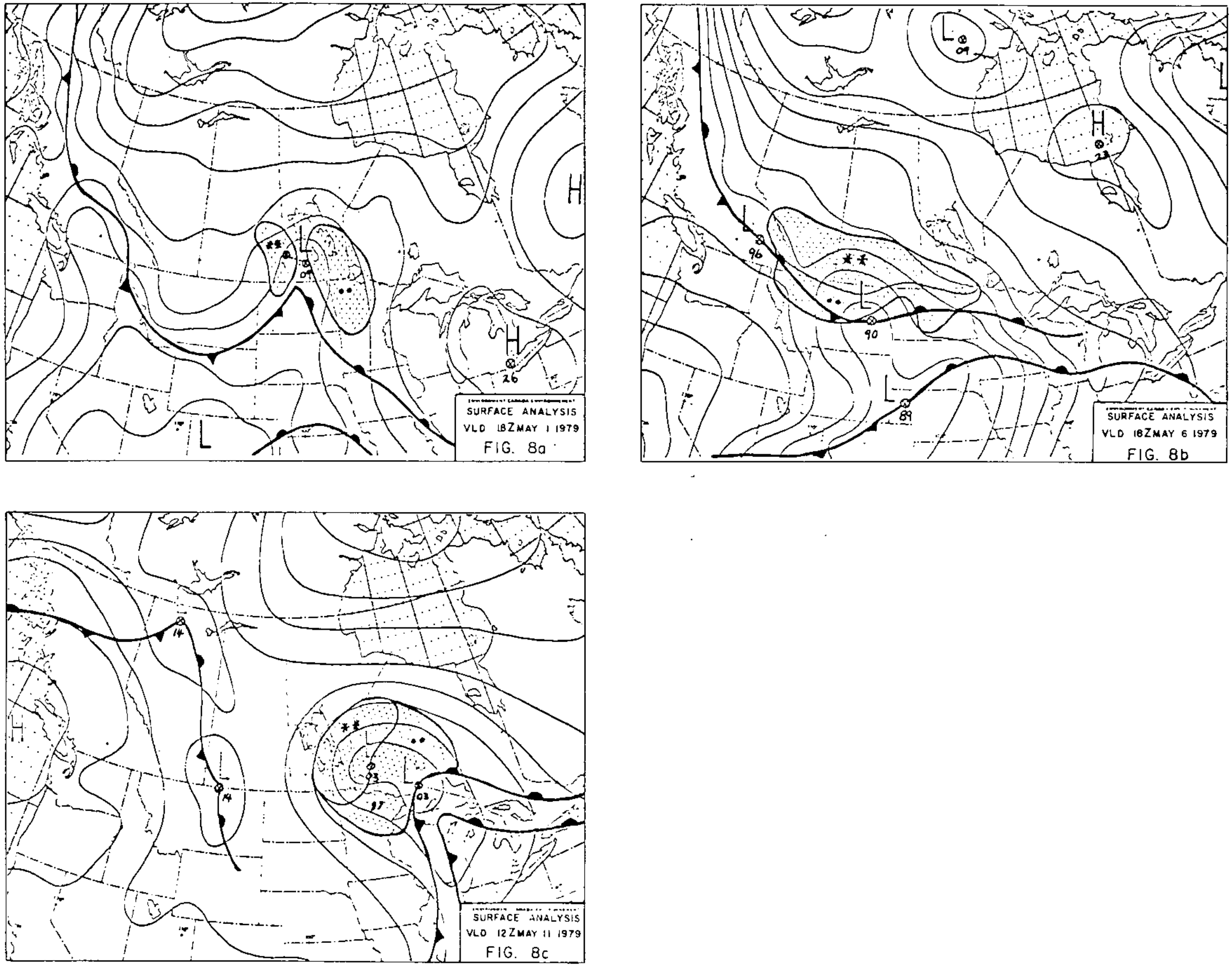

H
L
09
H
26
L
SURFACE ANALYSIS
VLD 18ZMAY 1 1979
FIG. 8a
L
09
H
23
L
96
L
90
L
89
SURFACE ANALYSIS
VLD 18ZMAY 6 1979
FIG. 8b
14
14
H
L
03
97
03
SURFACE ANALYSIS
VLD 12ZMAY 11 1979
FIG. 8c

FIGURE 8

TABLE 1

TEMPERATURE AND PRECIPITATION FROM NOVEMBER 1978 TO MAY 1979
WINNIPEG, MANITOBA AND FARGO, NORTH DAKOTA

	1978		1979				
Temperature and Precipitation	November	December	January	February	March	April	May
Winnipeg, Manitoba							
Mean Temperature (°C)	-8.4	-17.8	-22.5	-22.0	-9.9	-0.6	7.3
Departure from Normal (°C)	-4.0	-4.1	-4.2	-6.3	-1.8	-3.9	-3.3
Total Snowfall (cm)	36.4	20.4	9.3	20.9	38.1	22.7	8.3
Total Precipitation (mm)	42.6	20.9	9.0	20.1	45.3	73.5	93.1
Departure from Normal (mm)	+15.4	+2.0	-14.6	+1.0	+19.1	+36.2	+35.9
Fargo, North Dakota							
Mean Temperture (°C)	-5.1	-13.7	-20.1	-18.6	-6.4	2.2	10.2
Departure from Normal (°C)	-32.	-3.2	-5.6	-6.8	-2.1	-3.5	-2.3
Total Snowfall (cm)	21.6	29.7	14.8	49.5	10.9	6.9	2.0
Total Precipitation (mm)	28.2	11.9	11.2	44.2	50.8	77.2	51.3
Departure from Normal (mm)	+9.9	-3.8	-1.5	+33.0	+29.7	+24.4	-6.9

TABLE 2

PRECIPITATION NOVEMBER 1 TO MARCH 30, 1979

Station	Total (mm)	Normal (mm)	Percent of Normal
Winnipeg	136.5	119.2	114
Pilot Mound	150.5	117.9	127
Grand Forks	120.0	90.3	132
Fargo	128.0	85.8	149

TABLE 3

PRECIPITATION - APRIL 1979

Station	Total (mm)	Normal (mm)	Percent of Normal
Winnipeg	73.5	37.3	197
Pilot Mound	77.0	42.2	182
Morris (to April 23)	81.5	26.5	307
Altona	108.0	33.4	323
Emerson	76.0	35.1	216
Pembina	74.4	31.5	236
Grand Forks	80.8	32.3	250
Fargo	77.2	52.8	146

TABLE 4

BEGINNING AND ENDING OF MELT
APRIL 1979

Station	Date Melt Began	Date Melt Ended	Duration in Days
Winnipeg, Manitoba	9	19	10
Glen Lea	5	18	13
Morden	10	19	9
Plum Coulee	8	20	12
Sperling	8	21	13
Cavalier, N.D.	14	22	8
Cooperstown	9	19	10
Grand Forks	8	18	10
Fargo	10	12	2
Langdon	8	25	17
Mayville	9	19	10
Sharon	7	22	15
Valley City	9	17	8
Agassiz Refuge, Minn.	8	18	10
Caribou	9	18	9
Crookstown	9	15	6
Fosston	6	18	12
Mahnomen	9	18	9
Ottertail	13	20	7
Average	9	19	10

TABLE 5

RED RIVER BASIN PRECIPITATION
APRIL 23 to 30, 1979

MANITOBA

	mm		mm
Winnipeg	23.0	Carman	50.2
Emerson	16.0	Miami	34.0
Plum Coulee	47.0	St. Claude	63.2
Roland	47.2	St. Elizabeth	34.8
Morden	33.8	Green Ridge	27.2
Sprague	28.2	Fannystelle	40.6
Graysville	55.8	Elm Creek	54.1
Pilot Mound	37.6	Deerwood	51.0
Glenlea	9.4	Manitou	33.0
Niverville	26.1	Morden	41.6
Steinbach	20.9	Starbuck	23.9
Marchand	36.1		

NORTH DAKOTA

Adams	22.6	Chaffee	15.0
Drayton	18.0	Colgate	45.0
Grafton	26.9	Cooperstown	33.5
Grand Forks	39.4	Fargo	17.0
Hannah	12.7	Hillsboro	36.6
Hansboro	18.0	Mayville	47.2
Langdon	22.6	Sharon	53.6
Park River	29.5	Valley City	32.5
Pembina	20.6		
Petersburg	30.0		
Walhalla	38.9		

MINNESOTA

Ada	17.5	Georgetown	23.6
Agassiz Refuge	71.9	Hallock	12.4
Argyle	48.0	Halstad	40.4
Caribou	1.3	Hawley	17.0
Crookston	51.3	Karlstad	44.7
Detroit Lakes	40.1	Mahnomen	23.1
Fosston	27.4	Oklee	57.7
Red Lake Falls	60.5	Elbow Lake	5.8
Tamarac W.R.	47.2	Fergus Falls	8.4
Thief River Falls	91.9	Ottertail	22.6
Wannaska	67.3	Rothsay	15.2
Roseau	50.0	Wheaton	7.4

TABLE 6

PRECIPITATION NORTH OF THE U.S. BOUNDARY
APRIL 30 TO MAY 14, 1979

Station	Total (mm)	Normal (mm)	Percent of Normal
Pilot Mound	34.0	25.3	134
Altona	31.2	21.0	148
Deerwood	37.7	26.5	142
Graysville	45.6	22.8	200
Morden	43.5	25.7	169
Plum Coulee	33.0	26.8	123
Roland	25.3	22.3	113
Steinbach	22.7	27.6	82
Winnipeg	31.3	23.5	133
Starbuck	20.6	26.8	76
Sprague	33.0	24.9	132

APPENDIX 2

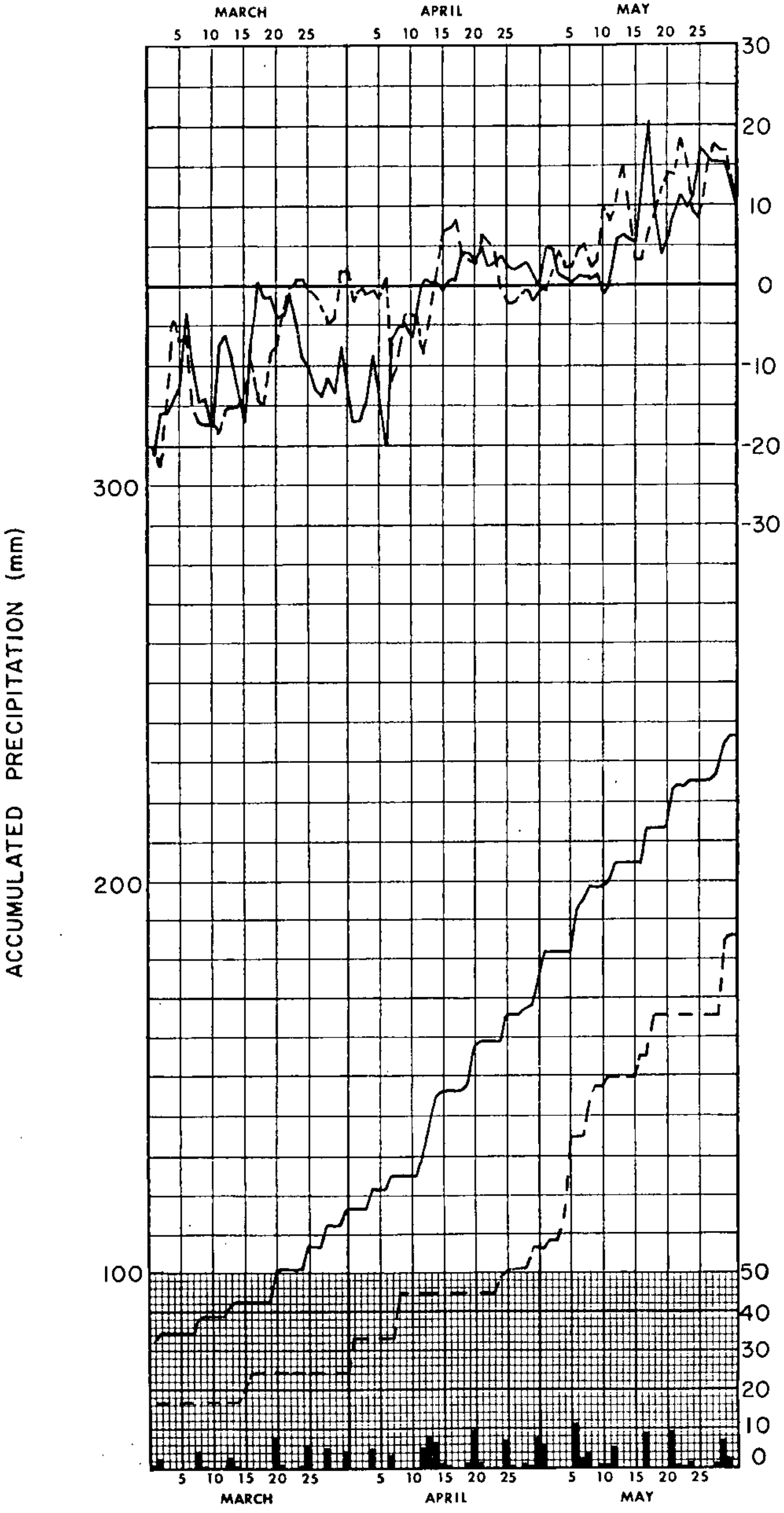
TEMPERATURE AND PRECIPITATION GRAPHS

1979 and 1950 APRIL TO MAY

Temperature and Precipitation Graphs
March-April-May 1979 and 1950

Brandon
Emerson*
Fargo
Grand Forks
Morden
Winnipeg

* For the period in 1979 of March 1-30, April 27-May 28 when data was not collected at Emerson the values from Pembina were plotted.



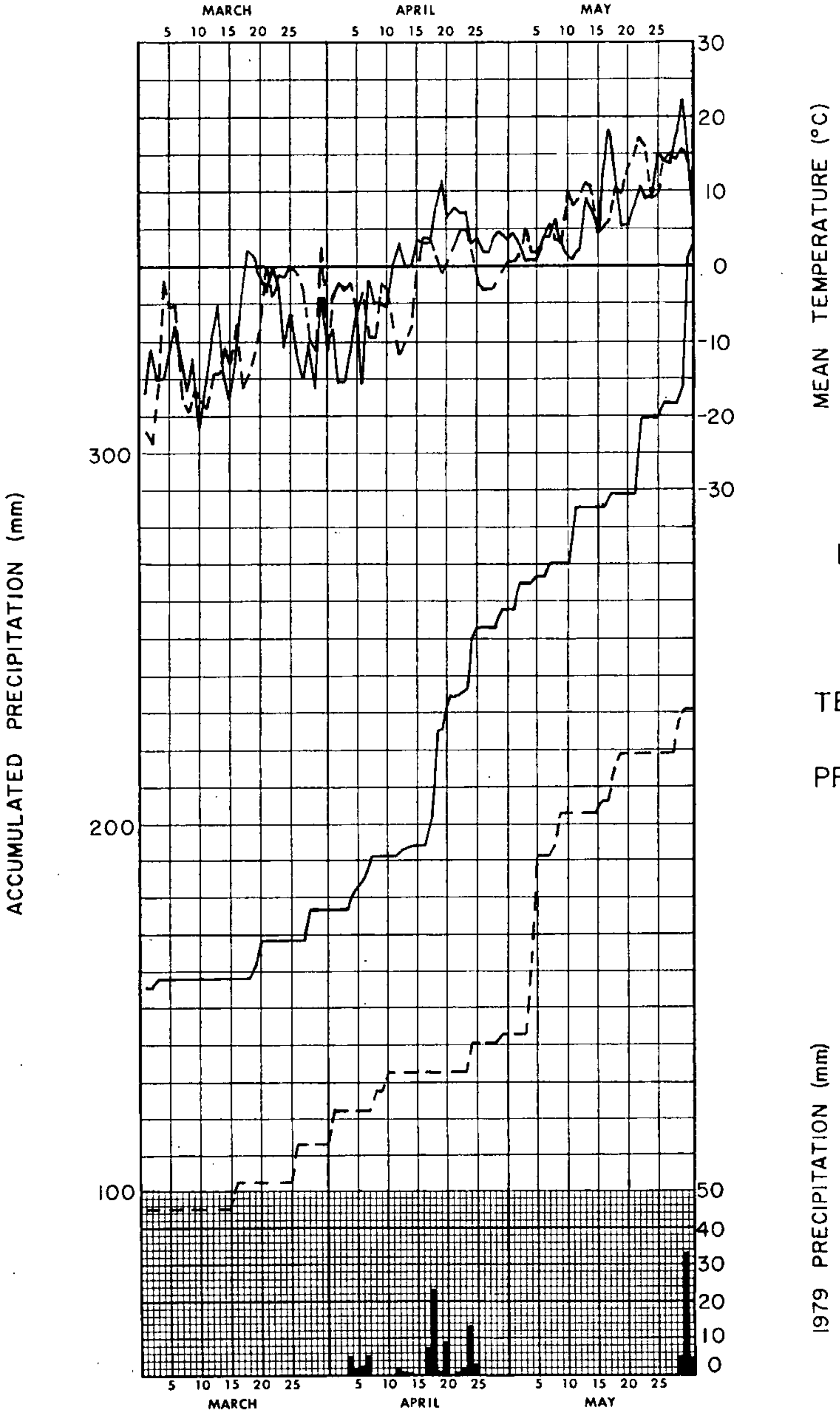
BRANDON

TEMPERATURE
AND
PRECIPITATION

LEGEND

1979 ———

1950 - - -

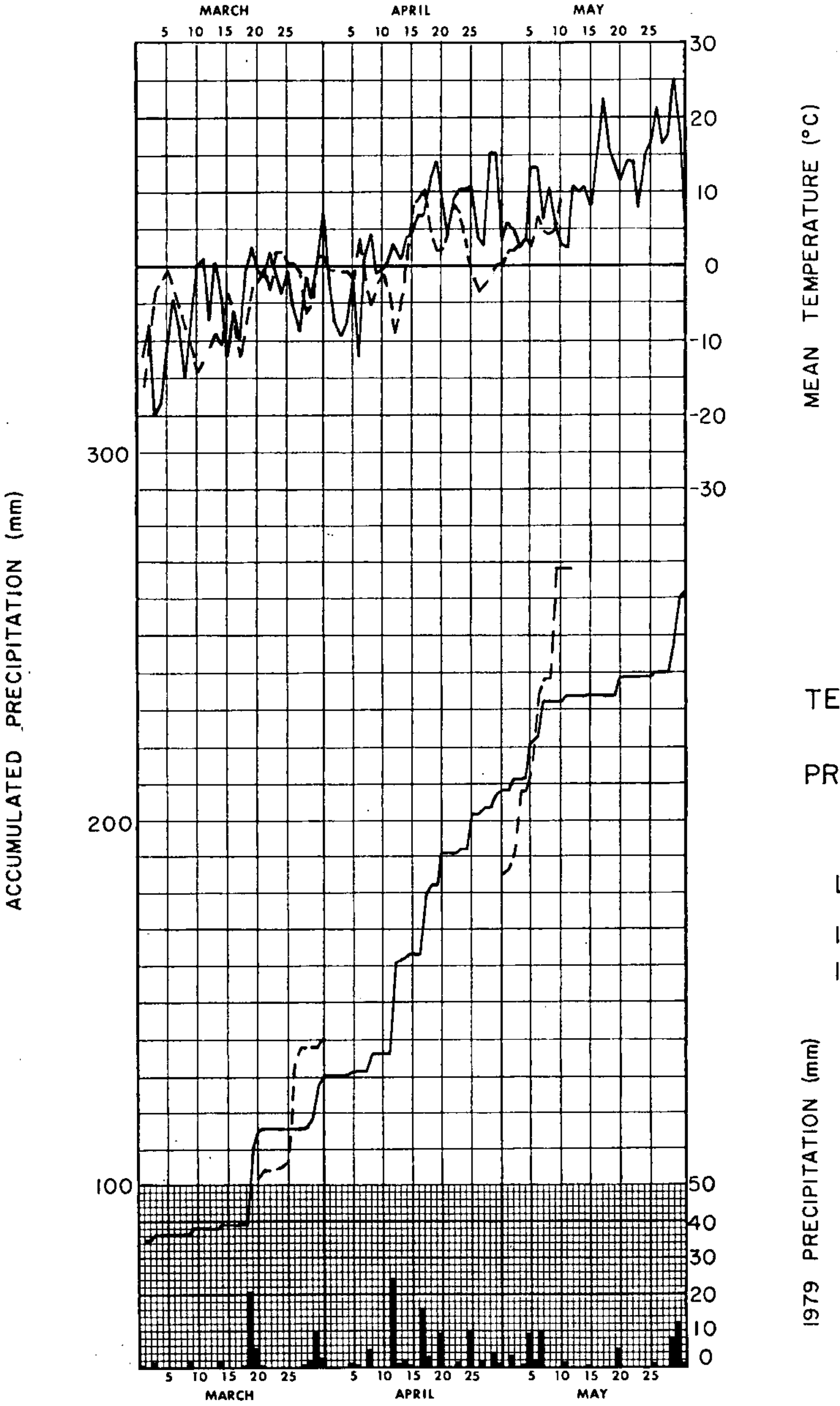


EMERSON

TEMPERATURE
AND
PRECIPITATION

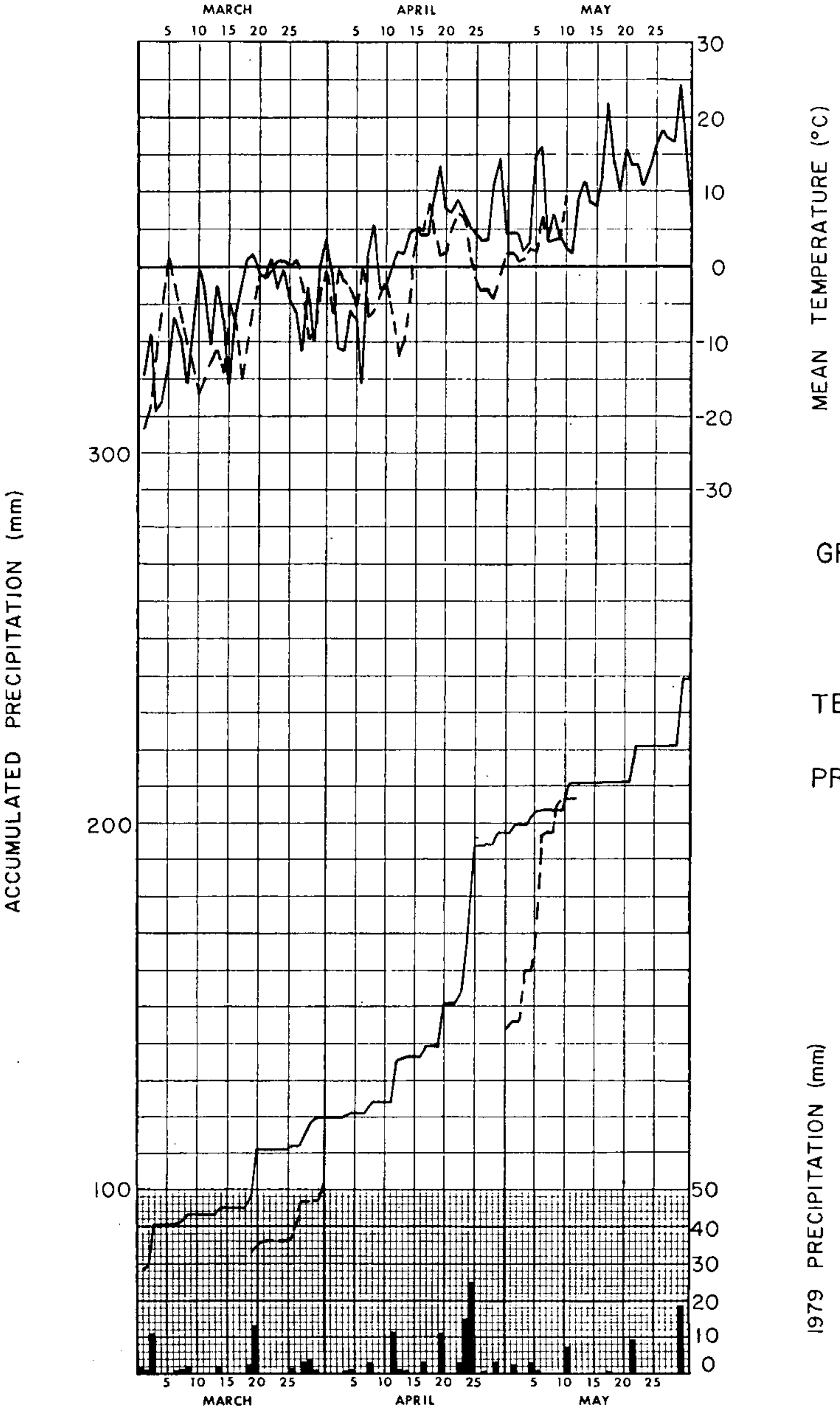
LEGEND

1979 ——
1950 - - -



FARGO

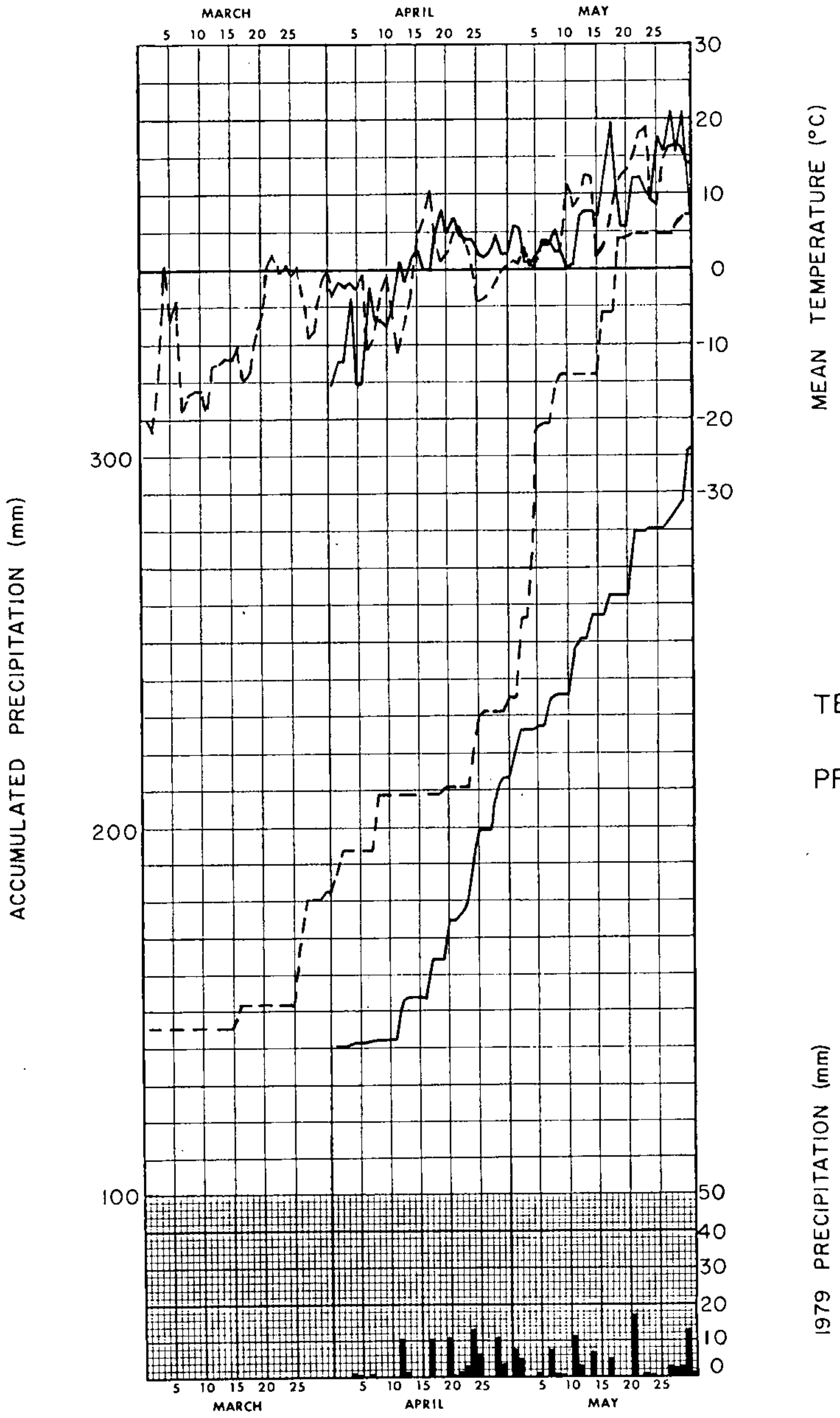
TEMPERATURE
AND
PRECIPITATION



GRAND FORKS

TEMPERATURE
AND
PRECIPITATION

LEGEND
1979 ——
1950 - - -



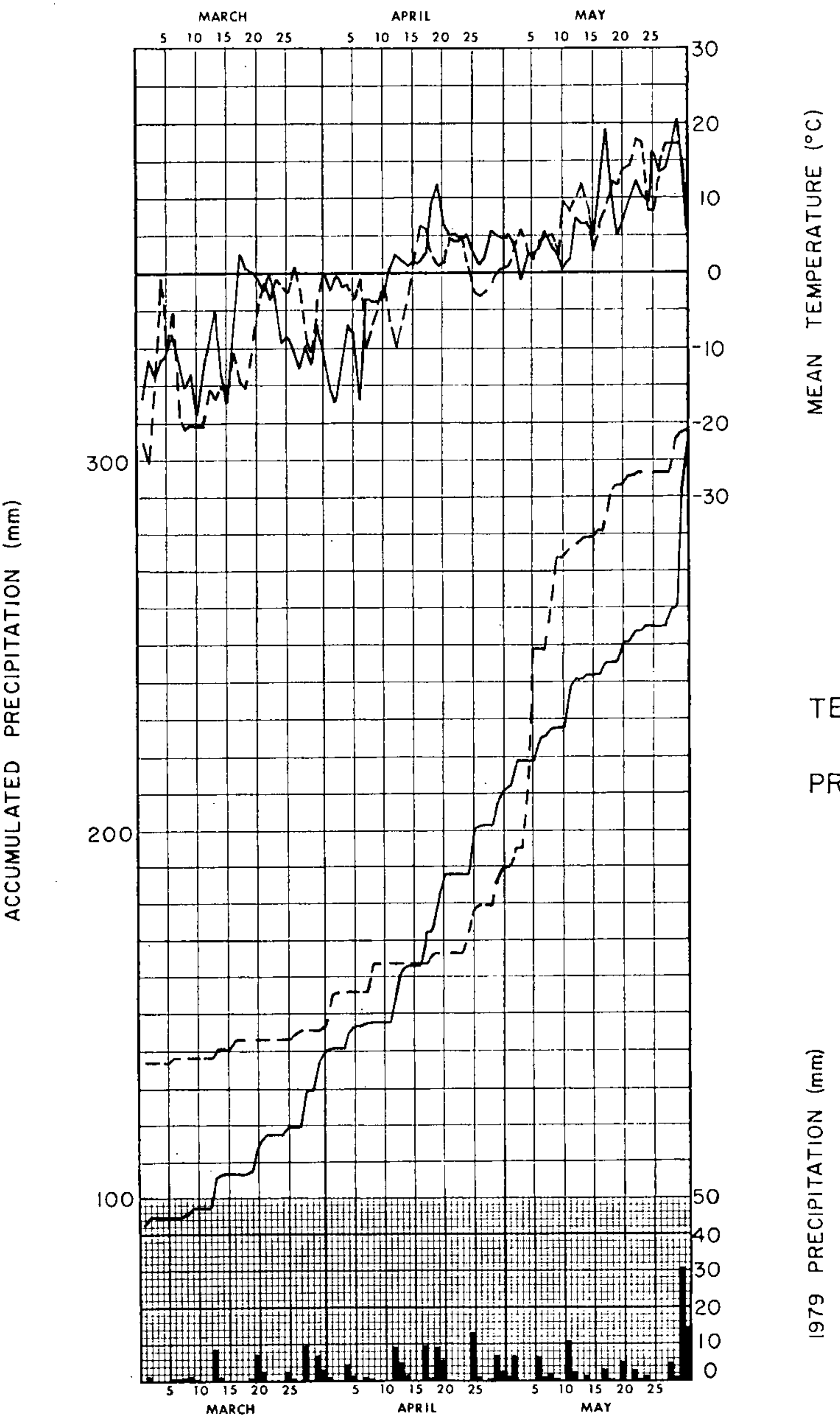
MORDEN

TEMPERATURE
AND
PRECIPITATION

LEGEND

1979 ——

1950 ---



WINNIPEG

TEMPERATURE AND PRECIPITATION

LEGEND

1979 ———

1950 - - -

APPENDIX 3

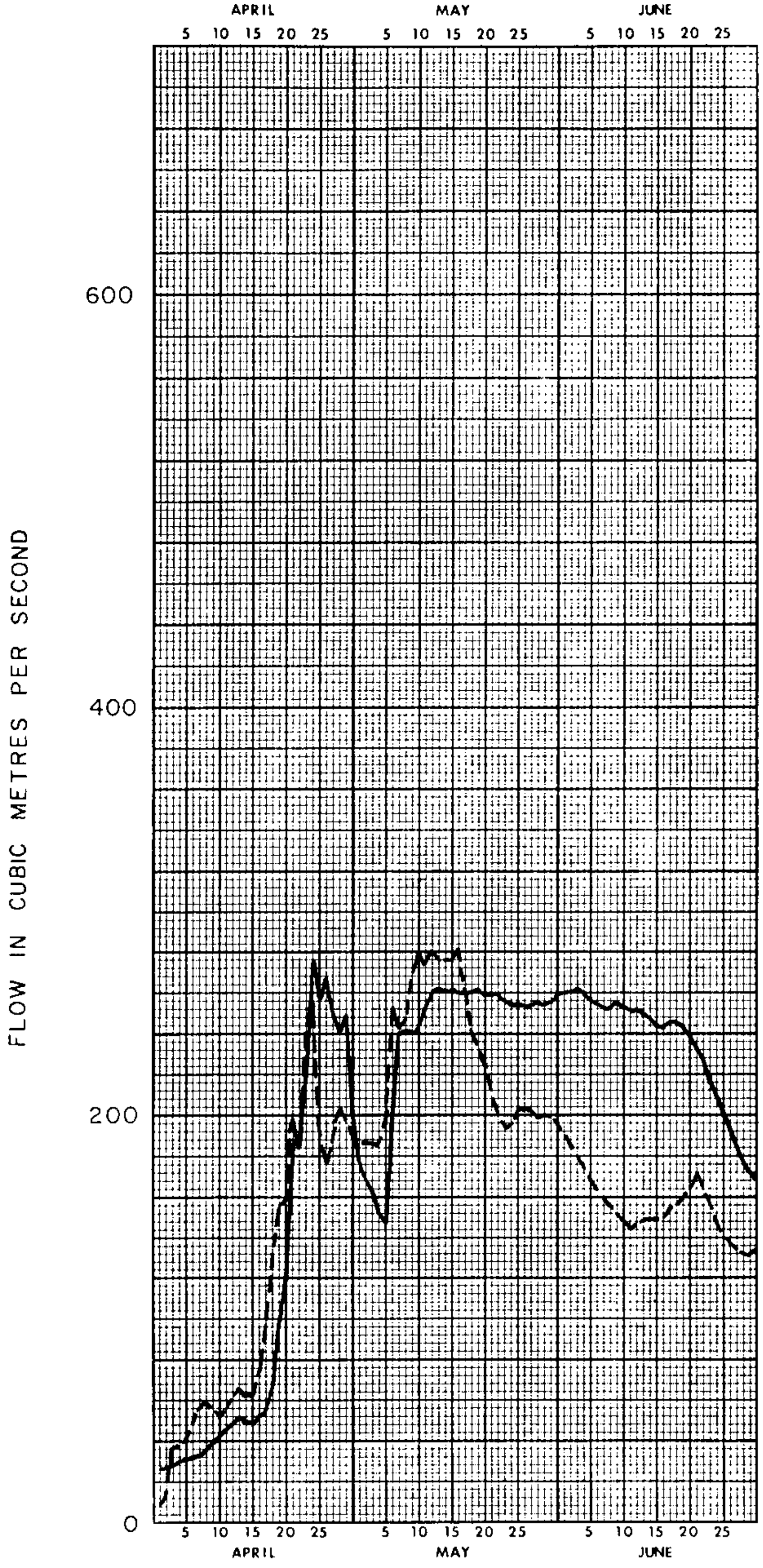
HYDROGRAPHS

1979 and 1950 APRIL TO JUNE

HYDROGRAPHS 1979 - 1950 APRIL TO JUNE

	LOCATION	
STATION NAME	LATITUDE	LONGITUDE
Assiniboine River at Headingley	49 52 09 N	97 24 10 W
Assiniboine River Diversion near * Portage La Prairie	49 58 00 N	98 22 50 W
Assiniboine River near Brandon	49 52 20 N	100 06 10 W
Assiniboine River near Holland	49 41 54 N	98 53 56 W
Assiniboine River near Portage La Prairie	49 56 09 N	98 16 48 W
Boyne River near Carman	49 31 00 N	97 56 40 W
Buffalo Lake Channel near Altona	49 05 28 N	97 36 35 W
Deadhorse Creek at Morden	49 11 47 N	98 06 38 W
Hespeler Floodway near Rosenfeld	49 14 10 N	97 33 00 W
La Salle River at Sanford	49 40 45 N	97 25 46 W
Morris River near Rosenort (stage)	49 29 22 N	97 28 51 W
Pembina River at Neche	48 59 20 N	97 33 05 W
Pembina River near Windygates	49 01 53 N	98 16 40 W
Plum River near Rosenfeld	49 11 30 N	97 24 00 W
Rat River near Otterburne	49 27 42 N	97 00 26 W
Red Lake River at Crookston	47 46 32 N	95 36 33 W
(Red River above (Floodway -	49 45 24 N	97 07 36 W
Winnipeg) (Red River -	49 47 10 N	97 08 13 W
Red River at Emerson	49 00 30 N	97 12 40 W
Red River at Emerson (stage)	49 00 30 N	97 12 40 W
(Red River at Floodway Control Structure) (stages)	49 45 -- N	97 08 -- W
Red River at James Ave. Pumping Station (stage)	49 53 45 N	97 07 50 W
Red River near Lockport	50 06 28 N	96 55 54 W
Red River near Ste. Agathe	49 43 40 N	97 10 52 W
Red River near Ste. Agathe (stage)	49 33 40 N	97 10 52 W
Red River of the North at Fargo	46 51 40 N	96 47 00 W
Red River of the North at Grand Forks	47 56 34 N	97 03 10 W
Riviere Aux Marais near Christie	49 03 30 N	97 18 50 W
Roseau River near Dominion City	49 11 53 N	97 03 15 W
Roseisle Creek near Roseisle	49 30 10 N	98 19 40 W
Seine River Diversion near Ste. Adolphe	49 41 50 N	97 05 30 W
Seine River near Prairie Grove	49 45 15 N	96 56 10 W
Sheyenne River at West Fargo	46 53 28 N	96 54 24 W
Souris River near Wawanesa	49 36 05 N	99 40 55 W
Sprague Creek near Sprague	48 59 33 N	95 39 43 W
Sturgeon Creek at St. James	49 52 52 N	97 16 43 W
Wild Rice River near Abercrombie	46 28 05 N	96 47 00 W

* now known as Portage Diversion near Portage La Prairie

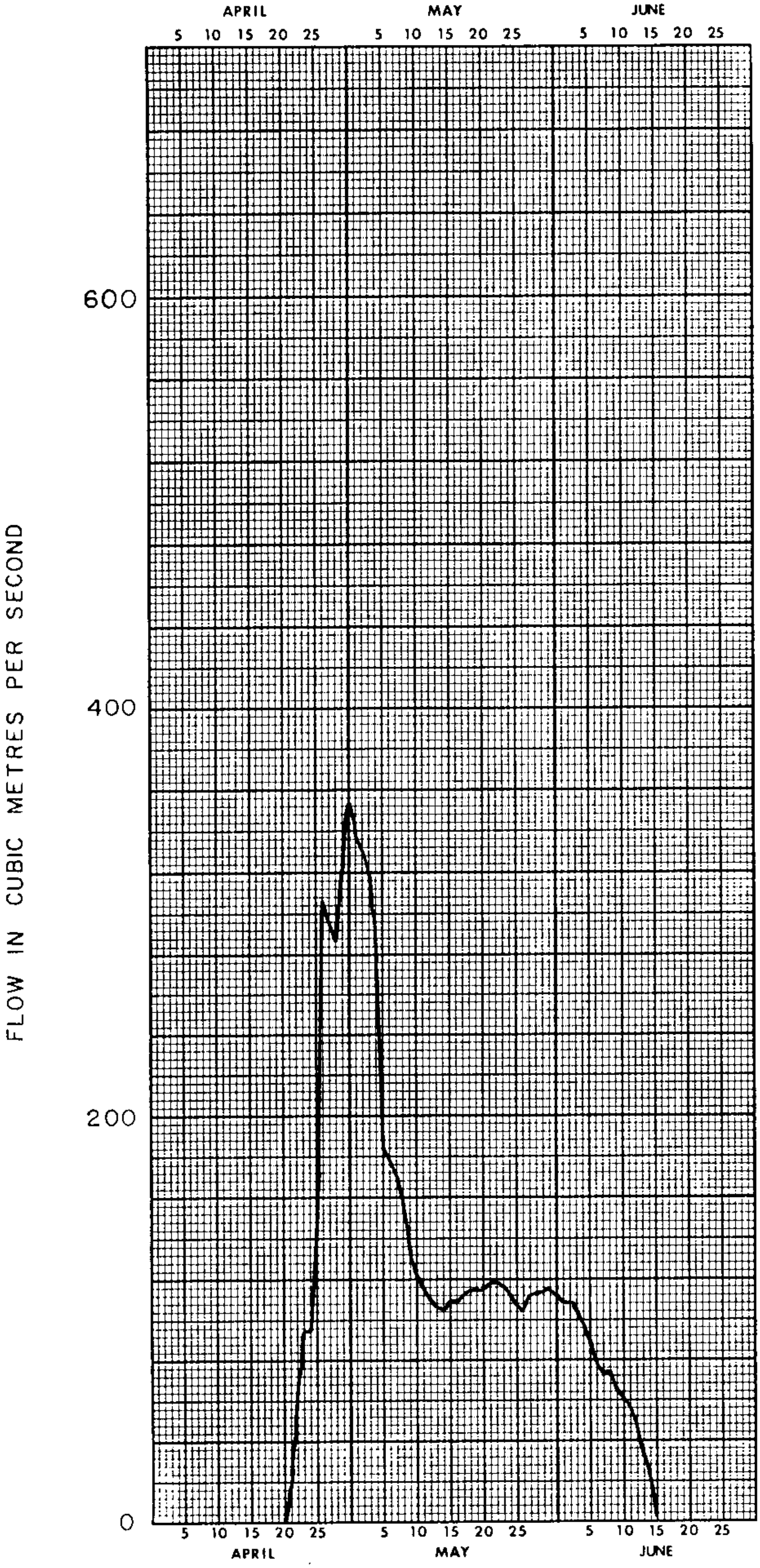


ASSINIBOINE RIVER
AT HEADINGLEY
05MJ001

DISCHARGE
HYDROGRAPHS

LEGEND

1979 ——
1950 - - - -



ASSINIBOINE RIVER DIVERSION NEAR PORTAGE LA PRAIRIE

05LL018

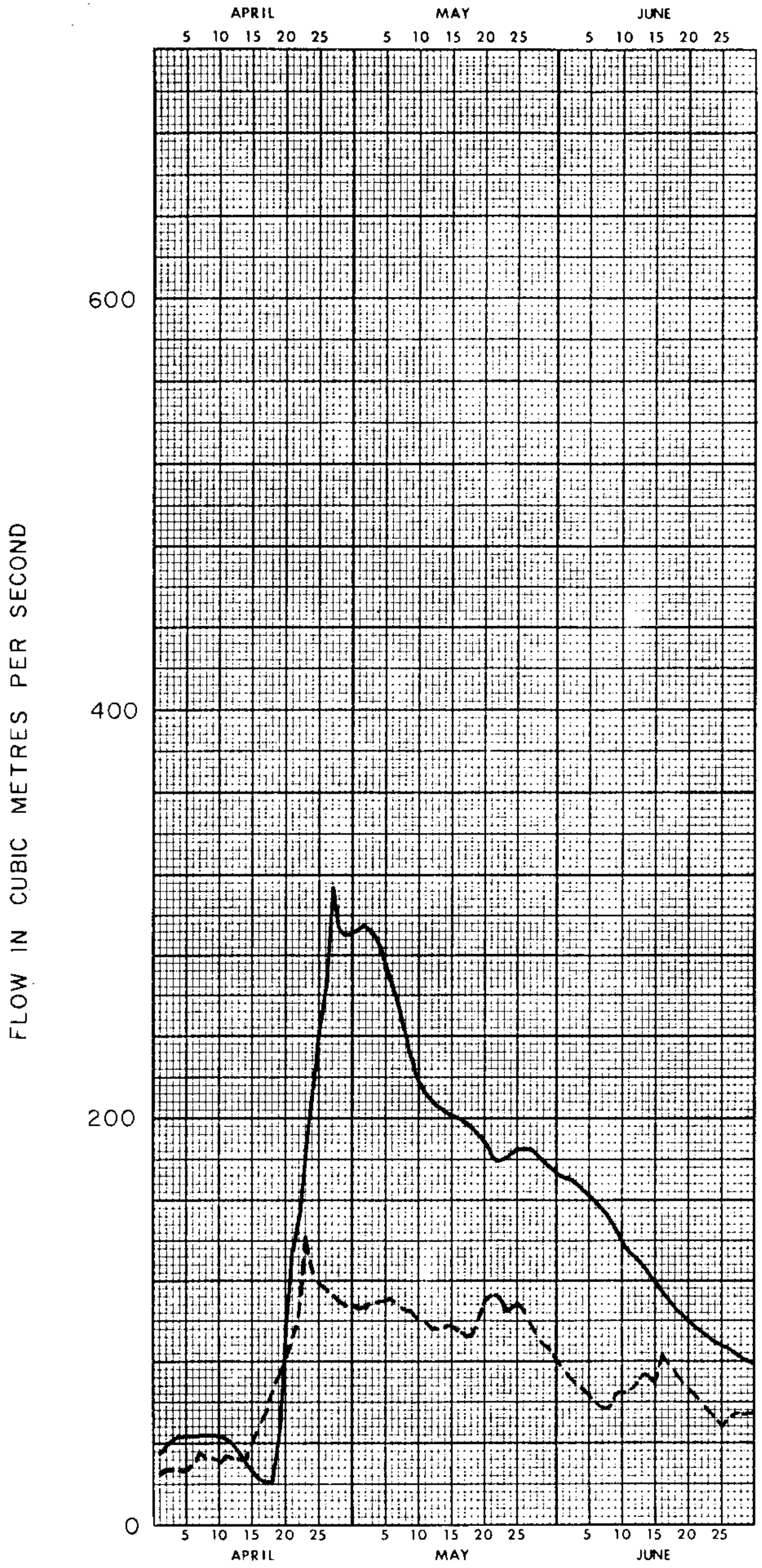
DISCHARGE HYDROGRAPHS

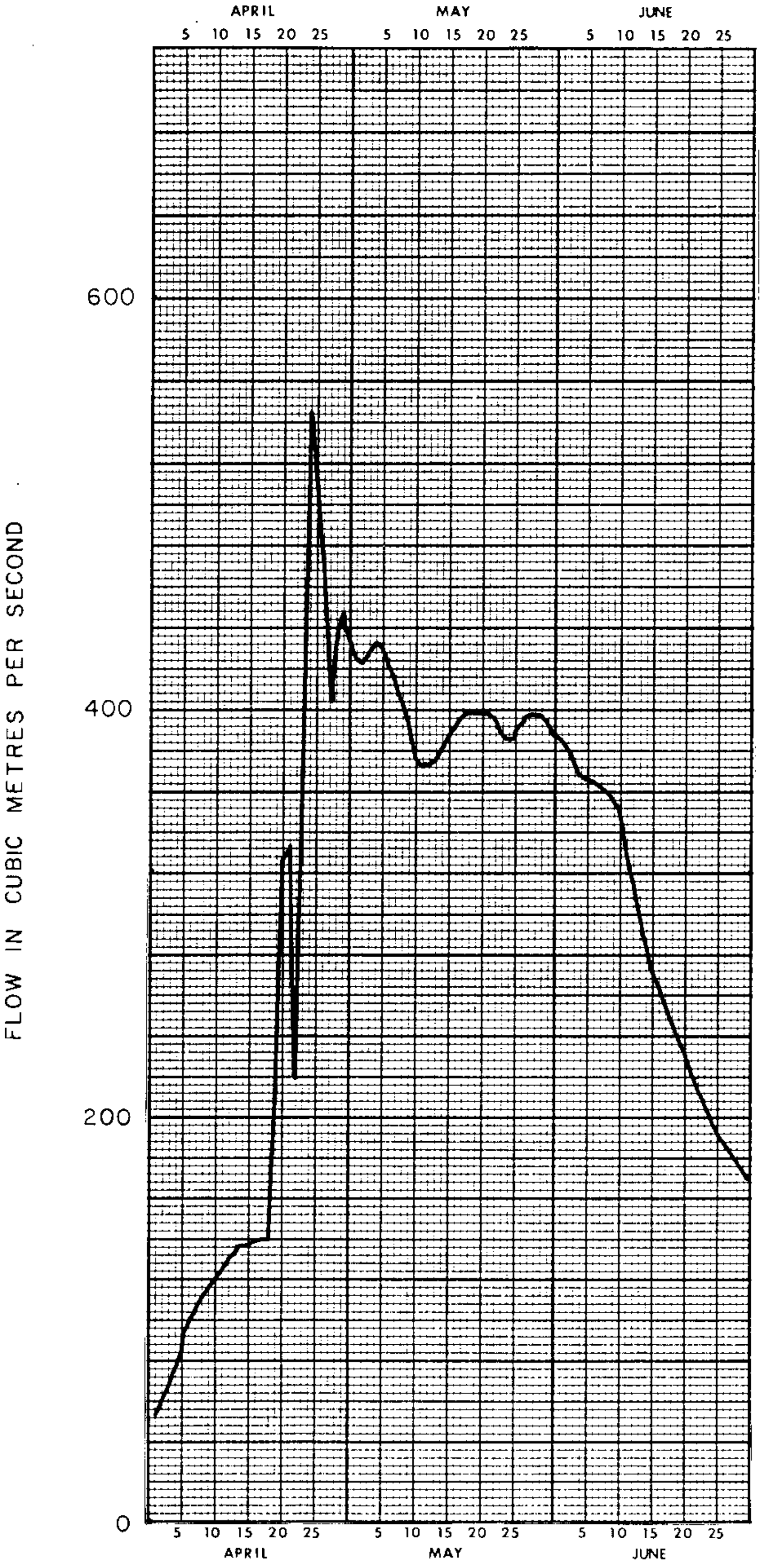
LEGEND

1979 ——
1950

ASSINIBOINE RIVER
NEAR BRANDON
05MH013

DISCHARGE
HYDROGRAPHS





ASSINIBOINE RIVER

NEAR HOLLAND

05MH005

DISCHARGE HYDROGRAPHS

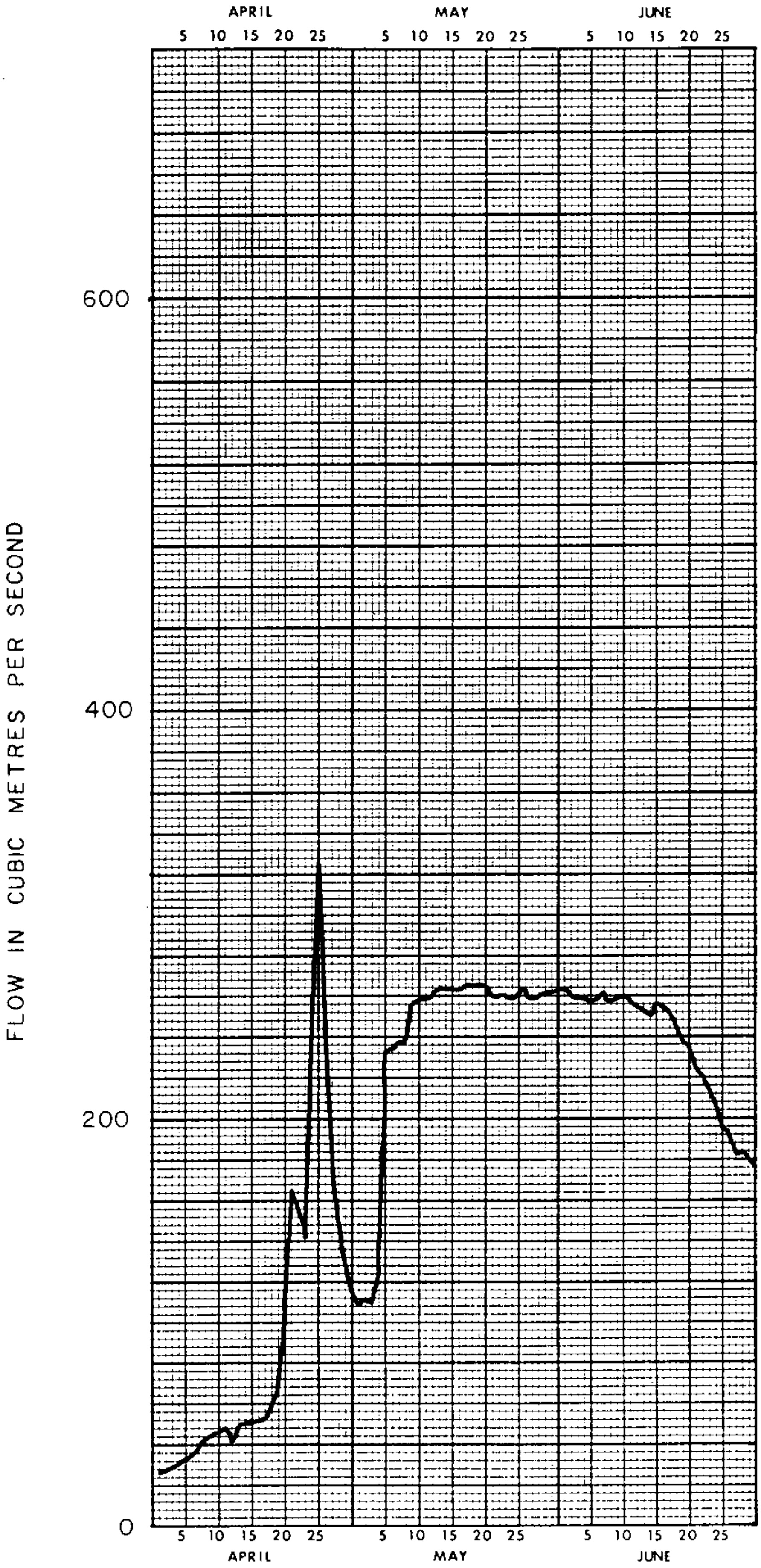
LEGEND

1979 ——

1950

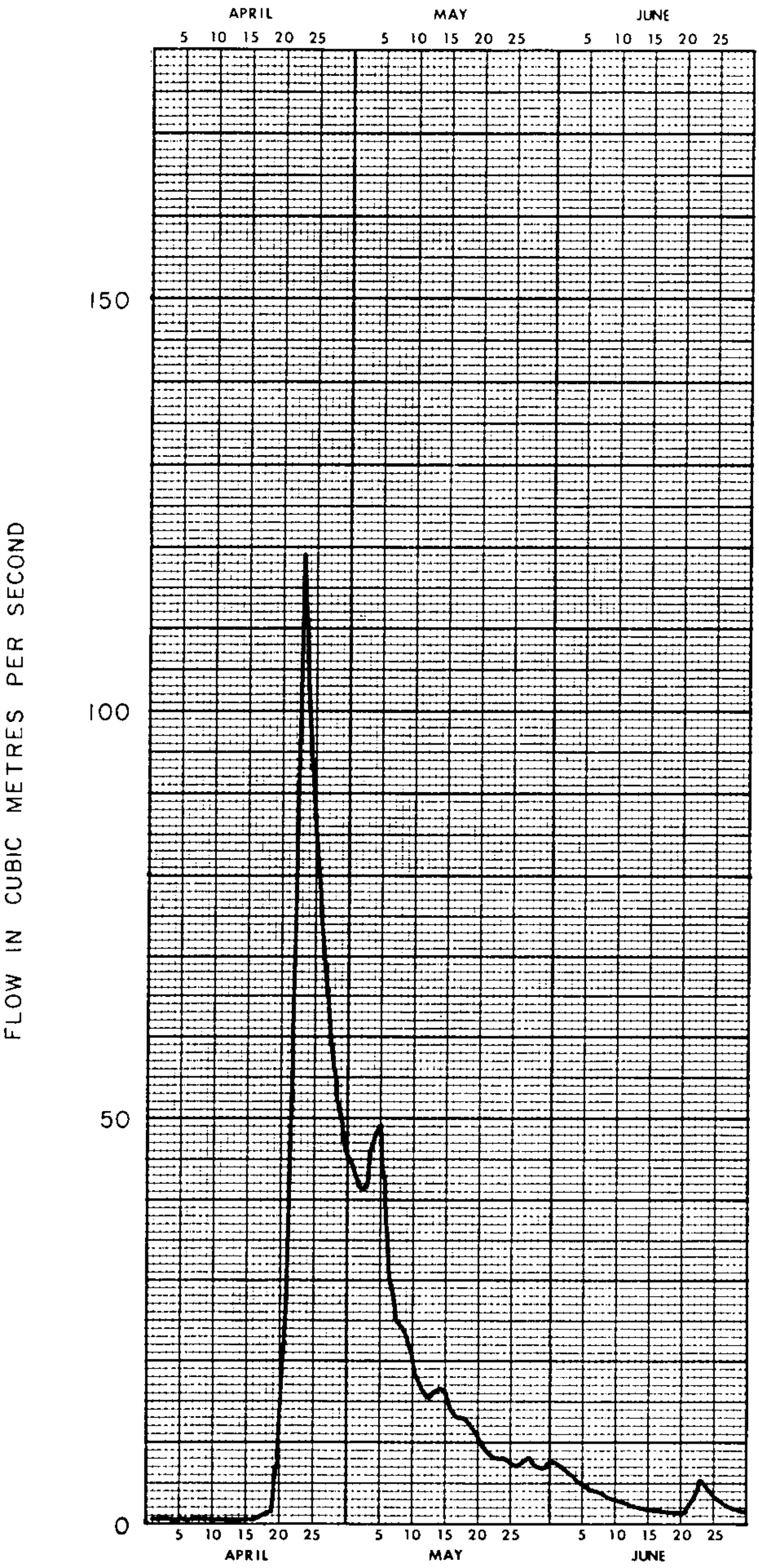
ASSINIBOINE RIVER
NEAR
PORTAGE LA PRAIRIE
05MJ003

DISCHARGE
HYDROGRAPHS



LEGEND

1979 ——
1950

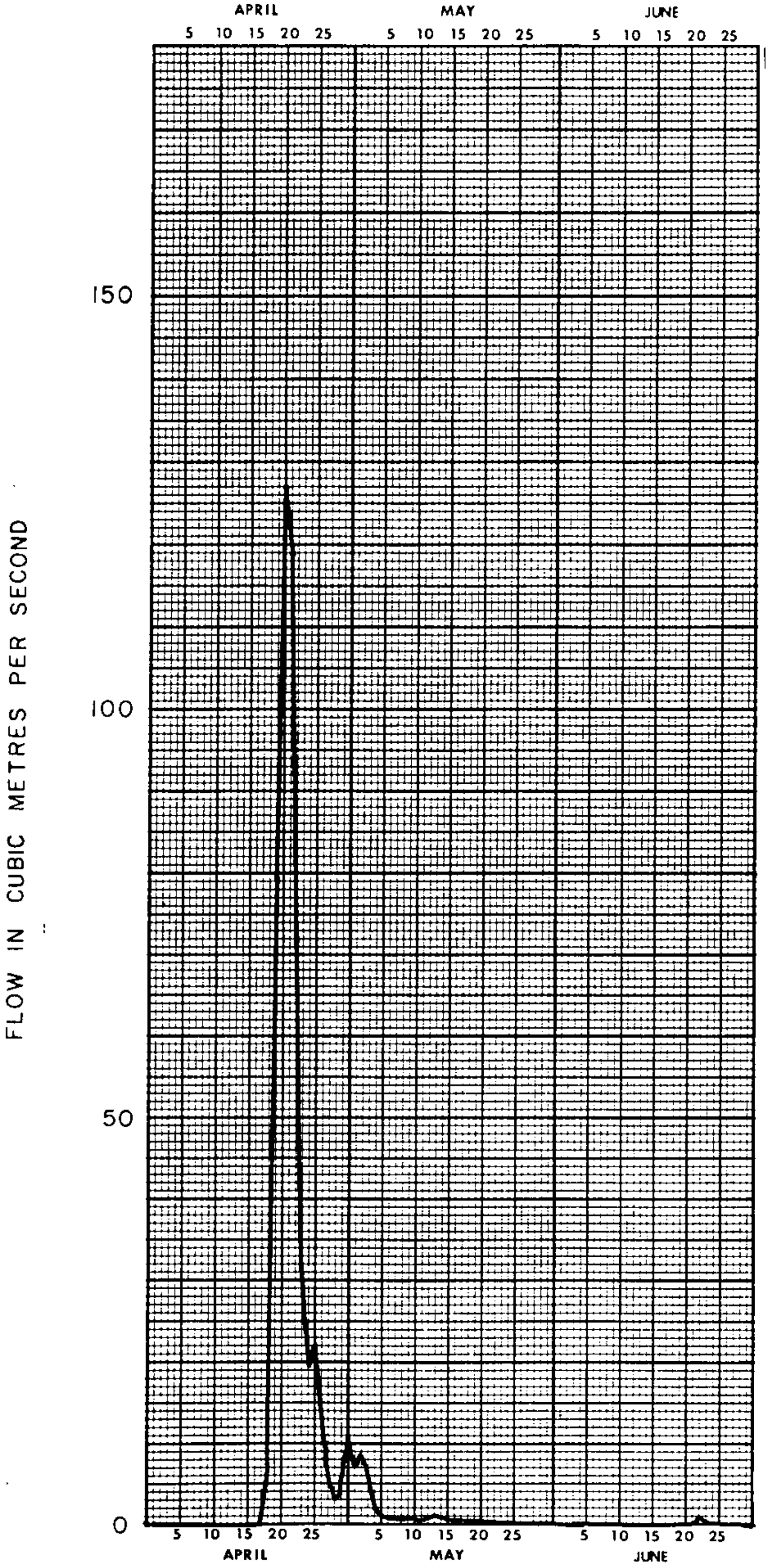


BOYNE RIVER
NEAR CARMAN
05OF003

DISCHARGE
HYDROGRAPHS

LEGEND

1979 ——
1950

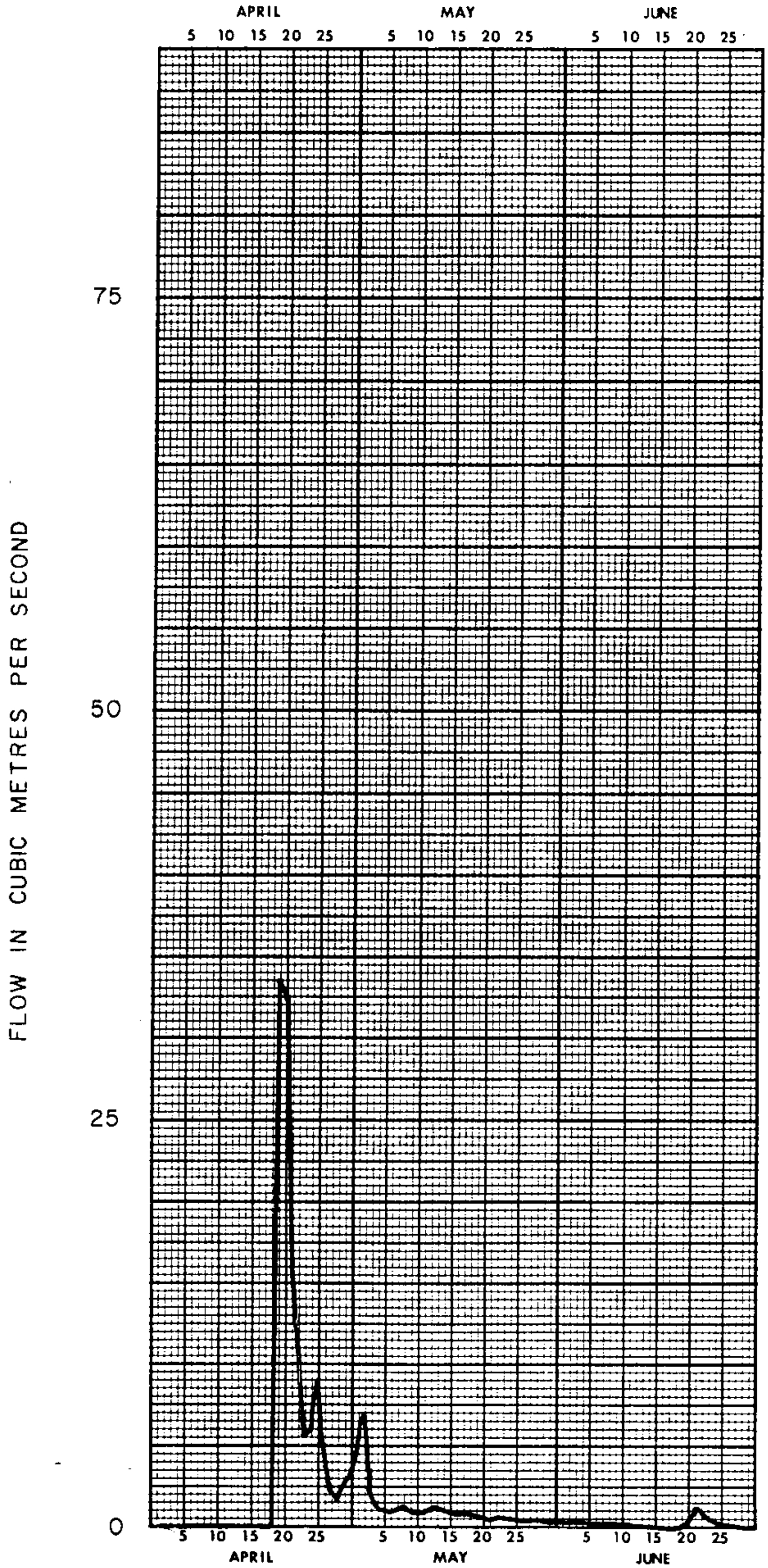


BUFFALO LAKE CHANNEL NEAR ALTONA 05OC025

DISCHARGE HYDROGRAPHS

LEGEND

1979 ——
1950



DEADHORSE CREEK
AT MORDEN
05OC015

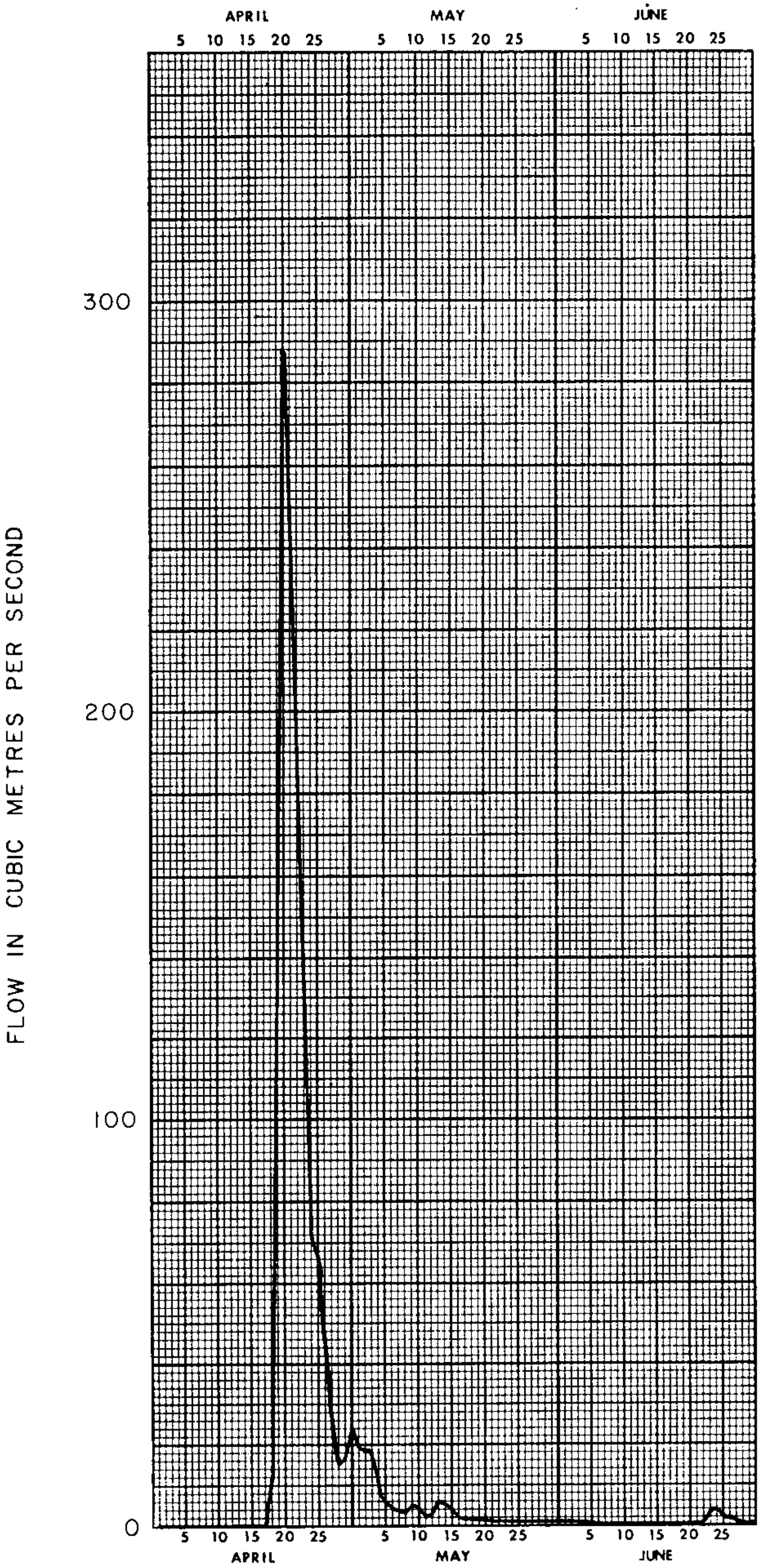
DISCHARGE
HYDROGRAPHS

LEGEND

1979 ——
1950

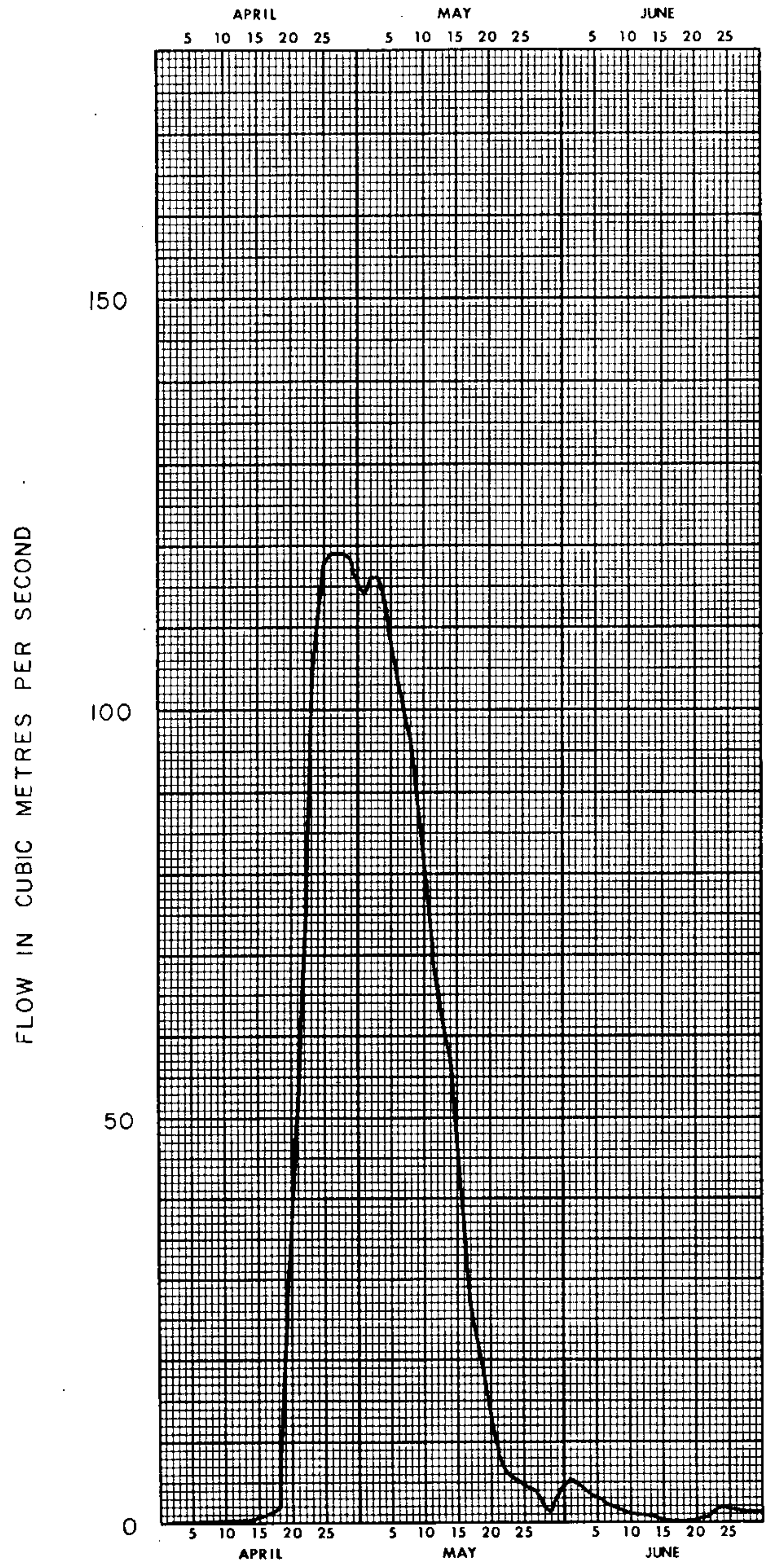
HESPELER
FLOODWAY
NEAR ROSENFELD
05OC016

DISCHARGE
HYDROGRAPHS



LEGEND

1979 ——
1950 ----



LA SALLE RIVER

AT SANFORD

05OG001

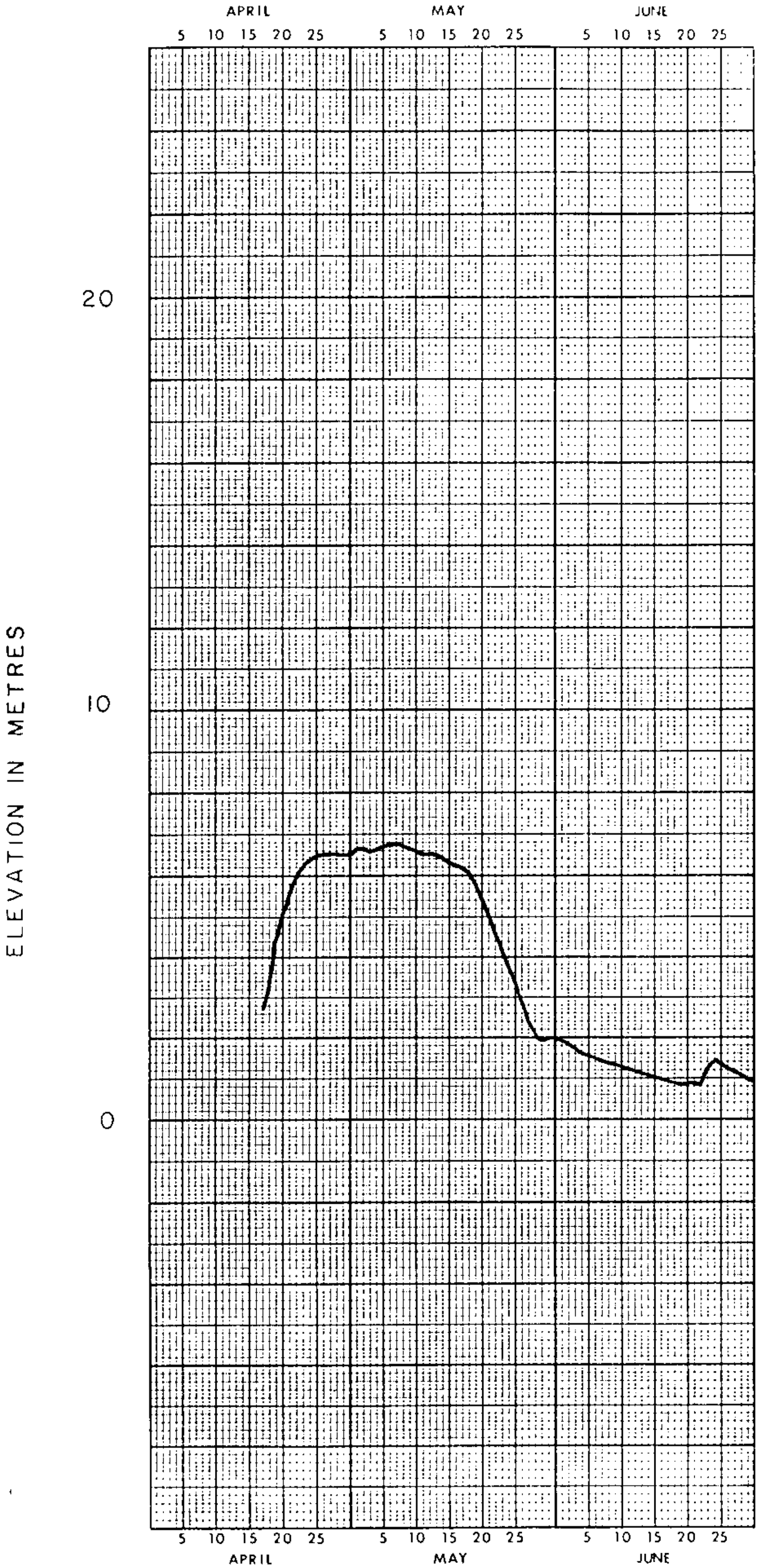
DISCHARGE

HYDROGRAPHS

LEGEND

1979 ——

1950

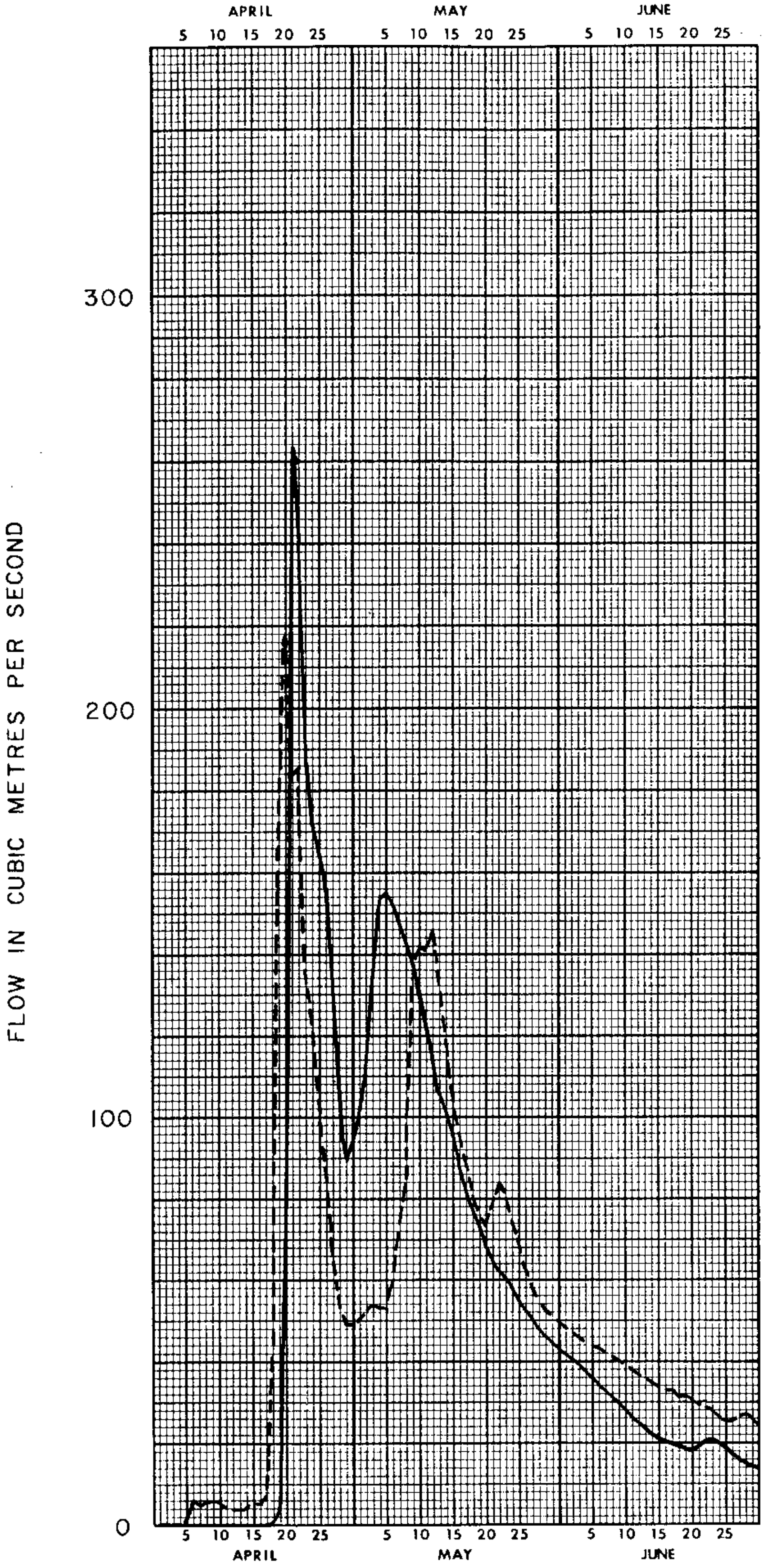


MORRIS RIVER
NEAR ROSENORT
05OF020

STAGE
HYDROGRAPHS

LEGEND

1979 ——
1950

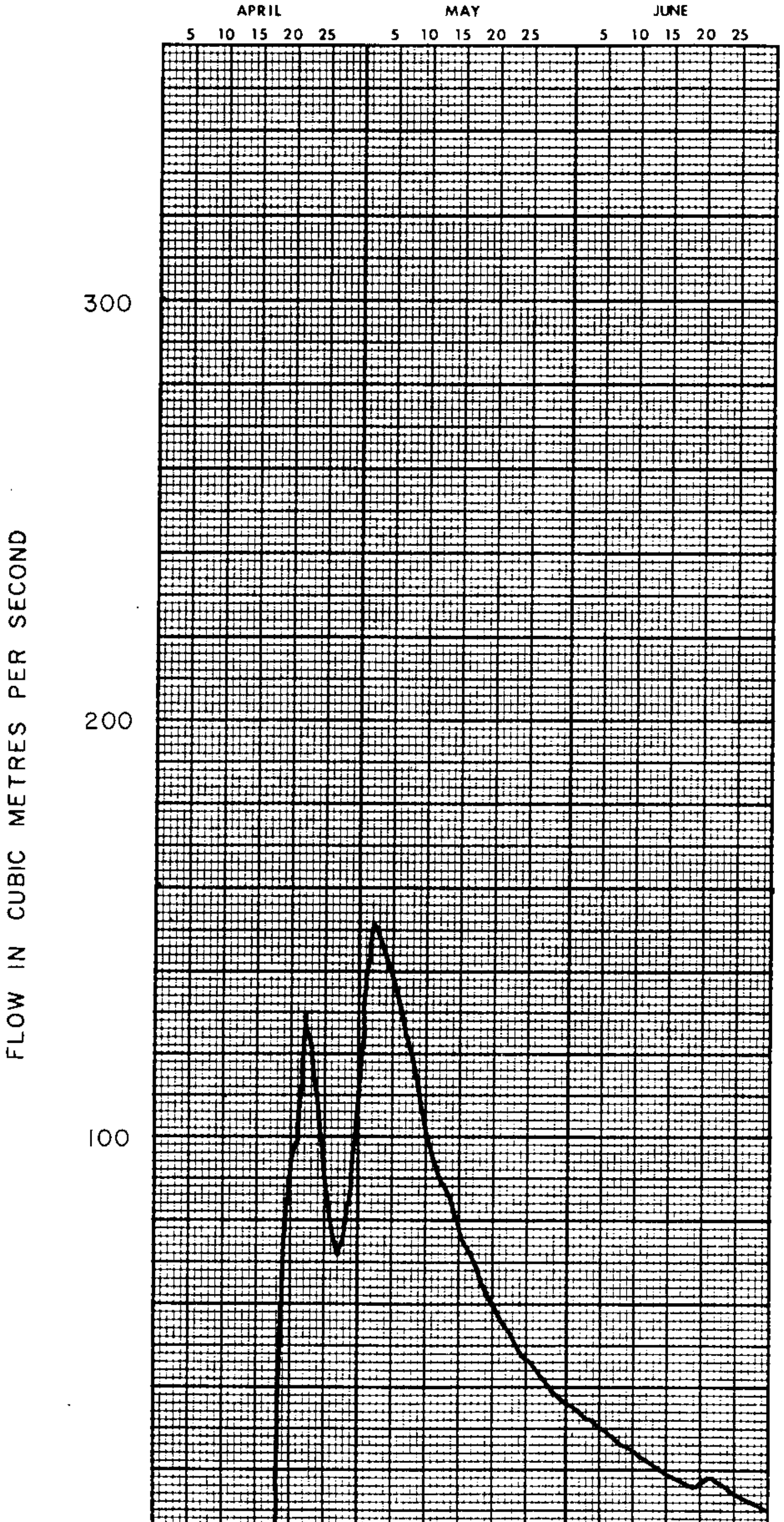


PEMBINA RIVER
AT
NECHE
05OC004

DISCHARGE
HYDROGRAPHS

LEGEND

1979 ——
1950 - - - -

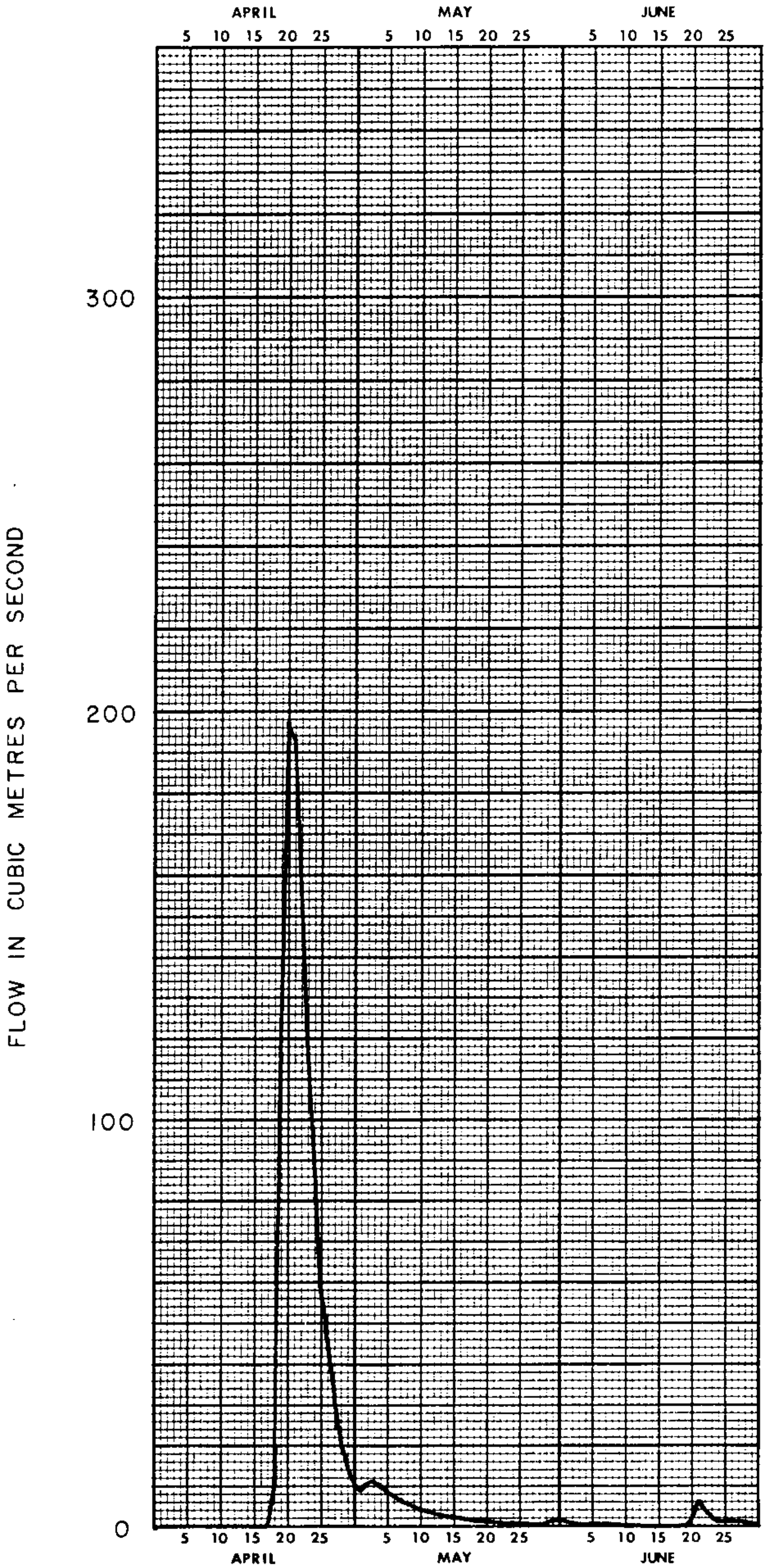


PEMBINA RIVER
NEAR
WINDYGATES
05OB007

DISCHARGE
HYDROGRAPHS

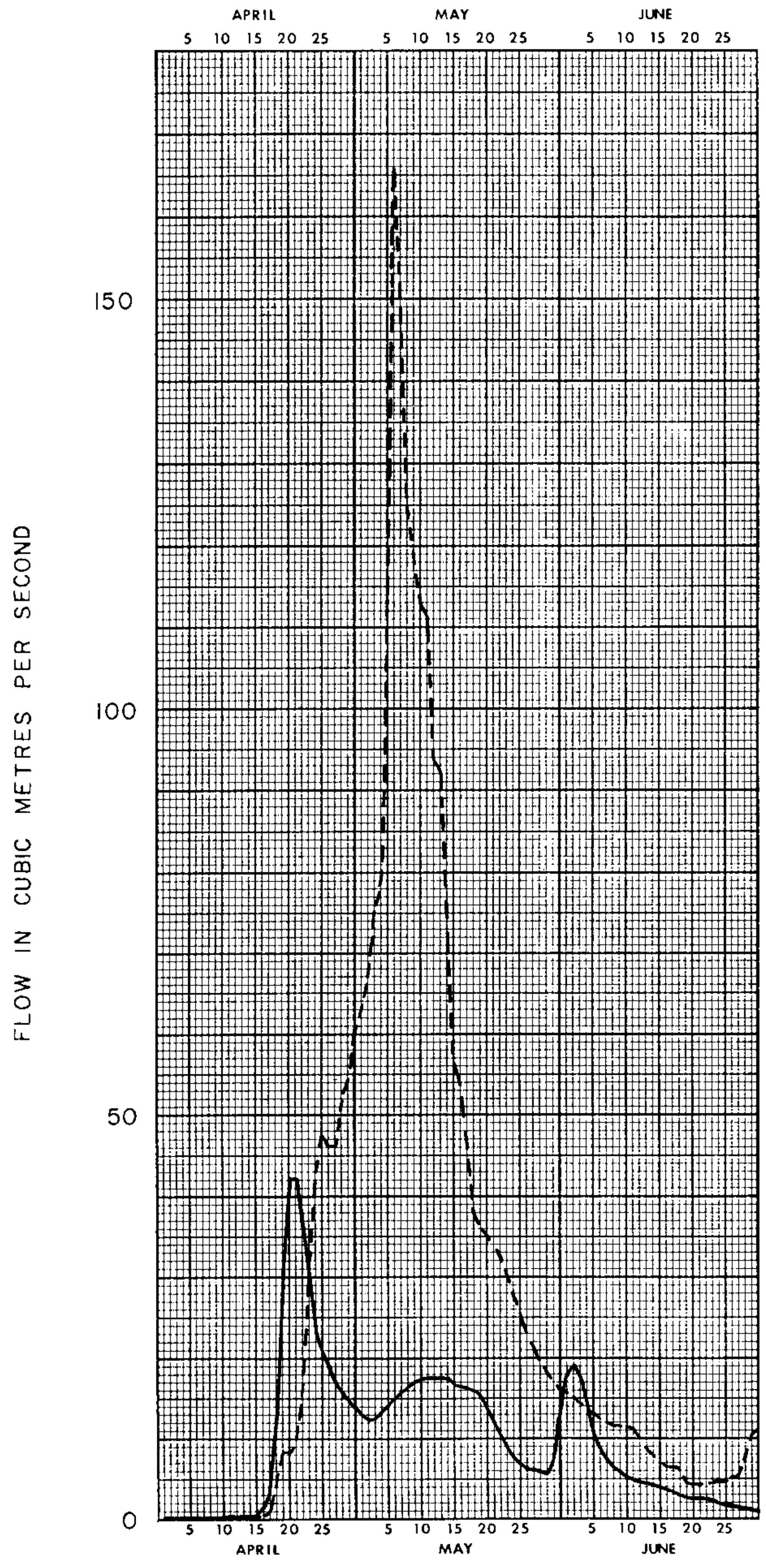
LEGEND

1979 ——
1950



PLUM RIVER
NEAR ROSENFELD
05OC019

DISCHARGE
HYDROGRAPHS

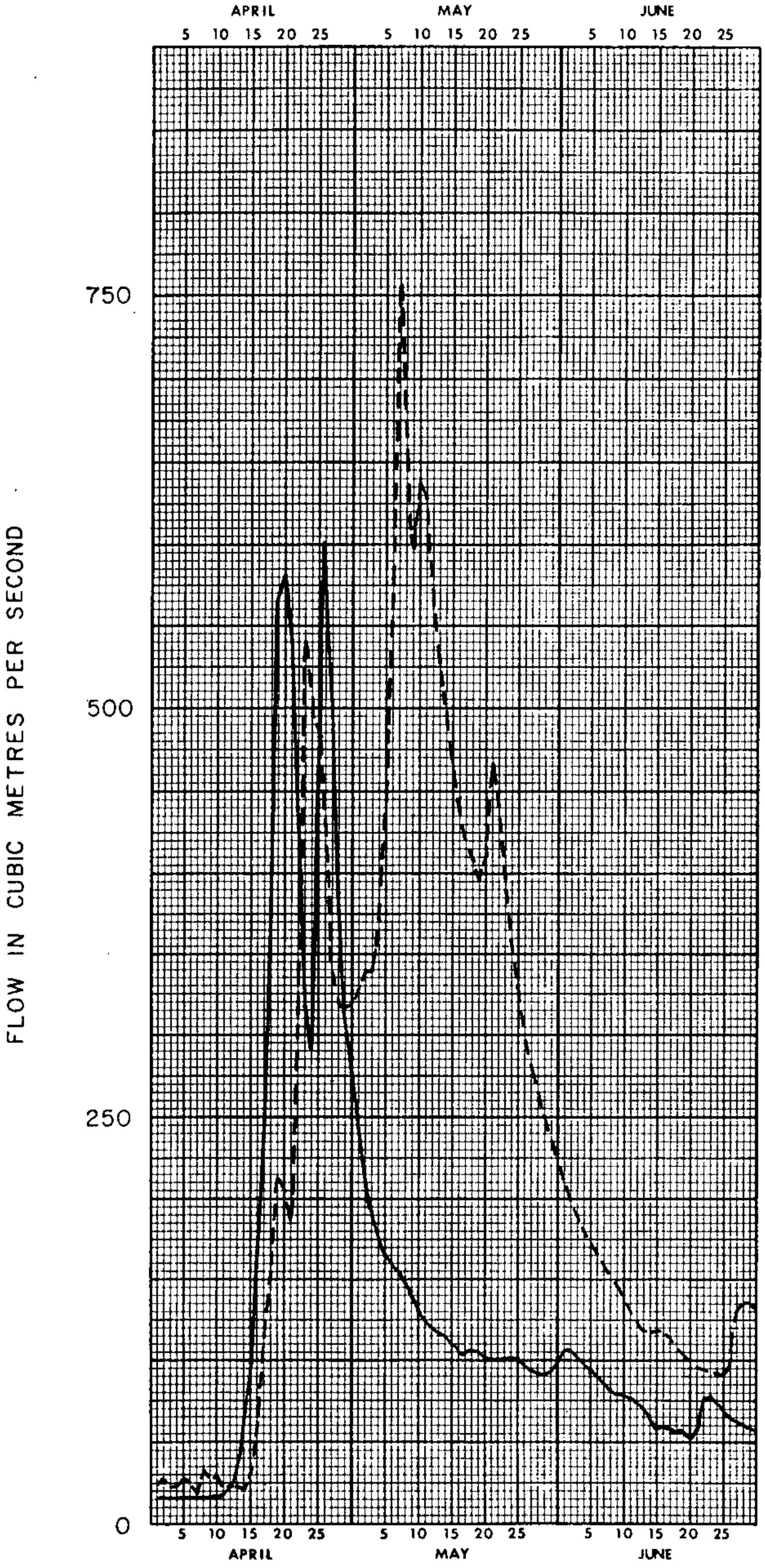


RAT RIVER
NEAR
OTTERBURNE
05OE001

DISCHARGE
HYDROGRAPHS

LEGEND

1979 ———
1950 - - - -



RED LAKE RIVER
AT CROOKSTON
05079000

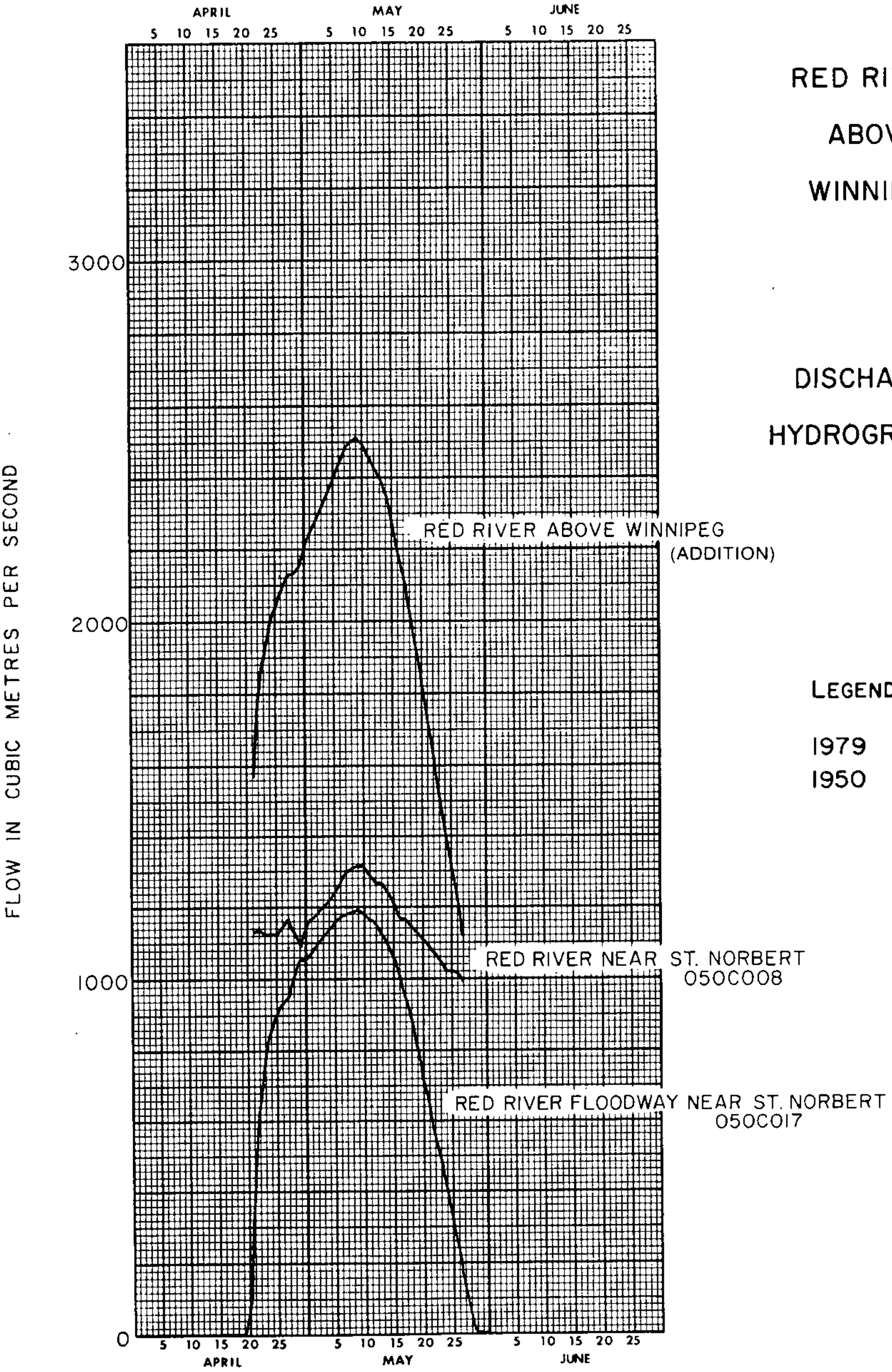
DISCHARGE
HYDROGRAPHS

LEGEND

1979 ———
1950 - - - -

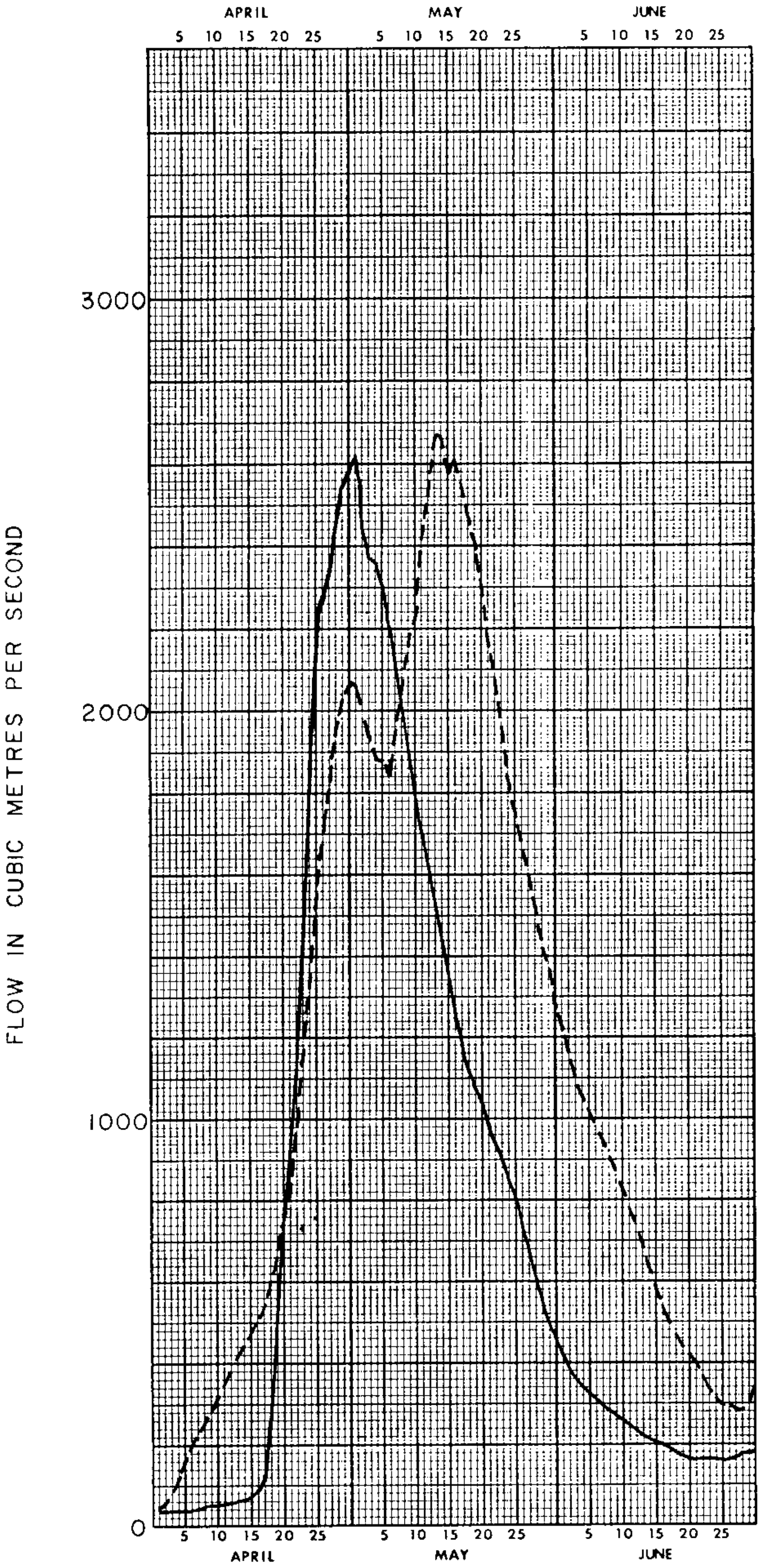
RED RIVER
ABOVE
WINNIPEG

DISCHARGE
HYDROGRAPHS



LEGEND

1979 ——
1950



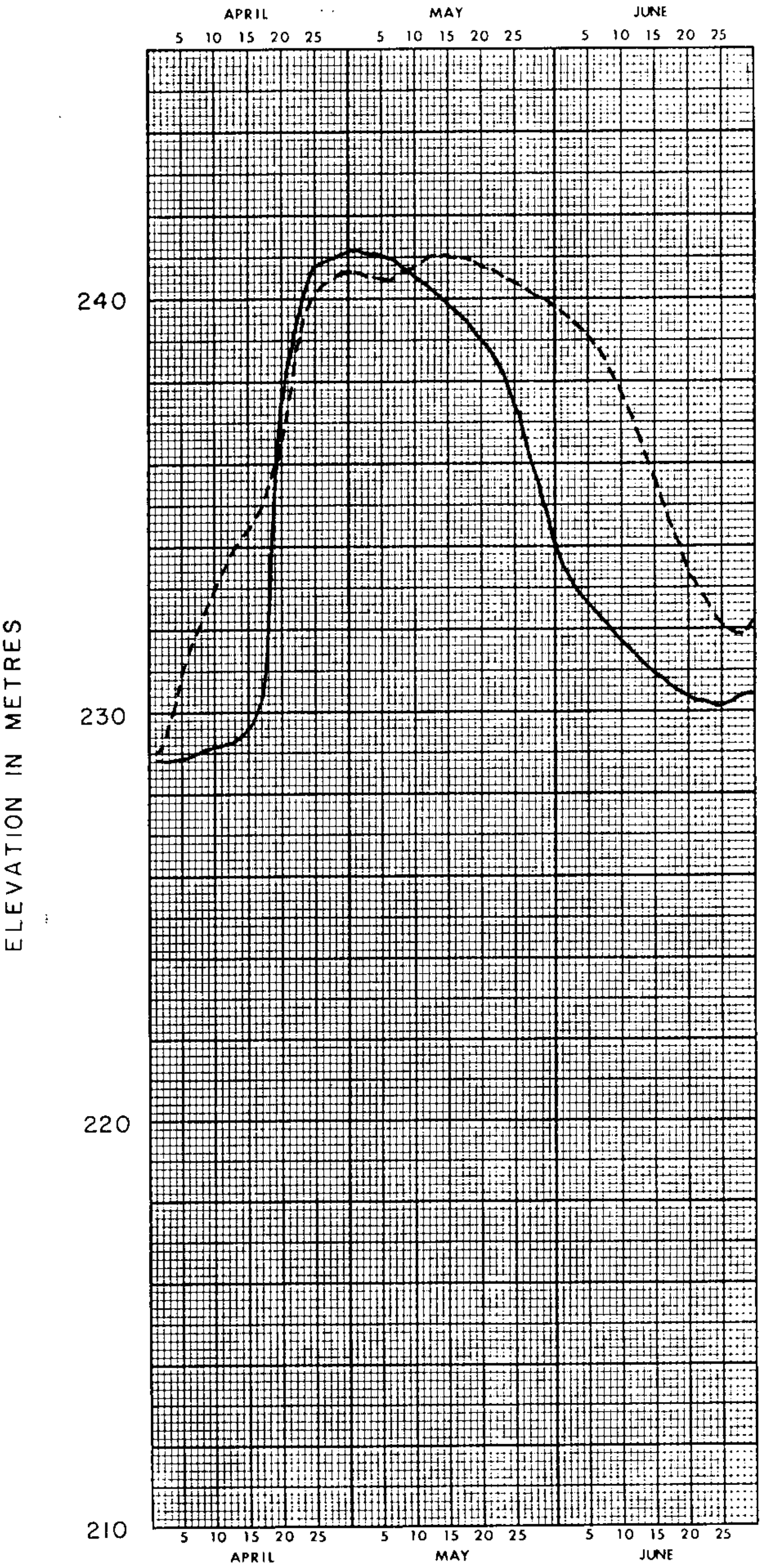
RED RIVER
AT EMERSON
05OC001

DISCHARGE
HYDROGRAPHS

LEGEND

1979 ——

1950 - - - -



RED RIVER
AT EMERSON
05OC001

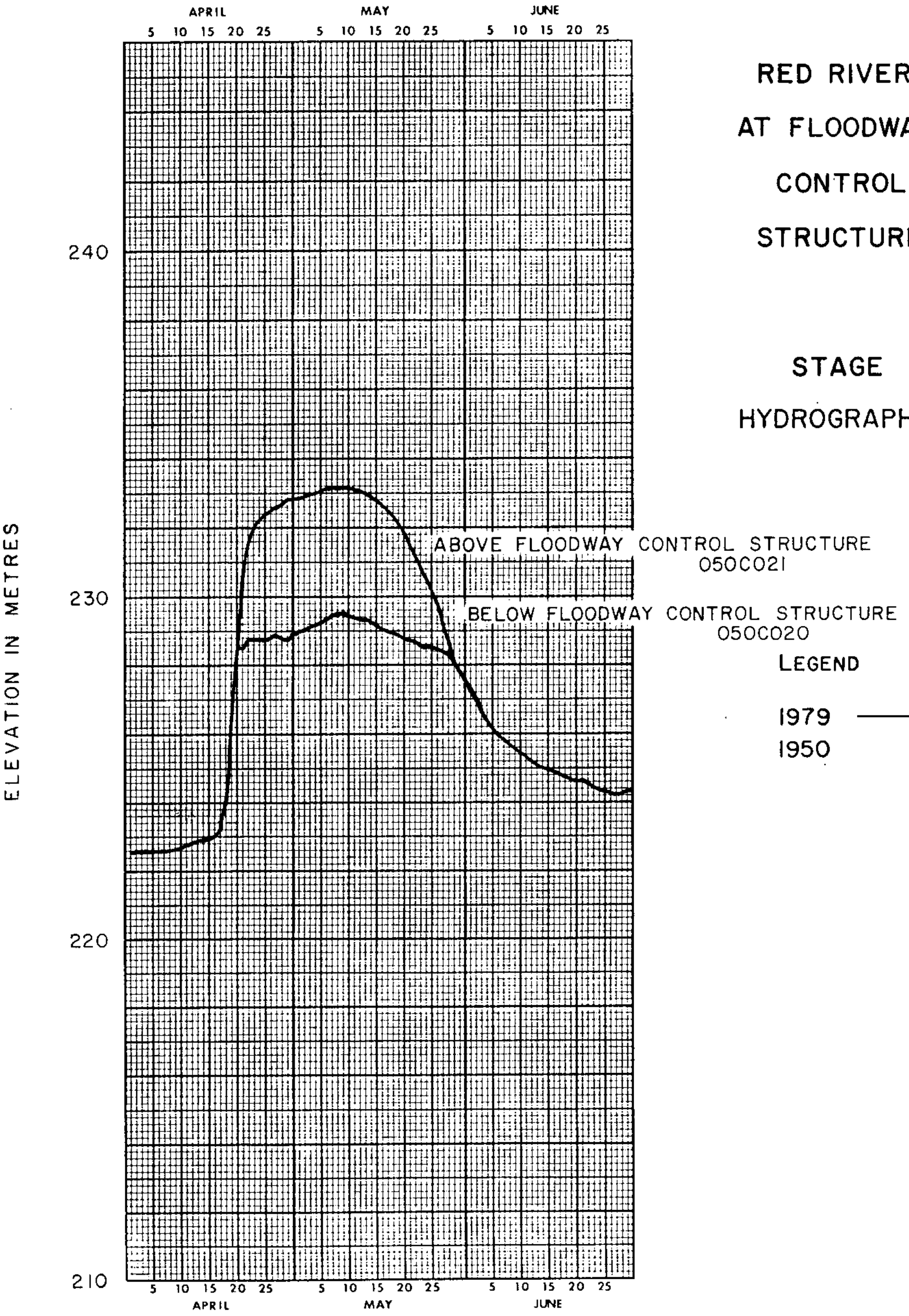
STAGE HYDROGRAPHS

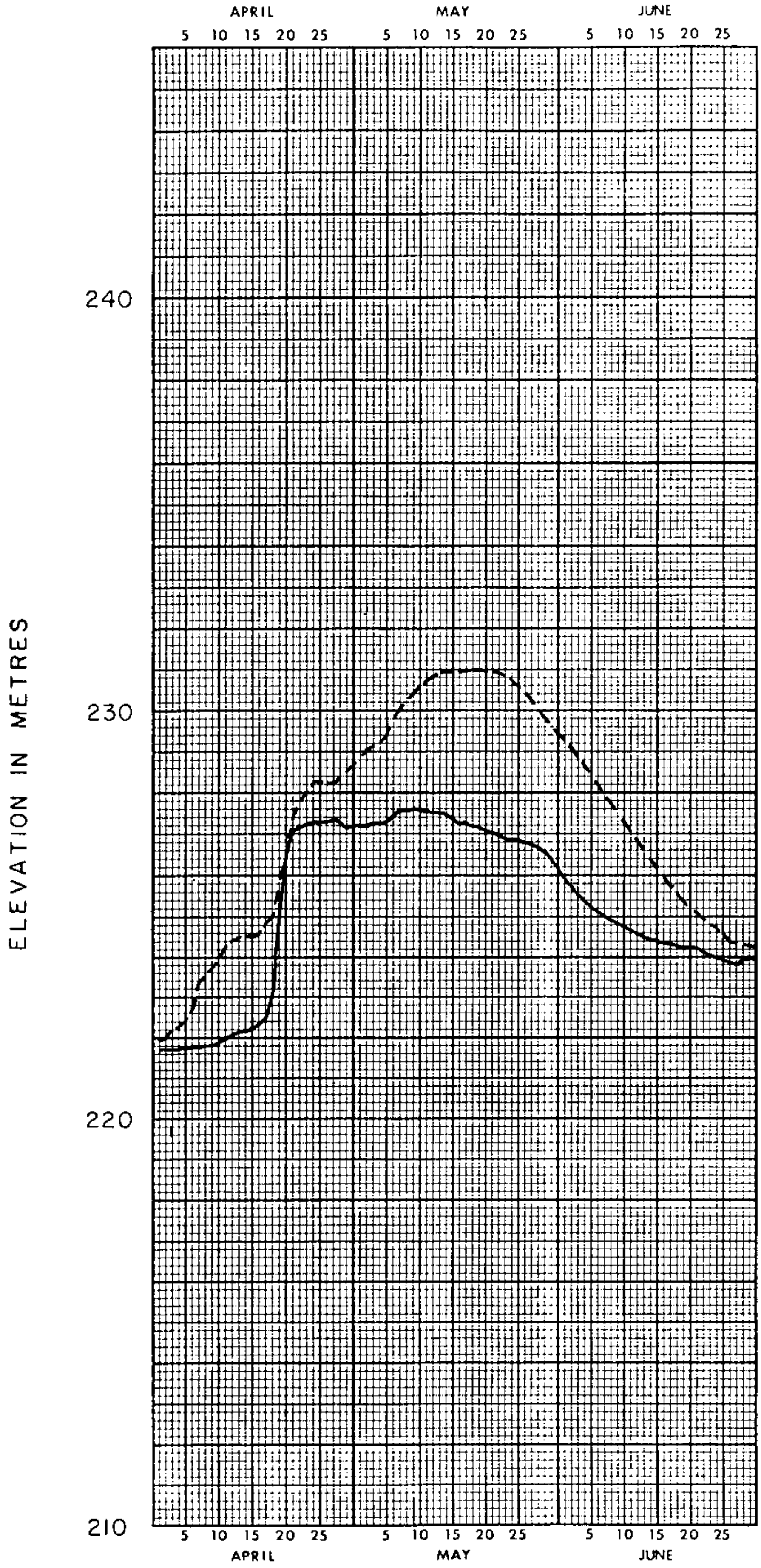
LEGEND

1979 ——
1950 ----

RED RIVER AT FLOODWAY CONTROL STRUCTURE

STAGE HYDROGRAPHS





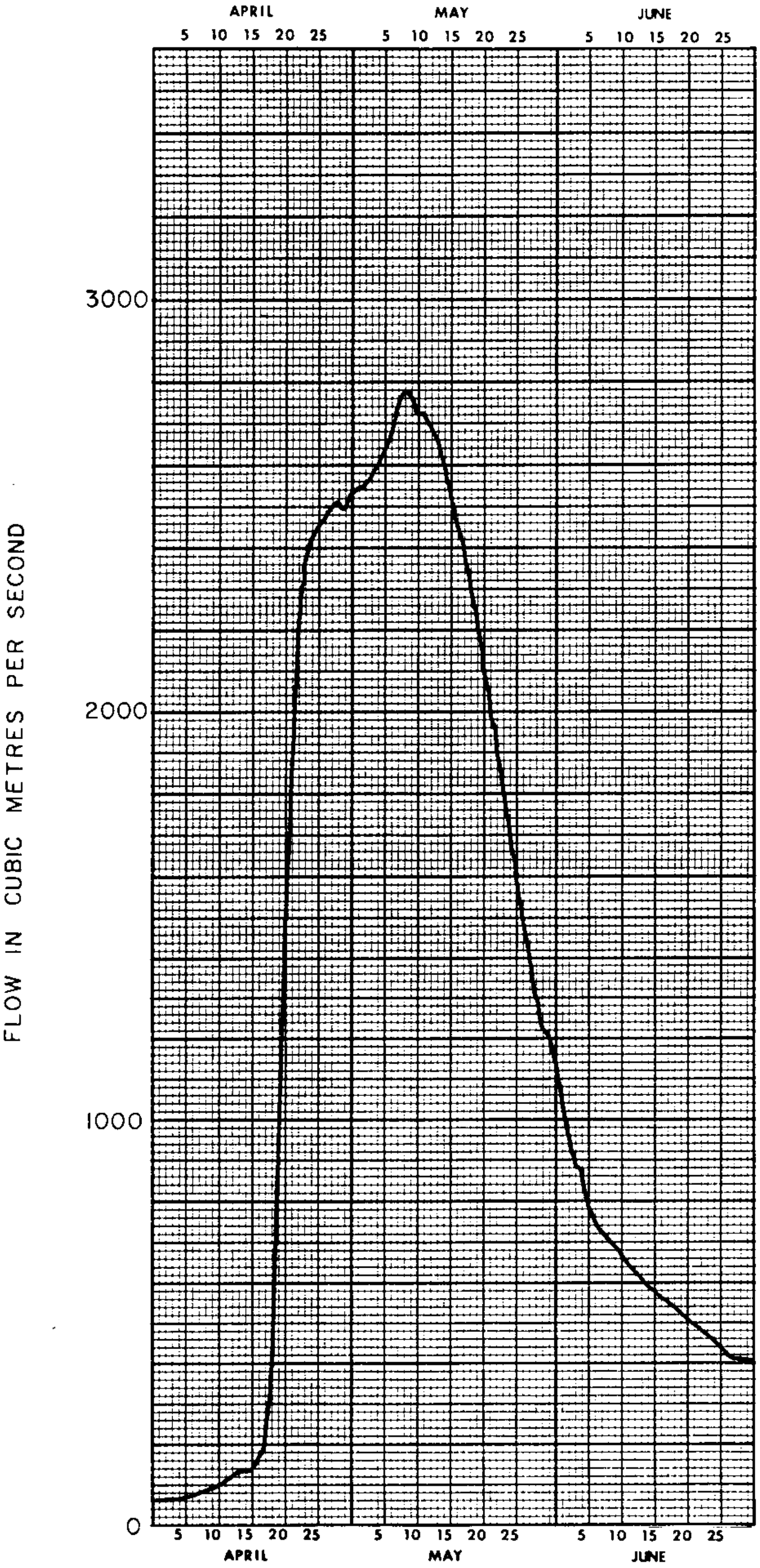
RED RIVER
AT JAMES AVE.
PUMPING STATION
050J015

STAGE
HYDROGRAPHS

LEGEND

1979 ——

1950 - - - -

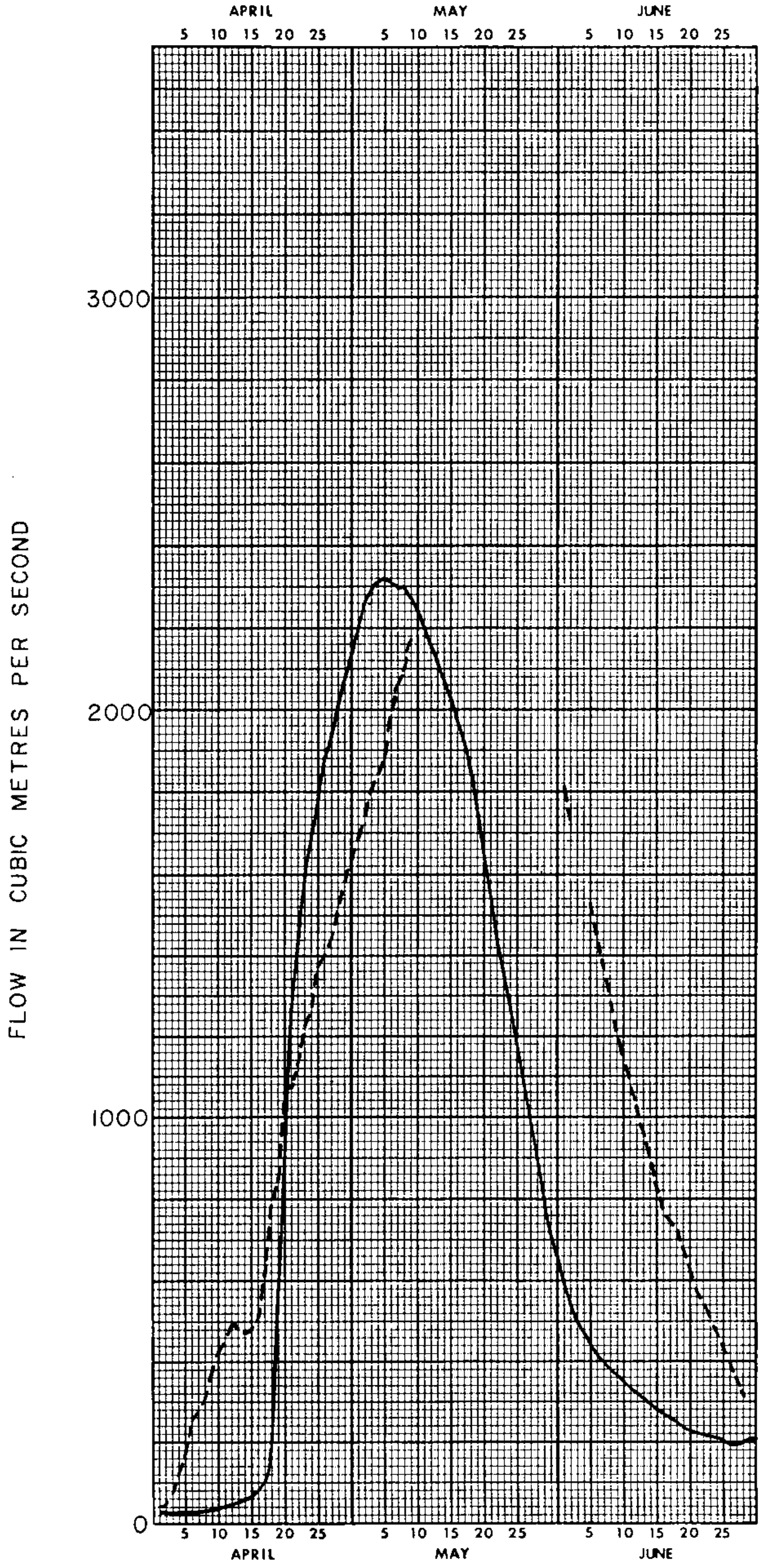


RED RIVER
NEAR LOCKPORT
05OJ010

DISCHARGE
HYDROGRAPHS

LEGEND

1979 ——
1950



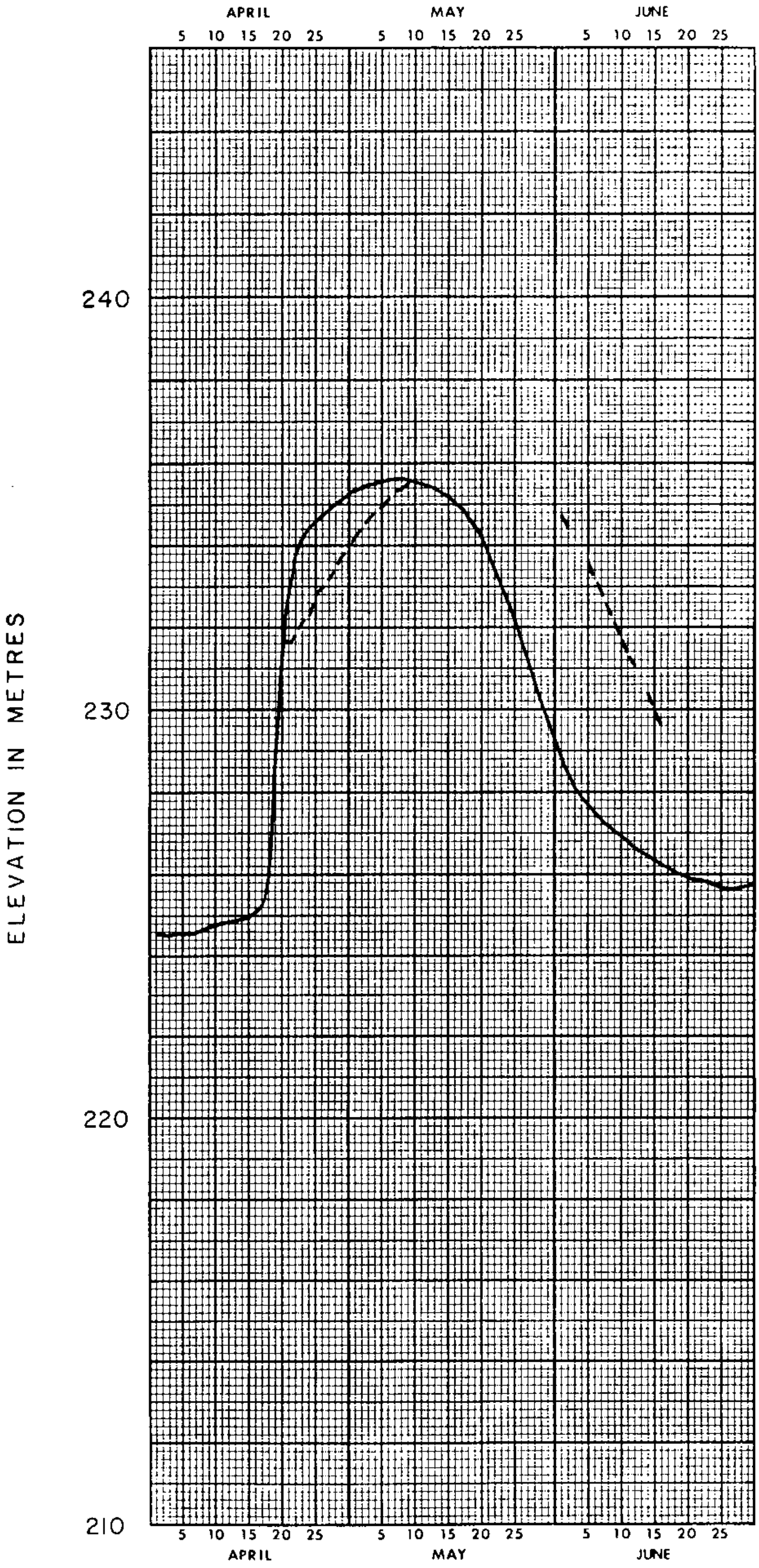
RED RIVER
NEAR
STE. AGATHE
05OC012

DISCHARGE
HYDROGRAPHS

LEGEND

1979 ——
1950 ----

Note: *With high water mark elev. of 235.67 in 1950, the estimated peak flow was 2550 CMS which occured sometime during the period from May 15 to 18. The estimated peak flow was based on a flood routing formula and above noted HWM. 1950 data from Red River at Ste. Agathe 05OC005.*



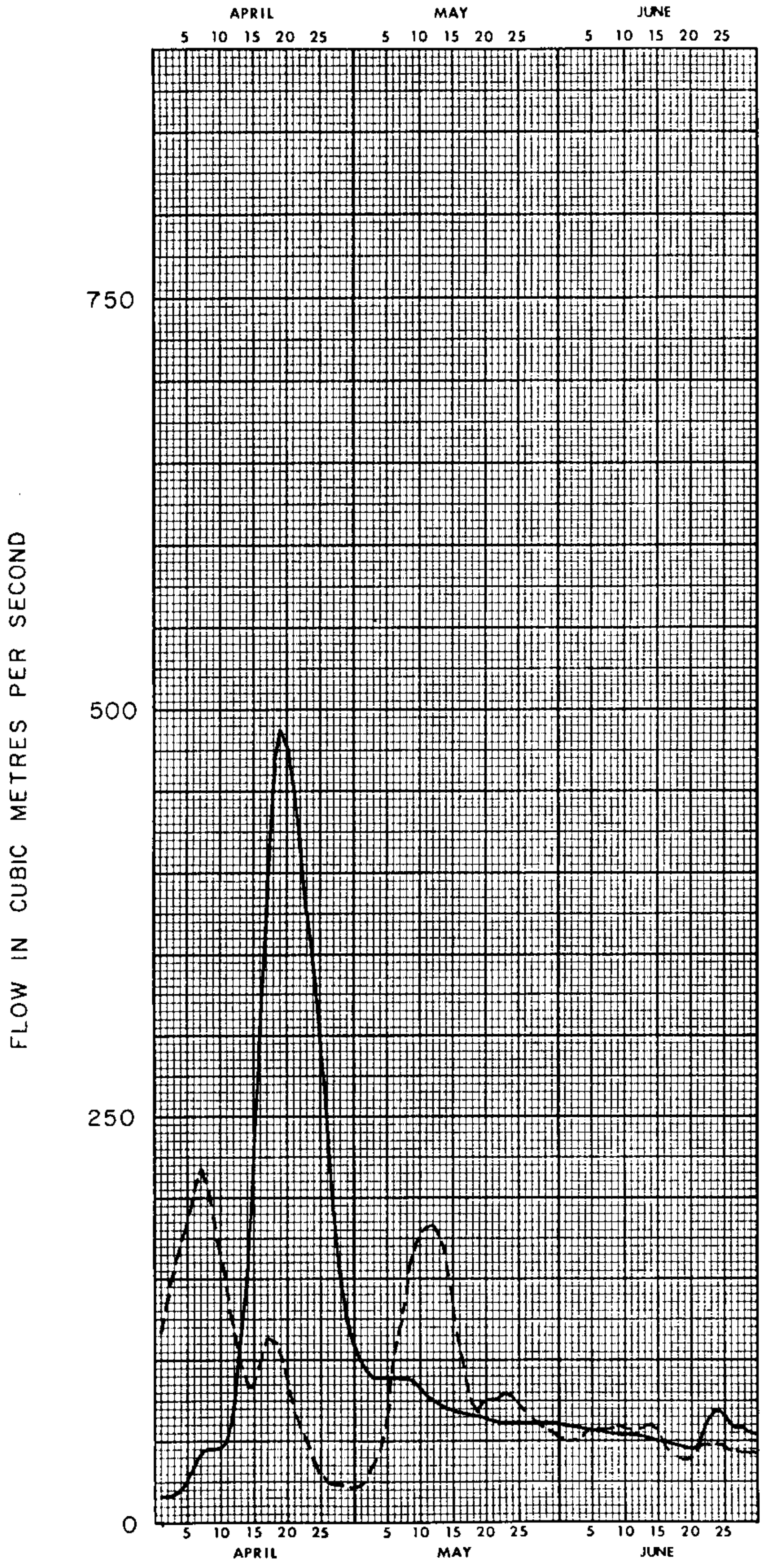
RED RIVER
NEAR
STE. AGATHE
05OC012

STAGE
HYDROGRAPHS

Note: 1950 data from Red River at Ste. Agathe 05OC005.

RED RIVER
OF THE NORTH
AT FARGO
05054000

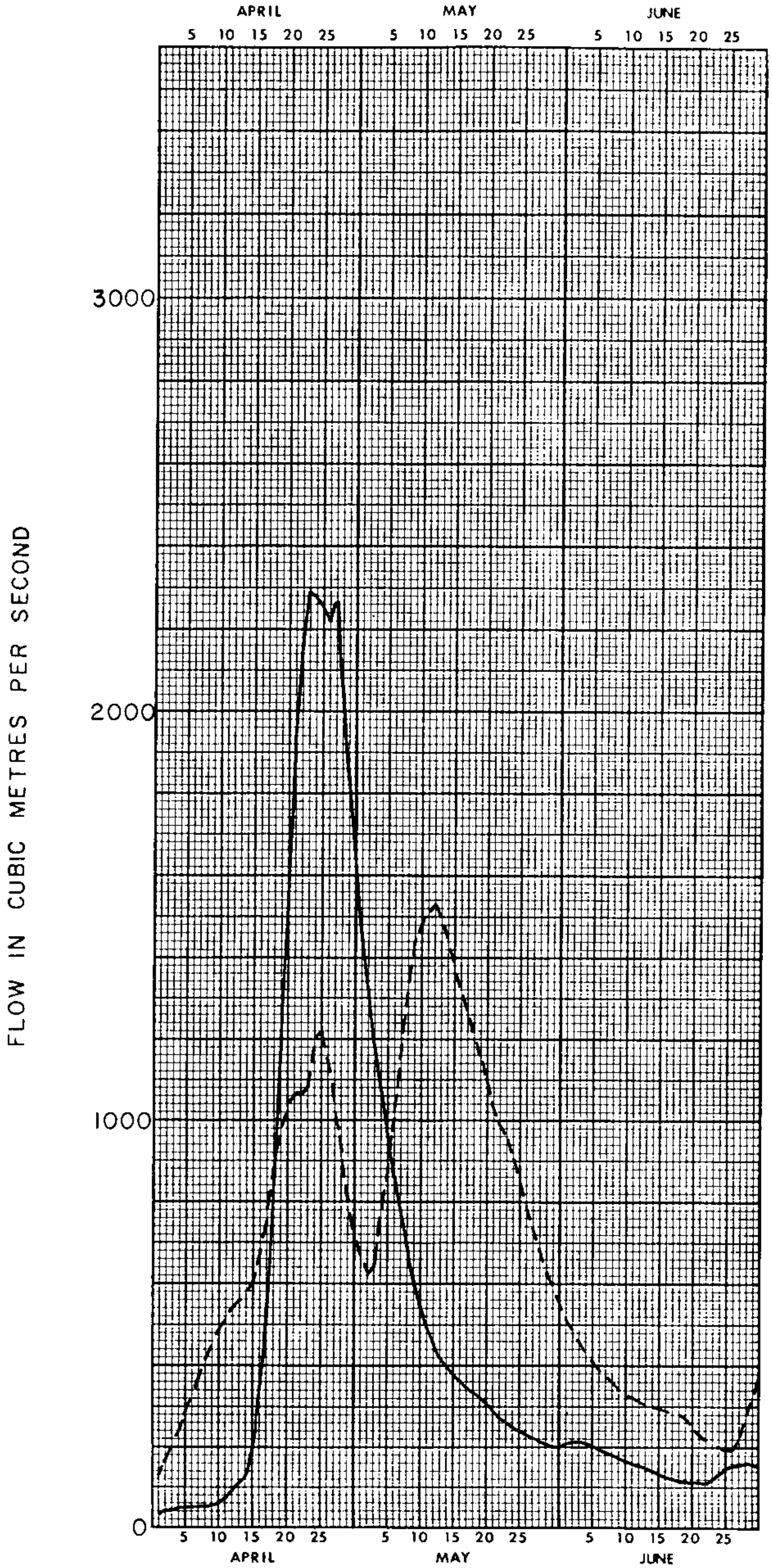
DISCHARGE
HYDROGRAPHS



LEGEND

1979 ———

1950 - - - -

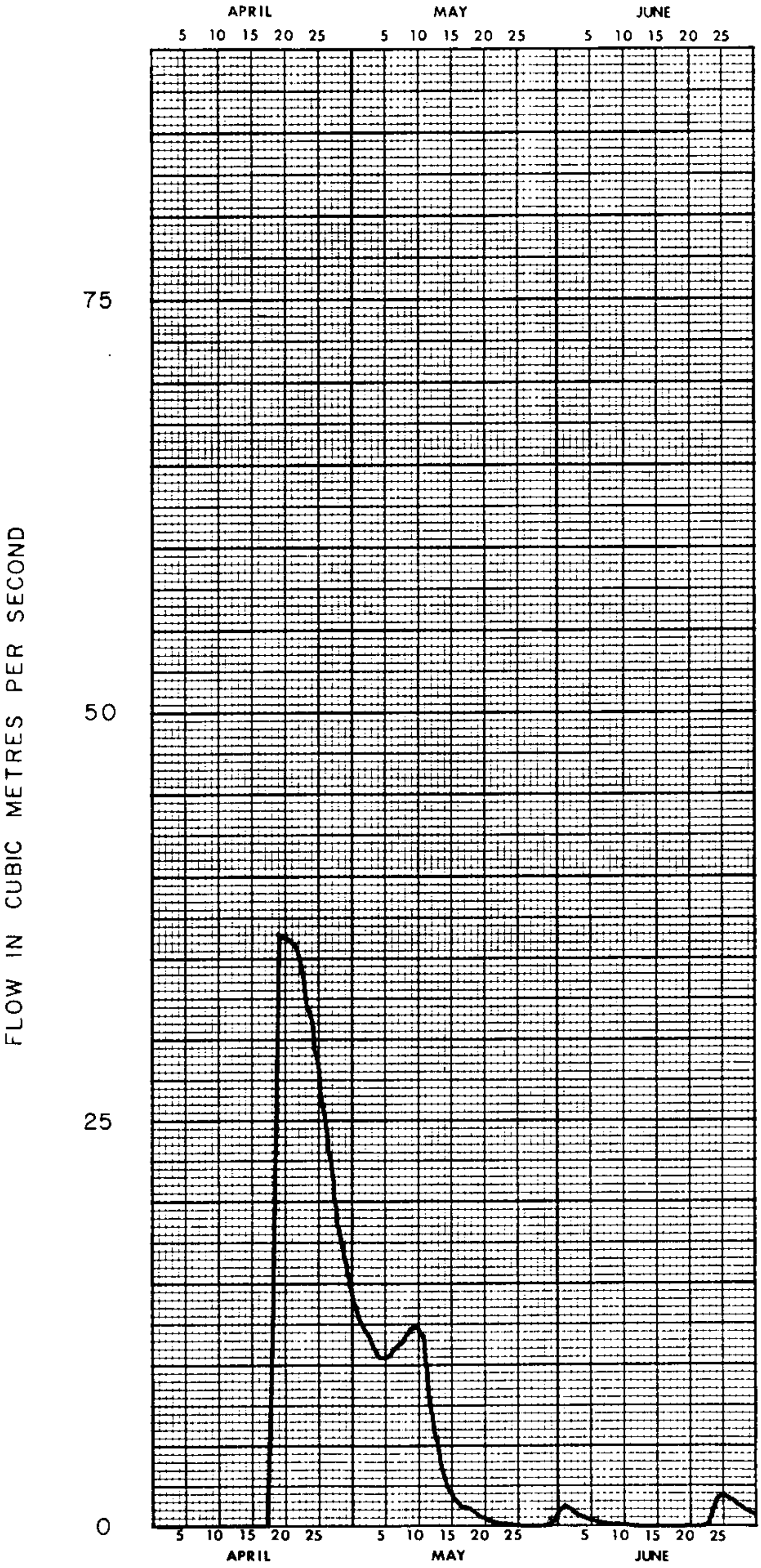


RED RIVER
OF THE NORTH
AT GRAND FORKS
05082500

DISCHARGE
HYDROGRAPHS

LEGEND

1979 ——
1950 - - - -



RIVIERE AUX MARAIS

NEAR CHRISTIE

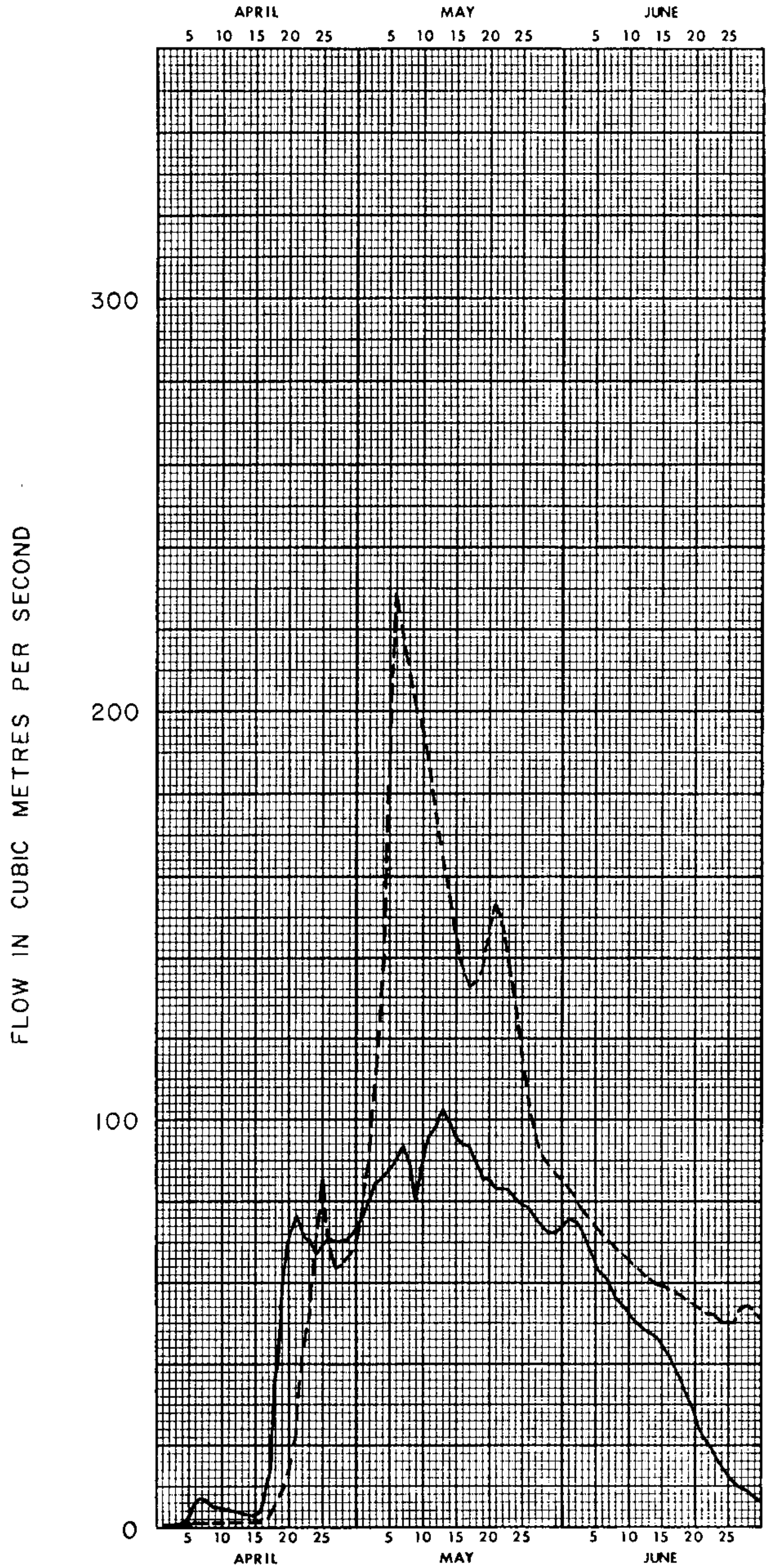
05OC022

DISCHARGE HYDROGRAPHS

LEGEND

1979 ——

1950



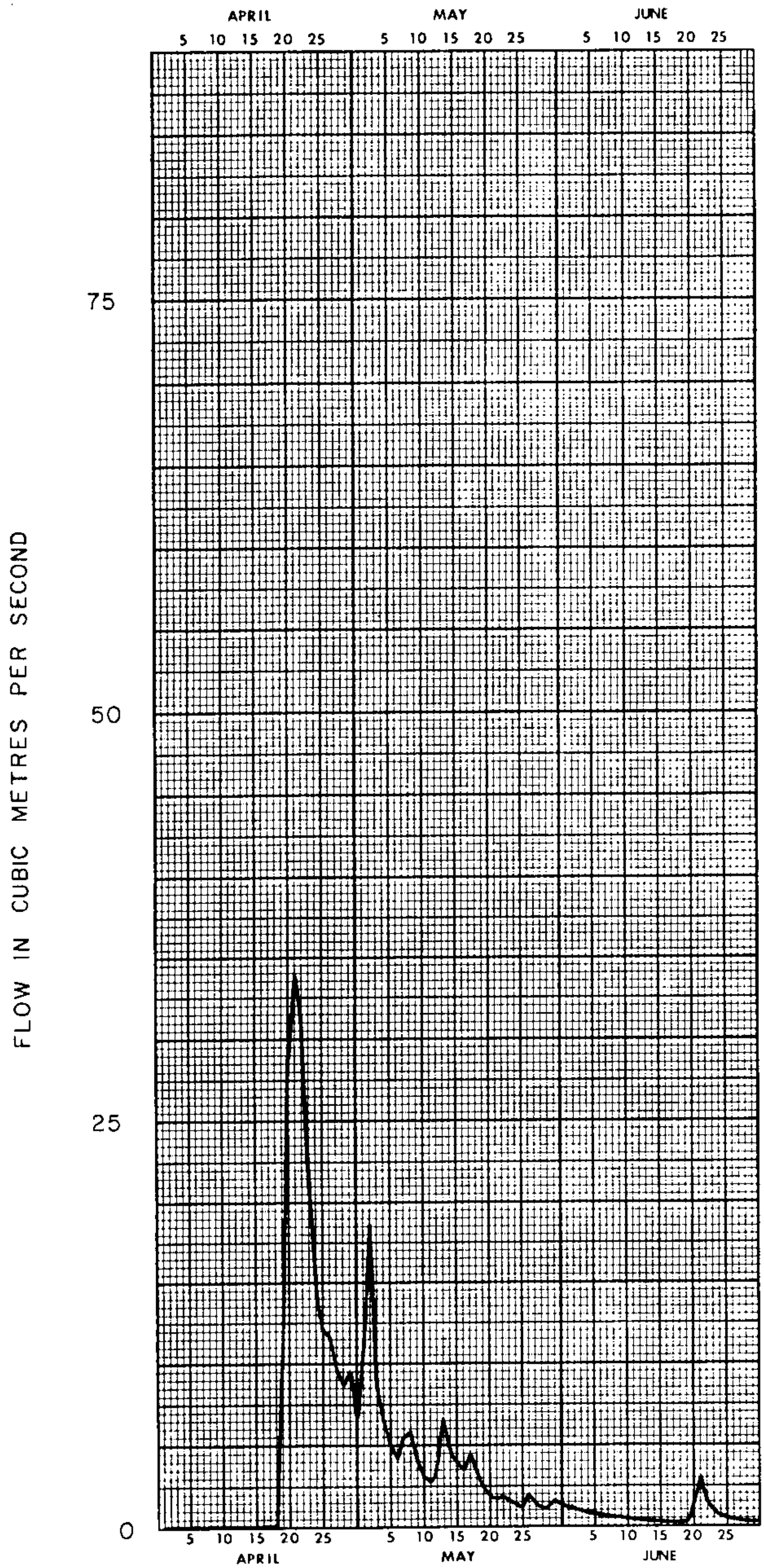
ROSEAU RIVER
NEAR
DOMINION CITY
05OD001

DISCHARGE
HYDROGRAPHS

LEGEND

1979 ———

1950 - - - -

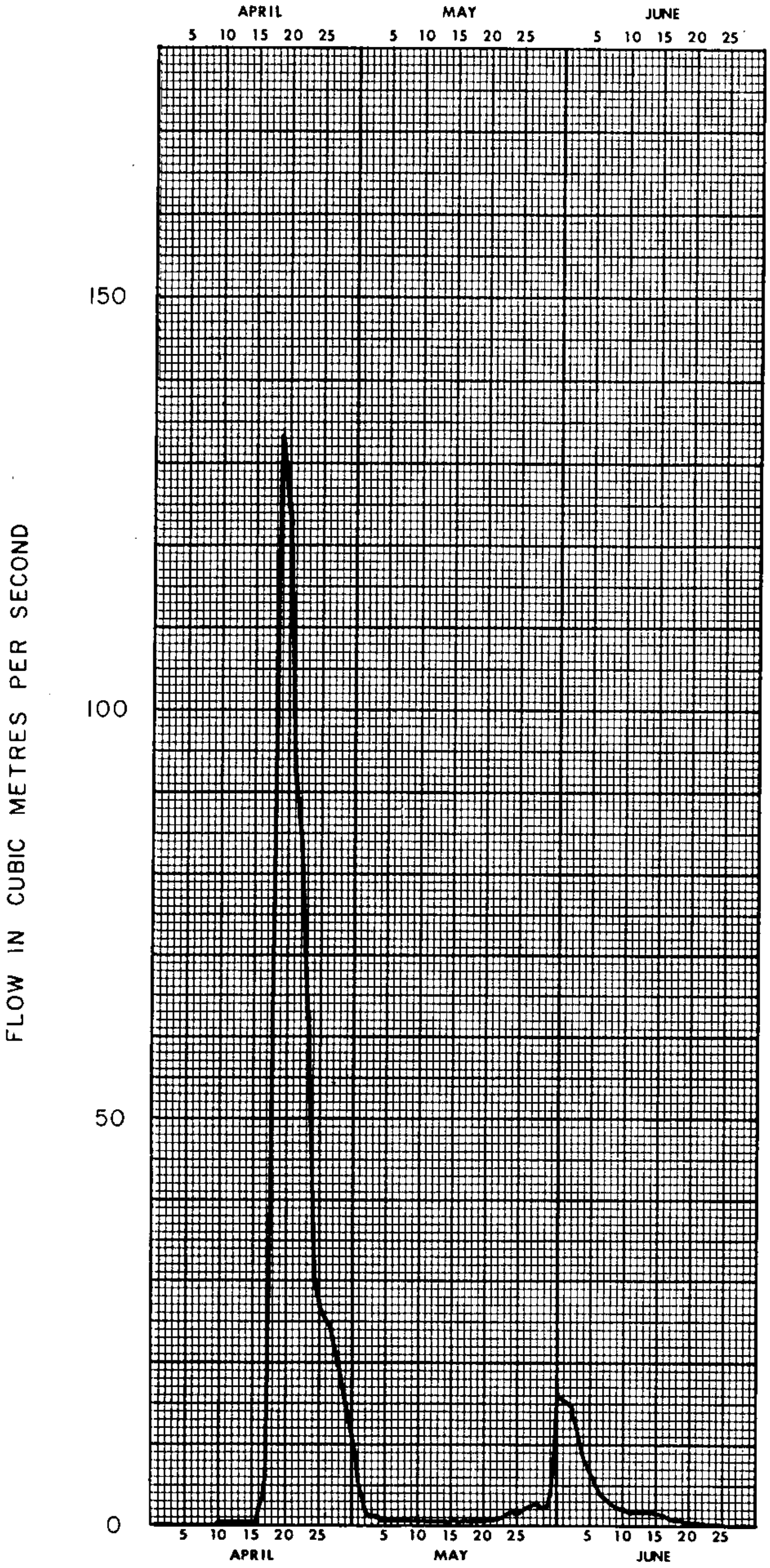


ROSEISLE CREEK
NEAR
ROSEISLE
050F009

DISCHARGE
HYDROGRAPHS

LEGEND

1979 ——
1950

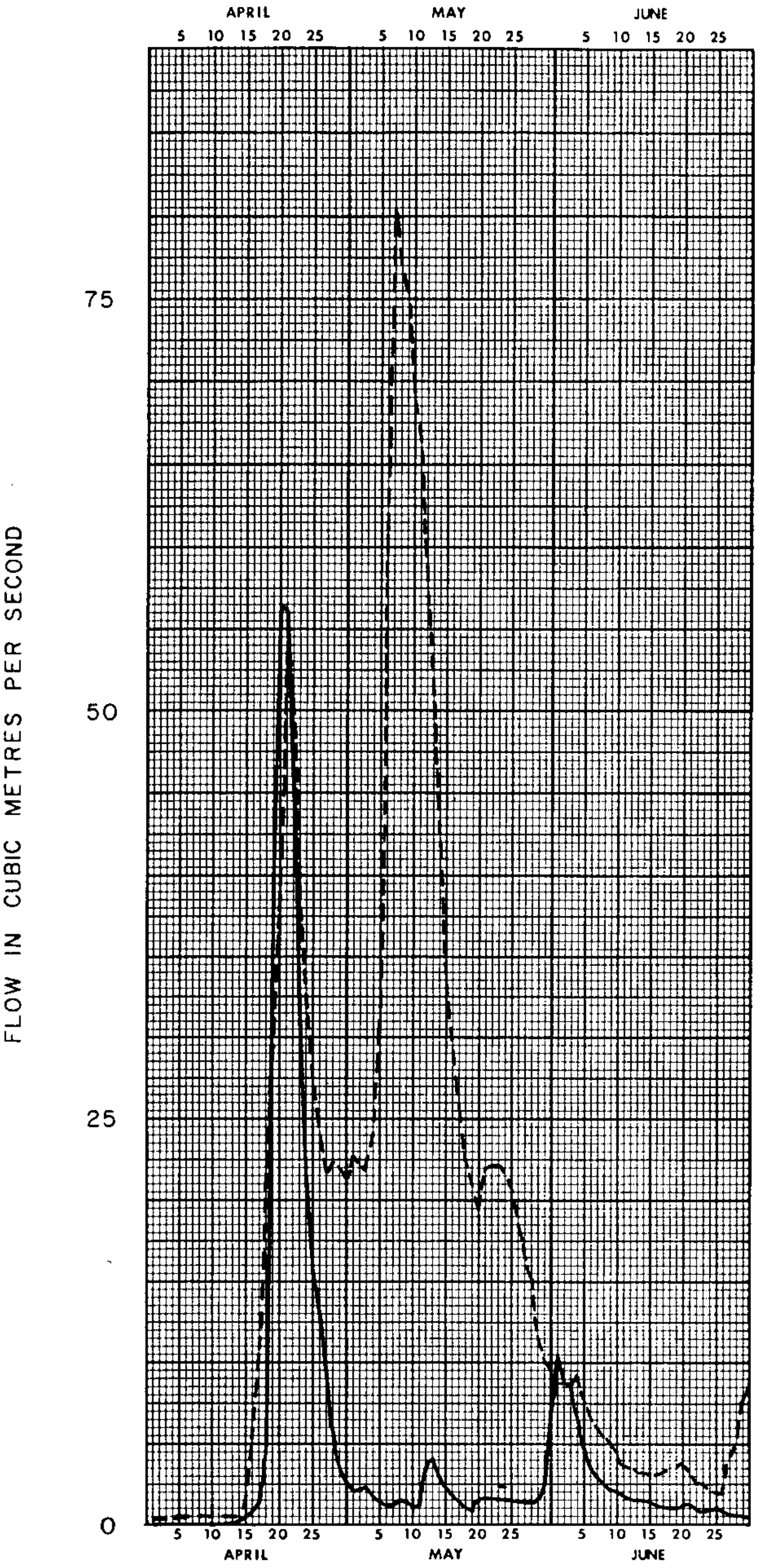


SEINE RIVER
DIVERSION
NEAR STE. ADOLPHE
05OE013

DISCHARGE
HYDROGRAPHS

LEGEND

1979 ——
1950

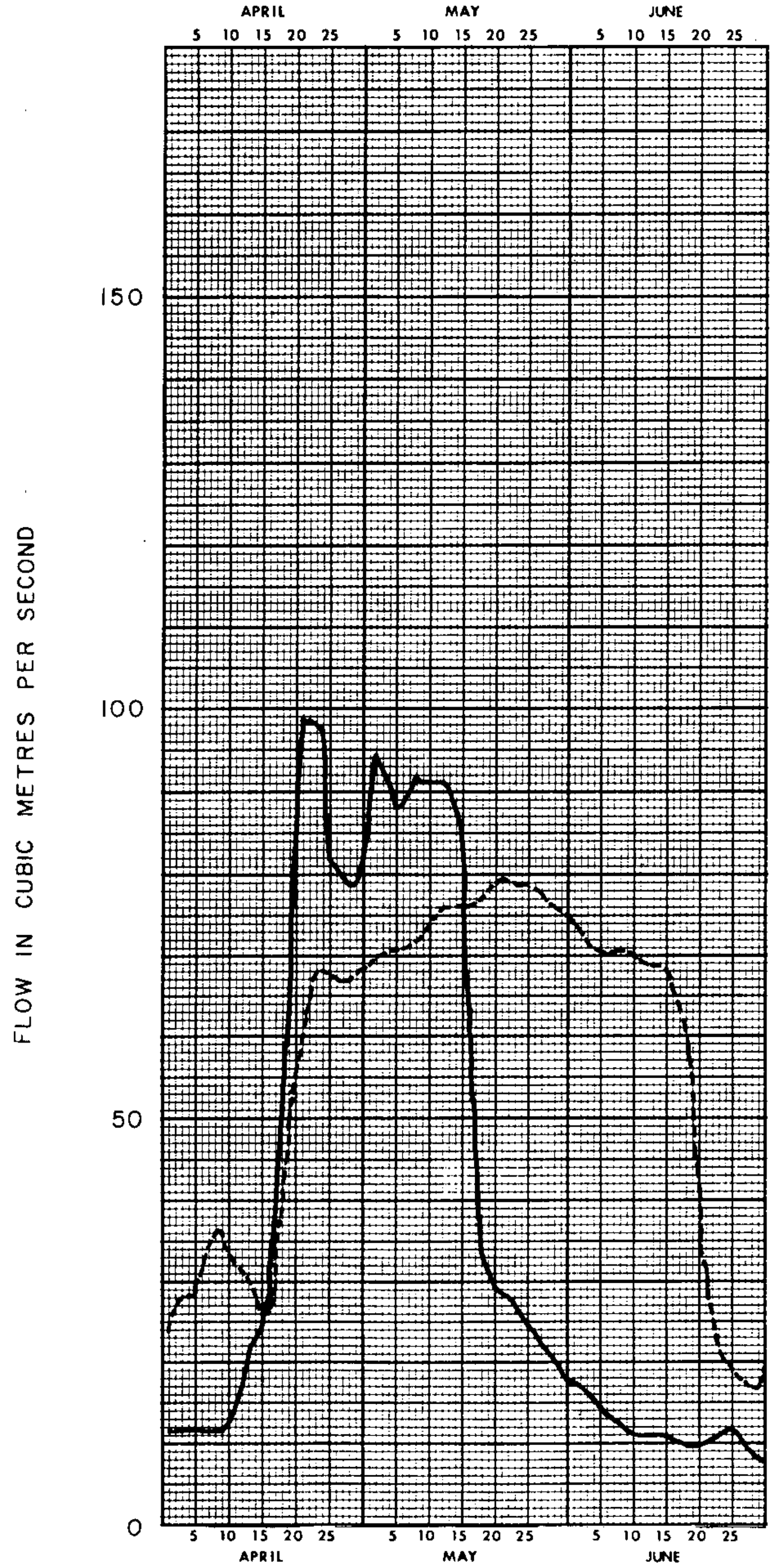


SEINE RIVER
NEAR
PRAIRIE GROVE
05OH006

DISCHARGE
HYDROGRAPHS

LEGEND

1979 ———
1950 - - - -



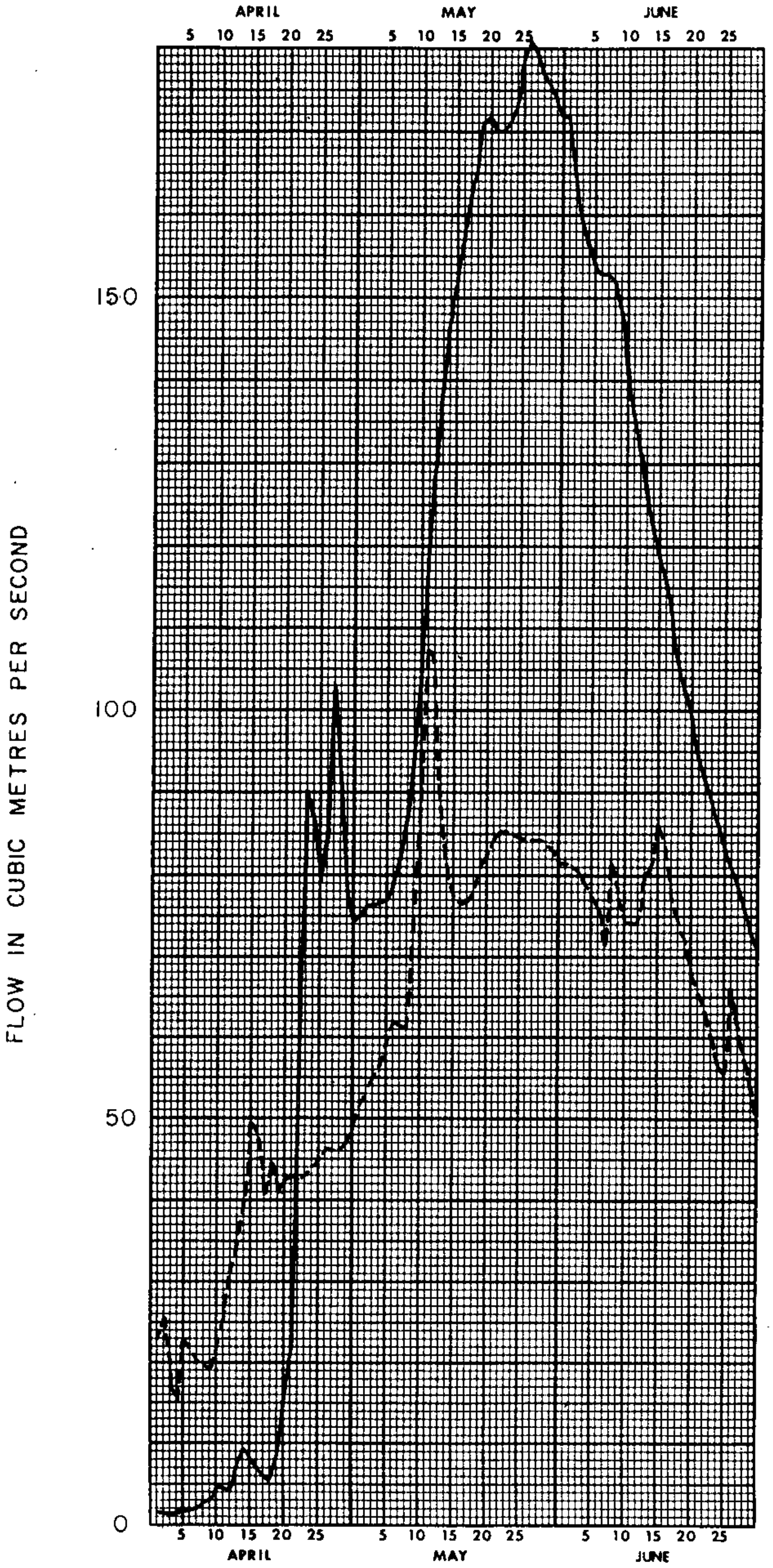
SHEYENNE RIVER
AT WEST FARGO
05059500

DISCHARGE
HYDROGRAPHS

LEGEND

1979 ——

1950 - - - -

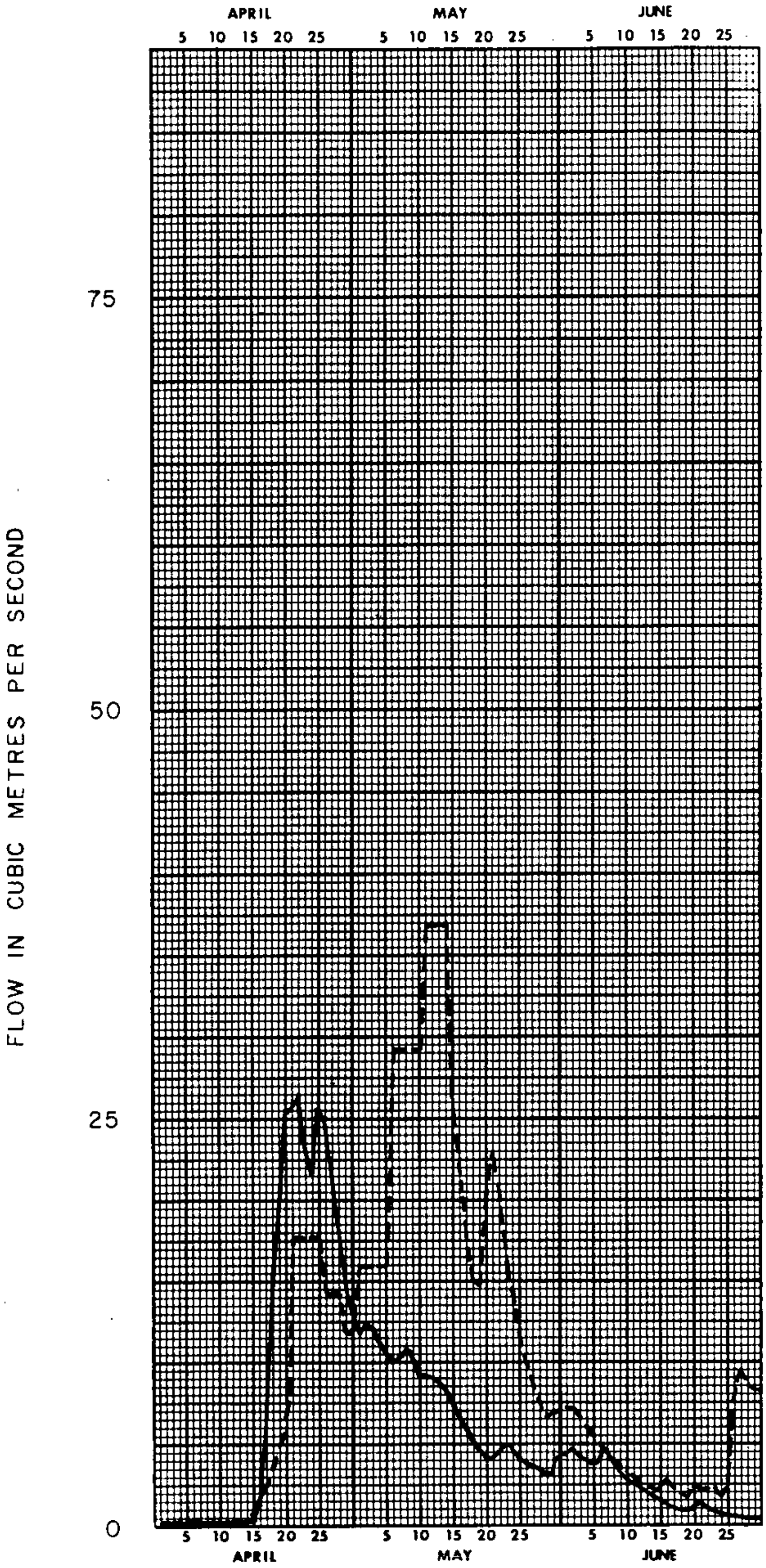


SOURIS RIVER
AT WAWANESA
05NG001

DISCHARGE
HYDROGRAPHS

LEGEND

1979 ——
1950 ----



SPRAGUE CREEK

NEAR

SPRAGUE

05OD031

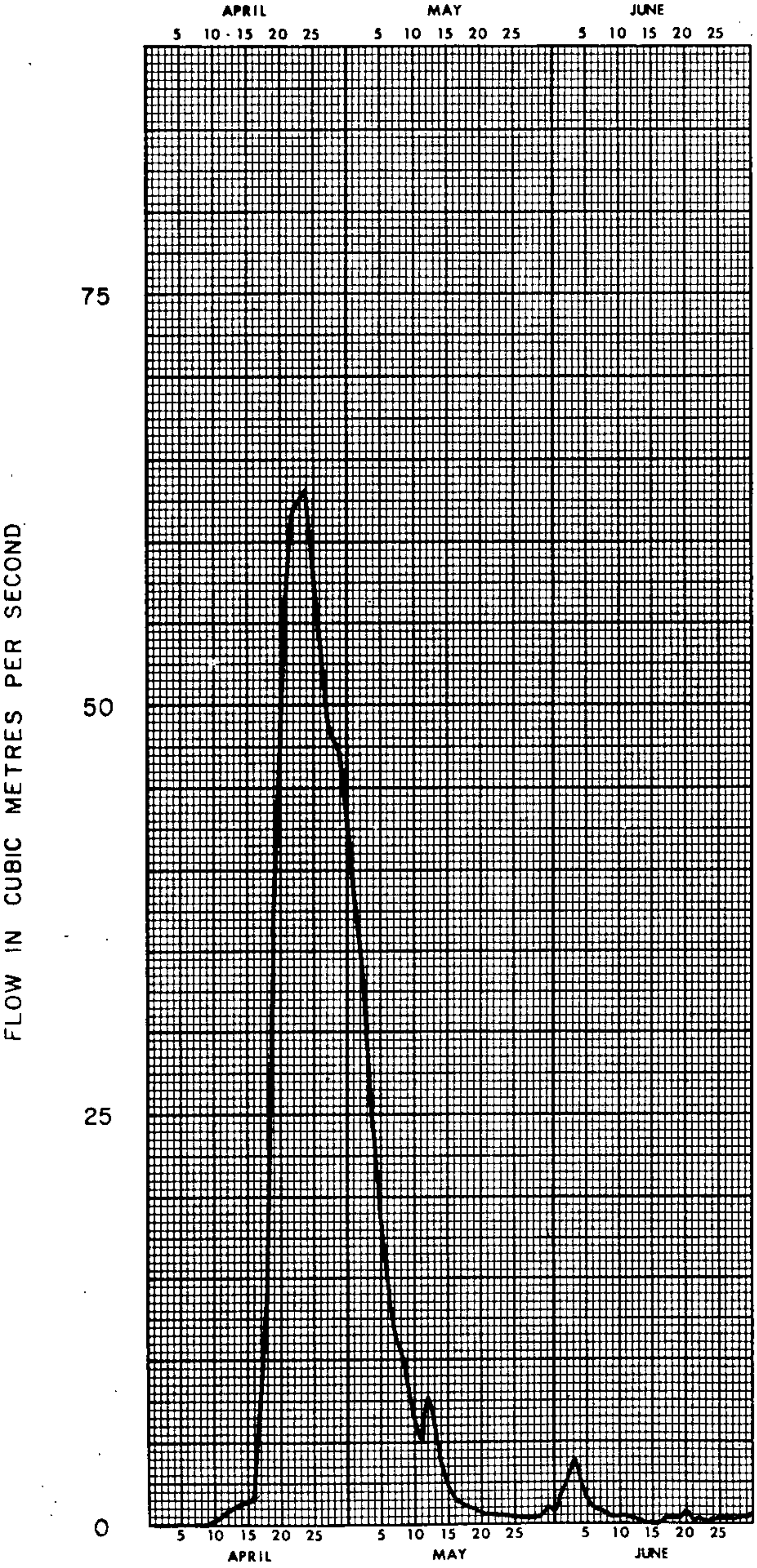
DISCHARGE

HYDROGRAPHS

LEGEND

1979 ——

1950 ----



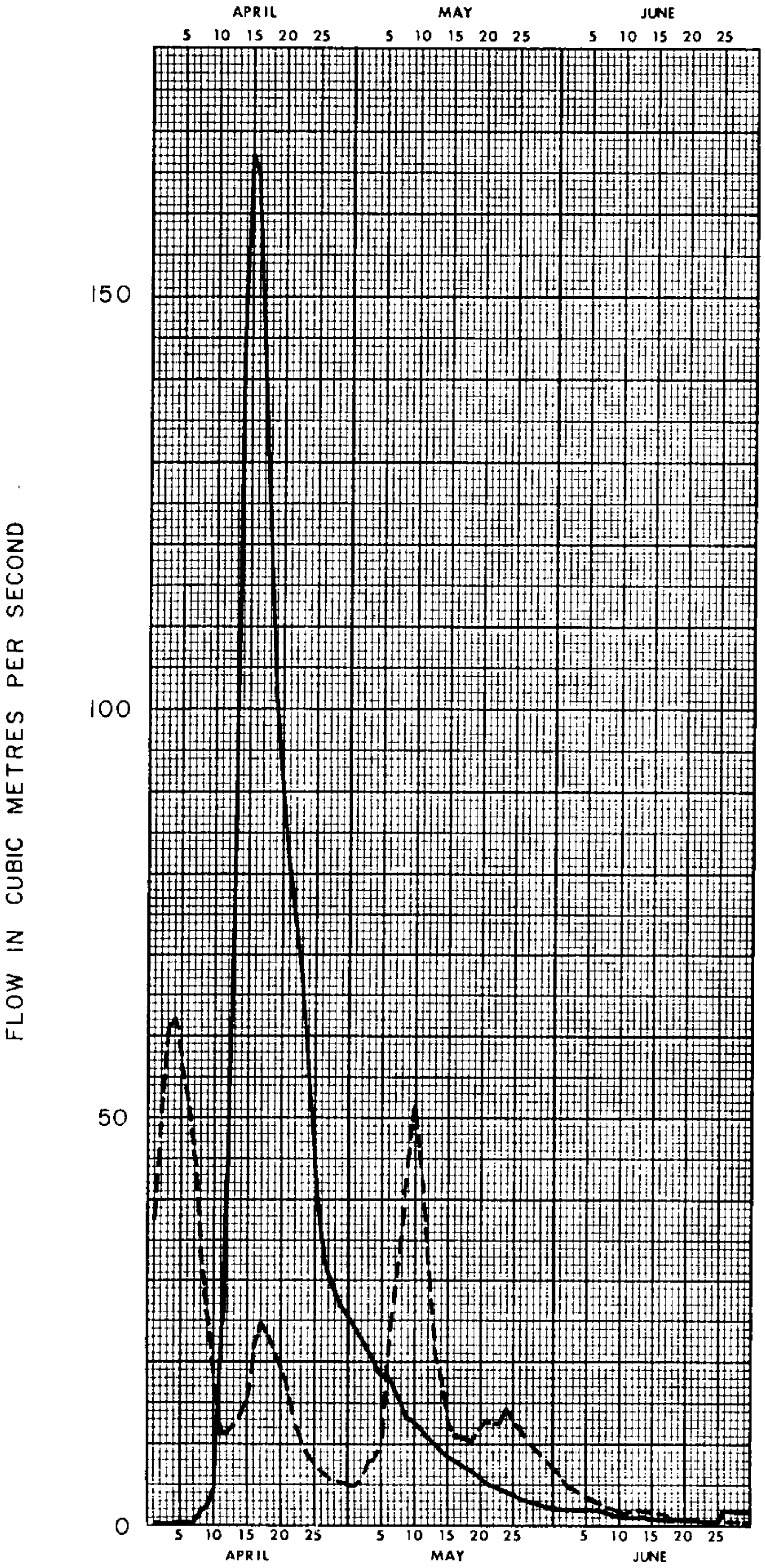
STURGEON CREEK
AT ST. JAMES
05MJ004

DISCHARGE
HYDROGRAPHS

LEGEND

1979 ——

1950



WILD RICE RIVER
NEAR
ABERCROMBIE
05053000

DISCHARGE
HYDROGRAPHS

LEGEND

1979 ——

1950 - - - -