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CRITICAL DURATIONS OF SNOWMELT PERIODS  
IN THE LIARD AND HAY RIVER FLOODS

BY

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ABSTRACT

The greatest flood levels ever recorded at Fort Simpson, NWT occurred in April 1963 during the spring break-up of the Liard River. At approximately the same time the town of Hay River was inundated by flood-waters of the Hay River. In this paper an attempt is made to determine the flood producing meteorological factors. Due to the absence of streamflow and snow course data in these basins it was necessary to limit the investigation to the observed climatological parameters.

It is shown by an analysis of snow-depth on ground observations that the rate of depletion of the snow-pack for durations of 20-25 days following the start of the spring thaw is a critical factor in producing floods on these rivers. Very moist antecedent conditions also contributed to the 1963 floods.

CANADA - DEPARTMENT OF TRANSPORT - METEOROLOGICAL BRANCH

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INTRODUCTION

At the end of April 1963 following a three-week spring thaw, which removed much of the heavier than normal winter snowfall over the Hay River basin, severe flooding occurred at the island townsite of Hay River. Flood waters rose as much as 20 feet at the mouth of the river where the onrushing ice-filled waters met the still-solid ice barrier of Great Slave Lake. Reports (2) indicate that flooding was prevalent as well on lowlands along the northerly-flowing river, and in particular, at the Indian settlement of Habay approximately 170 miles upstream from Hay River.

At about the same time spring break-up on the Liard River resulted in a very similar flood pattern at Fort Simpson, where the Liard joins the Mackenzie River. At this island location the break-up of the fast-moving Liard normally precedes the spring break-up of the Mackenzie River by several days, and ice jams and high waters are not unusual. However, in the period of recorded history flooding had not occurred at the Fort Simpson settlement prior to 1963 (4). In April 1963 more than 80% of the island on which the settlement is situated was inundated as massive ice jams at the junction with the still-frozen Mackenzie River blocked the overflowing Liard. Flood waters of the Liard River reached approximately 50 feet above normal water level at this location. (Personal Communication - John Turner)

Meteorological conditions leading to the floods at Fort Simpson and Hay River were similar, and in both the Liard and Hay River watersheds the amount and rate of snowmelt were major factors. The saturated state of the basins at the start of the winter season was a contributing cause, as were the lower temperatures to the north and east which maintained solid ice over Great Slave Lake and the Mackenzie River during the break-up period of the Liard and Hay Rivers.

TOPOGRAPHY AND CLIMATOLOGY

The Liard River Basin

The Liard River and its tributaries drain an area of 60,000 square miles of rolling plain and mountainous country in the Northwest Territories, Yukon Territory and British Columbia. The Liard has its source in the mountains of the Yukon about 100 miles northwest of Watson Lake (Fig. 1).

It follows southeastward along the broad Rocky Mountain Trench to meet the north northward-flowing Kechika River within a few miles of the weather station site at Smith River. Below the confluence of these rivers the Liard winds through steep canyons as it cuts eastward through the Rocky Mountains. The river falls off to the plains below then turns northeastward towards Fort Simpson and the Mackenzie River. The Fort Nelson, Petitot and South Nahanni Rivers join the Liard River system in the lower part of its course. Two of these rivers drain rugged mountain terrain to the south and west, while the third rises in low rolling country to the east. The mountainous terrain of the western two-thirds of the Liard River watershed contrasts sharply with the gently-sloping lowlands east of the Rockies. In elevation the Liard descends from more than 2000 feet above sea level in the Yukon to about 400 feet where it joins the Mackenzie River.

While meteorological stations are widely separated in this sparsely-settled section of northwestern Canada, at least five are located within the 60,000 square mile watershed of the Liard River (fig. 1). These include Watson Lake (Y.T.), Smith River, Fort Nelson and Beatton River (B.C.), with continuous records of approximately 20 years, and Fort Simpson (N.W.T.) which dates back more than 40 years.

The climate of the Liard River drainage basin is typically continental. While low pressure areas frequently move through the Mackenzie River valley in summer and fall, and less often in spring, the persistent anticyclonic conditions in the months of November through February are indicative of the long periods of cold weather in these months. In the lower courses of the Liard River system the annual precipitation averages about 13 inches, of which more than half occurs as rain during the summer. The season for snowfall is long and although the winter months are normally the driest of the year, totals reach 45 to 50 inches. During the months November through March, when mean daily temperatures are below 32°F, periods of thaw are infrequent and the snow accumulates steadily as winter progresses. While the eastern plains remain deep in the cold Arctic air in winter, the mountainous western portions of the basin are often in maritime air swept inland by the Pacific low pressure areas which move northward into the Gulf of Alaska. As a result mean daily temperatures in winter are some 10 to 15 degrees higher in the headwater valleys, and snowfall totals are almost twice those of the lowland areas. Periods of thawing weather during the winter cause very little run-off, but instead tend to consolidate the snow-pack. On the average, the melting of the winter's snow starts in the upper reaches of the basin during the second week in April and progresses to the lower plains near the end of the month.

#### The Hay River Basin

With a drainage area of approximately 11,000 square miles the Hay River watershed is only one-fifth the size of the Liard River basin. Despite the contrast in size, many of the climatological and topographical features are common to both basins.

The Hay River rises in foothills in British Columbia about 60 miles east of Fort Nelson. In the headwaters regions the Hay River and the

Chinchaga which joins it near the Alberta settlement of Habay are swiftly-flowing rivers. Below the confluence the northern half of the drainage channel leading to Great Slave Lake has more gradual slopes and swamp conditions often prevail.

As in the Liard watershed, snowfall is considerably greater in the higher terrain near the headwaters than over the lowlands to the north-east. Similarly, temperatures are higher and the spring break-up normally occurs almost one week earlier in the upper reaches of the river than near its mouth at Great Slave Lake. Snowfall ranges from 70 inches at the headwaters to 50 inches at Great Slave Lake.

Although Hay River is the only station within the basin with a satisfactory period of record, the reports from Fort Vermilion and Fort Resolution were considered to be representative of conditions in the central and northern areas. In addition, reports for Fort Providence, Fort Nelson and Peace River were used in the evaluation of rates of snow depletion (Fig. 1). Reports from a number of climatological stations operated by the Alberta Forestry Branch are useful for establishing temperature, precipitation, and snow depth patterns in the Hay River watershed for April 1963. Unfortunately, data for the winter and spring months of earlier years are not available for comparison.

#### CONTRIBUTING FACTORS

##### Antecedent Moisture Conditions - Prior to the Winter Season 1962-63

While the major factors leading to the spring floods in the Liard and Hay River valleys are found in the meteorological factors during the winter and spring 1962 - 1963, the antecedent causes date back to the heavy snowfall of the previous winter. Snowfall, during the winter of 1961-62, ranged from 140 to 250 percent of normal over both watersheds, and, at most of the reporting stations, the seasonal totals were the greatest on record (Table 6). With below normal temperatures during the spring months of 1962, the snow-pack melted slowly and, despite the heavy accumulation of snow, flooding during the run-off period was not a problem. However, by the time the winter snows had disappeared, water levels in storage lakes and depressions were high. Rainfall was much greater than normal during the ensuing summer months (Figs. 3 and 4), and by the fall freeze-up in 1962, both basins were in a saturated state favourable for maximum run-off of the new snow-pack in the spring of 1963.

Autumn freeze-up was at least 10 days later than the average date (Table 4), and rather abrupt. Snow which fell in early October had melted and, with general rainfall just prior to freeze-up, the ground was in a saturated state at month's end, and there was little insulating snow cover. Cold weather which preceded the first major snowfalls of the winter, late in November, resulted in deep frost penetration.

### Antecedent Moisture Conditions - Winter and Spring

Winter snowfall at most of the weather reporting stations in the two watersheds, though not record-breaking as in the previous winter, ranged from 130 to 200 percent of normal (Table 6). Fort Vermilion was the only station to report less than normal snowfall, although reports from forestry stations in the vicinity indicated that snowfall had been heavier up-river. An early March thaw had caused some settling of the snow-pack near the headwaters of both river systems. However, over the greater portions of the basins, most of the winter snowfall was still on the ground at the start of the spring thaw during the second week in April. The snow cover was depleted rapidly during the following three weeks, as the thaw continued without interruption.

### The Weather and Circulation of April 1963

While it is evident from temperature comparisons in Tables 1 and 2, that April 1963, was a mild month, particularly at stations in the lower reaches of the Liard and Hay River basins, the magnitude of the temperature departure from normal during the spring thaw is best illustrated in Table (3). During the first ten days of the month, mean daily temperatures at locations in both river basins averaged 5 to 8 degrees below normal values for this period. Following a reversal in the temperature trend about April 10th, mean daily temperatures for the last 20 days of the month ranged from 4 to 10 degrees above long-period average values. The greatest departures from normal occurred at locations to the east of the mountains. However, even at these stations, average temperatures for the 20-day period were considerably lower than values for the same period in 1952 and 1960.

Normally in the Liard and Hay River basins, the melting of the accumulated winter snowfall starts in the southwestern upper reaches about April 10th, and progresses northeastward to the junction with the Mackenzie River and the entrance to Great Slave Lake about April 24th. (See Fig. 2). In 1963, however, the advance of the spring thaw varied considerably from the usual pattern and, following a cold spell in early April, thawing conditions were general along the entire lengths of the two river systems by April 10th. In a basin-wide thaw of this nature, larger quantities of melt water would be available at the river mouth at break-up time than if the spring thaw had progressed regularly over the basin during the usual 14-day interval.

The below normal temperature trend which had started in north-western Canada in March continued into April. During the first week of April, a low pressure vortex over the Canadian Arctic Archipelago dominated the upper-air flow over northern Canada, while blocking high pressure areas over Greenland and western Alaska completed the high latitude circulation pattern (See Fig. 5).

In the period April 1st to 10th, cold Arctic air covered the basins of the Liard and Hay Rivers. Middle-tropospheric short-wave troughs, rotating around the central vortex, permitted temporary decrease in the depth of the cold air mass on April 1st and again on April 6th, but the persistent cold anticyclone was quickly re-established at the surface, in their wake.

During the second week in April, a major adjustment of the middle-tropospheric circulation pattern resulted in the retrogression of the blocking high pressure ridge over Greenland to a position northwest of Hudson Bay. At the same time, a new long-wave trough developed over Alaska, while the upper trough over northern Canada moved off to the northeast. The pattern at high latitudes became markedly meridional in character with the stream of westerlies displaced southward into the United States. This reversal of the upper-air circulation pattern over northwestern Canada was marked at the surface by the eastward retreat of the cold anticyclone. In the southerly to southwesterly gradient to the west of the high pressure area, daily mean temperatures throughout the Liard and Hay River basins climbed to above normal values on April 10th and, with only temporary interruptions, the above normal temperature regime persisted during the remainder of the month. During this period a cellular circulation pattern predominated over northern Canada, and for 16 of the 20 days, the high pressure ridge over the drainage basins of the Liard and Hay Rivers was a stable feature of the upper level (500-millibar) chart (Fig. 6). Generally, Maritime Arctic air covered the basins, with the Arctic front lying just to the east, although on April 15th and April 26th, short-wave upper troughs, moving southeastward over the area, initiated short duration outbreaks of Continental Arctic air.

Examination of the mean cloudiness data for stations in both watersheds reveals that, in the mountainous upper reaches, the cloud cover for April 1963, was about normal for the month, while to the east of the mountains there was considerably less cloud than usually occurs in this period. Two hundred and sixty-six hours of bright sunshine were recorded during April 1963, at Fort Simpson, considerably more than the normal value of 190 hours, but somewhat below the 293 hours recorded in April 1956. Thus in eastern sections of the basins, particularly in the later stages of the thaw when bare patches were evident, the energy imparted to the snow-pack by solar radiation was greater than normal.

The average upper-air temperatures as given by radiosonde ascents at Fort Nelson, Fort Smith and Norman Wells, during the periods April 1-10, and April 11-30, 1963, may be compared with decadal values in Table 5. For the first 10 days of April, temperatures at 850 millibars (approximately 5000 ft.) and 700 millibars (approximately 10,000 ft.) were 1 to 3°C below normal, while during the remainder of the month values at these levels were 2 to 4°C above normal. In the earlier period, temperatures were below freezing at all levels above the surface, while during the spring thaw (April 11-30), the freezing level averaged 5000 ft. in the mountainous western regions, and dropped off to 3000 feet to the east of the divide. Thus practically all of the snowmelt which contributed to the April floods occurred at levels below 5000 feet.

Precipitation during the spring thaw was not considered to be significant as amounts were small at all stations, and considerably below the long term averages for April (Figs. 3 and 4).

### Flood and River Break-Up Patterns

Floods in the Liard and Hay River drainage basins occur primarily during the river break-up periods in the spring. During the discharge of ice, irregularities along the courses of the rivers frequently cause ice jams to form. The tremendous pressure of the impounded ice and water behind these barriers eventually leads to their collapse, but if the jam persists long enough serious flooding will occur. According to Burbidge and Lauder (1) the processes which lead to the break-up of the river ice in the spring are the increased lift exerted beneath the ice by a large run-off flow, the melting of the anchored shore ice and the force on the ice by the river current.

In a survey of break-up patterns along the Mackenzie River system, Mackay (4) found that the Liard River ice is usually released one to two weeks before the Mackenzie River ice breaks up. During this period ice jams at the junction with the Mackenzie River hold back the flood waters of the Liard occasionally raising water levels as much as 40 feet. However, prior to 1963, flood waters had not reached the Fort Simpson settlement.

Flooding at the mouth of the Liard River in April 1963 differed from the general pattern only in the magnitude of the flood stage. Mr. John Turner who was Officer-in-Charge of the weather observing station at Fort Simpson at the time of the flood reported that the Liard River ice started to break up on April 30th. The initial discharge cut a channel through the still-frozen Mackenzie ice before a large ice jam formed on the Mackenzie River. During the next three days the barrier in the Mackenzie held firm while swollen ice-filled waters inundated a large portion of the island community. It was estimated that peak flood waters were about 50 feet above normal river level. The 30-inch-thick Mackenzie River ice (3) did not break up until May 9th.

The flood pattern at Hay River was very similar. The solid ice on Great Slave Lake presented a firm barrier to the rushing ice-filled waters of the Hay River which swept across the island on which the town is located. Reports from ice reconnaissance aircraft indicated that on May 3rd, three days after the initial flood stage on the Hay River, Great Slave Lake had 10 tenths ice cover. There was fast ice around Big Island and although small channels had been cut in the lake ice near shore, jammed river ice had no entry. At this time the ice-choked waters of the Hay River were backed more than one mile up-river from the townsite.

### DECREASE IN DEPTH OF SNOW-PACK AS INDICATOR OF POTENTIAL FLOODS

#### Data Available

Accurate forecasts of run-off from snowmelt, or rain, or both, require an adequate network of stations where a number of parameters such as temperature, precipitation, insolation, evaporation, soil moisture and wind are observed. For the Liard and Hay River basins sufficient data of this type are not available to assess contributions of snowmelt to flood flows. An attempt is

made in this investigation to use the data from observations of the depth of snow on the ground as a possible flood indicator. Daily measurements of snow on the ground are available for the period 1955-1963 for 11 stations in or near the basins. These are Beaton River, Fort Nelson, Fort Providence\*, Fort Simpson, Fort Vermilion\*, Hay River, Peace River\*, Smith River, Teslin, Watson Lake and Wrigley\*.

#### Investigation Method

To evaluate the depletion of the snow-pack during each melting season, daily observations of depth of snow on the ground were analyzed for each station. Cumulative 5-day values were then calculated.

Portions of the area of the basin were assigned to each station for which data were available, using the Thiessen polygon method (6). The decrease in depth of the snow-pack for consecutive 5-day periods was listed for each station and melt season. These values were then weighted, depending on the proportion of the total basin under consideration.

The maximum depletion of the snow-pack for various durations, averaged over each drainage basin, was then determined for each melt season (7).

#### RESULTS

As the 1963 season produced the greatest floods at both Hay River and Fort Simpson the maximum decrease of snow-pack for various durations in 1963 were compared with those of the 8 previous melt seasons. The results of this analysis are given in tables 8 and 9.

Examination of the values of maximum decrease of snow-pack for the various periods in each melt season shows that in the Liard River basin 1963 values were highest for a 25-day duration, while in the Hay River basin 1963 values were greatest for a 20-day period. These comparisons suggest that maximum depletions of snow-pack for 20- and 25-day periods are significant flood indicators for the Hay River and Liard River basins respectively.

The validity of such an assessment is supported by another consideration. The most severe flood on an ice-blocked river will likely occur when the run-off from snowmelt reaches its maximum in the period from the date of the beginning of the melt season in the basin to the time the river ice breaks up at the point of investigation. As shown in Table 7 the time interval from the mean date of the start of the melt season over the basin to the average date of river-ice break-up at the mouth is about 20 days for the Hay River and 25 days for the Liard River. These time intervals may be described as the "critical periods" in the development of snowmelt floods of this type.

The decrease of depth of snow-pack may be used as an indicator of potential floods for other rivers having similar characteristics -

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\* - indicates broken period of record

that is where flood flows are caused almost entirely by snowmelt, and where the melt season starts in the head-waters and progresses toward the mouth of the river. The mean "critical period" - different with each river - can be determined from climatological records. If sufficient parameters required for the forecast of river flows are not available a representative number of snow-on-ground observations in, or near the basin and temperature forecasts, will make it possible to assess potential spring floods for rivers of this kind.

#### CONCLUSIONS

While several factors, in combination, contributed to the 1963 spring floods at Hay River and Fort Simpson, the major factor was found to be the rapid basin-wide melting of an abnormally heavy snow accumulation. Very high soil moisture, the result of record snowfall during the previous winter and much above normal summer rainfall, was also an important contributing cause.

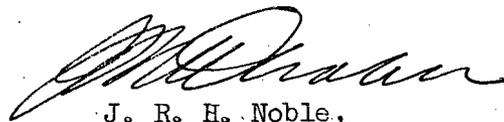
The analysis of maximum depletion of snow-pack for various durations during the spring seasons 1955 to 1963 gave higher values in 1963 for 20- and 25-day periods for the Hay River and Liard River basins respectively, than for the same durations in any other melt season.

On the average these durations are the same as the periods from the mean dates of the start of the thawing seasons over the basins to the times of break-up at the mouths of the rivers. It may be concluded that for the Hay River and Liard River basins the maximum snow-pack depletion during 20- and 25-day periods respectively are useful criteria for assessing flood potential.

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APPROVED,



J. R. H. Noble,  
Acting Director.

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TABLE 1

MONTHLY TEMPERATURE DATA - HAY RIVER BASIN  
October 1962 - April 1963

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
<u>HAY RIVER</u>							
Mean Temperature	38.1	12.4	-1.9	-19.3	-7.0	-2.4	27.2
Departure from Normal	4.8	2.6	4.7	-7.7	1.8	-5.2	4.6
<u>FORT VERMILION CDA</u>							
Mean Temperature	38.8	15.7	1.2	-10.5	1.1	13.3	36.4
Departure from Normal	4.4	4.3	5.8	-1.8	5.0	2.3	4.3
<u>FORT RESOLUTION</u>							
Mean Temperature	36.5	11.4	-2.6	-19.6	-8.8	-4.8	26.6
Departure from Normal	4.5	0.4	6.4	-3.5	2.4	-4.0	6.2
<u>YELLOWKNIFE A</u>							
Mean Temperature	33.1	3.1	-8.2	-24.8	-14.0	-8.2	23.6
Departure from Normal	2.1	-4.1	4.7	-10.1	0.2	-9.6	6.3

TABLE 2

MONTHLY TEMPERATURE DATA - LIARD RIVER BASIN  
October 1962 - April 1963

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
<u>FORT NELSON A</u>							
Mean Temperature	37.2	13.1	1.5	-10.1	3.5	-14.0	34.4
Departure from Normal	2.3	2.4	6.3	-2.8	3.0	-3.0	0.0
<u>BEATTON RIVER A</u>							
Mean Temperature	36.4	20.0	6.3	-0.2	10.4	14.9	32.0
Departure from Normal	1.4	5.0	3.9	-1.7	4.8	-4.3	0.5
<u>SMITH RIVER A</u>							
Mean Temperature	34.3	10.9	-1.0	-4.4	5.3	13.3	30.6
Departure from Normal	1.7	1.9	5.8	1.6	5.2	-3.4	1.8
<u>WATSON LAKE A</u>							
Mean Temperature	35.6	12.0	-3.7	-4.0	5.2	11.5	29.9
Departure from Normal	1.6	3.7	4.1	3.6	6.4	-4.5	-1.3
<u>FORT SIMPSON</u>							
Mean Temperature	34.8	6.7	-5.5	-18.9	-7.7	1.4	29.4
Departure from Normal	4.0	0.7	5.5	-3.8	1.7	-2.9	4.0

TABLE 3

Mean Daily Temperatures April, 1963

and

Comparison with Long Term Averages

	<u>Mean Daily Temperature °F</u>			
	<u>April 1-10 inclusive</u> 1963	<u>Long Term Average*</u>	<u>April 11-30 inclusive</u> 1963	<u>Long Term Average</u>
<u>LIARD BASIN</u>				
Beatton River	20.5	25.5	37.7	32.7
Fort Nelson	20.7	28.5	41.2	37.4
Smith River	17.0	25.0	37.4	32.4
Watson Lake	16.7	25.8	36.4	33.7
Fort Simpson	13.6	18.8	37.2	29.0
<u>HAY RIVER BASIN</u>				
Hay River	9.1	16.8	36.2	26.3
Fort Vermilion	24.4	26.5	43.4	35.7
Fort Nelson	20.7	28.5	41.2	37.4

\* Averages based on periods of record of 18 to 30 years within the period 1931-1960

TABLE 4

DATE OF THE START OF THE FREEZING SEASON

Date When the Mean Daily Temperature  
Falls Below 32°F in the Autumn

1962                      The Decade 1951 - 1960  
Average    Earliest    Latest

LIARD RIVER BASIN

Fort Nelson	Nov. 2	Oct. 21	Oct. 5	Nov. 7
Watson Lake	Nov. 2	Oct. 20	Oct. 6	Nov. 10
Fort Simpson	Oct. 31	Oct. 12	Oct. 5	Oct. 24

HAY RIVER BASIN

Hay River	Oct. 31	Oct. 21	Oct. 6	Nov. 4
Fort Resolution	Oct. 31	Oct. 20	Oct. 6	Nov. 3
Fort Vermilion	Nov. 3	Oct. 22	Oct. 3	Nov. 7

TABLE 5  
UPPER AIR TEMPERATURES APRIL 1963 AND  
COMPARISON WITH 1951 - 1960 DECADAL  
AVERAGES

	Average Temperature °C at 1200Z*			
	April 1 - 10 Decade 1963		April 11 - 30 Decade 1963	
<b>FORT NELSON</b>				
850-mbs.	-4.9	-7.7	-1.5	0.4
700-mbs.	-14.7	-15.3	-12.4	-9.6
<b>FORT SMITH</b>				
850-mbs.	-8.9	-11.7	-5.3	-2.1
700-mbs.	-16.9	-16.2	-14.1	-9.6
<b>NORMAN WELLS</b>				
850-mbs.	-11.2	-10.5	-7.6	-3.1
700-mbs.	-17.8	-16.7	-14.9	-11.8

\* During April 1963 these values were practically the same as the averages for the 0001Z observations.

TABLE 6  
WINTER SNOWFALL 1962 - 1963 AND COMPARISON  
WITH AVERAGE AND EXTREME SNOWFALL SEASONS

Station	<u>LIARD RIVER BASIN</u>							
	Winter 62-63 Total (Inches)	Average Snowfall* Inches	Period	Heaviest Snowfall** Inches	Season	Second Heaviest Snowfall	Heaviest Winter Season	
Beatton River	96.0	74.4	10	100.9	1961-62	99.0	1959-60	
Fort Nelson	95.3	66.8	13	133.4	1961-62	108.1	1944-45	
Smith River	100.9	75.4	11	128.5	1961-62	107.6	1960-61	
Watson Lake	110.3	77.0	12	123.8	1951-52	113.8	1961-62	
Fort Simpson	67.1	45.2	30	87.0	1961-62	75.3	1950-51	
<u>HAY RIVER BASIN</u>								
Hay River	94.5	46.8	30	120.2	1961-62	99.7	1960-61	
Fort Resolution	70.4	50.6	21	81.8	1935-36	70.4	1962-63	
Fort Vermilion	47.6	51.2	30	89.8	1954-55	69.2	1961-62	

\* The number of years on which the average is based.  
\*\* The entire period of record at each station has been used.

TABLE 7  
THAWING PERIOD PRIOR TO RIVER BREAK-UP

	AVERAGE DATE *	
	Start of Thawing Season	Break-Up at River Mouth
LIARD RIVER BASIN		
Fort Nelson	Apr. 9	
Watson Lake	Apr. 12	
Beatton River	Apr. 6	
Fort Simpson	Apr. 20	May 7
HAY RIVER BASIN		
Fort Vermilion **	Apr. 10	
Hay River	Apr. 23	May 6

\* Decade 1951-1960 except Watson Lake, Beatton River  
and Hay River 1957-1963

\*\* located just outside the basin

TABLE 8

LIARD RIVER BASIN

Maximum Decrease in Snow-depth for various Durations

YEAR	MELT PERIOD	DURATION IN DAYS																	
		5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	
1955	MAR 5-MAY 14	3.4	6.4	9.3	10.4	12.9	15.4	17.1	19.7	22.4	25.3	26.5	27.0	27.1	29.7				
1956	MAR 5-MAY 9	7.7	12.1	14.9	17.4	18.4	19.1	23.9	26.7	29.5	30.2	30.9	31.1	31.6					
1957	MAR 5-MAY 19	6.3	9.0	11.7	14.4	16.0	17.1	22.9	25.0	26.1	26.6	31.6	34.3	34.7	34.9	36.3			
1958	MAR 5-MAY 9	3.8	6.4	9.4	12.3	15.4	17.6	20.5	23.6	24.9	26.9	28.2	29.5	29.5					
1959	MAR 5-MAY 19	<u>9.8</u>	13.8	17.5	19.2	21.6	23.4	27.1	28.9	30.6	31.9	32.8	33.3	33.3	35.1	35.6			
1960	MAR 5-MAY 9	9.4	<u>17.1</u>	<u>21.9</u>	23.8	28.2	<u>32.9</u>	34.6	34.8	36.1	37.8	38.2	38.4	38.6					
1961	MAR 5-MAY 29	7.3	14.2	17.2	18.7	20.8	36.5	28.0	30.1	34.4	35.9	38.0	39.7	41.9	43.4	43.7	44.1	44.1	
1962	MAR 5-MAY 19	8.7	16.3	17.5	19.5	27.5	31.7	<u>35.1</u>	<u>36.3</u>	<u>36.7</u>	<u>39.9</u>	<u>41.2</u>	<u>42.5</u>	<u>44.7</u>	<u>46.6</u>	<u>47.9</u>			
1963	MAR 5-MAY 14	8.9	15.2	21.3	<u>26.5</u>	<u>31.2</u>	32.7	34.2	34.7	34.7	35.4	35.4	35.5	36.9	44.3				

(The maximum value for each duration has been underlined).

TABLE 9  
HAY RIVER BASIN

Maximum Decrease in Snow-depth for Various Durations

YEAR	MELT PERIOD	DURATION IN DAYS																	
		5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	
1955	MAR 5-MAY 14	8.4	10.6	16.2	17.8	20.6	23.3	23.6	24.1	24.1	27.2	29.1	31.0	31.0	31.1				
1956	MAR 5-MAY 9	10.3	<u>16.7</u>	19.1	20.2	20.9	21.2	21.2	26.7	32.5	33.2	33.2	33.2	33.2					
1957	MAR 5-MAY 19	8.4	10.4	10.4	11.8	19.0	19.3	20.0	28.4	29.5	29.9	29.9	29.9	30.6	31.6	31.6			
1958	MAR 5-MAY 9	6.5	9.7	12.7	14.9	18.1	21.1	22.5	24.8	26.0	27.4	29.7	31.3	31.3					
1959	MAR 5-MAY 19	6.8	9.0	11.5	12.2	14.9	15.4	16.2	16.7	17.0	18.8	19.0	19.0	19.0	19.4	19.4			
1960	MAR 5-MAY 9	8.6	13.9	17.0	17.8	18.7	23.5	25.5	26.3	27.2	27.4	27.4	27.4	27.4					
1961	MAR 5-MAY 29	8.9	15.0	19.2	20.0	22.3	26.3	27.1	27.8	32.0	32.8	33.0	34.4	34.6	35.6	36.6	36.8	37.3	
1962	MAR 5-MAY 19	10.1	13.6	15.6	20.3	<u>27.0</u>	<u>29.4</u>	<u>30.9</u>	<u>31.6</u>	<u>32.6</u>	<u>33.8</u>	<u>35.3</u>	<u>36.0</u>	<u>37.0</u>	<u>37.2</u>	<u>37.3</u>			
1963	MAR 5-MAY 14	<u>11.6</u>	15.9	<u>20.2</u>	<u>21.8</u>	22.6	23.0	23.4	23.6	23.6	25.7	25.8	25.8	26.1	29.6				

(The maximum value for each duration has been underlined)

TABLE 10

Rank of Events of Maximum Decrease in Snow-depth  
During the 1963 Snowmelt Season Compared  
With the 1955 to 1962 Values (tables 8 and 9)

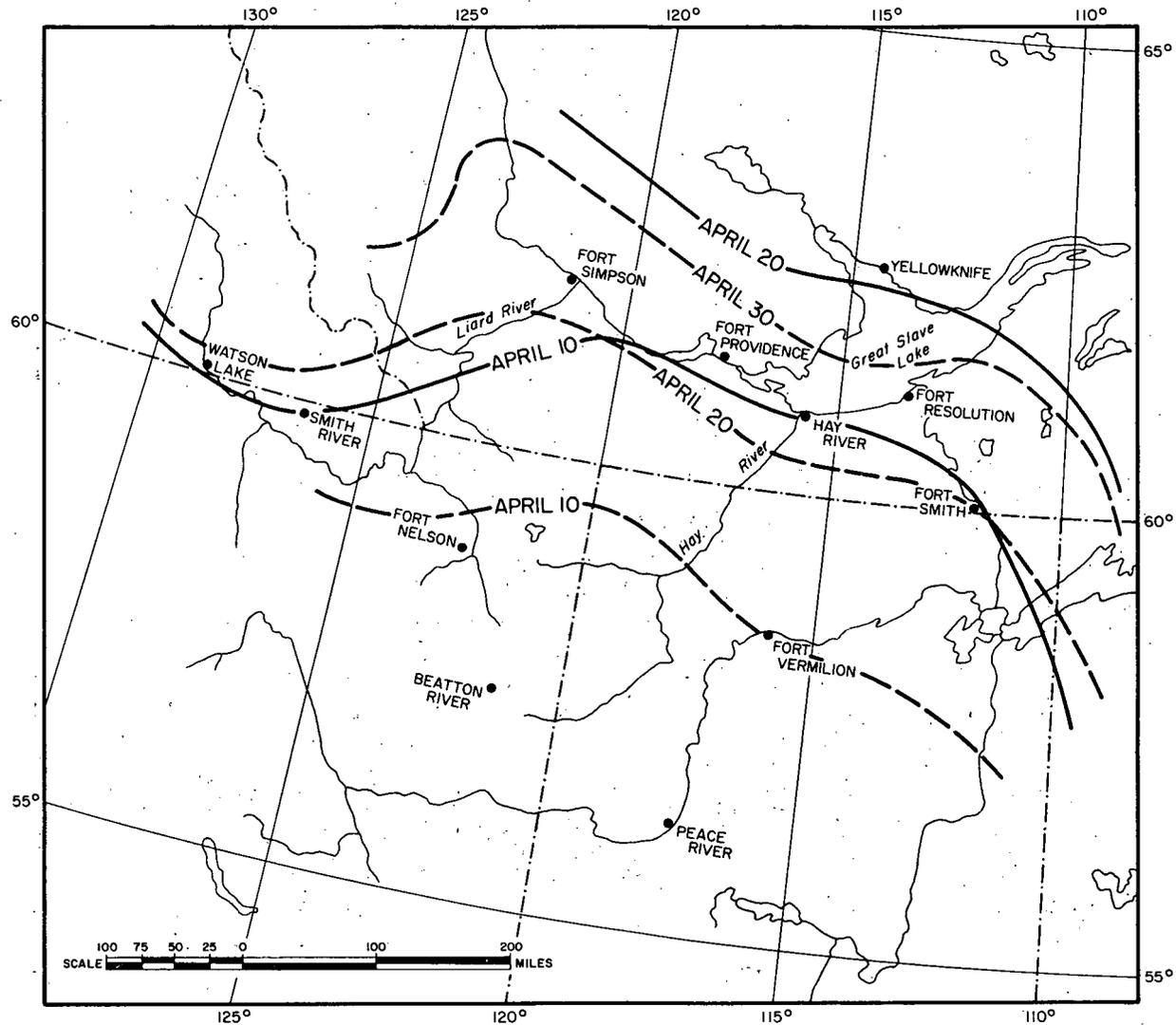
<u>Duration in Days:</u>	<u>5</u>	<u>10</u>	<u>15</u>	<u>20</u>	<u>25</u>	<u>30</u>	<u>35</u>	<u>40</u>	<u>45</u>	<u>50</u>	<u>55</u>	<u>60</u>	<u>65</u>	<u>70</u>
Liard River Basin	3	3	2	1	1	2	3	3	3	4	4	4	4	2
Hay River Basin	1	2	1	1	2	5	5	8	8	8	8	8	8	7

TABLE 11

Maximum Average Decrease in Snow-depth  
(in inches)

<u>Year</u>	<u>Liard River Basin</u> <u>(for a 25 Day</u> <u>Period)</u>	<u>Hay River Basin</u> <u>(for a 20 Day</u> <u>Period)</u>
1955	12.9	17.8
1956	18.4	20.2
1957	16.0	11.8
1958	15.4	14.9
1959	21.6	12.2
1960	28.2	17.8
1961	20.8	20.0
1962	27.5	20.3
1963	31.2	21.8





START OF THAWING SEASON  
(Mean Daily Temperature -32°F)

--- MEAN DATE DURING THE DECADE 1951-1960  
— DATE IN 1963

Figure 2

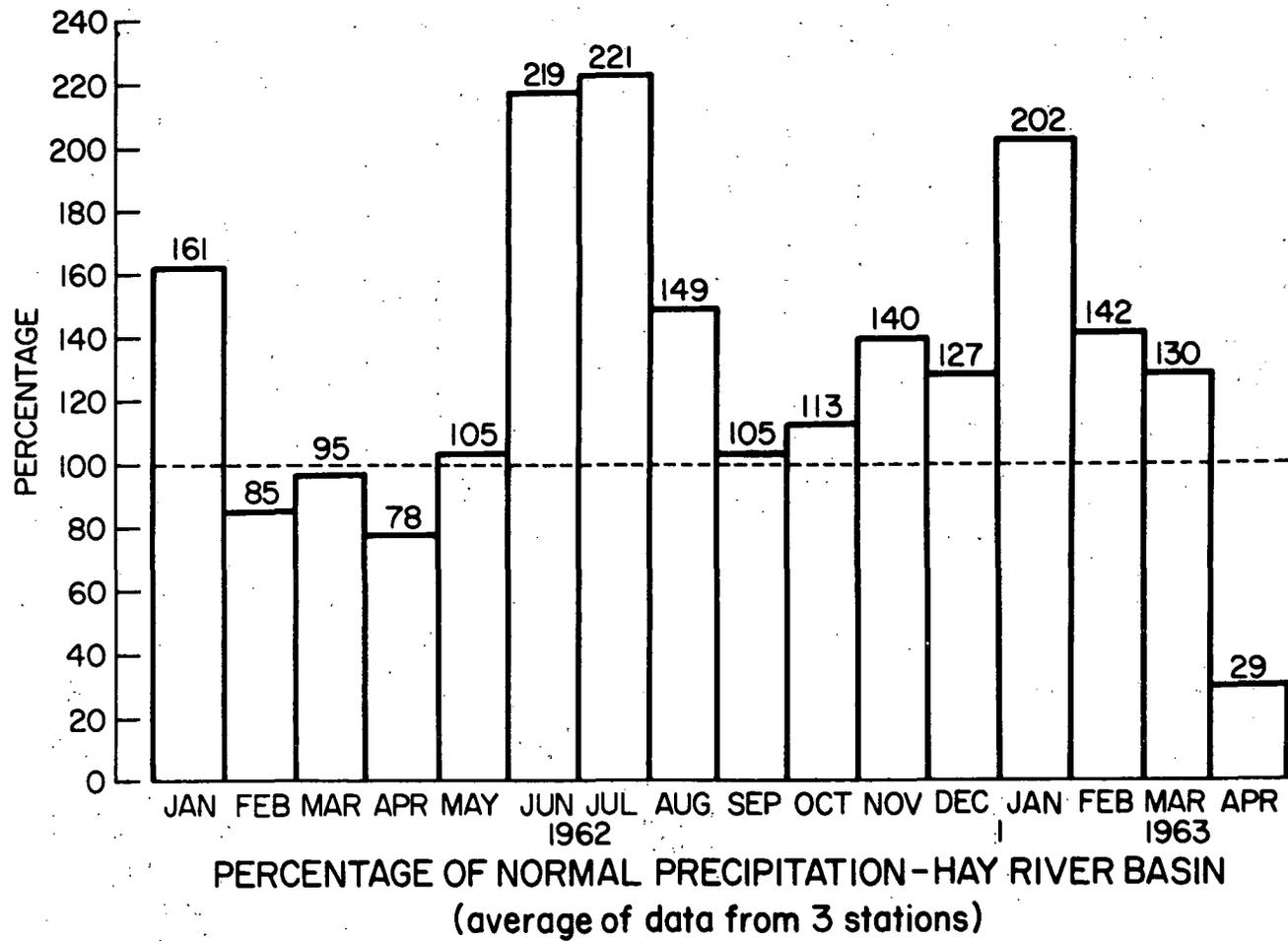


Figure 3

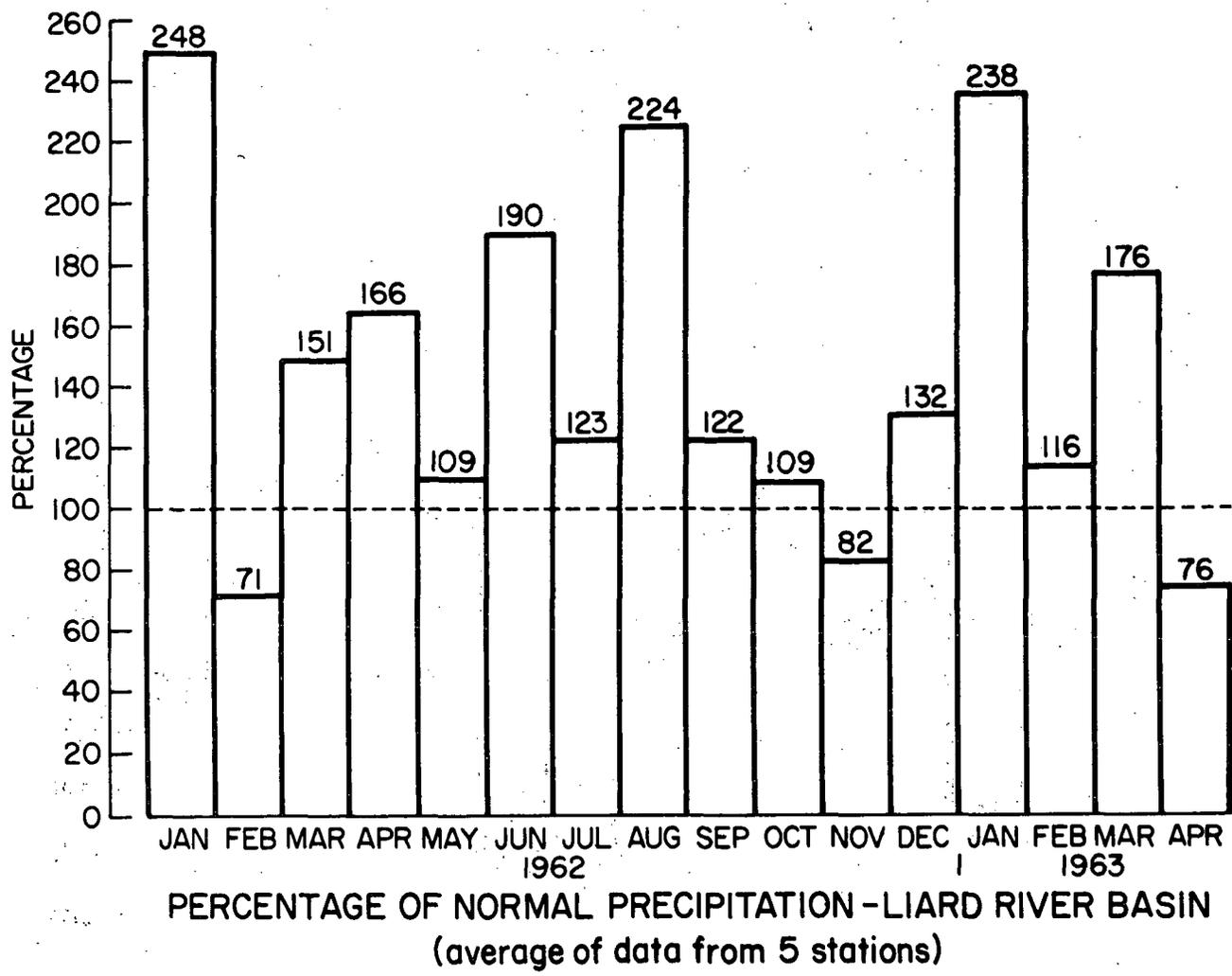
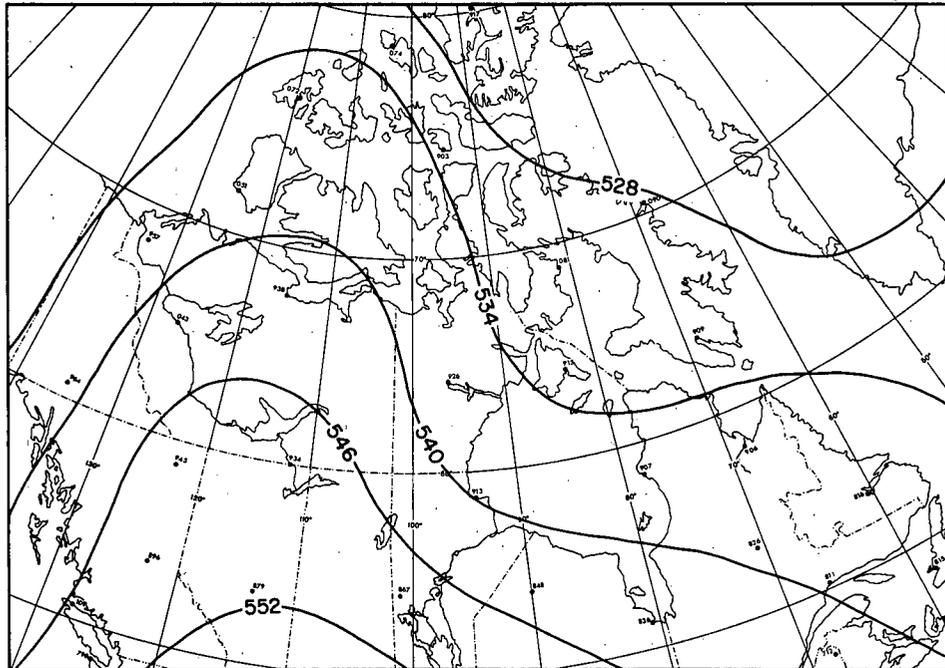
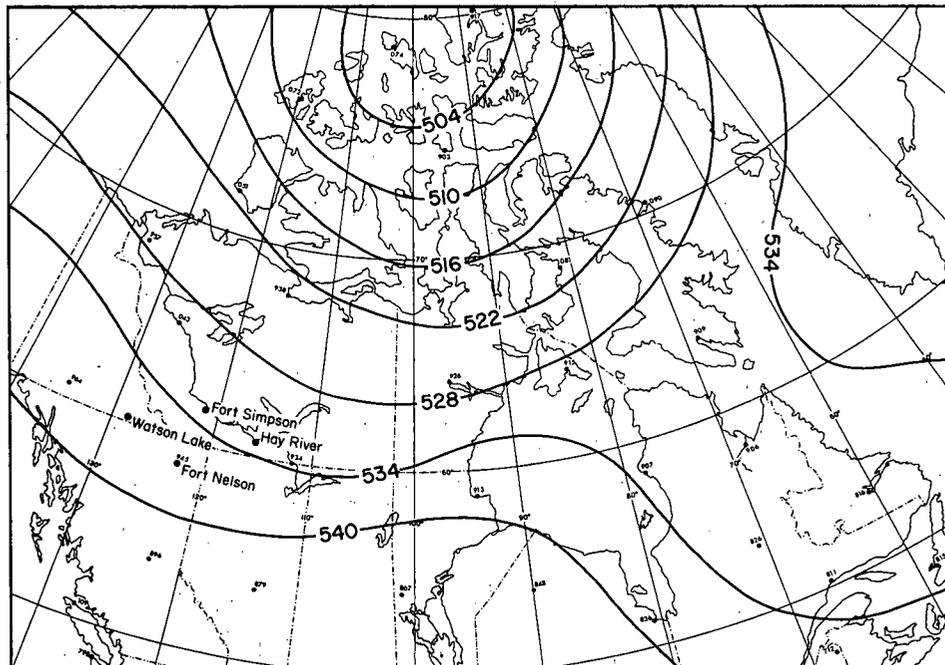


Figure 4



MEAN 500MB CHART - APRIL 11-30, 1963

Figure 5



MEAN 500MB CHART - APRIL 1-10, 1963

HEIGHT IN 10'S OF METERS

Figure 6

CIR-4030  
TEC-517  
29 April 64.

UDC: 551.579.2

Canada  
Department of Transport - Meteorological Branch

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