Environment Canada Environnement Canada

Flood of June 1964 in the Oldman and Milk River Basins, Alberta

L. A. Warner

TECHNICAL BULLETIN NO. 73

INLAND WATERS DIRECTORATE,
WATER RESOURCES BRANCH
OTTAWA, CANADA, 1973

Environment Canada Environnement Canada

Flood of June 1964 in the Oldman and Milk River Basins, Alberta

L. A. Warner

TECHNICAL BULLETIN NO. 73

INLAND WATERS DIRECTORATE,
WATER RESOURCES BRANCH
OTTAWA, CANADA, 1973

Cat. No.: En 36-503/73

CONTRACT #02KXKL327-3-8060
THORN PRESS LIMITED

Contents

Illustrations

Illustrations (cont'd)

Tables

Abstract

Severe flooding occurred in June 1964 as a result of historical maximum peak discharges in the headwaters of many streams in Montana and South western Alberta. The flooding was caused by a storm that extended along the foothills, parallel to the eastern slope of the Rocky Mountains, and 200 miles northward from Helena Mountain.

This report deals primarily with the flood on the Canadian side of the International Boundary but considerable reference is made to the Montana flood area which has been described in the Geological Survey Water-Supply Paper 1840-B, "Floods of June 1964 in Northwestern Montana."

In addition to the basic streamflow and other pertinent data, the report contains background information and some flood analysis. A location map is enclosed showing the area affected by the flood along with stream gauging, meteorological observation and snow course stations. A detailed description of the Upper South Saskatchewan and Milk River drainage basins is included, followed by a description of the flood of June, 1964.

The description of the flood is covered under the following topics: Antecedent Hydrologic Conditions; Meteorological Studies (Depth—Area—Duration analysis) by Atmospheric Environment Service; Progress of the Flood (Oldman River basin to South Saskatchewan River and downstream to South Saskatchewan River at Lemsford and the Milk River downstream to its eastern crossing of the International Boundary); Maximum Discharges in 1964; Maximum Unit Discharges in 1964; and Effect of Storage and Diversion.

A section dealing with flood damage is included followed by a brief discussion of former floods in the Oldman and Upper Missouri basins. Flood frequency analyses are given for several of the hardest hit streams in the area. A discussion concerning the determination of peak flows by various data collection agencies is given followed by an explanation of the streamflow data tables provided.

Throughout the report, numerous tables, figures and photographs are provided to enhance the basic data.

An excellent summary entitled "Meteorological Developments Contributing to the Flood", by R. A. Dightman, United States Weather Bureau, is included as an Appendix.

CHAPTER 1

Introduction

In June 1964, severe flooding occurred as a result of historical maximum peak discharges in the headwaters of many streams in Montana and Southwestern Alberta.

The main flood-producing areas affecting Alberta were Glacier National Park in Montana and Waterton Lake National Park in Alberta. The principal streams rising in these adjoining areas are the Waterton, Belly and St. Mary Rivers. Flooding beyond these areas was confined to the larger streams having their sources along the Continental Divide.

The flood was primarily attributable to an extreme rainfall on June 7 and 8 but was influenced by pre-existing conditions. Precipitation during May in the headwaters of the Oldman River had been 100 percent above normal. Temperatures in the flood area had been generally below normal for the March to May period, thereby delaying the usual snowmelt-runoff pattern. To the end of April, the water equivalent of the snow pack in the St. Mary basin was 121 percent of the 1943-57 average. Large scale melting of the snow pack began towards the latter part of May and continued into June at a sustained high rate. The resulting increase in soil moisture content and streamflow contributed to the rapid response of most streams when the storm struck June 7 and 8. The onslaught of the rain, totalling up to 16 inches at higher elevations along the Continental Divide in Montana and over 10 inches in the Waterton Park area of Alberta, followed a belt approximately 70 miles wide that ran parallel to the eastern slope of the Rocky Mountains and along the foothills for some 200 miles north of Helena, Montana.

Floods in the area claimed the life of a Lethbridge policeman, and a Cardston resident was one of 30 victims in Montana, a major disaster area. Surface transportation was paralyzed over a great area in Northwestern Montana and Southwestern Alberta. Farms and ranches along flood plains on both sides of the border were extensively damaged.

The rapid rise of streams near the Continental Divide left little time for protective measures; however, flood warnings issued by the Water Survey of Canada to provincial and municipal authorities probably reduced the ultimate damages and may have saved lives. Although complete and accurate reports on personal losses attributable to the flood are not available, damages in the State of Montana were estimated to be in excess of 55 million dollars and those in Canada to be in excess of one million dollars.

Hydrometric coverage during the flood runoff was excellent. With the well-equipped stream gauging network available in the Oldman River basin, relatively complete and accurate records of stage were obtained. Some forty-one Water Survey of Canada, United States Geological Survey, and International Gauging Stations are reported herein. The data obtained should prove of importance to water resource managers as a necessary aid in developing accurate forecast techniques and in various water supply investigations.

Much of the discharge data included in this report have been published in the regular series of annual Surface Water Data in Canada publications. Daily discharges for 1964 were published in a report of the Water Resources Branch (1966). The data for stations of interest to this report have been segregated and provided in greater detail herein; hourly discharges covering a period before and after the peak are given when available.

In addition to basic data, this report contains pertinent background information and some flood analysis. A location map is enclosed in the pocket inside the back cover showing the area affected by the flood and, as well, the various stream gauging, meteorological observation, and snow course stations. A detailed description of the South Saskatchewan River and Milk River drainage basins is included, followed by a description of the flood of June, 1964.

The description of the flood is covered under the following topics: Antecedent Hydrologic Conditions; Meteorological Studies (Depth—Area—Duration analysis) by Atmospheric Environment Service; Progress of the Flood (Oldman River basin to the South Saskatchewan River and downstream to the South Saskatchewan River at Lemsford and the Milk River downstream to its eastern crossing of the International Boundary); Maximum Discharges in 1964; Maximum Unit Discharges in 1964; and Effect of Storage and Diversion.

A section dealing with flood damage is included followed by a brief discussion of former floods in the Oldman and Upper Missouri basins. Flood frequency analyses are given for several of the hardest hit streams in the area. A discussion concerning the determination of peak flows by various data collection agencies is given followed by an explanation of the streamflow data provided.

Throughout this report, several illustrations in the form of tables, figures and photographs are provided to enhance the basic data.

To make this report more complete, a paper by R. A. Dightman, United States Weather Bureau, on meteorological developments contributing to the flood, is included as an Appendix.

LOCATION MAP

The general location map (Figure 1, in pocket) delineates the area affected by the flood of June 1964. The map differentiates between the stream gauging stations maintained solely by the Water Survey of Canada and stations of the United States Geological Survey; those stations maintained co-operatively by both agencies are designated "International". Also shown are the Canadian meteorological observation stations and four snow course locations in the headwaters of the St. Mary River.

The rainfall zones delineated (A through F) were used to facilitate the depth–area–duration analysis by the Meteorological Branch, now known as the Atmospheric Environment Service, Environment Canada.

DESCRIPTION OF THE SOUTH SASKATCHEWAN RIVER DRAINAGE BASIN

The following description of the basin is taken, with a few minor changes, from the report by the Water Resources Branch (1963).

The South Saskatchewan River drainage basin may be divided into three general regions which are significantly different in geology, topography, climate and vegetative cover and which therefore have a markedly different effect on the regime of the streams in the basin. These three regions may be termed the mountains, foothills and plains regions.

A large proportion of the annual runoff in the basin has its source in snow and glacial melt at relatively high elevations in the mountains region. Contributions from this region, although they are most significant in terms of the total annual discharge, have not been the primary cause of any known extreme summer floods in the South Saskatchewan River or its major tributaries. Such floods have been caused invariably by excessive rainfall at lower elevations on the eastern slopes of the Rocky Mountains or in the foothills region. The June 7 and 8 rainstorm of 1964 produced excessive rainfall in a belt approximately 70 miles wide and 200 miles long that ran parallel to the eastern slope of the Rocky Mountains and along the foothills. The flood in the Oldman River basin resulting from this storm typifies the extreme summer flooding that can occur in this region.

Extreme stages, usually associated with ice jams, occur in some years during spring snowmelt in the plains region. Intense precipitation may occur anywhere in the plains region during summer thunderstorms but the effect of such storms on streamflow in the South Saskatchewan River or any of its major tributaries is usually not significant except when they occur, as they did in June 1953, during periods of intense precipitation in the foothills areas. An understanding of these variations in the precipitation – runoff relationships in the three regions is necessary for a full appreciation of the characteristics of extreme floods in the South Saskatchewan River basin.

Mountain Region

The headwaters of the main tributaries lie in the mountain region, which extends northward from Glacier Park in Montana in a widening belt between the Continental Divide to the west and the foothills in the east. The region is less than 10 miles wide at the International Boundary and expands steadily to the north, reaching a width of about 60 miles at the northern limits of the watershed. The mountains rise abruptly from the foothills, particularly to the south where the break of slope is conspicuous against an embayment, often termed the Rolling Plains.

Local relief in the mountains is extreme, the larger stream valleys lying between 4,200 and 5,000 feet in elevation and the surrounding peaks reaching elevations of 8,000 to 11,500 feet. The major streams emerge from the mountains and enter the foothills region at about 4,200 feet in elevation. Mountain ranges have a marked northwest to southeast trend in that part of the basin lying north of the Highwood River and a more north-to-south trend in the southern areas. Local relief, average elevations of mountain peaks, and incidence of glaciers tend to increase with distance north of the International Boundary.

Temperatures, precipitation and snowfall vary widely with topography and elevation. A paper by Curry and Mann (1965) of the Eastern Rockies Forest Conservation Board, deals with a network of climatological stations established in the early 1950's to define the characteristics and distribution of precipitation and other parameters in the Rocky Mountains Forest Reserve. Figure 2, showing isohyets of normal annual precipitation, has been extracted from that paper and presented herein.

Snowfall varies widely across the region and from season to season. Snow packs 14 feet deep have been recorded near Lake Sherburne, while much heavier packs probably occur in some places where conditions are particularly favourable for snow accumulation.

The timber line lies at about the 7,000-foot level. Most of the region below that elevation is covered with a heavy forest where spruce and pine predominate. Infiltration, evapotranspiration and runoff characteristics below the timber line are typical of areas with heavy forest mantles. Above the timber line, where the heaviest snow accumulations occur, runoff is primarily the result of snowmelt and is largely confined to the months of June through September. A pronounced diurnal fluctuation in runoff is characteristic at this elevation.

Foothills Region

The foothills region is the belt lying parallel to and immediately east of the mountain region. Its eastern boundary is not well defined because of the dissected nature of the ridges and the masking of the underlying strata by glacial deposits, but it is roughly delineated by the 3,000-foot contour. The northern boundary of the South Saskatchewan River basin lies between the Red Deer and Clearwater Rivers but it too is not well defined in the foothills region. Local relief in the foothills may exceed 1,000 feet in places with the whole region tending to lie between the 3,000-foot and 6,000-foot contours. Vegetative cover varies from forest to rolling grassland.

The larger streams cross the foothills from west to east, the longitudinal valleys between the ridges being occupied by small tributaries. The principal streams enter the region from the mountains at an elevation of about 4,200 feet. They may be considered as having passed into the plains region at a line through Fort MacLeod, Calgary and Red Deer at about 3,000 feet in elevation; the fall in the main streams during their passage through the foothills is about 1,200 feet and slopes may reach as much as 20 feet per mile.

Well known topographic influences on weather are associated with the foothills and mountain region. Normal precipitation occurs when cyclones cross the Divide from the west. However, a thrust of tropical maritime air from the south can be forced upward against the foothills and the eastern slopes of the mountains, releasing heavy precipitation. The most southerly portions of the region are the first and most frequently to be invaded by the tropical air masses and the highest average precipitation in the basin is therefore recorded in the foothills and mountain region near the International Boundary. Water content in the snow pack at the end of the winter season is invariably higher in the Glacier Park area than at Lake Louise in the Bow River basin some 200 miles to the north.

The southern portions of the foothills region receive frequent winter chinooks and winter snow cover tends to be appreciably lighter than elsewhere in the region. The tendency toward heavier winter snow cover in the mountains, lighter snow cover in the foothills and heavier summer precipitation in the southern portions of the basin results in wider departures from normal in the runoff pattern in the Oldman River basin than in the Bow and Red Deer River basins to the north.

Plains Region

The plains region encompasses that portion of the basin lying generally east of a line through Fort MacLeod, Calgary and Red Deer. Most of this region appears to have reached the peneplain stage prior to the last ice age. Such irregularities that remained were afterwards masked by glacial deposits so that the landscape tends to be created more by land use than by changes in relief. The only significant anomalies are the Milk River Ridge in Southern Alberta and the Cypress Hills on either side of the Alberta-Saskatchewan boundary in the extreme south of these provinces. These two ridges, dividing the South Saskatchewan and Missouri River watersheds, rise more than 1,000 feet above the surrounding plains to maximum elevations exceeding 4,000 feet.

The Cypress Hills area is the source of the only significant tributaries of the South Saskatchewan River rising outside the mountains or foothills region. Elsewhere in the plains region, the variability of the deposits ranging from coarse gravel to fine clay, and the lack of pronounced slopes, produce an unorganized drainage pattern over large parcels of the country. There are, within the broader boundaries of the major basin, many undrained potholes, marshy areas, and small basins with interior drainage. Old drainage channels created during the retreat of the ice sheet interrupt the surface which otherwise appears flat and monotonous.

There is a general eastward slope from an elevation of about 3,000 feet at the edge of the foothills to 1,600 feet at Saskatoon. The Oldman River flows eastward across the southern portion of the region to its confluence with the Bow River near Medicine Hat to form the South Saskatchewan River. The South Saskatchewan River turns north to meet the Red Deer River near the Alberta-Saskatchewan boundary and then winds east and north across Saskatchewan to Saskatoon. Total fall during the passage across the plains is about 1,400 feet, the average river gradient varying between about two and four feet per mile.

The few tributaries rising in the plains region make only very minor contributions to the total discharge in the main streams and the water that is gathered in the mountains and foothills passes across the plains in a quantity out of all proportion to the local yield. More than five-sixths of the annual discharge in the South Saskatchewan River at Saskatoon is derived from about one-quarter of its drainage basin lying in the foothills and mountains of Alberta and Montana, over 300 miles to the south and west.

Average annual precipitation in the plains region is about 13 inches, about one-quarter of which occurs as winter snowfall. All runoff from spring snowmelt has usually occurred by the end of April. Many of the prairie drainage channels are dry during the summer while the discharge in others is very low or intermittent. Thunderstorms with intense precipitation may produce sharp rises upon occasion during the summer months but their effect on extreme floods in the larger mountain-fed streams traversing the region is relatively insignificant. Spring floods on the larger streams occasionally occur in the plains region as a result of ice jams during the break-up period in March or April. Spring runoff from the prairies, which is usually near its peak on these occasions, contributes to the severity of this type of flood. However, spring floods of this nature

are usually more localized and less severe than the extreme floods during the summer months.

DESCRIPTION OF THE MILK RIVER DRAINAGE BASIN

The Milk River has its origin in springs scattered throughout the rolling foothills on the east side of the St. Mary Lakes and River. This tract of hilly country is shown on the maps as St. Mary Ridge and forms part of the divide between waters flowing to Hudson Bay and those flowing to the Gulf of Mexico through the Missouri and Mississippi Rivers.

The catchment area of the Milk River is very large, extending through about 2 degrees of latitude but, as its basin is for the most part cut off from mountainous areas, the river does not receive a constant supply of water from permanent bodies of snow and ice, and its volume is subject to sudden fluctuations due largely to precipitation.

The river is formed by three principal branches — the South, Middle, and North forks. Along the North and South forks there are no flats of magnitude and the banks are in most places comparatively low but steep and the valleys narrow. In its course through Canada the stream receives a few small, unimportant tributaries that rise in the Sweetgrass Hills, but practically all the area immediately north of the river is drained into Pakowki Lake.

The area drained by the Milk River might be expected to present a great variety of topographic conditions and in a sense it does, for the range in elevation is between about 1,900 and 7,000 feet above sea level. The greatest part of this whole area, however, might be appropriately described as rolling prairie and foothill country. The outstanding topographic limits of the basin are the foothills of the Rocky Mountains in the Blackfeet Reserve; the Milk River Ridge which extends northeastward into Canada; the Cypress Hills and Wood Mountain on the north; and the Sweetgrass Hills, the Bear Paw and Little Rocky Mountains on the south. Between these limits can be found almost all varieties of prairie country, from level plains to steep, broken, clay cliffs, bare of vegetation, but, generally, the area is extremely rolling and is broken by numerous channels that carry much water during the freshet season but are dry for 10 or 11 months a year. Springs are numerous but small and have little effect on the flow in the main drainage channels.

Description of the Flood of June 1964

ANTECEDENT HYDROLOGIC CONDITIONS

This report deals mainly with the flood in the Oldman River basin and the reader should consult the publication of the United States Geological Survey (1967) for details concerning antecedent conditions in the Missouri and Columbia River basins.

Precipitation during May in the headwaters of the Oldman River basin was 100 percent above normal. Some

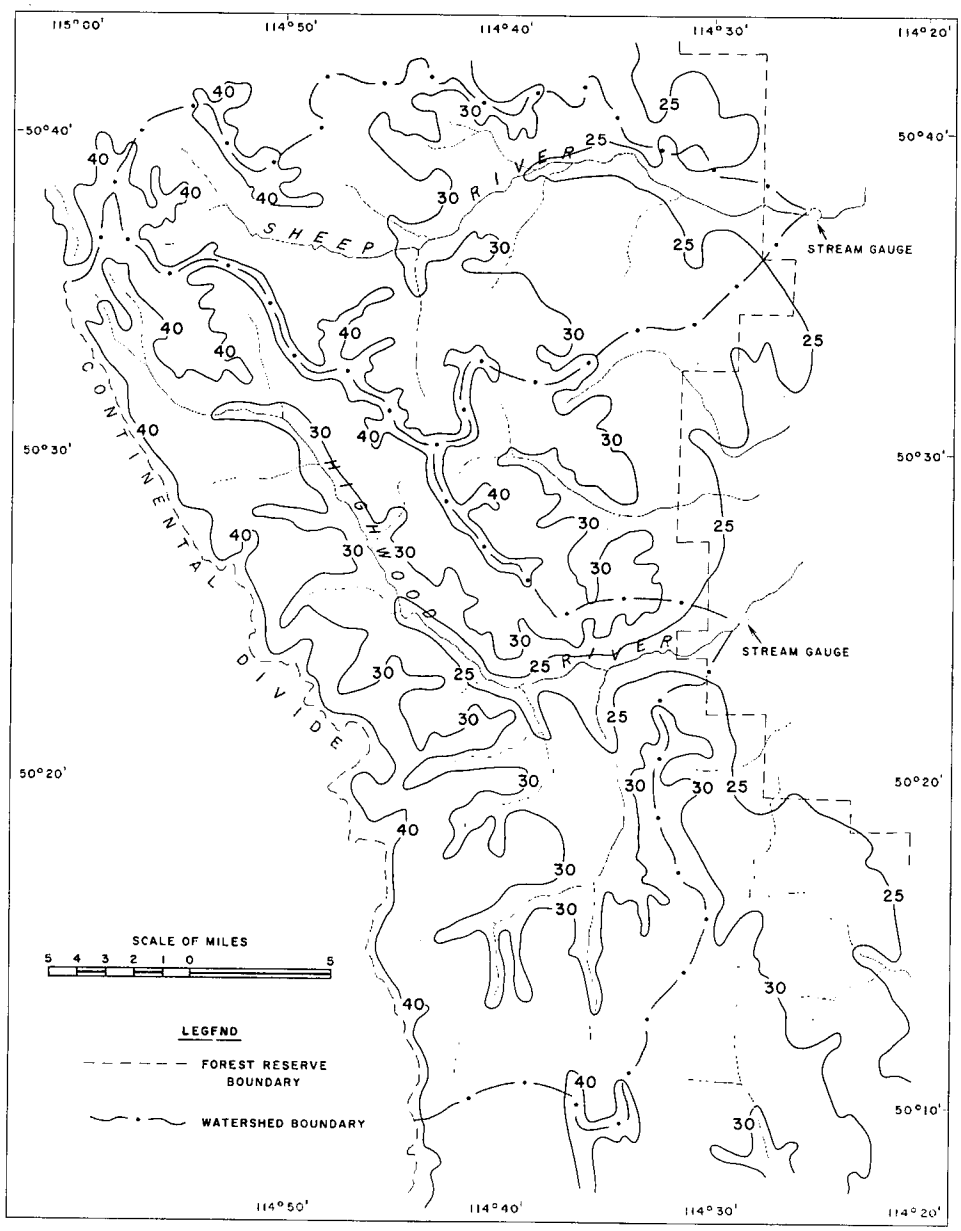


Figure 2. Isohyets of normal annual precipitation.

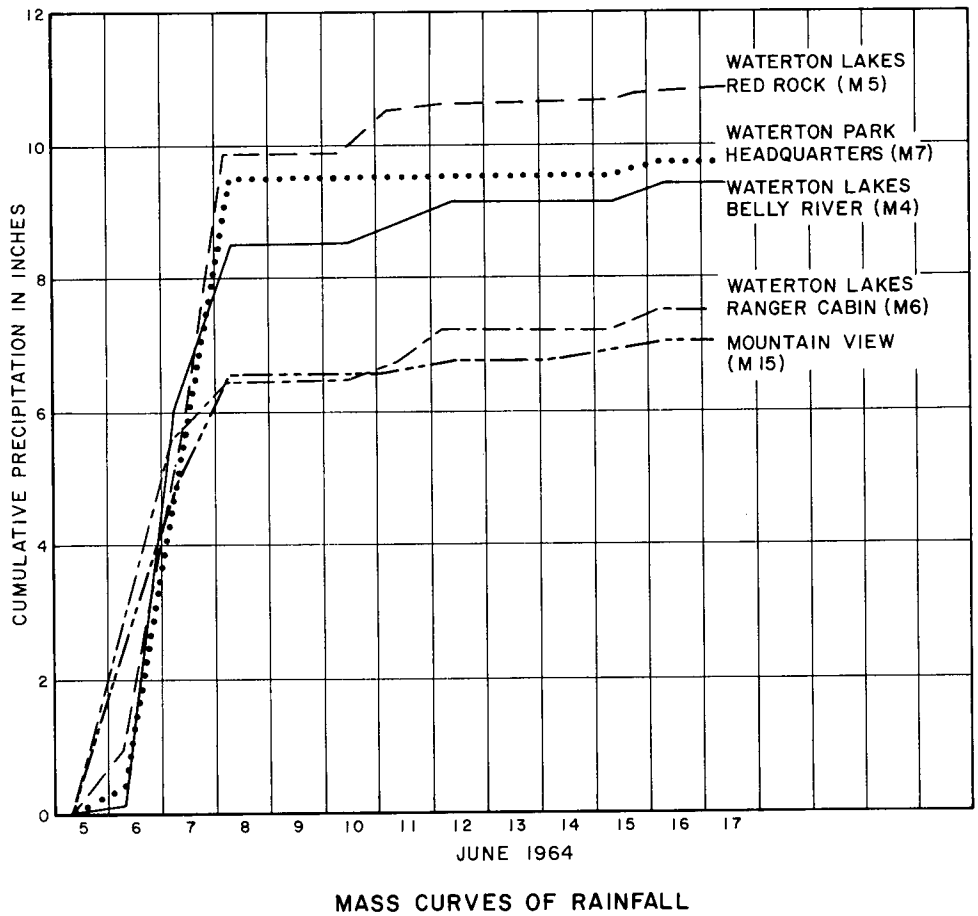


Figure 3. Mass curves of rainfall (for 5 Canadian observation stations).

notable rainfall totals for that month were 6.23 inches, 8.87 inches, and 8.99 inches respectively, at Waterton Lakes Belly River (M4 on Fig. 1), Waterton Lakes Red Rock (M5 on Fig. 1), and Waterton Park Headquarters (M7 on Fig. 1). April precipitation (snowfall) in that same area was roughly 70 per cent above normal and two significant totals were 9.80 inches and 7.57 inches water equivalent respectively, at Waterton Lakes Belly River (M4 on Fig. 1) and Waterton Lakes Red Rock (M5 on Fig. 1).

Temperatures in the flood area were generally below normal for the March-to-May period, thus delaying the usual snowmelt-runoff pattern. Table 1 shows a summary of the St. Mary River basin snow survey data. The locations of the four snow courses are indicated on Figure 1. To the end of April, the water equivalent of the snow pack in the St. Mary River basin was 121 percent of the 1943-57 average.

Table 1. 1964 St. Mary Snow Survey

Map Index No.	Snow Course	Survey Date	Mean Snow Depth in inches	Water Equivalent in inches	1943-57 Average Water Equivalent in inches
S1	Iceberg Lake	April 30	79.9	39.4	27.1
S2	Peigan Pass	April 29	93.1	45.2	38.4
S3	Mount Allen	April 29	110.6	50.8	47.3
S4	Ptarmigan	April 30	98.0	46.6	37.8

Large scale melting of the snow pack began towards the latter part of May and continued into June at a sustained high rate. The resulting high soil moisture content and high streamflow were conducive to the rapid response of most streams in the flood area when the storm of June 7 and 8 struck.

METEOROLOGICAL DEVELOPMENTS CONTRIBUTING TO THE FLOOD

Dightman's paper, which appears as an appendix to this report, gives synoptic features of the storm together with the rainfall pattern which is shown on the isohyetal map of total storm precipitation. A few miscellaneous notes concerning interesting phenomena that occurred during the storm are given, followed by a meteorological comparison with previous floods in the general area.

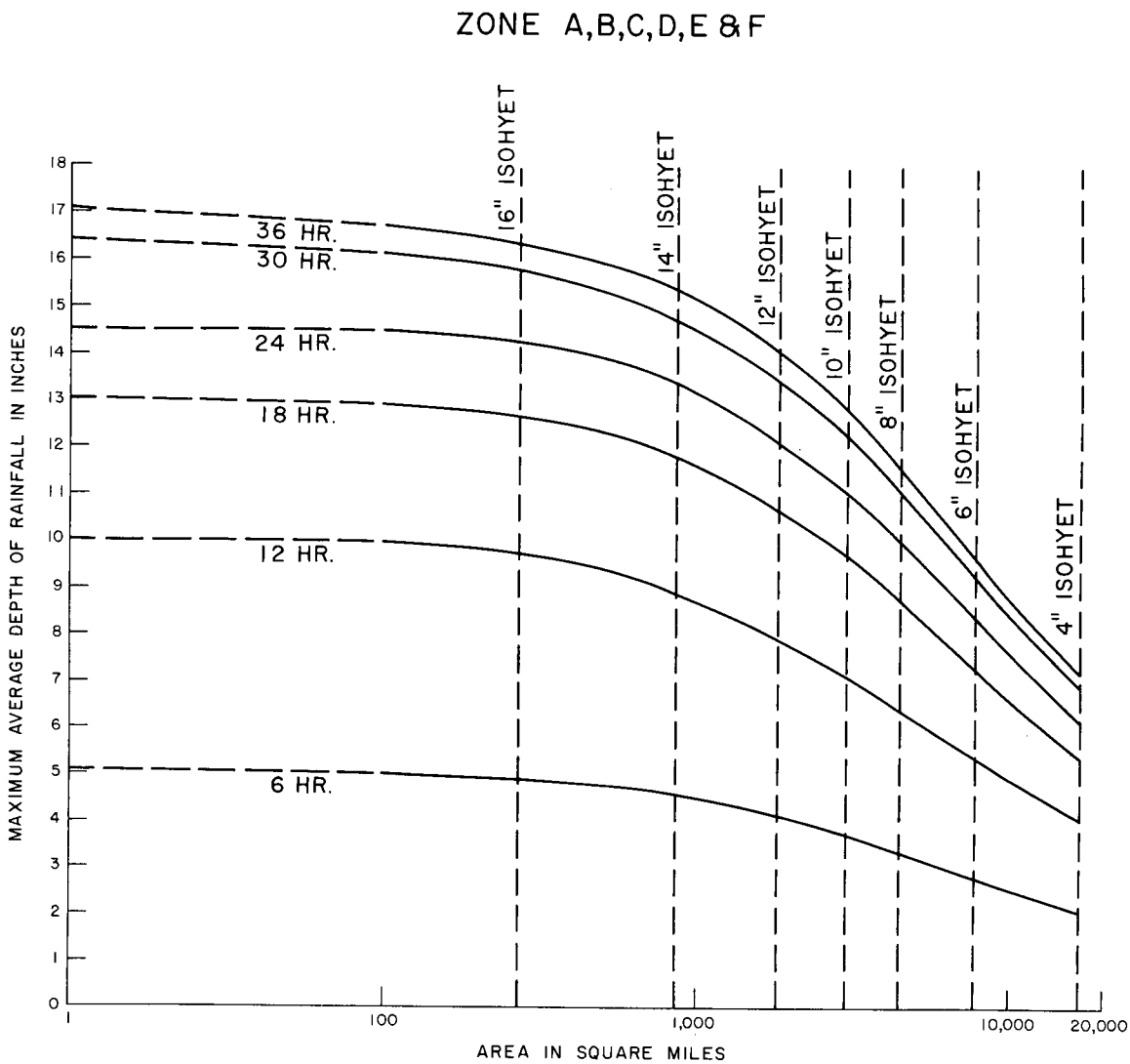


Figure 4. Depth–area–duration analysis–zone A, B, C, D, E & F.

METEOROLOGICAL STUDIES

The following section of this report deals with meteorological observations and hydrometeorological studies carried out by the predecessors of the Atmospheric Environment Service, Environment Canada. Table 2 lists rainfall data collected at 19 gauging locations in southwestern Alberta. Figure 2 shows isohyets of normal annual precipitation on the Sheep and Highwood River basins. As will be seen in Dightman's account of the storm, the data from these Canadian gauges were used to complete the isohyetal map of rainfall shown in the Appendix in Figure A4. Figure 3 shows mass curves of rainfall for five of these stations which were quite near the storm centre. Figures 4 through 9 are the result of a depth-area-duration analysis by Atmospheric Environment Service, based on their own interpretation and version of the isohyetal map of rainfall. The rainfall zones (A through F) that are referred to in these figures are delineated on Figure 1.

PROGRESS OF THE FLOOD

The severity of the June 1964 flood was felt primarily in the headwaters of the Oldman River and Milk River basins which are located in the southwestern corner of Alberta and northwestern Montana. This section of the report will deal with flood flows in the Oldman River from its headwaters to the mouth; the three major tributaries of the Oldman above its main stem, namely the St. Mary, Belly and Waterton Rivers; two minor tributaries, the Crowsnest River at Frank and Castle River near Beaver Mines; and the South Saskatchewan River as far downstream as Lemsford. Also included is an account of the flood flows in the Milk River from its head-

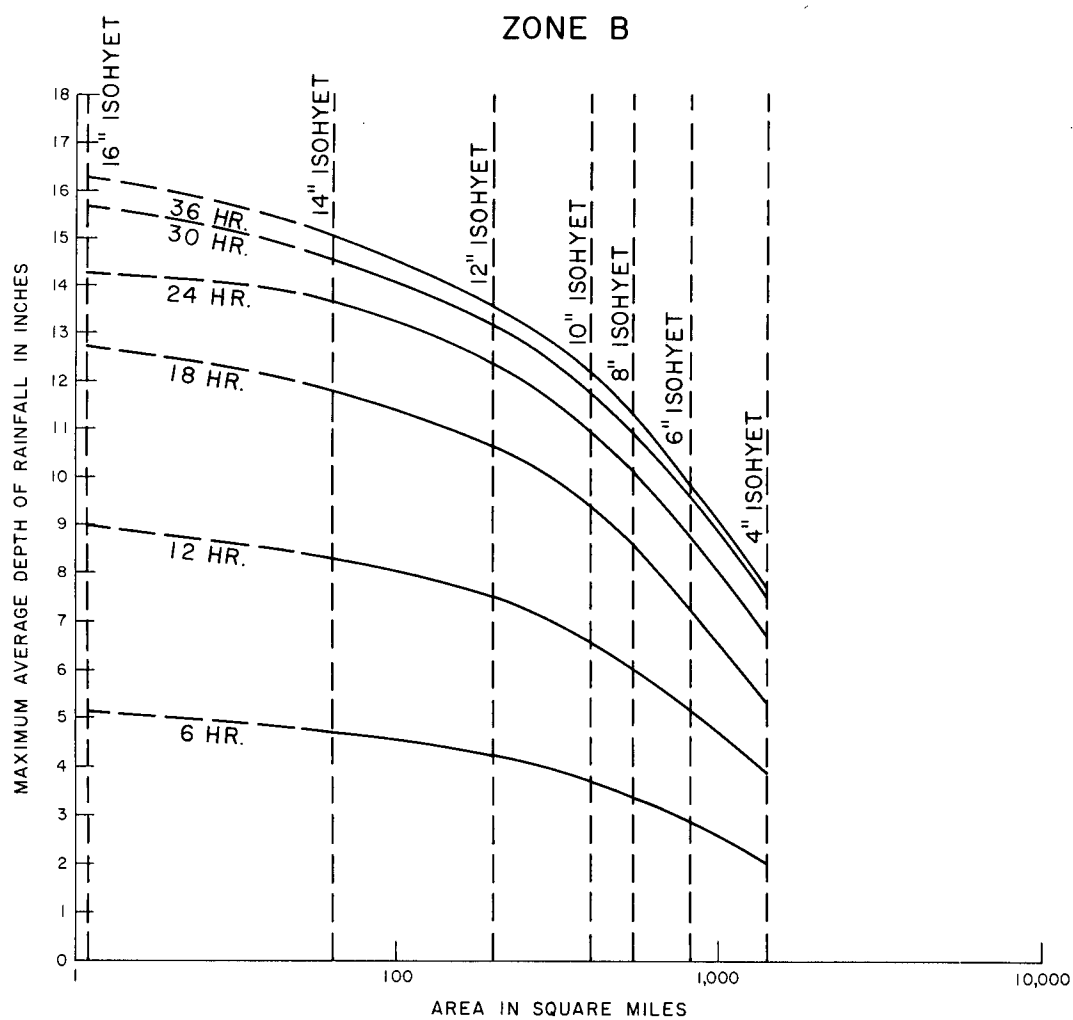


Figure 5. Depth–area–duration analysis–zone B.

waters to its eastern crossing of the International Boundary.

Concerning drainage areas and periods of record for the stations discussed in the following sections, refer to Table 3 which appears on pages 15 to 17 of this report.

South Saskatchewan River Basin

Oldman River and tributaries above Monarch: The northernmost tributaries of the Oldman River, being on the outside edge of the storm, did not have peaks much higher than normal for the beginning of June. The Oldman River near Waldron's Corner peaked at 1200 hours, June 8, with a flow of 4,950 cfs, or 8.98 cfsm (cubic feet per second per square mile of drainage area) and the Crowsnest River at Frank peaked at 2000 hours, June 7, with a flow of 1,780 cfs, or 11.0 cfsm (Fig. 10). With its headwaters farther south, the Castle River received much more precipitation than the Crowsnest or Oldman Rivers. As a result, the Castle River reached a peak of 18,000 cfs or 56.4 cfsm at 2100 hours on June 8, the only one of the three rivers on which a new period of record high was set. Farther downstream, the Oldman River near Monarch had a peak discharge of 27,100 cfs or 7.86 cfsm at 2200 hours, June 9. This flow was only 40 per cent of the historical peak discharge of 67,450 cfs recorded in 1953.

Belly River: The Belly River rises in Glacier National Park in the State of Montana. Rainfall in excess of 10 inches in the headwaters produces historical maximum peak discharges at all stations. Progressing downstream, the Belly River at International Boundary recorded a peak discharge of 12,000 cfs or 160 cfsm at 1900 hrs., June 8; the Belly River near Mountain View, 16,400 cfs or 136 cfsm at 1900 hrs., June 8; the Belly River near Stand Off, 11,700 cfs or 24.6 cfsm at 0800 hrs., June 9 (see Fig. 11).

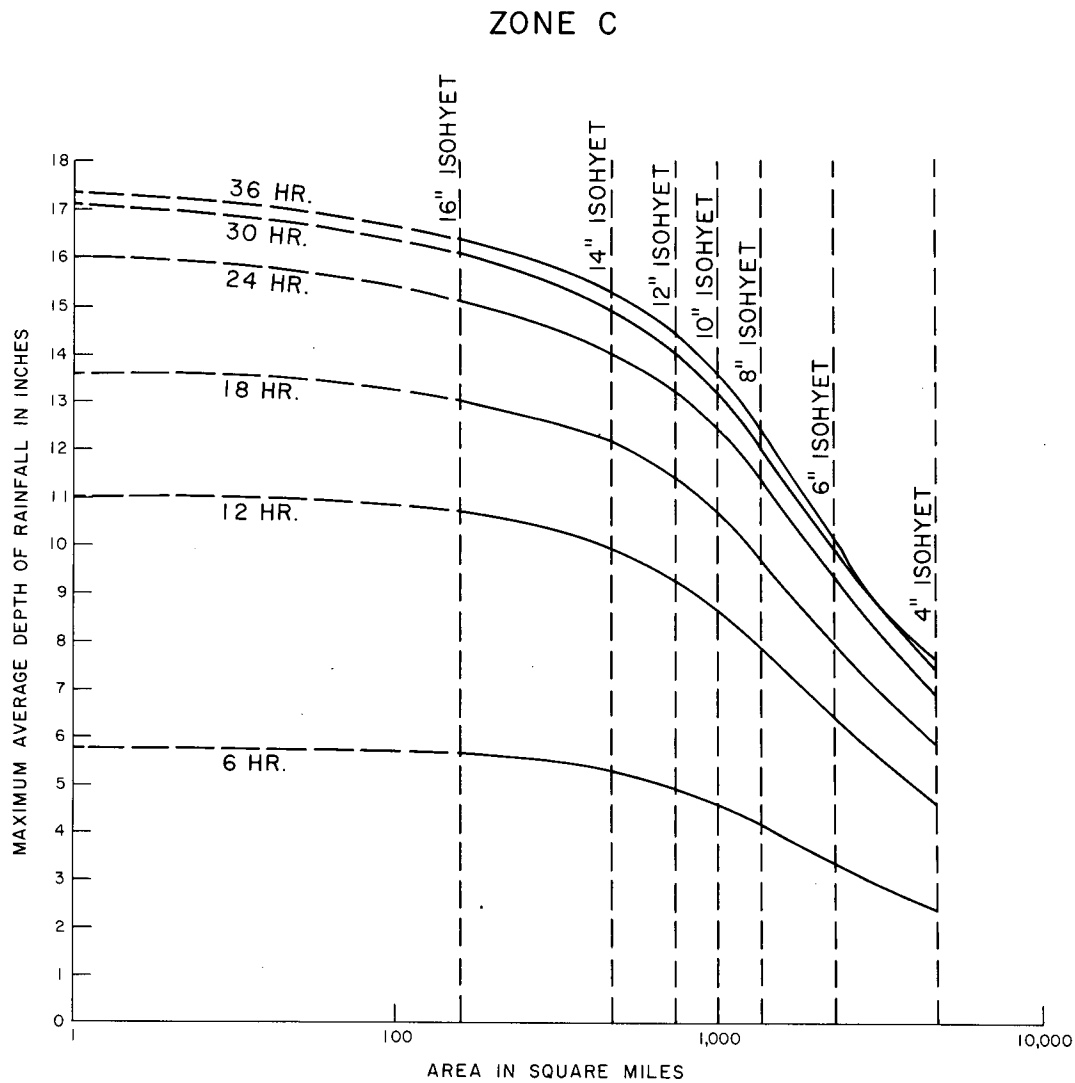
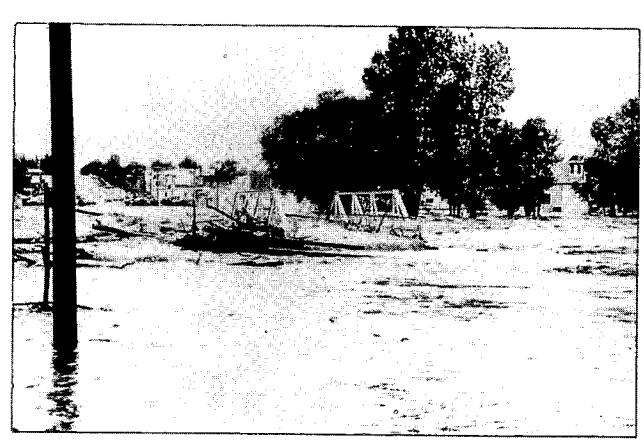


Figure 6. Depth–area–duration analysis–zone C.

Photograph 1. Looking south across Lee Creek at No. 2 Highway bridge on 8 June 1964.



Photograph 2. Looking west across Lee Creek at low traffic bridge on 8 June 1964.

Photograph 3. Looking east across Lee Creek at low traffic bridge on 8 June 1964.

Photograph 4. Looking north across Lee Creek above confluence with St. Mary River, June 8, 1964.

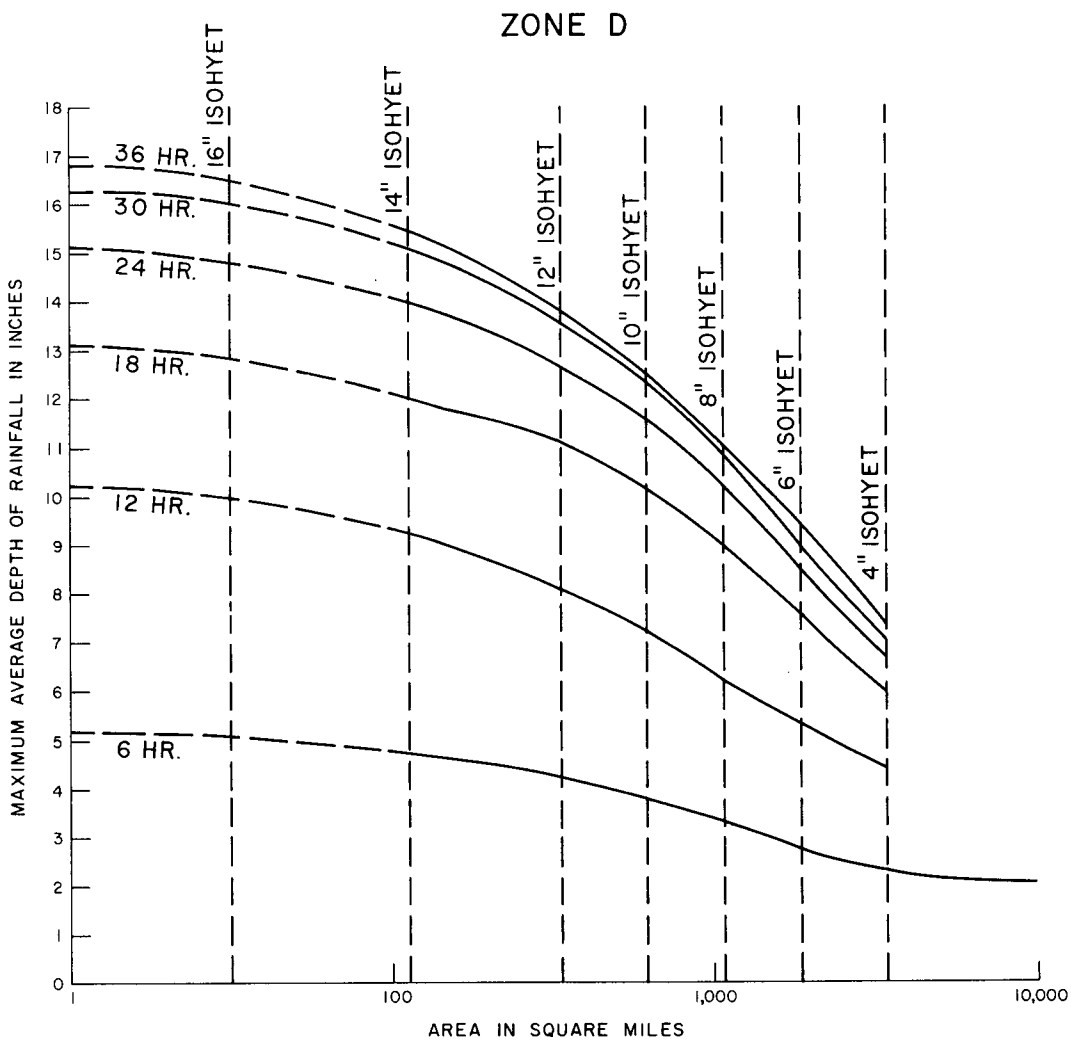


Figure 7. Depth–area–duration analysis–zone D.

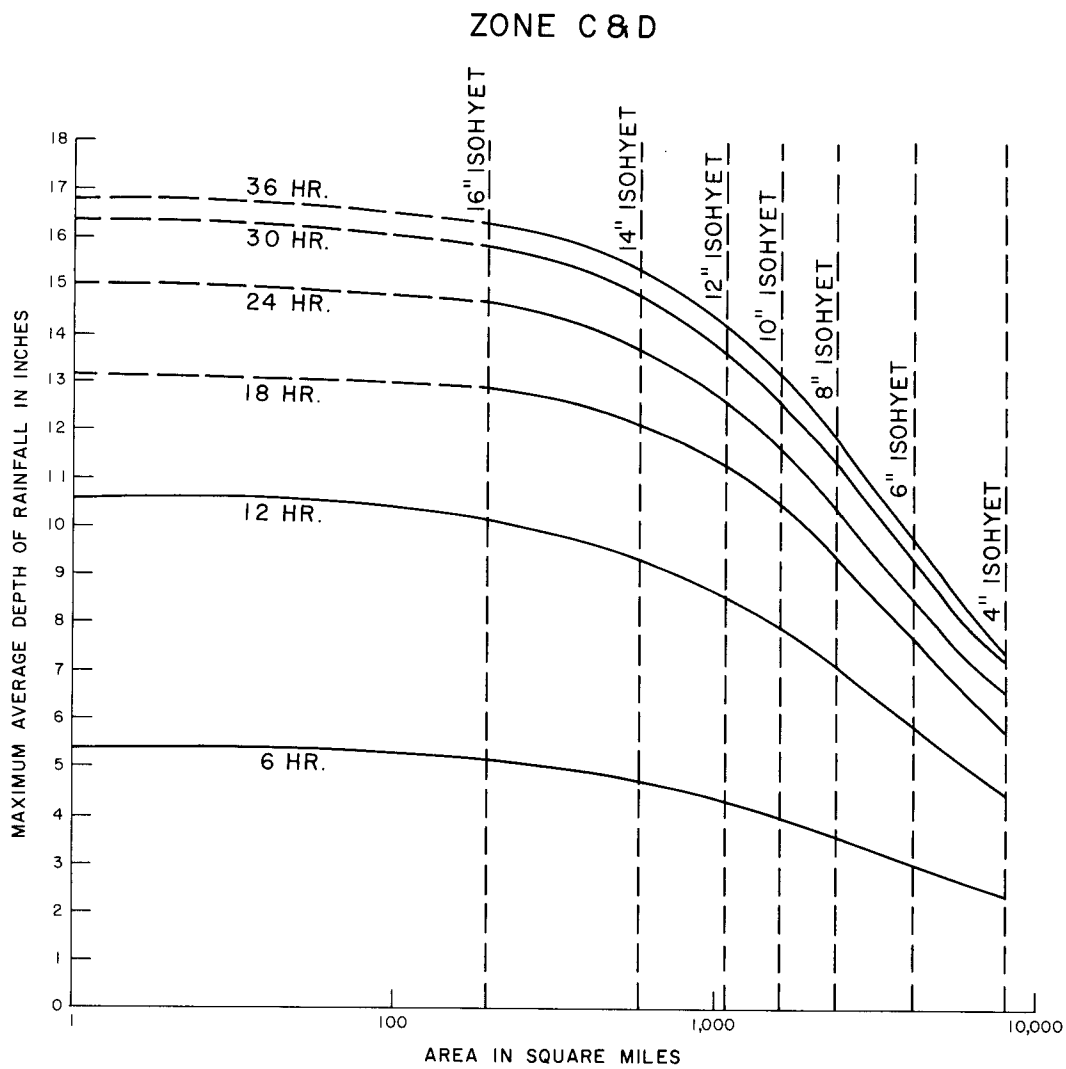


Figure 8. Depth–area–duration analysis–zone C & D.

Waterton River and Tributaries: Like the Belly River, the Waterton River also rises in Glacier National Park. The June 7 and 8 storm subjected all stations on the Waterton River and its tributaries to maximum period of record peak discharges. The Waterton River near International Boundary recorded a peak discharge of 12,400 cfs or 203 cfsm at 1700 hrs., June 8; Waterton River near Waterton Park, 25,700 cfs or 108 cfsm at 0400 hrs., June 9; Drywood Creek near Twin Butte, 1,180 cfs or 100 cfsm at 1130 hrs., June 8; and Waterton River near Stand Off, 19,400 cfs or 28.8 cfsm at 2000 hrs., June 9 (see Fig. 12). Two minor tributaries of the Waterton River, Boundary Creek near International Boundary and Street Creek at International Boundary, recorded maximum peaks of 5,930 cfs and 5,740 cfs respectively. The discharge of 5,740 cfs was derived from a drainage area of 6 square miles, thereby yielding a maximum unit peak of 957 cfsm.

St. Mary River and Tributaries: The St. Mary River flows from the St. Mary Lakes and Lake Sherburne which are situated in Glacier National Park, Montana. Historical maximum peak discharges were recorded at most gauging stations on the St. Mary River and its tributaries. Progressing downstream, Swiftcurrent Creek at Many Glacier reached 6,700 cfs or 213 cfsm at 1600 hrs., June 8; Swiftcurrent Creek at Sherburne, which is controlled by the outlet structure at Lake Sherburne peaked at 2,360 cfs at 1630 hrs., June 11; St. Mary River at International Boundary rose to 21,000 cfs or 44.8 cfsm at 1630 hrs., June 8. Other extremes included Rolph Creek near Kimball, 630 cfs or 6.95 cfsm at 1800 hrs., June 8; Lee Creek at Cardston, 11,400 cfs or 97.4 cfsm at 1700 hrs., June 8; St. Mary River near Lethbridge, 16,200 cfs at 0400 hrs., June 11 (see Fig. 13).

Oldman River below Monarch: Flood flows from the

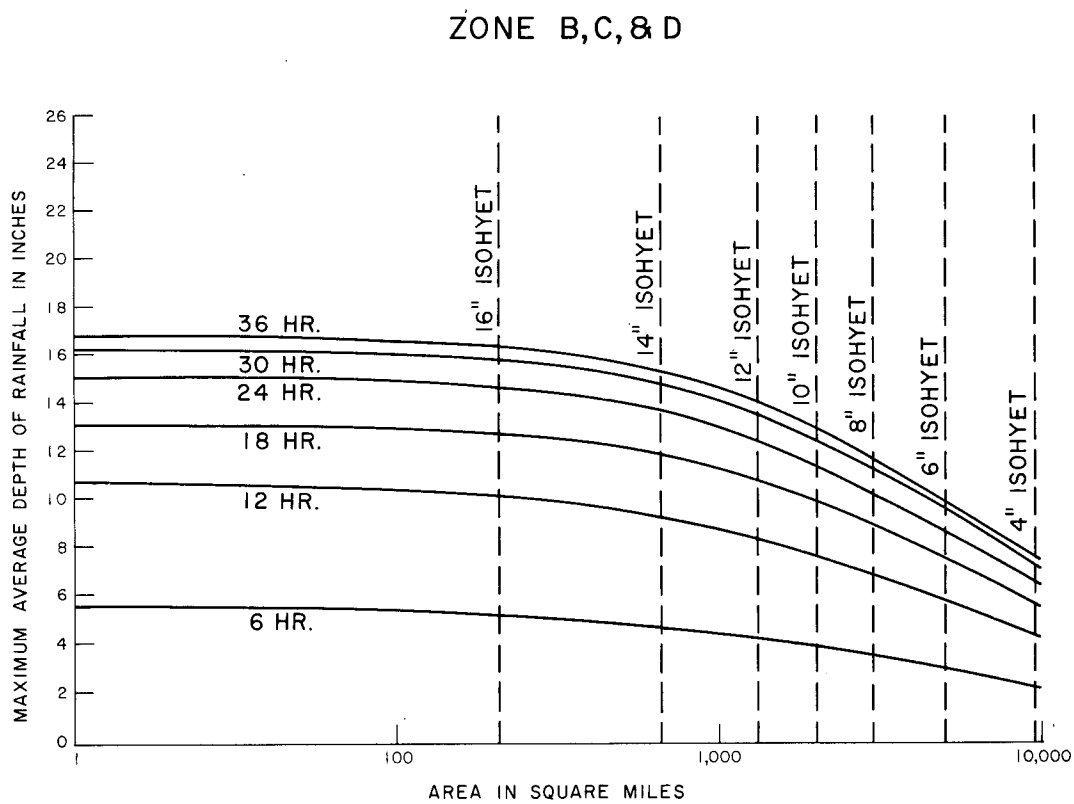


Figure 9. Depth–area–duration analysis–zone B, C & D.

TABLE 2. Daily precipitation in inches

Map Index No.	Precipitation Station	June 5	June 6	June 7	June 8	Total
	Rocky Mountains					
M1	Beaver Mines		0.10	2.89	0.27	3.26
M2	Castle RS		0.49	2.55	0.48	3.52
M3	Coleman RS		0.44	0.99	0.12	1.55
M4	Waterton Lakes Belly River		0.14	5.86	2.50	8.50
M5	Waterton Lakes Red Rock		1.01	4.12	4.77	9.90
M6	Waterton Lakes Ranger Cabin		C	5.72	0.75	6.47
M7	Waterton Park HQ		0.45	C	9.07	9.52
M8	Willow Creek RS	T	0.27	0.75		1.02
	Oldman River Basin					
M9	Cardston		T	2.24	1.20	3.44
M10	Carway		0.03	3.42	1.18	4.63
M11	Cowley		T	0.19	0.26	0.45
M12	Fort Macleod Stand Off			0.25	0.04	0.29
M13	Lethbridge A		T	T	0.42	0.42
M14	Magrath			0.87	0.75	1.62
M15	Mountain View		C	4.94	1.55	6.49
M16	Pincher Creek		0.01	0.72	0.49	1.22
M17	Raymond			0.66	0.67	1.33
	Milk River					
M18	Milk River			1.38	0.43	1.81
M19	Warner		T	1.60	0.53	2.13

T – Trace
C – Included in amount given for the following day.

Belly, Waterton and St. Mary Rivers combined with Oldman River flows to produce a peak discharge of 74,000 cfs at 1200 hours, June 10, at Oldman River near Lethbridge (see Fig. 14). The Oldman River near the Mouth, a new gauging station in 1964 attained a peak discharge of 68,200 cfs at 0600 hours, June 11.

Table 3 (Cont.)

Map Index No.	Station No.	Gauging Station	D. A. mi.^{2}	Period of Record	Maximum Flood prior to 1964 (footnote *g*)			Maxima – Flood of June 1964					Remarks
					Date	G. H.	Discharge	Time hrs.	Date	G. H.	Discharge		
											cfs	cfsm	
G30	11AA25	Milk River at Western Crossing of International Boundary	397	1931-68	June 1948	6.83	4,750	0600	June 9	9.77	7,930*(ad)*	20.0	International Gauging Station
G31	11AA31	Milk River at Eastern Crossing of International Boundary	2,590	1909-68	March 1952	9.34	9,530*(c)*	0700	June 11	6.71	7,770	3.00	International Gauging Station
G32	11AA5	Milk River at Milk River	1,040	1909-68	May 1927	11.41	8,730	2300	June 9	10.40	8,110	7.80	International Gauging Station

Stream-Gauging Stations of the United States Geological Survey – Montana

US1	5-200	Kennedy Creek near Babb	60.6	1905-12	–	–	–	–	June 8	–	15,000*(d)*	248	
US2	6-785	North Fork Sun River near Augusta	258	1911-12 1945-64	1948	7.03	4,840	–	June 8	15.82	51,100*(d)*	198	
US3	6-800	Sun River near Augusta	609	1889-90 1904-64	1916	11.4	32,300	–	June 9	15.7	59,700*(c)*	98 *(c)*	
US4	–	Two Medicine Creek above Trick Falls, near East Glacier	26.8	–	–	–	–	–	June 8	–	13,600*(d)*	507	Miscellaneous Site
US5	–	South Fork Two Medicine River near East Glacier	78.2	–	–	–	–	–	June 8	–	25,600*(d)*	327	Miscellaneous Site
US6	6-920	Two Medicine River near Browning	317	1907-24 1951-64	1907	8.6 *(f)*	7,950	–	June 8	14.0	100,000*(d)*	315	
US7	6-925	Badger Creek near Browning	133	1951-64	1953	6.28	4,220	–	June 8	10.37	49,700*(d)*	374	
US8	–	North Fork Birch Creek near Dupuyer	19.0	–	–	–	–	–	June 8	–	8,890*(d)*	468	Miscellaneous Site
US9	–	South Fork Birch Creek near Dupuyer	25.3	–	–	–	–	–	June 8	–	9,770*(d)*	386	Miscellaneous Site

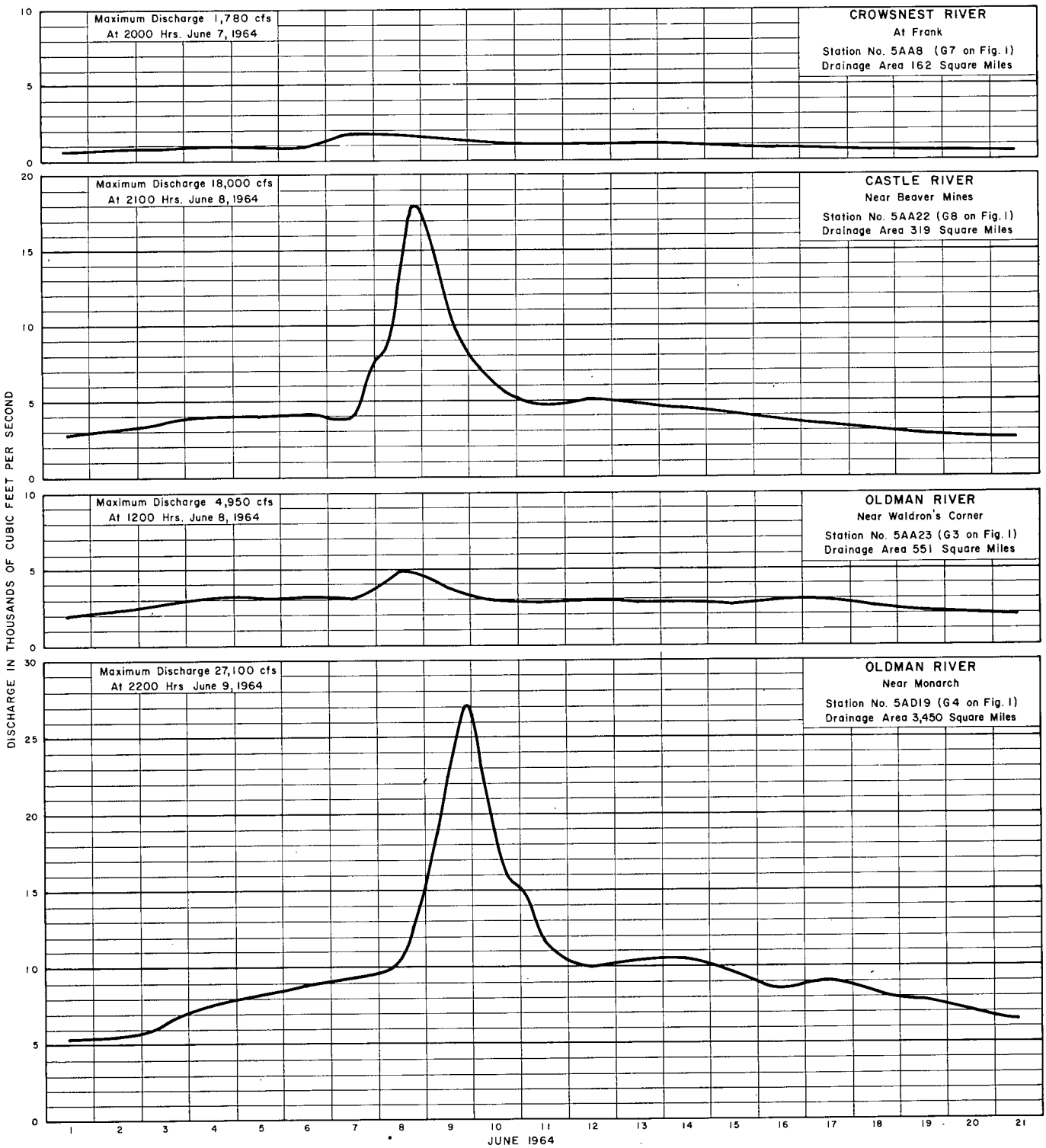


Figure 10. Hydrographs of peak flow period–Oldman River and tributaries above Monarch.

South Saskatchewan River: A peak discharge of 68,800 cfs was recorded on the South Saskatchewan River at Medicine Hat at 1800 hours, June 11; the South Saskatchewan River near Lemsford peaked at 63,500 cfs at 0400 hours, and remained at this high flow throughout the remainder of June 13 (see Fig. 15). These relatively

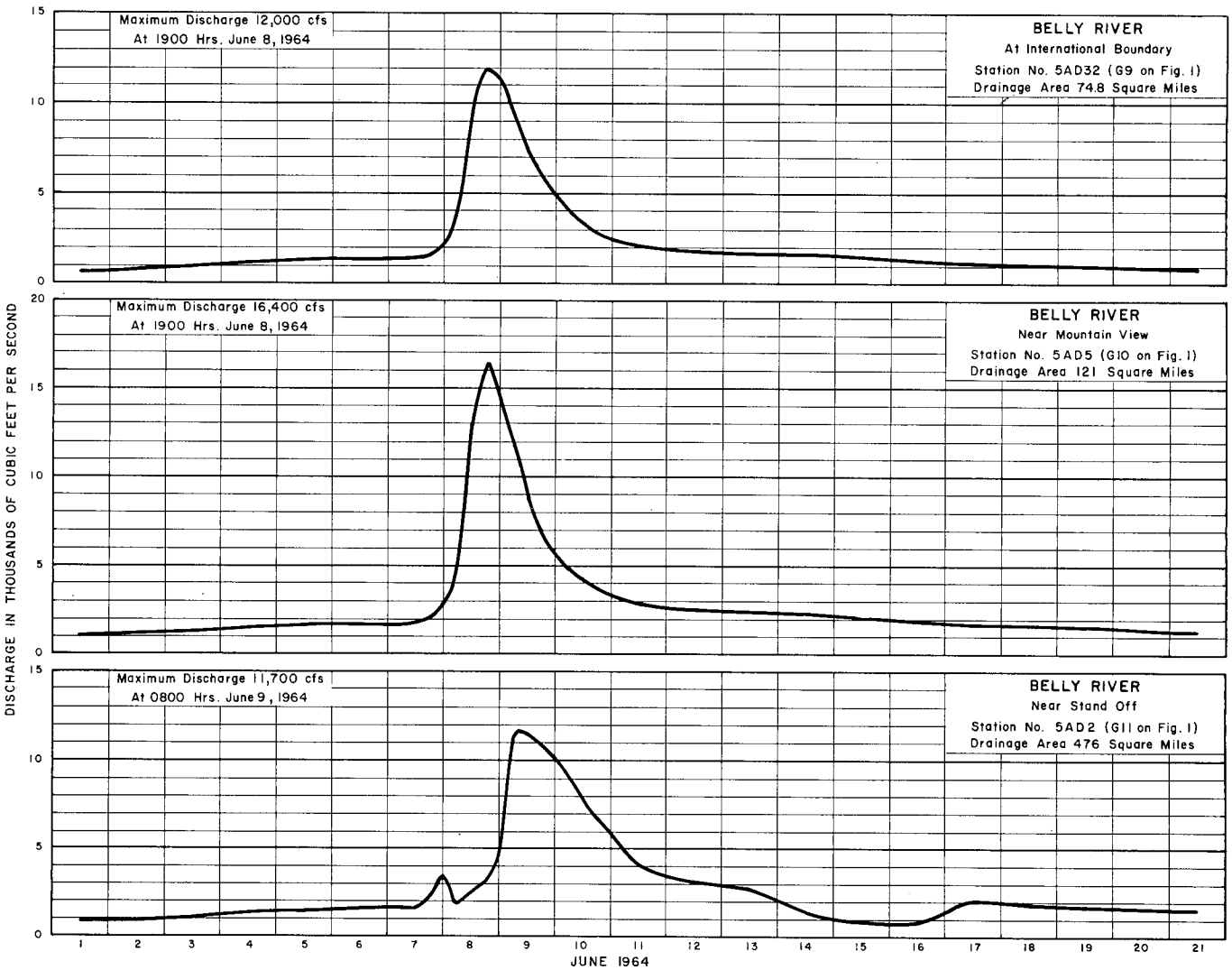


Figure 11. Hydrographs of peak flow period–Belly River.

low peaks in the South Saskatchewan River can be attributed to topography, reservoir and bank storage, little precipitation in the area east of Lethbridge, and low flows in the Bow River (in the order of 8,000-9,000 cfs during the flood on the South Saskatchewan). The recession curves for both South Saskatchewan stations mentioned above were gentle and the flows returned to normal mid-June values after 15-18 days.

Milk River Basin

The South Fork Milk River near Babb, Montana, reached a new maximum historical peak discharge of 12,000 cfs or 175 cfsm at 1300 hours, June 8. Moving downstream, the flood peak was progressively damped out by channel losses, lower slopes and pondage. The Milk River at Western Crossing of International Boundary reached a maximum historical peak of 7,930 cfs or 20.0 cfsm at 0600 hours, June 9.

Some of the significant peak discharges recorded on the Milk River system are as follows (see Fig. 16): North Fork Milk River above St. Mary Canal, 653 cfs or 10.6 cfsm at 1500 hours, June 8; North Milk River near International Boundary, 1,940 cfs at 1600 hours, June 8; Milk River at Milk River, Alberta, 8,110 cfs or 7.80 cfsm at 2300 hours, June 9; and Milk River at Eastern Crossing of International Boundary, 7,770 cfs or 3.00 cfsm at 0800 hours, June 11.

It should be noted here that there was a relatively large contribution to the flow in the North Milk River near International Boundary from the St. Mary Canal. The daily mean flow in the St. Mary Canal (2 miles above its confluence with the North Milk River) was 816 cfs on June 8. After June 8, the St. Mary Canal contributed little to the North Milk River since it had been washed out by Kennedy Creek.

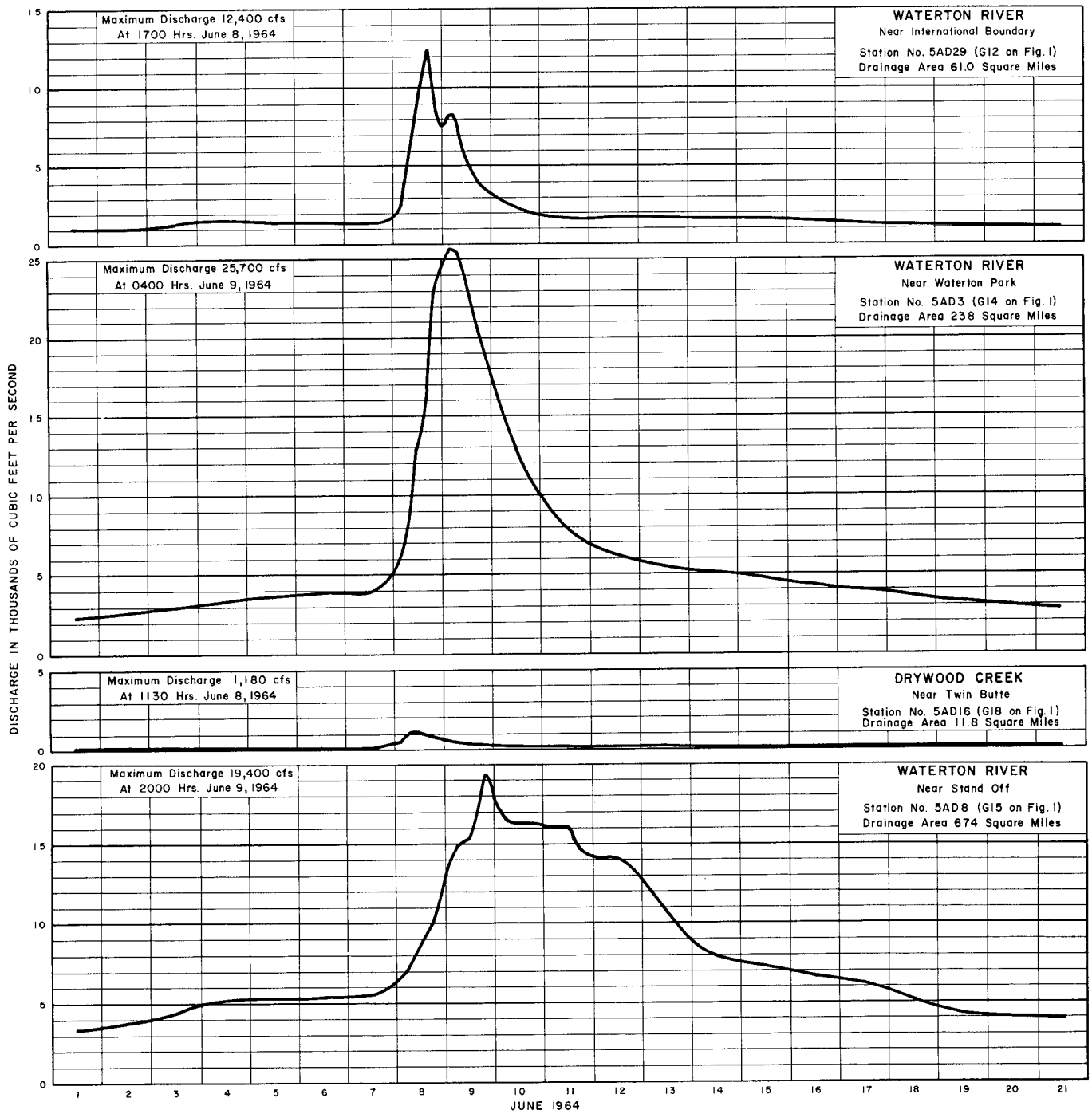


Figure 12. Hydrographs of peak flow period–Waterton River and tributaries.

MAXIMUM DISCHARGES IN 1964

A summary of peak gauge heights and discharges in the South Saskatchewan and Milk River basins during the June 1964 flood is presented in Table 3. The maximum discharges prior to 1964 for all reported stations are also given in addition to other pertinent information such as drainage areas and periods of record. The maximum discharge per unit of drainage area for most stations is shown in the far right column.

MAXIMUM UNIT DISCHARGES IN 1964

The maximum discharge per square mile (cfsm) from drainage areas of varying sizes is a useful factor in the study

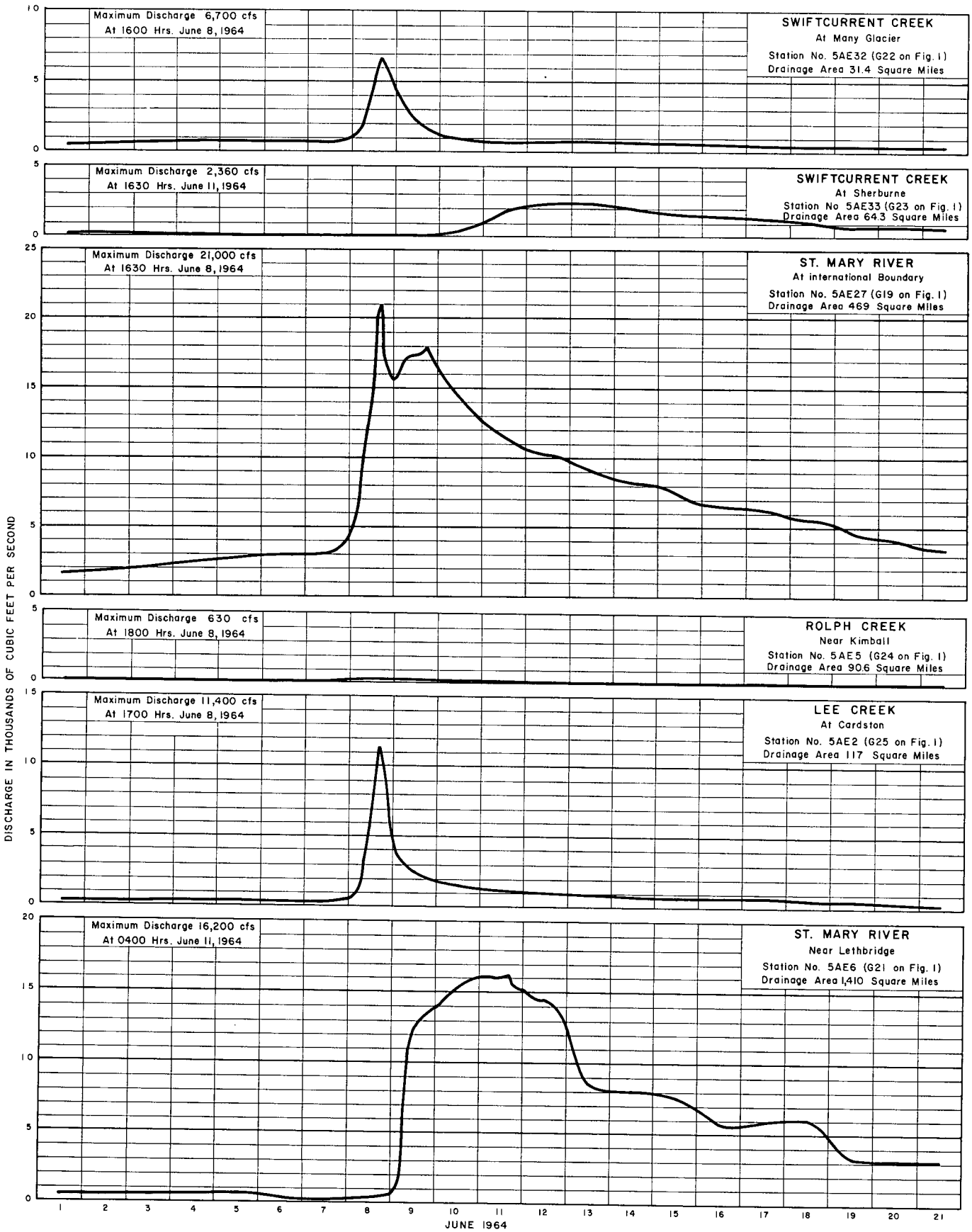


Figure 13. Hydrographs of peak flow period–St. Mary River and tributaries.

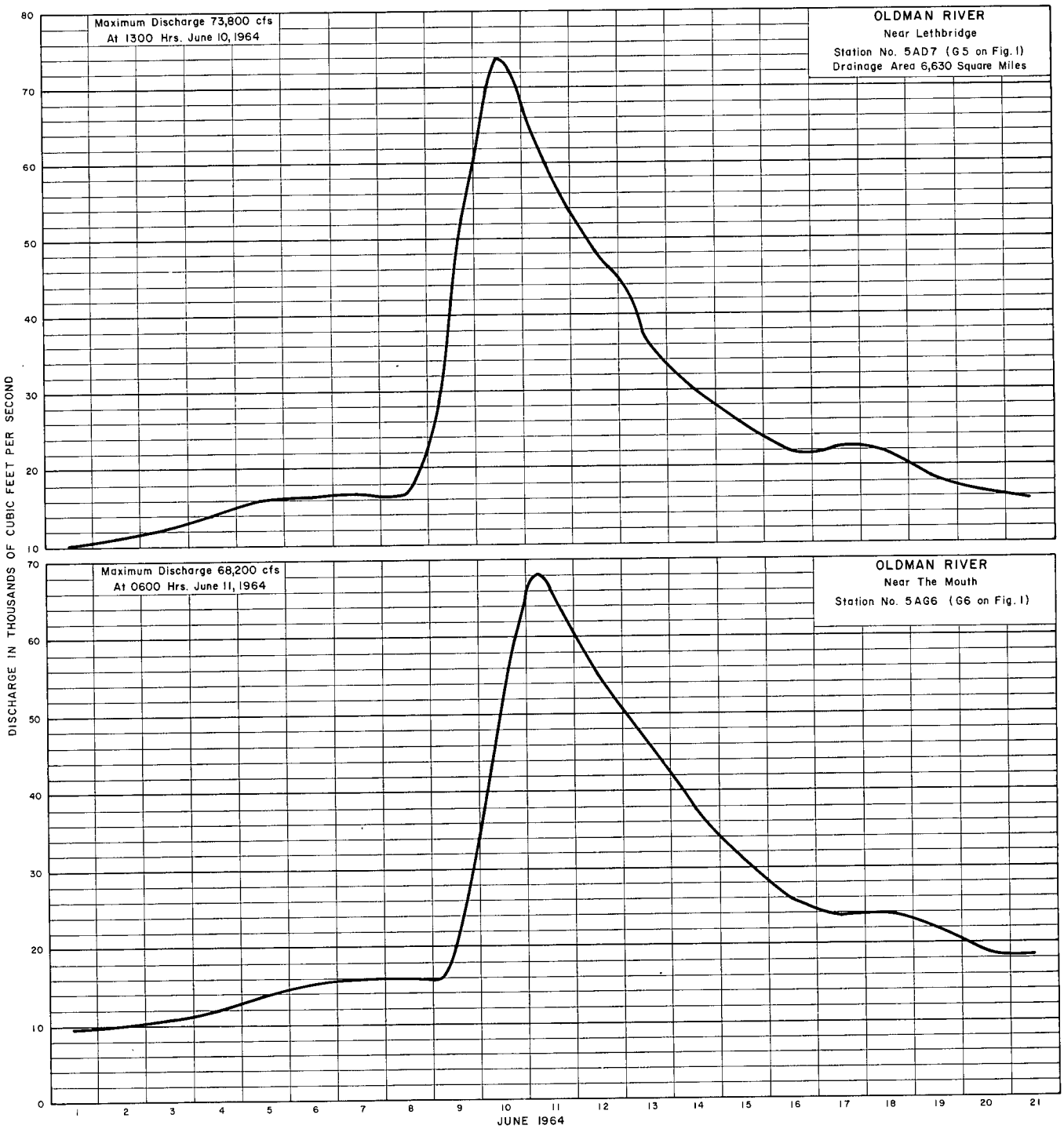


Figure 14. Hydrographs of peak flow period–Oldman River and tributaries below Monarch.

of extreme floods. On this basis, a flood may be compared with former floods in the same basin or in other areas; the relative contributions to the flood by various tributary areas in the basin may be assessed or the maximum discharge from ungauged areas estimated with the help of these data. Maximum discharges per square mile may also provide the basis for assessing the applicability to the basin of general flood potential formulae based on drainage area factors.

The maximum discharge per square mile of drainage area during the 1964 flood is given in Table 3 for many of

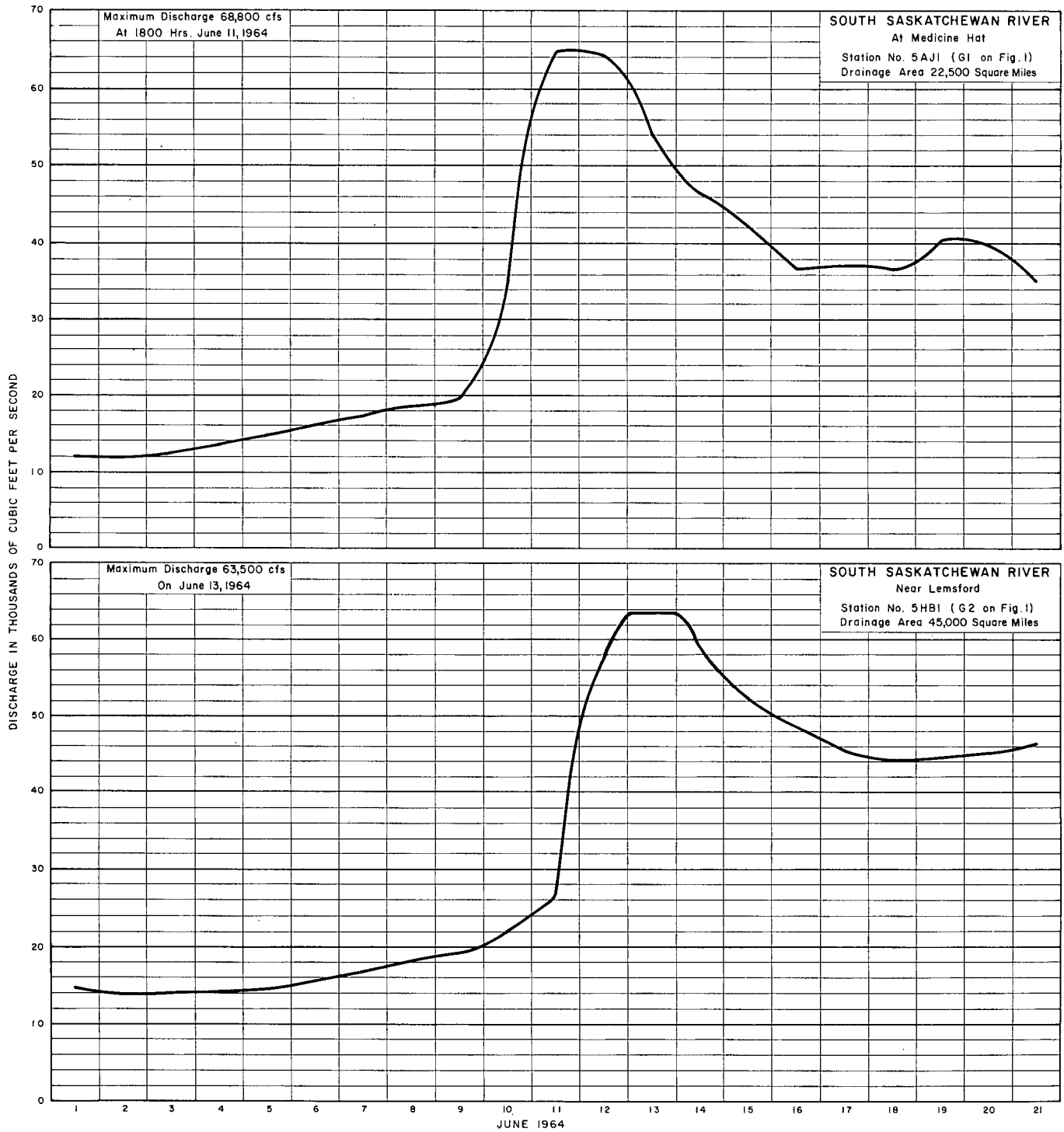


Figure 15. Hydrographs of peak flow period–South Saskatchewan River.

the stream gauging stations in the affected basins. Included also, in Table 3, is information concerning several outstanding unit peak discharges which occurred in Montana at United States Geological Survey gauging stations. These maximum unit discharges are plotted against their respective drainage areas in Figure 17. Also shown for comparative purposes are the maximum unit discharges recorded at some of those same stations during the 1953 flood.

The enveloping curve from Creager's equation with C = 30 is shown in Figure 17 for reference purposes. This value of C is taken from "Design Factors for Maximum Probable

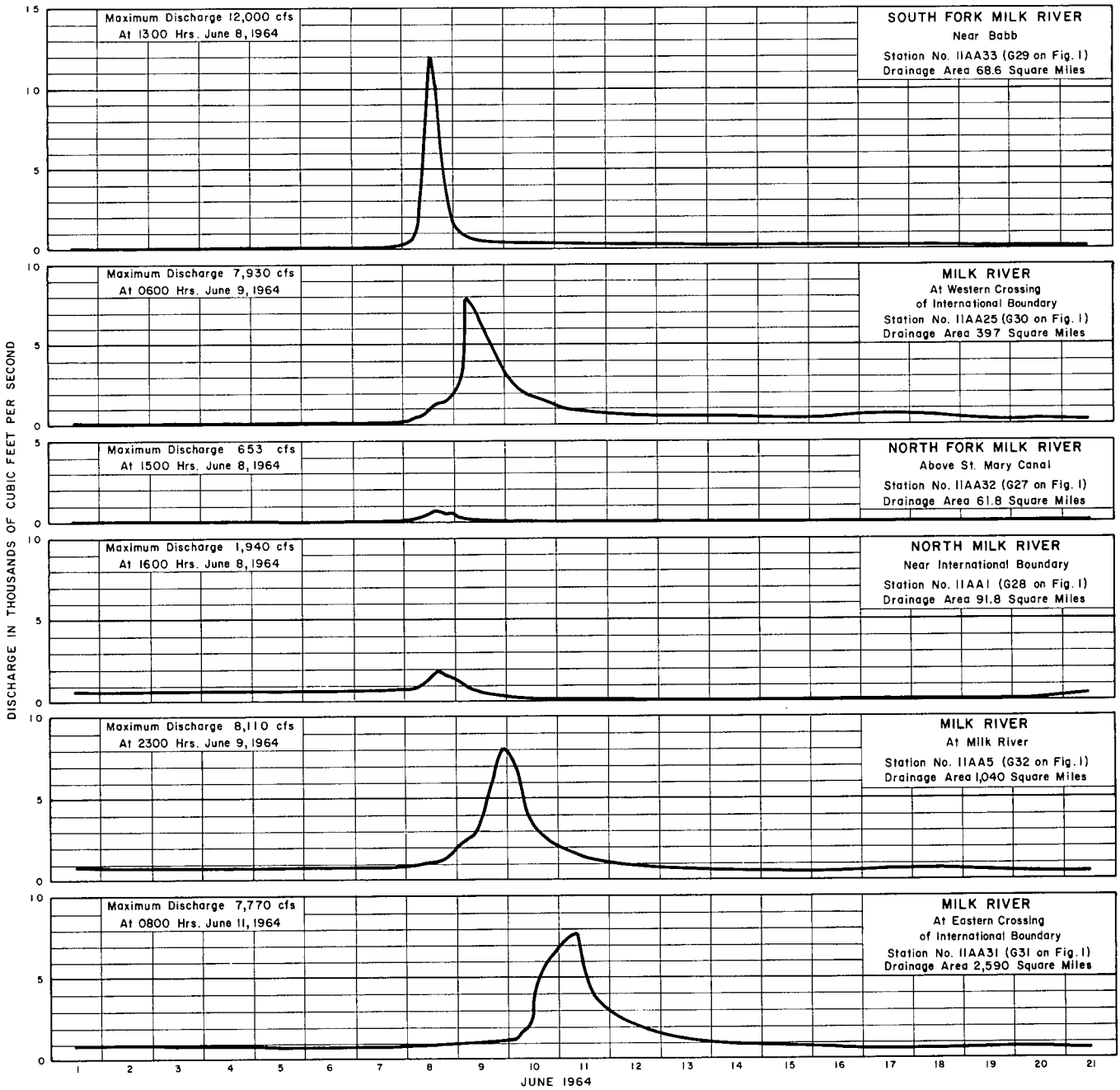


Figure 16. Hydrographs of peak flow period–Milk River basin.

Flood, General Engineering Report, South Saskatchewan River Project, Prairie Farm Rehabilitation Administration, 1952."

The region of highest runoff in June 1964 was the rugged timbered mountain area on the eastern front that rises abruptly from grassy glaciated plains and low foothills of about 4,500 feet altitude to the Continental Divide in a distance of 20 to 30 miles. The drainage areas of 300 square miles or less in the headwaters of the Oldman River basin produced historical maximum unit discharges. One noted exception is G7 – Crowsnest River at Frank. However, this station is located at the outer fringe of the storm area.

From Figure 17, it may be noted that, for the flood of June 1953, the maximum unit discharges at stations with 10 square miles or less of drainage area were very similar to those at others where drainage areas ranged up to several hundred square miles. It was noted then that the stations with the smallest drainage areas (10 square miles or less) are

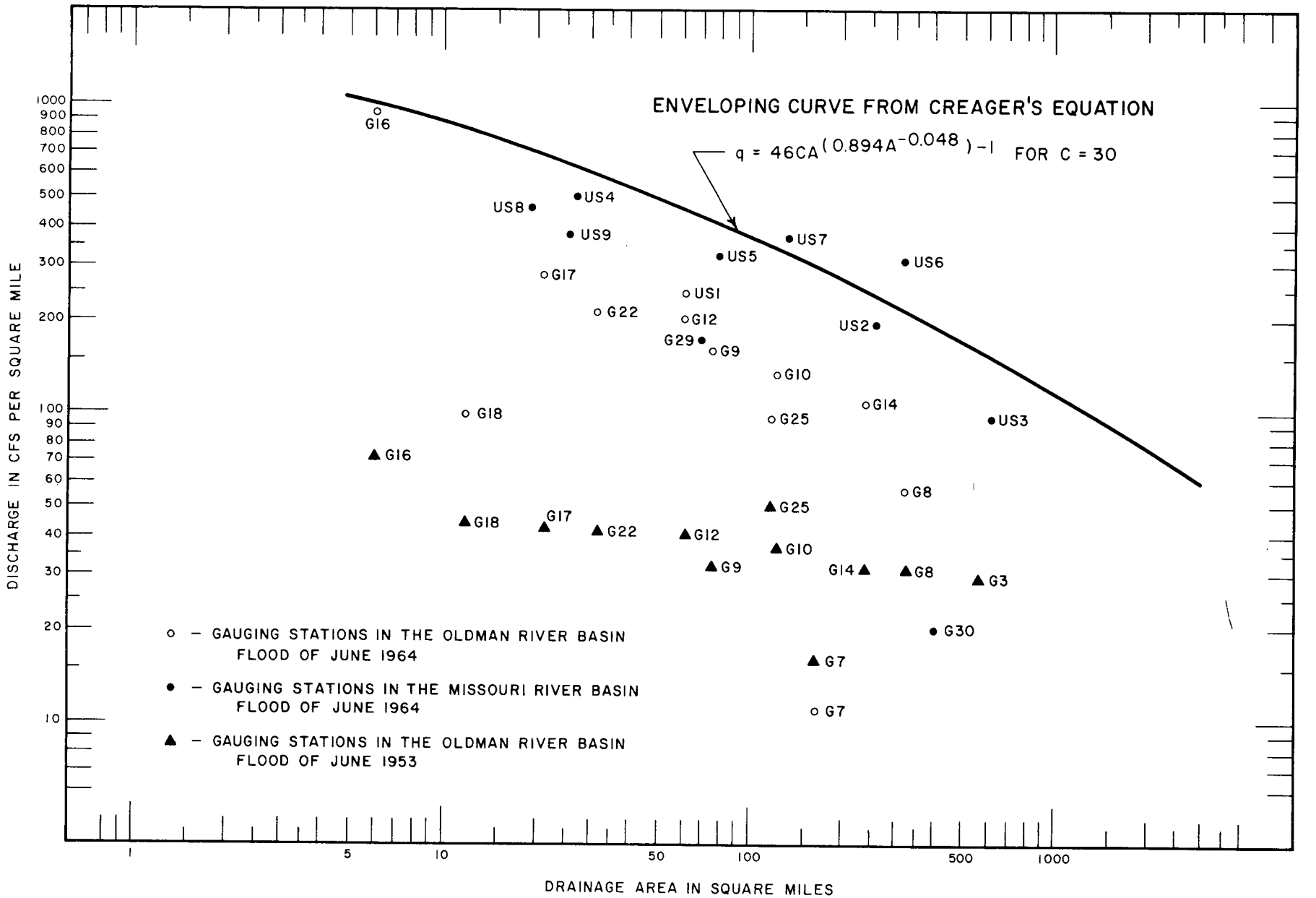


Figure 17. Plot showing maximum unit discharges versus drainage areas.

TABLE 4. Calculated Inflow to St. Mary Reservoir 1964 Flood

Date	Reservoir Elevation	Reservoir Rise	Reservoir Area (acres)	To Storage (cfs)	Canal Outflow (cfs)	Spillway Discharge (fsc)	Inflow (cfs)
June 8/64							
0800 hrs.	3,610.05		7,000		1,830		
1000 hrs.	10.35	0.20	7,050	8,460	1,850	920	11,230
1200 hrs.	10.60	0.25	7,100	10,640	1,760	1,100	13,500
1400 hrs.	11.00	0.40	7,200	17,270	1,540	1,360	20,170
1600 hrs.	11.50	0.50	7,300	21,900	1,490	1,700	25,090
1800 hrs.	12.00	0.50	7,400	22,200	1,480	2,100	25,780
2000 hrs.	12.60	0.60	7,530	27,100	1,180	3,900	32,180
2200 hrs.	13.30	0.70	7,700	32,300	930	4,840	38,070
2400 hrs.	13.80	0.50	7,825	23,500	890	5,500	29,890
June 9/64							
0200 hrs.	14.15	0.35	7,920	16,640	890	10,620	28,150
0400 hrs.	14.40	0.25	7,960	11,950	900	11,070	23,920
0600 hrs.	14.60	0.20	8,000	9,600	900	11,380	21,880
0800 hrs.	14.80	0.20	8,050	9,660	630	11,730	22,020
1000 hrs.	15.00	0.20	8,100	9,720	350	12,080	22,150
1200 hrs.	15.20	0.20	8,150	9,780	0	12,400	22,180
1400 hrs.	15.40	0.20	8,200	9,830	0	12,760	22,590
1600 hrs.	15.50	0.10	8,230	4,940	0	12,980	17,920
1800 hrs.	15.65	0.15	8,250	7,430	400	13,240	21,070
2000 hrs.	15.80	0.15	8,280	7,460	400	13,540	21,400
2200 hrs.	15.90	0.10	8,300	4,980	740	13,710	19,430
2400 hrs.	16.00	0.10	8,350	5,020	840	13,890	19,750
June 10/64							
0200 hrs.	16.10	0.10	8,360	5,025	850	14,090	19,965
0400 hrs.	16.20	0.10	8,400	5,040	850	14,290	20,180
0600 hrs.	16.25	0.05	8,410	2,600	850	14,400	17,850
0800 hrs.	16.35	0.10	8,420	5,000	850	14,540	20,390

all located at higher elevations in the mountain region. The fact that their maximum unit discharges did not appreciably exceed those for considerably larger drainage areas at intermediate elevations in the foothills was an indication that the flood was generated in the foothills and on the lower mountain slopes and that snowmelt was not an important factor.

EFFECT OF STORAGE AND DIVERSION

The overall effects of storage and diversion in the Oldman River basin were not significant. The extreme peaks registered on mountain streams in the Waterton Park area neutralized the influence of the few irrigation diversion systems that existed. A few minor diversions on the Belly River, for irrigation purposes, probably did not affect flood flows. No flood waters were stored in the Waterton Lake Reservoir since it was still under construction in June, 1964.

Lake Sherburne stored all inflow during the critical flood period (some 25,000 acre-feet during the period June 7-10), thus reducing the peak on Swiftcurrent Creek by about 10,000 cfs and ultimately having some beneficial effect on the flow of the St. Mary River.

Storage in the St. Mary Reservoir delayed the peak on the St. Mary River near Lethbridge by approximately 30 hours. If not for this storage, it is noted that the maximum daily flow in the St. Mary River near Lethbridge could have been in excess of 20,000 cfs, made up of flows from St. Mary River at International Boundary (17,000 cfs), Lee Creek at Cardston (2,750 cfs), and Rolph Creek near Kimball (180 cfs). Since these three stations peaked at about the same time (1800 hours on June 8), the instantaneous peak on the St. Mary River near Lethbridge might have reached about 33,000 cfs. Table 4 shows the calculated inflow – outflow for the St. Mary Reservoir from 0800 hours, June 8 to 0800 hours, June 10, 1964. The canal outflow shown was derived from stage record collected on the canal at the station St. Mary Reservoir near Spring Coulee (G20 on Fig. 1).

The St. Mary Canal, used to divert water to the North Milk River from the St. Mary River, had very little effect on the main Milk River or St. Mary River flows but, during the initial flood stage, had a significant effect on the flow of North Milk River at International Boundary. Kennedy Creek, at its junction with the St. Mary Canal, washed out the canal shortly thereafter.

The Belly-St. Mary River diversion canal diverted 1,410, 1,550 and 796 cfs respectively, on June 14, 15 and 16 to the St. Mary Reservoir. This occurred after the flood peaks and thus had little effect on downstream flooding.

The discharge of the Lethbridge Northern Irrigation District canal at Menzaghie's Bridge represents the total diversion to the L.N.I.D. from the Oldman River. In June 1964 the daily mean diversion averaged about 500 cfs and fluctuated very little from that amount.

Analysis of the Flood of June 1964

FLOOD DAMAGE

The most severe damage occurring as a result of the storm on June 7-8, 1964, was sustained in the State of Montana. Losses there were estimated at $55 million compared to an estimate in excess of $1 million for Canada. An excellent account of the damage in the flooded region is given in the report by the United States Geological Survey (1967). For that reason, this report will mention only a few of the more notable occurrences.

The area of severe flooding extended about 200 miles northward along the Continental Divide from Helena, Montana into Southern Alberta in a band approximately 70 miles wide. Flooding beyond this area was confined to the larger streams having their sources along the Divide. The main flood-producing areas affecting Southern Alberta were Glacier National Park in Montana and the adjoining Waterton Lakes National Park in Canada. The principal streams rising in these areas are the Waterton, Belly and St. Mary Rivers.

The Waterton Park townsite, which is bordered by Waterton Lake, was the scene of very severe flooding. The lake level rose four feet in a three-hour period early on June 8. Overbank flow from Cameron Creek also added to the flood waters. A brief 70-mph north wind created waves on the lake that smashed boats at the Waterton Lake pier. Main roads leading into the townsite were washed out and 150 residents were evacuated to the Prince of Wales Hotel.

Flooding and bridge washouts closed most highways crossing the Belly River. Severe flooding of lowlands along the Belly River forced the evacuation of some 250 people on the Blood Indian Reserve near Stand Off, Alberta. A Hutterite colony north of Stand Off was also threatened and all residents fled to higher ground. No injuries to those residents were reported but more than 200 head of cattle and 300 sheep were drowned.

Runoff was extremely high in the upper reaches of the St. Mary River. The road between Babb, Montana and the Many Glacier area was blocked by slides and gravel deposits and was washed out opposite the mouth of Boulder Creek. The resort town of St. Mary was evacuated when Divide Creek overflowed its banks. Early on June 8 the water was three feet deep in the streets. A highway employee drowned near St. Mary when a roadway collapsed, undermined by Divide Creek.

Kennedy Creek washed out a bridge on U.S. Highway 89 and a nearby section of the St. Mary Canal on June 8. A Cardston, Alberta, man drowned after he drove his car into the highway washout.

Lee Creek, which has its source in Glacier National Park, washed out the diversion dam for the municipal water supply and burst the main water supply pipes serving the town of Cardston. Six homes and several commercial buildings were also destroyed.

In the Missouri River basin, in Montana, the chief trouble maker was the Sun River, a mountain stream that joins the Missouri River at Great Falls. The Gibson Dam, which forms the irrigation reservoir below the confluence of the North and South Forks of the Sun River, overflowed to a depth of 3.23 feet above the parapet on June 8. Most of the town of Augusta, on Elk Creek, was inundated and the town of Sun River was completely flooded.

Some 3,000 persons were evacuated from the flooded areas of the city of Great Falls, Montana, where 680 homes and 24 business establishments were damaged. The Teton River and a tributary, Spring Creek, combined to flood the town of Choteau. The entire town of nearly 2,000 persons was evacuated when flood waters inundated some 640 homes and businesses to a depth of six feet.

The severity of the flooding in the Marias River basin upstream from the Tiber Reservoir was compounded by the failure of two irrigation dams and a community water supply dam. The failure of Swift Dam on Birch Creek released 30,000 acre-feet of stored water in a very brief time and caused the loss of 19 lives. The failure of the dam on Lower Two Medicine Lake in Glacier National Park released a flood wave on Two Medicine River on June 8 and led to the loss of nine lives. The Sullivan Reservoir, about one-half mile from Shelby, was breached, flooding a small part of that city.

In the upper Columbia River basin, to the west of the Continental Divide, severe flooding was confined to the upper reaches of the Blackfoot River and Flathead River drainage areas. Upstream from Flathead Lake, the Flathead River basin suffered the most severe flooding in modern times. All main bridges upstream from Columbia Falls were washed out or damaged beyond use. From Columbia Falls downstream to Flathead Lake, the Flathead River flooded more than 25,000 acres of lowlands.

Photograph 7. Waterton Lake rising, Main Street at Waterton townsite; 1900 hours, June 8.

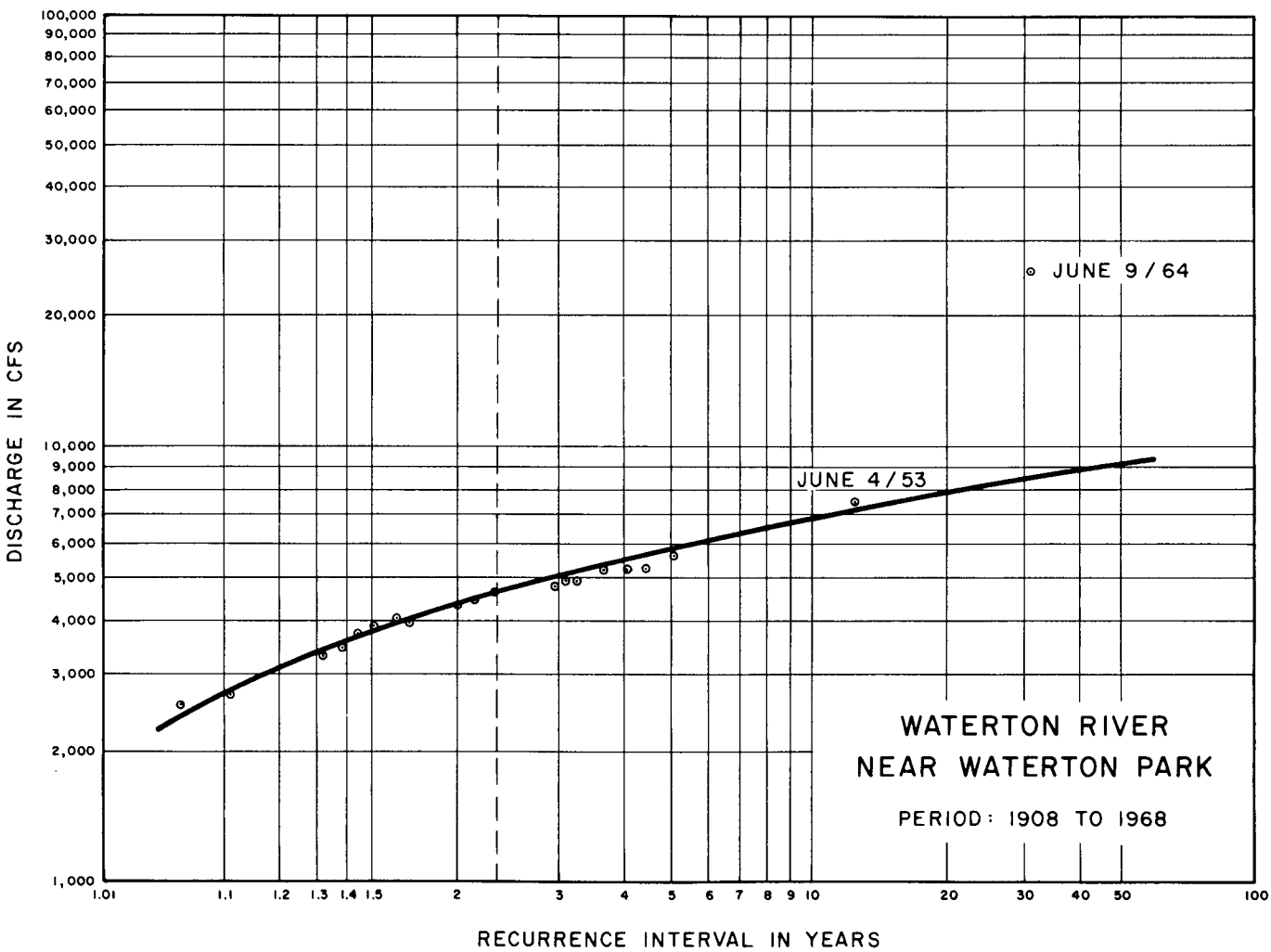


Figure 18A. Frequency curve: Waterton River near Waterton Park. (Intermountain category).

Photograph 8. Waterton Lake rising, Waterton townsite; 1000 hours, June 9.

Photograph 9. Cameron Creek, 300 feet below Cameron Falls in Waterton townsite; 1600 hours, June 9.

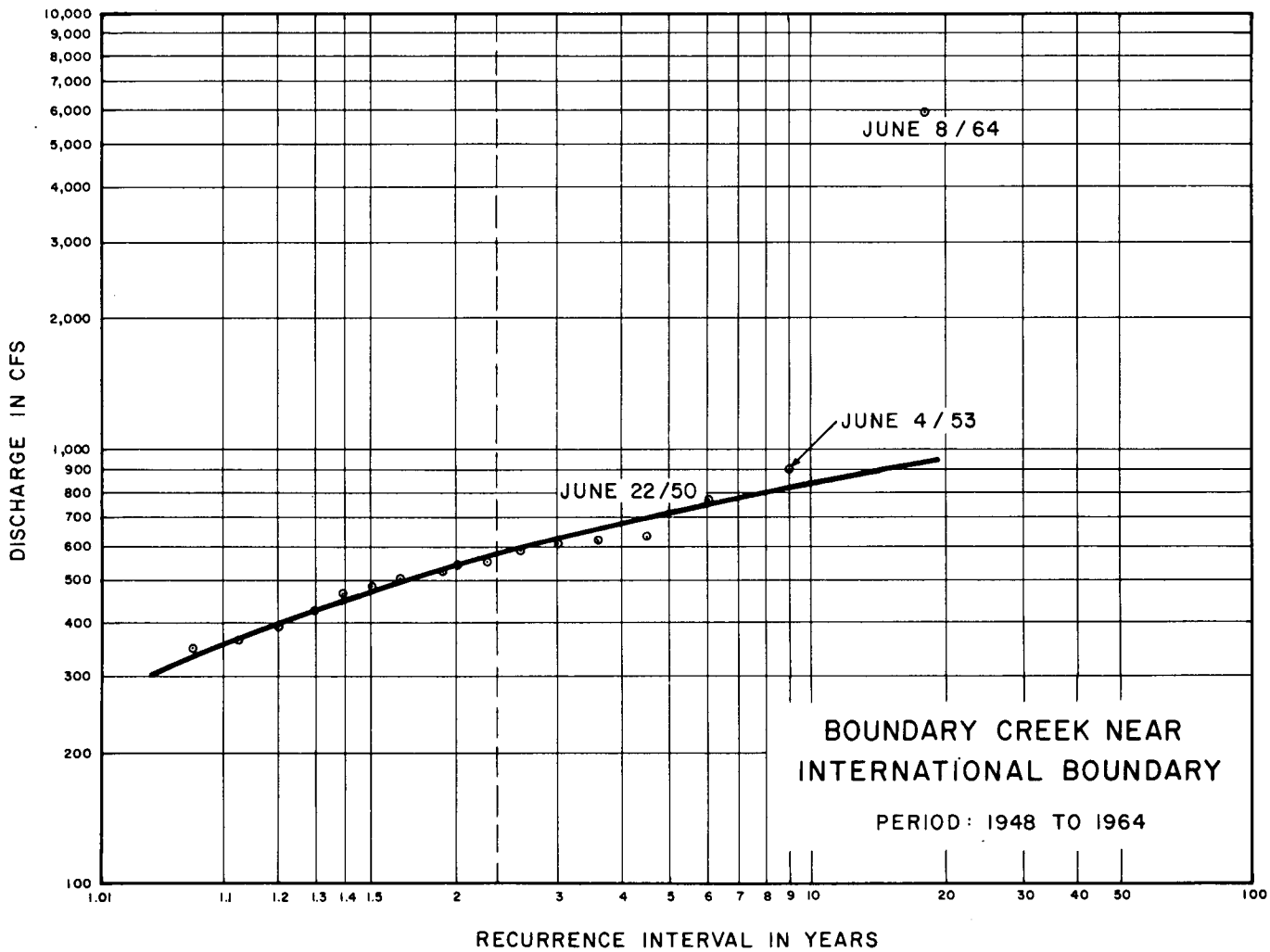
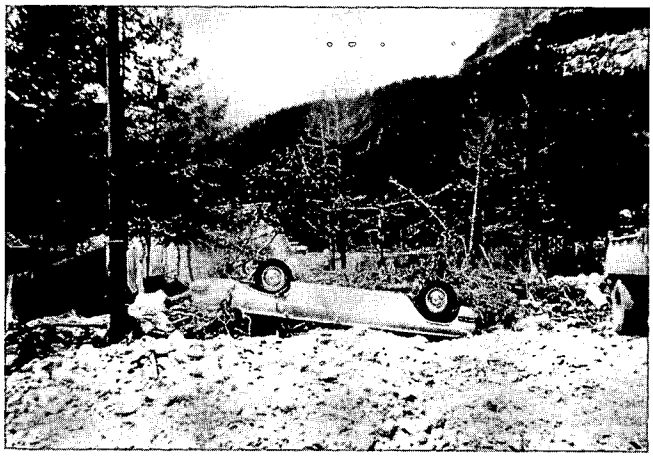
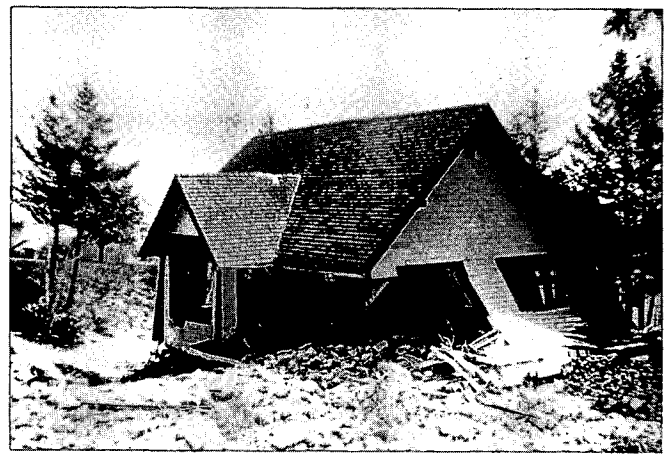


Figure 18B. Frequency curve: Boundary Creek near International Boundary. (Intermountain category).



Photograph 10. Aftermath of Cameron Creek flood in Waterton townsite.



Photograph 11. Aftermath of Cameron Creek flood in Waterton townsite. During the flood, Cameron Creek reverted to its original course rather than the man-made channel.

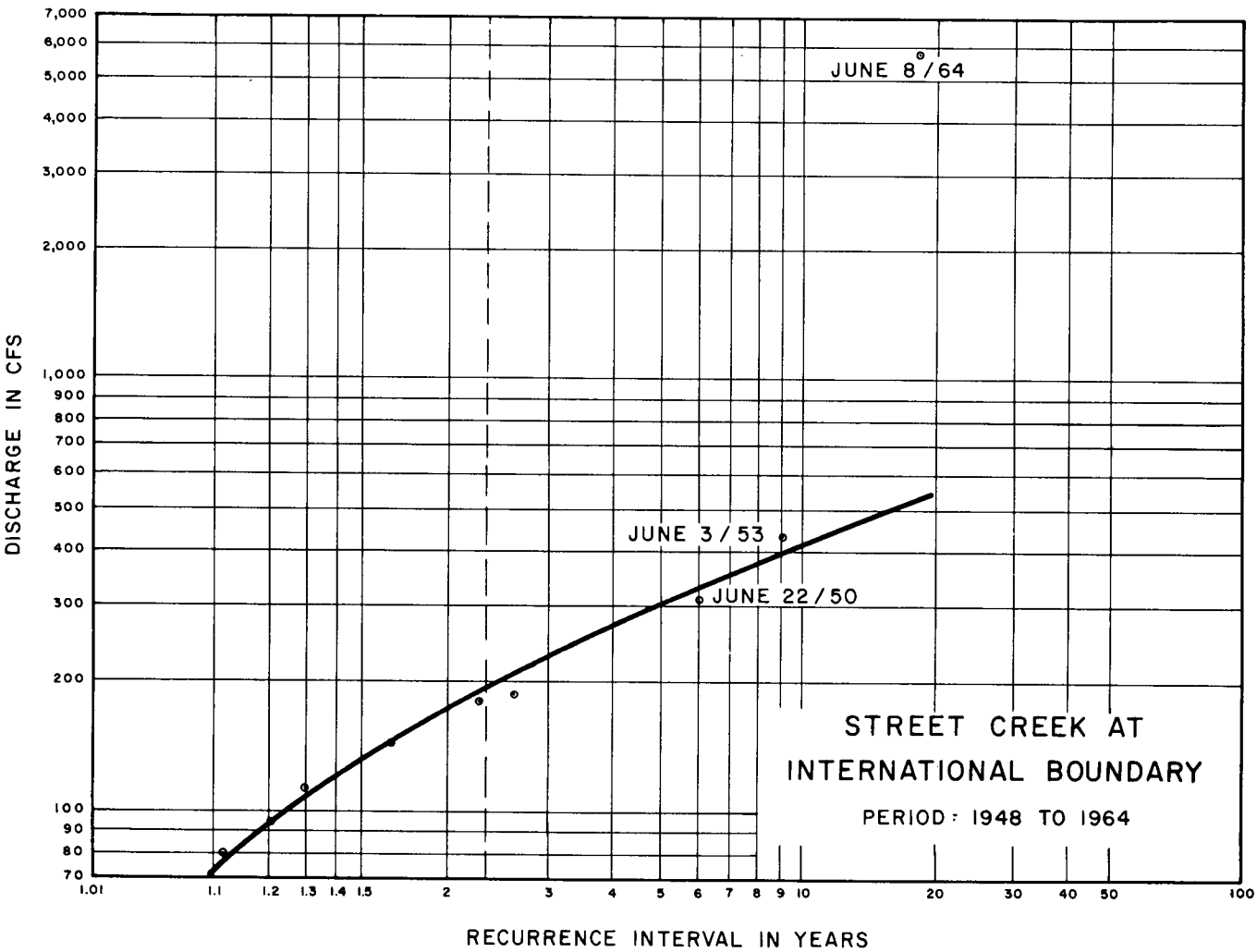
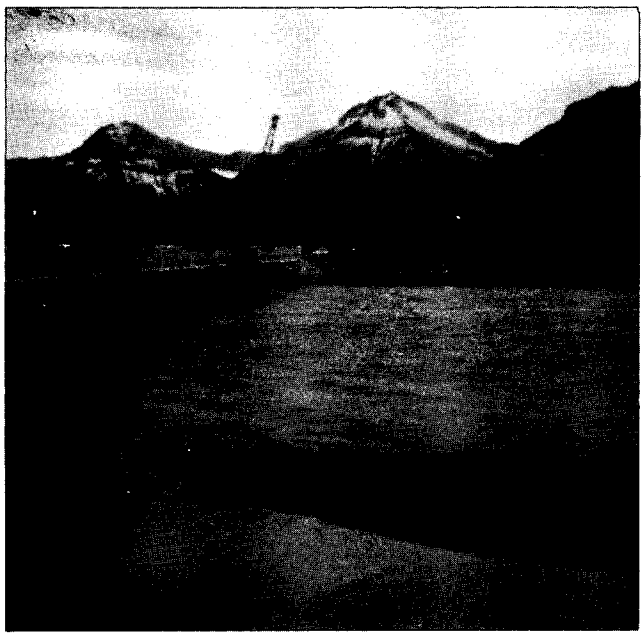


Figure 18C. Frequency curve: Street Creek at International Boundary. (Intermountain category).



Photograph 12. Blakiston Brook at bridge near golf course, Waterton townsite; 1815 hours, June 9.

Photograph 13. Waterton Lake at 1830 hours, June 9.

FORMER FLOODS

The June 1953 flood was the highest for the period of record (continuous, 1911 to date) on the South Saskatchewan River at Medicine Hat. The discharge recorded there was 151,800 cfs. The June 1964 flood produced a peak of 68,800 cfs. Since 1911, floods of lesser magnitude than those of 1953 occurred on the South Saskatchewan River in 1923, 1929 and 1932. Their respective discharges at Medicine Hat were 145,000 cfs, 122,000 cfs and 104,000 cfs. In the decade preceding the collection of streamflow records at this station, it is known that there were two floods higher than that recorded in 1953. These occurred in 1902 and 1908, the flood in 1902 being the greater with an estimated 200,000 cfs. The 1908 peak has been estimated at 185,000 cfs.

The Waterton, Belly and St. Mary Rivers all had high flows in 1902, 1908 and 1953. The maximum stages in 1908 on the Belly near Mountain View and the Waterton River near Waterton Park were slightly higher than those in 1964. The St. Mary River, upstream from Babb, Montana, may have had discharges in 1964 that exceeded those of 1908. The maximum discharge of the St. Mary River at International Boundary was 21,000 cfs in 1964 and approximately 40,000 cfs in 1908.

There have been significant floods in the Missouri River basin upstream from Fort Peck Reservoir in the years 1908, 1916, 1927, 1948 and 1953. The flood of June 1908 is considered to be the maximum for much of the area. Floods in the Milk River basin occurred in 1899, 1906, 1908, 1948, 1952 and 1953. During these years the central and lower parts of this basin were severely flooded. There was no serious flood in this area in June 1964. A report of the 1953 flood and a general review of some previous floods in the Missouri River basin have been published in the report by the United States Geological Survey (1957).

FLOOD FREQUENCY ANALYSIS

Generally, the floods of June 1964 were outstanding, particularly on streams that drained the mountain slopes on both sides of the Continental Divide. In the upper Oldman River basin, most streams had peak discharges that were the highest on record. Peak discharges in the Missouri River basin were also outstanding in the upper drainage areas of the Sun, Teton, Marias and Milk Rivers.

For the purpose of this report, the discussion of flood frequency will be confined to those stations located in the Oldman River basin, as far north as the headwaters of the Oldman River, and as far east as Lethbridge, Alberta. A frequency analysis of the affected streams in the Missouri River basin is presented in the report by the United States Geological Survey (1967).

In order to facilitate a regional flood frequency analysis, drainage areas in the region under study were divided into three categories with respect to their flood frequency characteristics (Water Resources Branch, 1963). These categories are Intermountain, Eastern Slopes, and Foothills. The names roughly describe the type of drainage in each case.

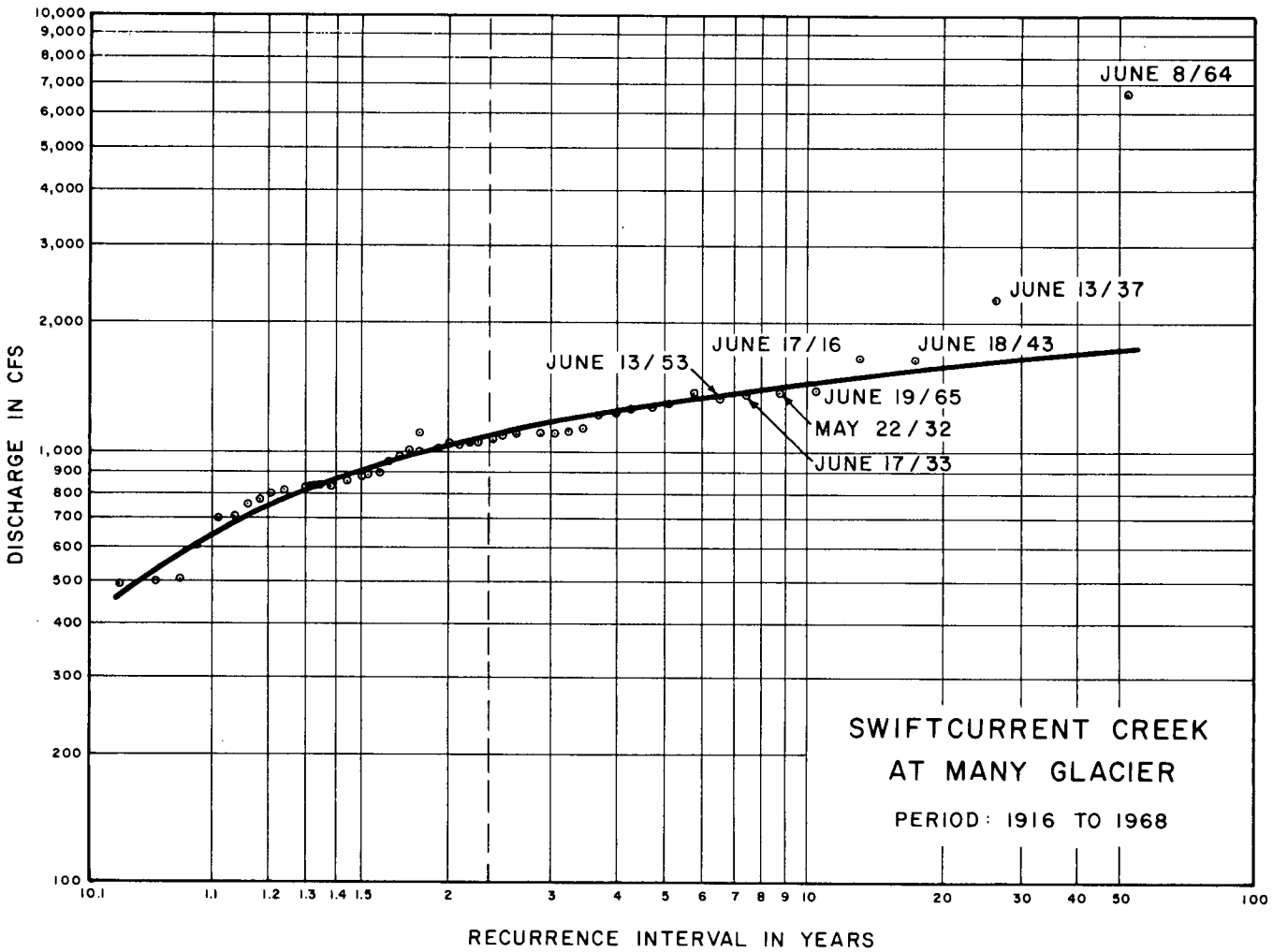


Figure 18D. Frequency curve: Swiftcurrent Creek at Many Glacier. (Intermountain category).

Intermountain Category: In general terms, this category comprises drainage areas lying west of the front or eastern wall of the Rocky Mountains barrier. Flood frequency characteristics for streams in this category are markedly different from those of other categories. Annual floods are appreciably higher than in basins of equivalent size outside this area.

Eastern Slopes Category: Any drainage basin lying in an area just east of the Rocky Mountain eastern wall barrier and west of the prairies which receives substantial contributions to the total runoff from above elevation 8,000 feet. The size of the drainage area above 8,000 feet may be small.

Foothills Category: Any drainage basin in the Eastern Slopes category which does not receive significant contribution to the runoff from above elevation 8,000 feet.

In the present report, frequency curves are presented for eleven stream gauging locations in the flood region. Four of these stations can be classified as Intermountain, one as Eastern Slopes and another as Foothills. The remaining five stations cannot be classified since their drainage areas fall in two or more categories.

Waterton River near Waterton Park: Intermountain (Fig. 18A). Period of record: 1908-33 and 1948-68. Mean annual flood: 4,700 cfs. Annual daily peaks are given for most years during the period 1908-68; missing peaks were derived from a simple correlation with nearby streams. Instantaneous peaks were recorded for the years from 1949 to 1968 while those for prior years were derived from a simple correlation with the annual daily peaks.

Boundary Creek near International Boundary: Intermountain (Fig. 18B) Period of record: 1947-64. Mean annual flood: 575 cfs. Instantaneous peaks were recorded for all years.

Street Creek at International Boundary: Intermountain (Fig. 18C) Period of record: 1947-55. Mean annual flood:

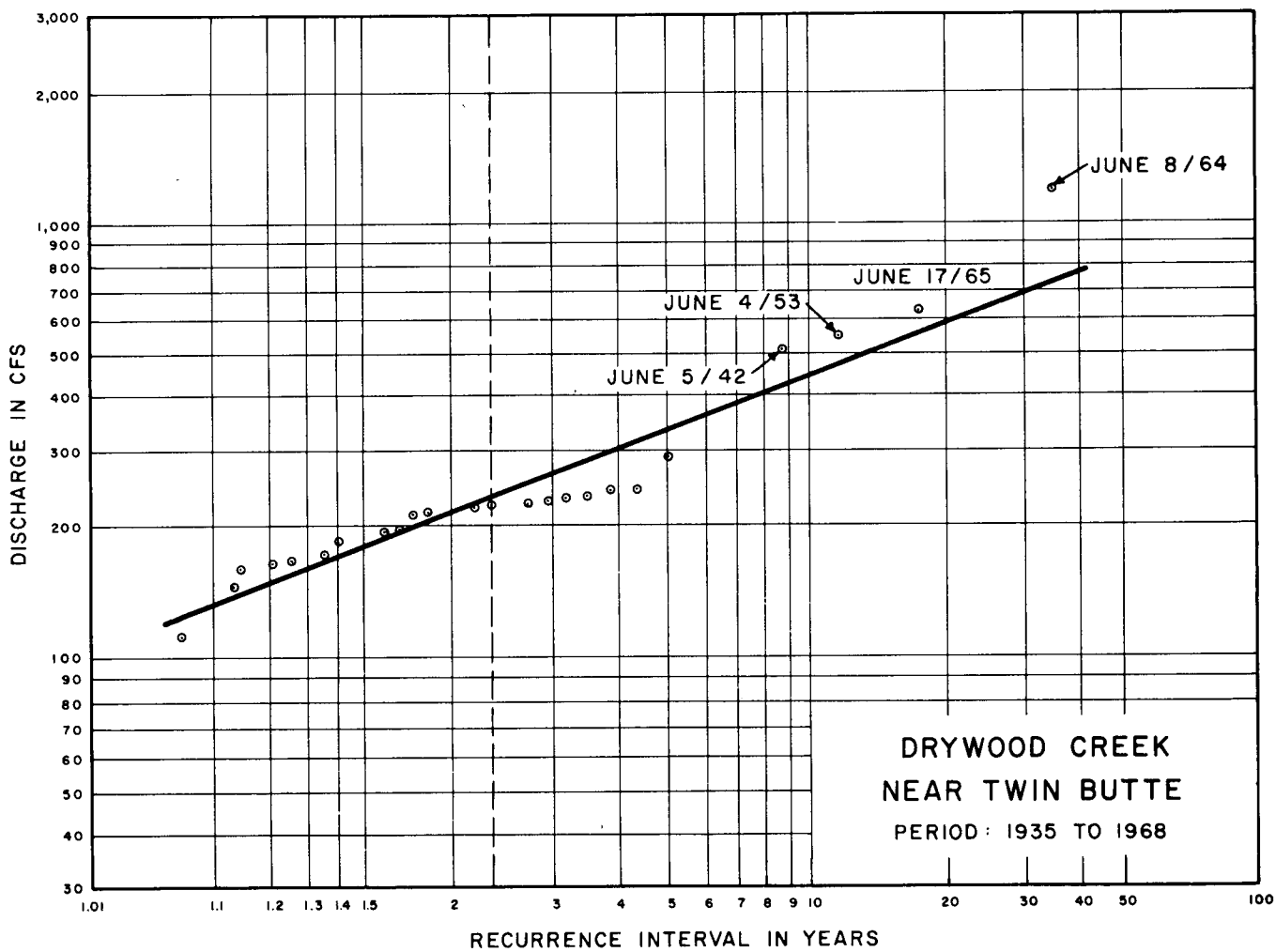


Figure 19. Frequency curve: Drywood Creek near Twin Butte. (Eastern slopes category).

195 cfs. Instantaneous peaks are given for most years. The record has been extended from 1955 to 1964 by simple correlation with nearby stations.

Swiftcurrent Creek at Many Glacier: Intermountain (Fig. 18D) Period of record: 1912-66. Mean annual flood: 1,190 cfs. Instantaneous peaks are given for all years 1916-66.

Drywood Creek near Twin Butte: Eastern Slopes (Fig. 19) Period of record: 1935-68. Mean annual flood: 230 cfs. Annual daily peaks are given for all years. Instantaneous peaks had been recorded for most years and those for missing years were derived from a simple correlation with annual daily peaks.

Lee Creek at Cardston: Foothills (Fig. 20) Period of record: 1909-14, 1920-68. Mean annual flood: 875 cfs. Missing annual daily peaks were derived from a simple correlation with nearby streams. Instantaneous peaks were recorded for most years after 1948. Instantaneous peaks for the period 1910 to 1948 were derived from a simple correlation with available annual daily peaks.

Castle River near Beaver Mines: (Fig. 21A) Period of record: 1945-68. Mean annual flood: 5,700 cfs. Instantaneous peaks were recorded for most years during the period of record and those missing were derived from a simple correlation with annual daily peaks.

Belly River near Mountain View: (Fig. 21B) Period of record: 1908, 1911-68. Mean annual flood: 2,050 cfs. Annual daily peaks were recorded for all years 1912-68 and those for 1908-11 were derived from a simple correlation with nearby streams. Instantaneous peaks were recorded for all years 1949-68 and those previous to 1949 were derived from a simple correlation with annual daily peaks.

Belly River near Stand Off: (Fig. 21C) Period of record: 1909-31, 1935-36, 1948-68. Mean annual flood: 2,450 cfs. Annual daily peaks are available for most years from 1909-68 and those missing were derived from a simple

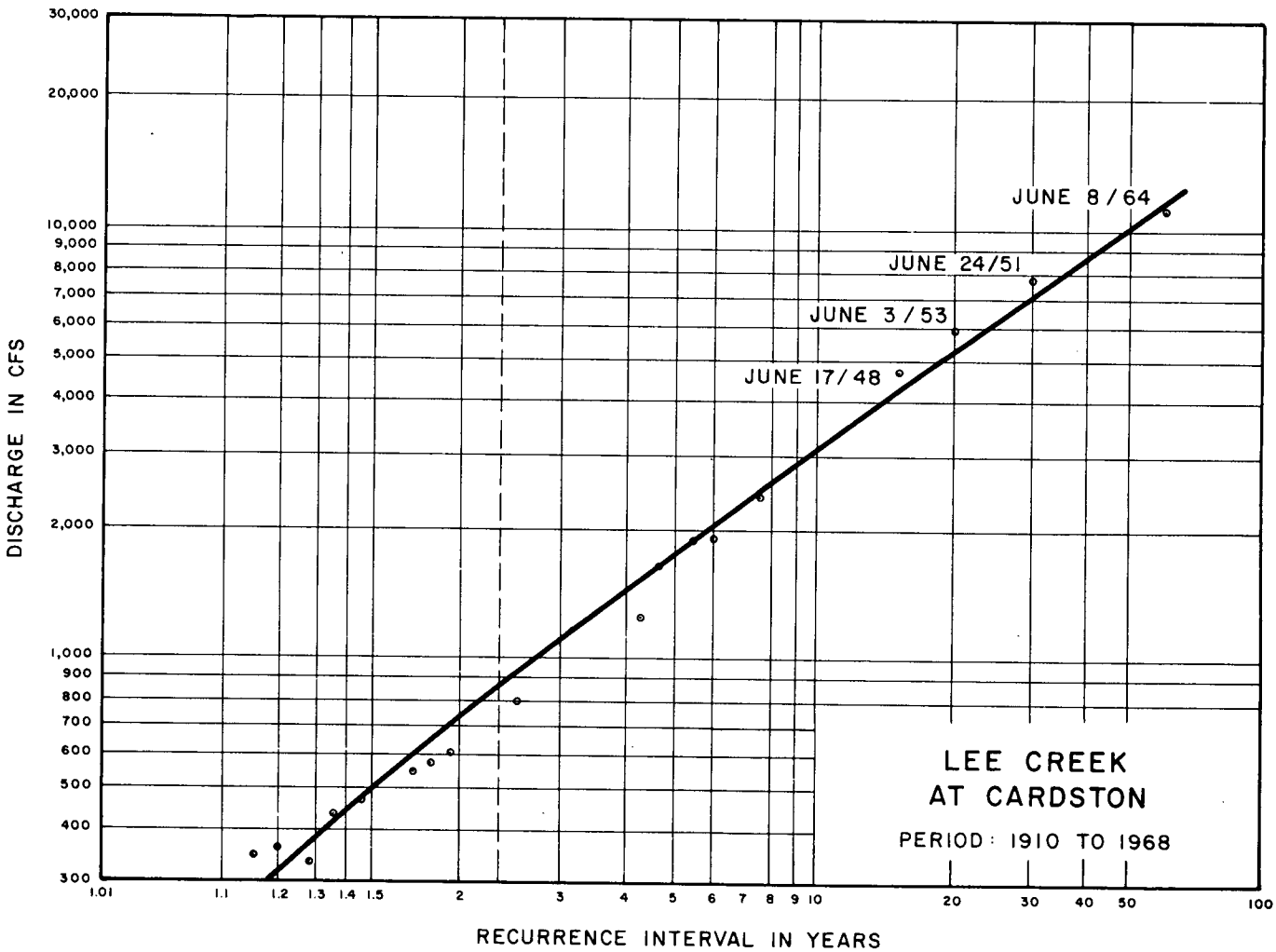


Figure 20. Frequency curve: Lee Creek at Cardston. (Foothills category).

correlation with nearby streams. Instantaneous peaks were recorded from 1950-68 and those for years previous to 1950 were derived from a simple correlation with annual daily peaks.

St. Mary River at International Boundary: (Fig. 21D) Period of record: 1902-68. Mean annual flood: 4,650 cfs. Annual daily peaks are given for all years 1903-68. Instantaneous peaks were recorded for all years 1939-68 and those for previous years were derived from a simple correlation with annual daily peaks.

St. Mary River near Lethbridge: (Fig. 21E) Period of record: 1911-68. Mean annual flood: 4,420 cfs. Annual daily peaks are given for all years 1912-68. Instantaneous peaks were recorded for most years 1932-68 and those previous to 1932 as well as missing peaks have been derived from a simple correlation with annual daily peaks.

Various procedures have been used in the analysis of streamflow records to determine probable frequency or recurrence intervals of flood stages of a given magnitude. The record at a single gauging station is only a sample of the long-term conditions at the site and any one of the various methods of flood frequency analysis of such a record, regardless of its relative merit, is subject to the same sampling error. Although the sampling error decreases with the length of record, it has been established (U.S.G.S. Water-Supply Paper 1943-A) that periods of record up to 25 years cannot define satisfactorily even short-term floods.

The flood frequency curves that are presented in this report have been derived, for the most part, from single station analyses. In all cases, instantaneous discharge peaks were used to rank the annual floods and plot the frequency curves. As explained previously in this section, the missing instantaneous maxima were derived from a simple correlation with the annual daily peaks. Only four of the eleven curves were based on records of less than 50-years duration. In three of those four cases, Street Creek at International Boundary, Boundary Creek near International Boundary, and Drywood Creek near Twin Butte, the

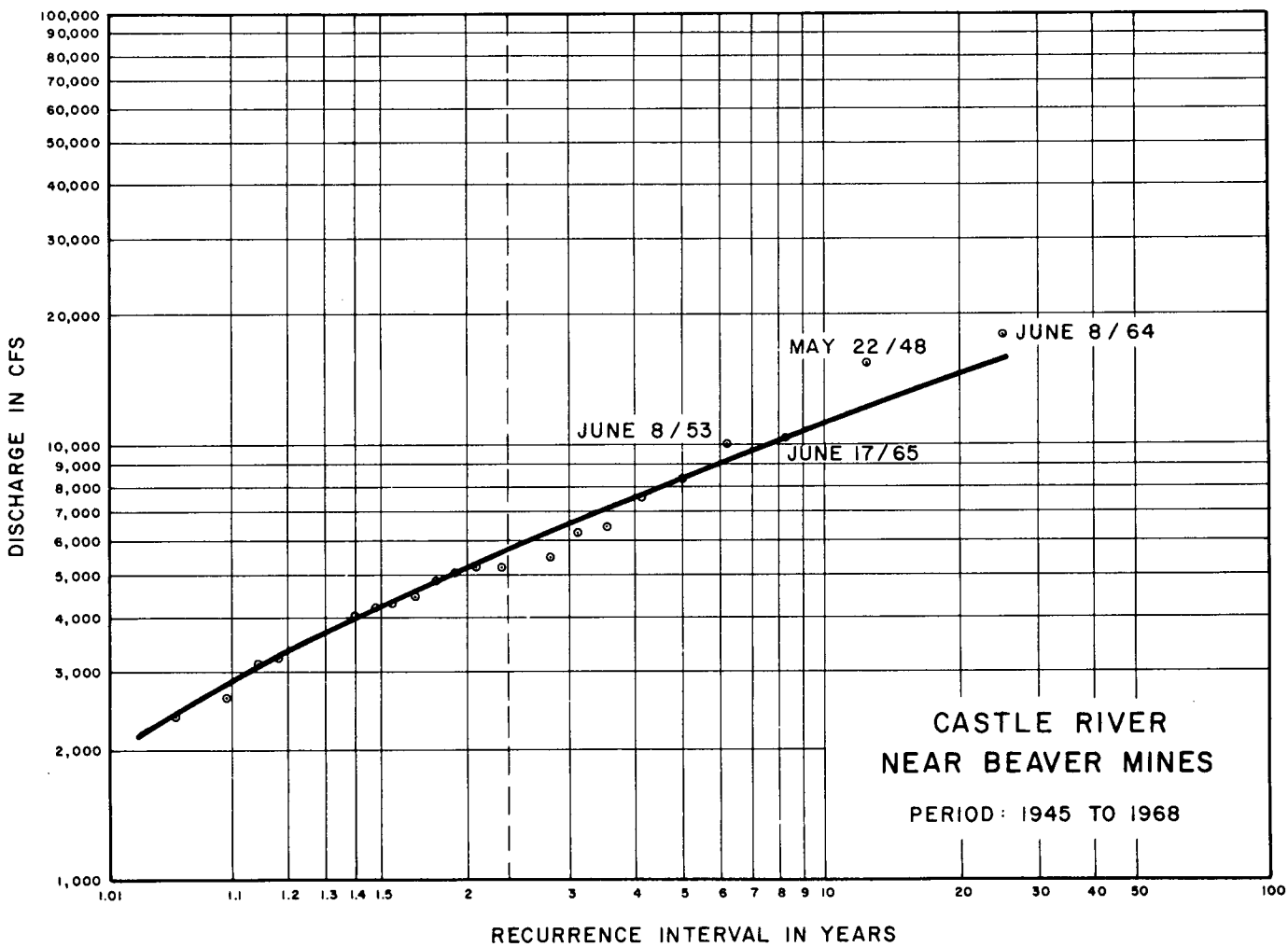


Figure 21A. Frequency curve: Castle River near Beaver Mines.

regional flood frequency curves derived by E.P. Collier (Water Resources Branch, 1963) even though they were derived using only the annual daily peaks on record, were used as a guide in drawing a line to fit the plotted points. The other case, Castle River near Beaver Mines, does not fall into any of the categorized regions.

Regional frequency curves are intended primarily for use in studying the flood frequency characteristics of ungauged drainage basins but they may also aid in the interpretation of the data available from an existing or discontinued gauging station (e.g., Street Creek at International Boundary). In the analysis of an individual station record, the shape of the frequency curve may not be obvious after the annual floods have been arranged in order and plotted; two or more curves may appear to fit the plotted data equally well. In these cases, the regional curve may be useful in selecting the best solution (e.g., Drywood Creek near Twin Butte). In other cases, the regional curve may define the frequency characteristics better than the curve resulting from a short-term record at the site.

One significant aspect of the flood characteristics of the region under study is the marked difference in the variability of the annual floods in the different basin categories, as indicated by the slopes of the frequency curves. The difference can be accounted for by the variations in the quantity, type and pattern of precipitation. Heavy snowfall produces high mean annual floods in the intermountain basins but snowmelt is relatively uniform during the summer months and the basins are not subjected to intense summer precipitation. Consequently, the long-term flood is not much greater than the mean annual flood.

The annual floods on streams in the eastern slopes category are attributable to rainfall on the lower slopes combined with some snowmelt at higher elevations. Mean annual floods are not as high as in the intermountain basins but the long-term flood appears to be many times greater than the mean annual flood because of the variations in the intensity of the summer rainstorms from year to year.

The annual summer peak on streams in the foothills category is attributable entirely to rainfall. In years of light

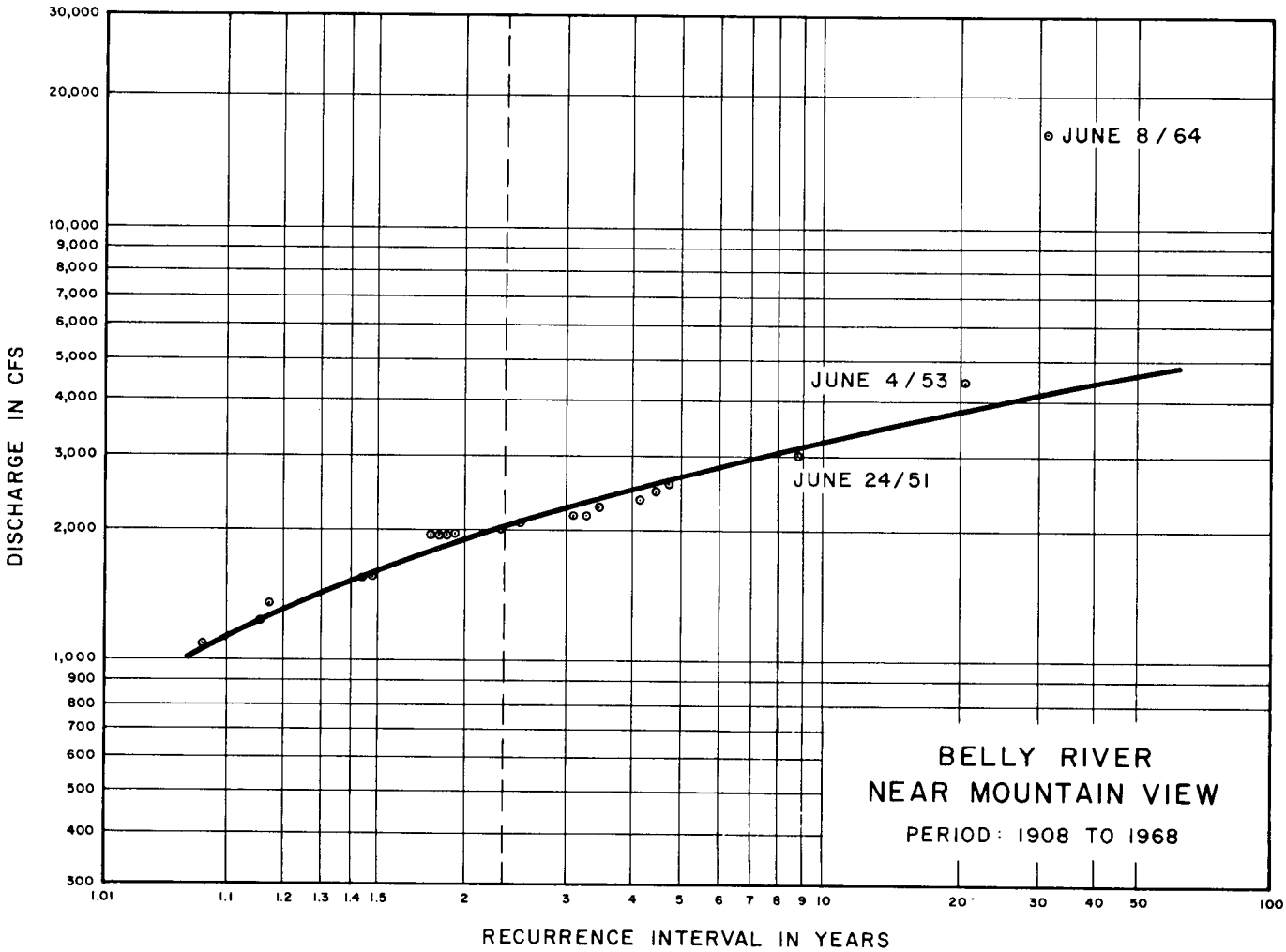


Figure 21B. Frequency curve: Belly River near Mountain View.

rainfall the summer peak is almost negligible and hence the mean annual flood is relatively low. High summer discharges do occur in some years, however, as a result of intense rainstorms. The effect of the extreme variations in the incidence of these summer rains is to produce long-term floods in the foothills streams which, in most cases, are over fifty times the mean annual peak flow.

DETERMINATION OF PEAK FLOWS

In general, it can be stated that hydrometric coverage of the June 1964 flood was excellent. Of the thirty-two stations described in this report, 28 were equipped with automatic stage recorders and the remaining four were subjected to at least once-daily staff or wire-weight gauge observations.

Under normal circumstances a hydrometric survey requires that enough current-meter measurements be made at each gauging location to completely define the relationship between gauge-height and discharge. During a flood period, however, some peaks at various stations are missed because it is often impossible for available field personnel to reach all stations at the critical periods. Also, measuring facilities such as cableways or bridges may have been destroyed.

Soon after the flood period, engineers and technical personnel from Canadian Government agencies and the United States Geological Survey estimated the peak discharge at eight gauging locations by the slope-area method. On the basis of these indirect measurements, the rating curves for these stations were extended to the peak stage with some confidence.

In eight other cases, where the channel configuration was not suitable and high-water marks not reliable for the use of slope-area measurements, the extension of the rating curve beyond the highest current-meter measurement was carried out by plotting the defined portion of the curve on logarithmic co-ordinates and extending it on a straight-line

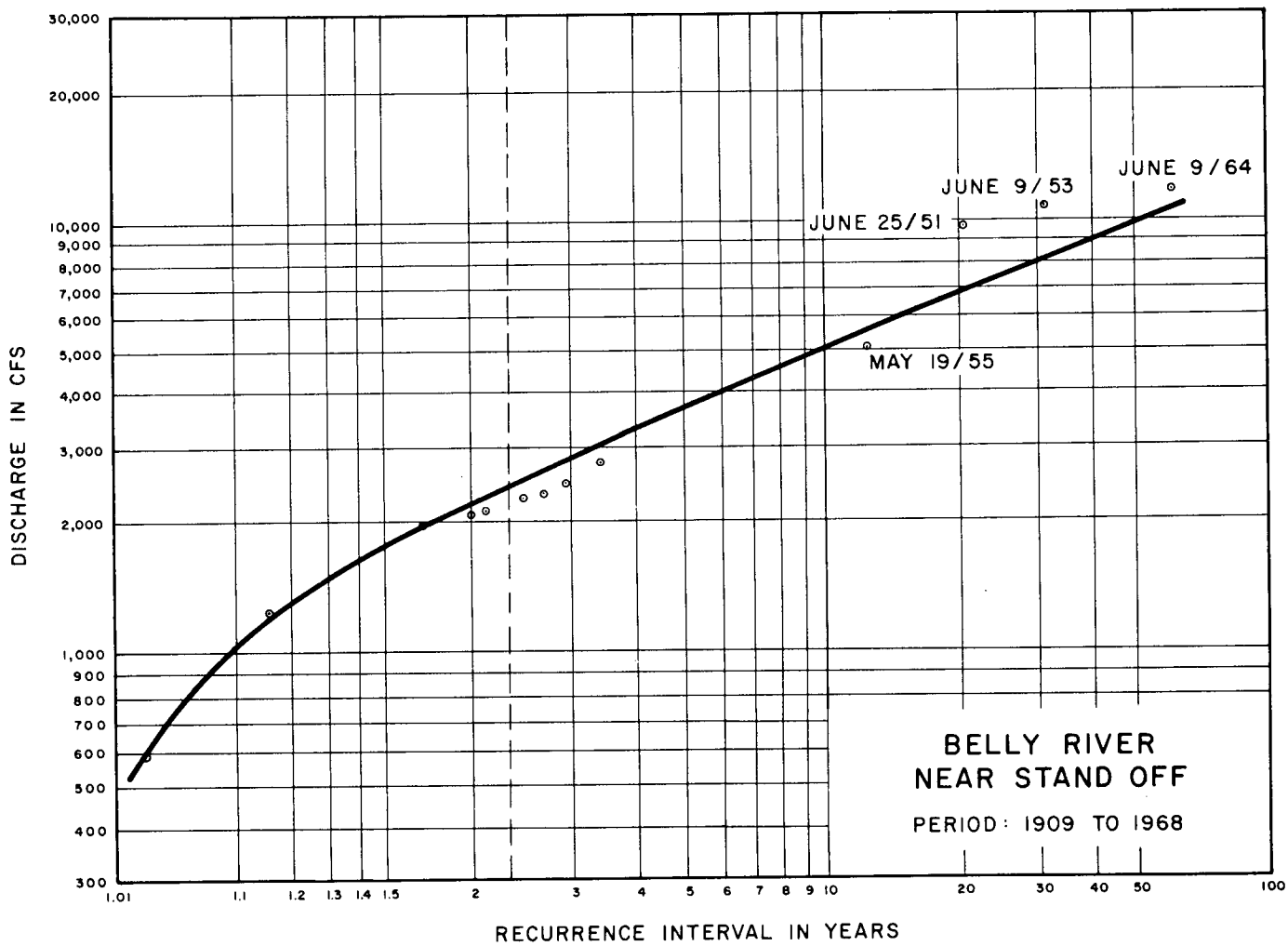


Figure 21C. Frequency curve: Belly River near Stand Off.

basis to the peak stage. This procedure is one which has been extensively employed in the analysis of hydrometric data and is based on the known tendency for the stage-discharge relationship in natural channels to follow a logarithmic curve over wide ranges in stage.

For one station, Belly River near Stand Off, it was necessary also to use a composite curve of high water measurements from previous years to extend the present rating. The stage-discharge relationships at the remaining fourteen stations covered in this report were adequately defined by standard current-meter measurements.

EXPLANATION OF STREAMFLOW DATA

Contained in this report are streamflow data for thirty-two Canadian and International Gauging Stations, twenty-six in the South Saskatchewan River basin and the remainder in the Milk River basin. The Water Survey of Canada and the United States Geological Survey co-operated in the collection of flood data for 14 of these stations which are designated international. Twenty-eight of the 32 gauging stations were equipped with automatic stage recorders and the rest with manual gauges at which one or more observations per day were obtained.

The information for each station is presented in a description of the station followed by a table of the daily mean discharge for the flood period and then, where available, by a second table containing more detailed gauge height and discharge data.

Station Descriptions

The name of the station is followed by the general index number under which the data are published in the surface water data publications and then by the map index number assigned for purposes of this report. The map index number is prefixed by the letter "G".

The latitude and longitude of the station is given,

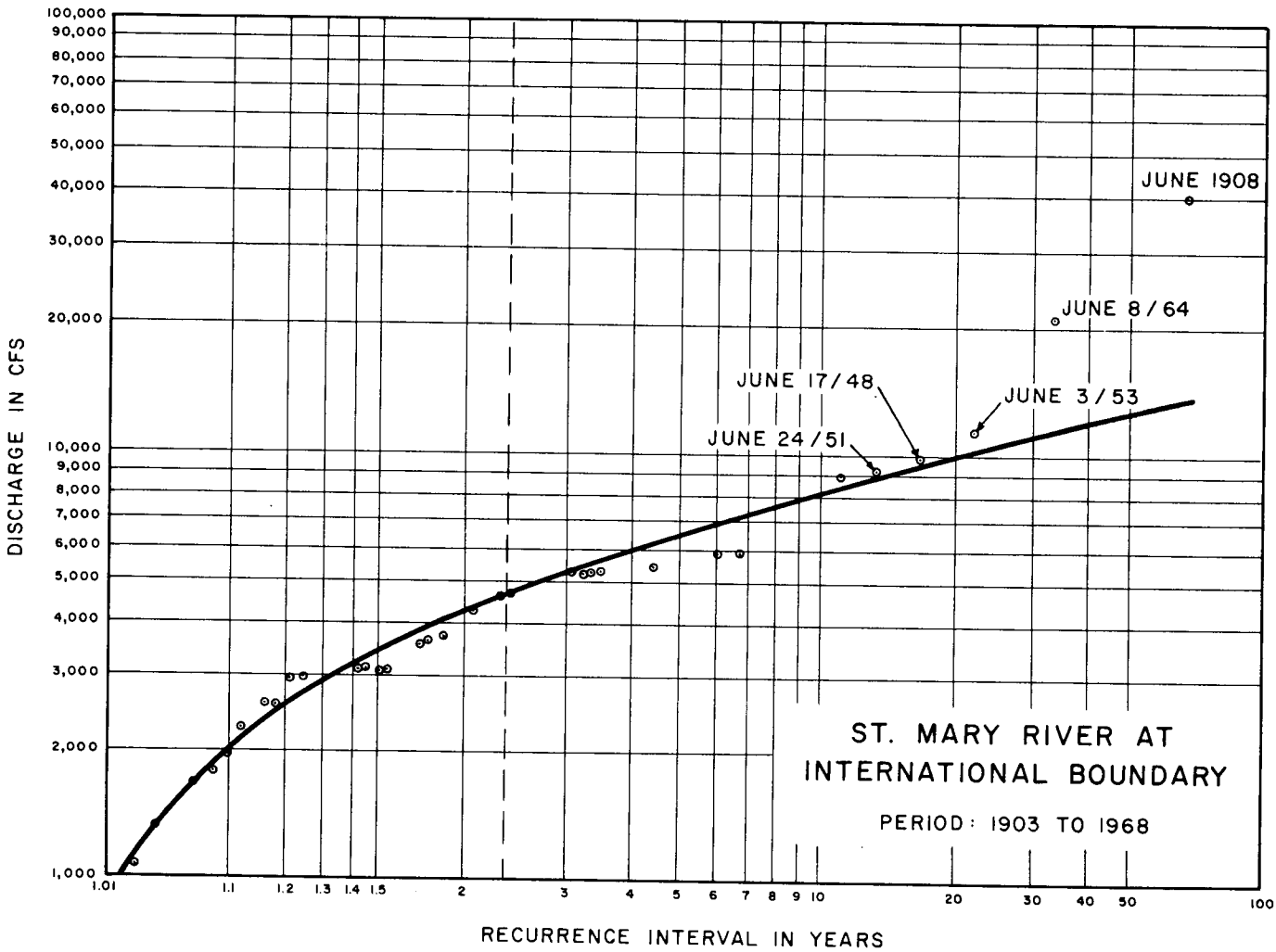


Figure 21D. Frequency curve: St. Mary River at International Boundary.

followed by its legal land location and usually by references to adjacent towns, bridges or other pertinent features.

Under "Drainage Area" is given the gross area of the catchment basin above the station, as determined by planimeter from topographic maps. No adjustments to the gross area have been made for non-contributing areas.

The source of the gauge-height record is also described. For stations with automatic stage recorders, the gauge heights were taken directly from the recorder chart. Where the station was equipped only with a manual gauge, the observer's readings were usually plotted and a graph drawn through them. The gauge height for any required time was then read from the graph.

In most cases where the description indicates that the station was equipped with an automatic stage recorder in 1964, the instrument was installed at some time after the station was originally established and some of the earlier years of record were obtained by manual gauge observations.

Under the heading "Discharge Record" in the description, the range of the rating curve defined by standard current-meter measurements is given. In addition, and where applicable, the method used to extend the rating curve to the peak gauge height is indicated.

The length of the period over which streamflow records have been collected at each station is given under the heading "Period of Record." Where there have been significant gaps in the record since the gauge was first installed, appropriate remarks to that effect are included. In some cases the records have been collected on a seasonal basis, for example, during the summer seasons only, and this is pointed out where applicable.

Under the heading "Maxima" are given the peak gauge height and discharge for the period of record. Notes on extreme floods, which occurred before the establishment of the gauging station, are also included where reasonably reliable information about them is available.

A few clarifying remarks, which do not appropriately

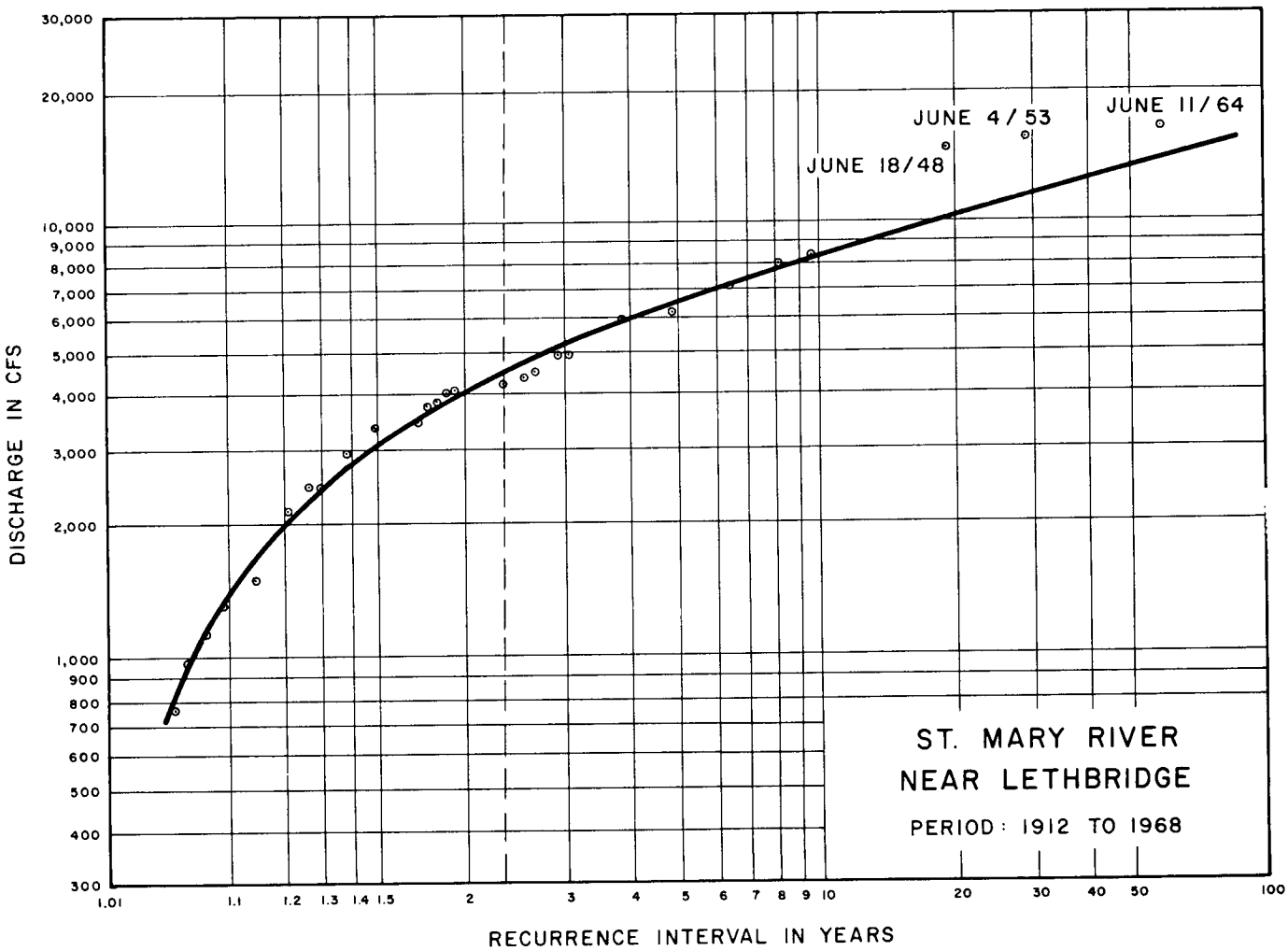


Figure 21E. Frequency curve: St. Mary River near Lethbridge.

fall under the other headings, are included at the bottom of most descriptions. For example, where there are upstream reservoirs or diversion works which may have had a significant effect on the peak flows, the existence of these works is noted. Changes in datum or location of the gauge or changes in the title under which the station records have been published are other examples of the type of information embodied in these remarks.

Daily Mean Discharge Tables

The figures in these tables are the mean discharges for each calendar day and they may be used to compare the total flow from day to day. The diurnal fluctuations and instantaneous maxima are not revealed in these daily averages.

Instantaneous Discharge Tables

These tables show the instantaneous gauge height and discharge at several times during those days in the flood period when the stage was changing rapidly. The data were selected from stage-recorder charts in such a way as to permit the reasonably accurate reproduction of hourly hydrographs. For some stations, it is evident that flood flows have caused a shift to a new stage-discharge relationship.

The gauging stations are arranged in the following tables in the order of the numbers assigned to each on the index map. For numbering purposes the stations were arranged in groups in the order shown below. In general, numbers were assigned in the downstream order, the main stem station preceding the tributary stations in each group.

The selected groups in the order in which they appear in the tables are as follows:

South Saskatchewan River main stem
Oldman River main stem and its western tributaries and

Oldman River southern tributaries — Belly River, Waterton River and St. Mary River.

References

Curry, G.E. and A.S. Mann. 1965. Estimating precipitation on a remote headwater area of western Alberta. Proceedings of 33rd Annual Western Snow Conference, 1965, Colorado State University, Fort Collins, Colorado, U.S.A.

Meteorological Branch. 1964. Monthly Record – Meteorological Observations in Canada – June 1964 and Supplement, Atmospheric Environment Service, Environment Canada, Ottawa, Ontario.

United States Geological Survey. 1967. Water Supply Paper 1840-B: Floods of June 1964 in Northwestern Montana. United States Government Printing Office, Washington, D.C., U.S.A.

Water Resources Branch. 1966. Water Resources Paper No. 145: Surface Water Data for Arctic and Western Hudson Bay Drainage and Mississippi Drainage in Canada – Water Year 1963-64. Water Management Service, Environment Canada, Ottawa, Ontario.

———. 1963. Water Resources Paper No. 113F: Flood of June 1953 in the South Saskatchewan River Basin. Water Management Service, Environment Canada, Ottawa, Ontario.

Water Survey of Canada. A Summary of Snow Survey Measurements, Alberta, Saskatchewan and Northwest Territories 1922-70. Water Management Service, Environment Canada, Calgary, Alberta.

APPENDIX A

Streamflow Data

SOUTH SASKATCHEWAN RIVER AT MEDICINE HAT - STATION NO. 5AJ1 (G1 on Fig. 1)

Location: Lat. 50° 02' 35", long. 110° 40' 40", Alberta, in N.W. ¼ sec. 31, tp. 12, rge. 5, W. 4th Mer., at traffic bridge in the city of Medicine Hat. Drainage Area: 22,500 square miles. Gauge-Height Record: Automatic stage recorder graph. Discharge Record: Stage discharge relationship in 1964 defined by current-meter measurements. Period of Record: June 1911 to date, except September and October 1911 and October 1934 to February 1935. Maxima: 151,800 cfs at 8:00 to 9:00 a.m., June 11, 1953 (g.h. 29.19). For 1964, 68,800 cfs at 6:00 p.m., on June 11 (g.h. 19.44). Remarks: Floods are known to have occurred in 1899, 1902 and 1908. Peak discharge is estimated to have been 200,000 cfs in 1902 and 185,000 cfs in 1908. Peak discharge in 1899 is believed to have been lower than in 1902 and 1908.

Daily Mean Discharge in cfs, 1964

Date	Discharge	Date	Discharge	Date	Discharge
1 June	12,000	8 June	18,700	15 June	42,300
2 June	12,000	9 June	19,600	16 June	37,000
3 June	12,500	10 June	35,100	17 June	37,300
4 June	13,600	11 June	64,800	18 June	36,700
5 June	14,700	12 June	64,300	19 June	40,200
6 June	16,300	13 June	54,000	20 June	38,800
7 June	17,100	14 June	46,400	21 June	35,100

SOUTH SASKATCHEWAN RIVER NEAR LEMSFORD - STATION NO. 5HB1 (G2 on Fig. 1)

Location: Lat. 51° 01' 20", long. 109° 07' 30", Saskatchewan, in S.W. ¼ sec. 10, tp. 24, rge. 23, W. 3rd Mer., at the ferry crossing on No. 30 Highway, thirty-two miles south of Kindersley. Drainage Area: 45,000 square miles. Gauge-Height Record: Automatic stage recorder graph. Discharge Record: Stage-discharge relationship in 1964 defined by current-meter measurements. Period of Record: Continuous September 26, 1958 to date. Maxima: Maximum daily discharge, 86,300 cfs on June 4, 1967 (g.h. 18.22). For 1964, maximum daily discharge, 63,500 cfs on June 13 (g.h. 16.33).

Daily Mean Discharge in cfs, 1964

Date	Discharge	Date	Discharge	Date	Discharge
1 June	14,600	8 June	18,200	15 June	52,300
2 June	13,900	9 June	19,300	16 June	48,600
3 June	14,000	10 June	22,200	17 June	45,400
4 June	14,100	11 June	26,400	18 June	44,000
5 June	14,500	12 June	57,100	19 June	44,500
6 June	15,600	13 June	63,500	20 June	45,000
7 June	16,600	14 June	58,200	21 June	46,300

OLDMAN RIVER NEAR WALDRON'S CORNER - STATION NO. 5AA23 (G3 on Fig. 1)

Location: Lat. 49° 48' 50", long. 114° 11' 00", Alberta, in N.E. ¼ sec. 10, tp. 10, rge. 2, W. 5th Mer., about eighteen miles by road north of Lundbreck and about twenty miles above confluence with Crowsnest River. Drainage Area: 551 square miles. Gauge-Height Record: Automatic stage recorder graph. Discharge Record: Stage-discharge relationship in 1964 defined by current-meter measurements. Period of Record: October 1949 to date. Maxima: 16,000 cfs at 11:00 p.m., June 8, 1953 (g.h. 12.72). For 1964, 4,950 cfs at 12:00 noon, June 8 (g.h. 6.81). Remarks: Data to 1960 have been reviewed and no revisions were found necessary.

Daily Mean Discharge in cfs, 1964

Date	Discharge	Date	Discharge	Date	Discharge
1 June	1,990	8 June	4,630	15 June	2,560
2 June	2,320	9 June	3,790	16 June	2,840
3 June	2,700	10 June	2,970	17 June	2,970
4 June	3,140	11 June	2,770	18 June	2,490
5 June	3,110	12 June	2,840	19 June	2,180
6 June	3,220	13 June	2,730	20 June	2,020
7 June	3,070	14 June	2,770	21 June	1,900

OLDMAN RIVER NEAR MONARCH - STATION NO. 5AD19 (G4 on Fig. 1)

Location: Lat. 49° 47' 25", long. 113° 07' 25", Alberta, in S.E. ¼ sec. 1, tp. 10, rge. 24, W. 4th Mer., about sixteen miles below confluence with Willow Creek and five miles above confluence with Belly River. Drainage Area: 3,450 square miles. Gauge-Height Record: Graph based on one or more daily wire-weight gauge readings. Discharge Record: Stage-discharge relationship in 1964 defined by current-meter measurements below 16,600 cfs and extended to peak stage by logarithmic plotting. Period of Record: October 1948 to date. Maxima: 67,450 cfs at 8:30 p.m., June 9, 1953 (g.h. 23.82). For 1964, 27,100 cfs on June 9 (g.h. 14.60). Remarks: Discharge is affected by diversion to irrigation projects upstream. Data to 1960 have been reviewed and no revisions were found necessary.

Daily Mean Discharge in cfs, 1964

Date	Discharge	Date	Discharge	Date	Discharge
1 June	5,480	8 June	11,400	15 June	9,530
2 June	5,540	9 June	22,000	16 June	8,570
3 June	6,340	10 June	19,700	17 June	9,070
4 June	7,520	11 June	12,300	18 June	8,320
5 June	8,220	12 June	9,970	19 June	7,870
6 June	8,870	13 June	10,400	20 June	7,020
7 June	9,330	14 June	10,500	21 June	6,500

Gauge Height in feet and Discharge in cfs at indicated time, 1964

Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge
	7 June			11 June				
M	10.64	9,570	6	11.72	13,700			
			N	11.22	11,700			
	8 June		6	11.03	11,000			
			M	10.84	10,400			
6	10.70	9,870						
N	10.95	10,700						
6	11.47	12,700						
M	12.07	15,100						
	9 June							
6	12.93	18,800						
N	13.65	22,400						
6	14.30	25,600						
10	14.60	27,100						
M	14.47	26,400						
	10 June							
6	13.83	23,200						
N	12.95	18,800						
6	12.30	16,000						
M	12.10	15,200						

OLDMAN RIVER NEAR LETHBRIDGE - STATION NO. 5AD7 (G5 on Fig. 1)

Location: Lat. 49° 42' 30", long. 112° 52' 30", Alberta, in N.W. ¼ sec. 1, tp. 9, rge. 22, W. 4th Mer., about eight miles downstream from confluence with St. Mary River. Drainage Area: 6,630 square miles. Gauge-Height Record: Automatic stage recorder graph. Discharge Record: Stage-discharge relationship in 1964 defined by current-meter measurements. Period of Record: September 1911 to September 1931, May 1932 to September 1948 and September 1957 to date, miscellaneous measurements in 1911 and some data in 1953. Prior to 1915, records were published under the title "Belly River near Lethbridge." Maxima: 149,000 cfs at 2:00 a.m., June 10, 1953 (g.h. 23.1). For 1964, 73,800 cfs at 1:00 p.m., June 10 (g.h. 18.55). It is reported that the flood of 1908 reached a gauge height of 26.7 feet and a corresponding discharge of about 200,000 cfs. Remarks: Discharge is affected by upstream storage and diversion to irrigation projects.

Daily Mean Discharge in cfs, 1964

Date	Discharge	Date	Discharge	Date	Discharge
1 June	10,200	8 June	17,700	15 June	25,700
2 June	11,000	9 June	41,000	16 June	22,000
3 June	12,200	10 June	70,000	17 June	22,300
4 June	13,800	11 June	60,100	18 June	21,800
5 June	15,900	12 June	48,800	19 June	18,400
6 June	16,300	13 June	37,600	20 June	16,700
7 June	16,800	14 June	31,200	21 June	15,600

Gauge Height in feet and Discharge in cfs at indicated time, 1964

Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge
	7 June			11 June				
M	9.20	16,400	6	17.37	63,200			
			N	16.95	59,800			
	8 June		6	16.55	56,600			
6	9.20	16,400	M	16.17	53,700			
N	9.25	16,600						
6	9.75	18,600		12 June				
M	10.63	22,100	6	15.82	51,200			
			N	15.40	48,300			
	9 June		6	15.12	46,300			
6	11.95	28,600	M	14.92	44,900			
N	14.35	41,500						
6	16.00	52,500						
M	17.05	60,600						
	10 June							
6	18.07	69,500						
N	18.57	74,000						
6	18.38	72,300						
M	17.85	67,600						

OLDMAN RIVER NEAR THE MOUTH - STATION NO. 5AG6 (G6 on Fig. 1)

Location: Lat. 49° 55' 08", long. 111° 48' 00", Alberta, in S.W. ¼ sec. 24, tp. 11, rge. 14, W. 4th Mer., twenty miles southeast of Vauxhall and six miles above confluence with South Saskatchewan River. Drainage Area: --. Gauge-Height Record: Automatic stage recorder graph. Discharge Record: Stage-discharge relationship in 1964 defined by current meter measurements to peak stage. Period of Record: June 1964 to date. Maxima: 68,200 cfs at 6:00 a.m., June 11, 1964 (g.h. 21.21).

Daily Mean Discharge in cfs, 1964

Date	Discharge	Date	Discharge	Date	Discharge
1 June	9,490	8 June	15,900	15 June	31,100
2 June	9,970	9 June	22,000	16 June	25,800
3 June	10,700	10 June	51,000	17 June	23,700
4 June	11,800	11 June	64,900	18 June	23,800
5 June	13,700	12 June	55,300	19 June	21,800
6 June	15,300	13 June	46,400	20 June	18,800
7 June	15,700	14 June	37,800	21 June	18,500

Gauge Height in feet and Discharge in cfs at indicated time, 1964

Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge
	8 June			12 June				
M	13.60	15,700	N	19.57	55,100			
			6	19.29	52,800			
	9 June		M	19.00	50,500			
6	13.72	16,300						
N	14.40	19,900						
6	15.58	26,800						
M	16.72	34,000						
	10 June							
6	18.00	43,000						
N	19.17	51,900						
6	20.12	59,500						
M	20.80	64,900						
	11 June							
2	21.11	67,400						
6	21.18	67,900						
N	20.99	66,400						
6	20.61	63,400						
M	20.26	60,600						

CROWSNEST RIVER AT FRANK - STATION NO. 5AA8 (G7 on Fig. 1)

Location: Lat. 49° 35' 33", long. 114° 24' 20", Alberta, in N.W. ¼ sec. 30, tp. 7, rge. 3, W. 5th Mer., about five hundred yards south of Canadian Pacific Railway Depot. Drainage Area: 162 square miles. Gauge-Height Record: Automatic stage recorder graph. Discharge Record: Stage-discharge relationship in 1964 defined by current-meter measurements. Period of Record: July to October 1910; mainly March to October 1949 to 1963; continuous January 1911 to March 1920 and March 1964 to date. Maxima: 2,610 cfs at 12:30 a.m., June 9, 1953 (g.h. 8.58). For 1964, 1,780 cfs at 8:00 p.m., June 7 (g.h. 7.58). Remarks: Gauge datum and location changed since 1949. Data to 1960 have been reviewed and no revisions were found necessary.

Daily Mean Discharge in cfs, 1964

Date	Discharge	Date	Discharge	Date	Discharge
1 June	660	8 June	1,680	15 June	921
2 June	722	9 June	1,460	16 June	824
3 June	788	10 June	1,160	17 June	752
4 June	900	11 June	1,030	18 June	680
5 June	886	12 June	1,080	19 June	620
6 June	872	13 June	1,080	20 June	588
7 June	1,120	14 June	1,040	21 June	557

CASTLE RIVER NEAR BEAVER MINES - STATION NO. 5AA22 (G8 on Fig. 1)

Location: Lat. 49° 29' 20", long. 114° 08' 40", Alberta, in N.W. ¼ sec. 24, tp. 6, rge. 2, W. 5th Mer., near Beaver Mines and about fifteen miles above the confluence with the Oldman River. Drainage Area: 319 square miles. Gauge-Height Record: Automatic stage recorder graph. Discharge Record: Stage-discharge relationship in 1964 defined by current-meter measurements below 6,800 cfs and by slope-area measurements at peak stage. Period of Record: February 1945 to December 1949 and April 1950 to date. Maxima: 18,000 cfs at 9:00 p.m., June 8, 1964 (g.h. 11.04) Remarks: Records prior to April 1950 include the flow of Beaver Mines Creek.

Daily Mean Discharge in cfs, 1964

Date	Discharge	Date	Discharge	Date	Discharge
1 June	2,740	8 June	12,700	15 June	4,130
2 June	3,080	9 June	12,300	16 June	3,720
3 June	3,530	10 June	6,460	17 June	3,390
4 June	3,960	11 June	4,750	18 June	3,070
5 June	3,980	12 June	5,120	19 June	2,760
6 June	4,130	13 June	4,780	20 June	2,620
7 June	4,660	14 June	4,470	21 June	2,480

Gauge Height in feet and Discharge in cfs at indicated time, 1964

Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge
	6 June			10 June				
M	6.15	3,900	6	7.52	7,180			
			N	7.20	6,320			
	7 June		6	6.92	5,590			
6	6.10	3,810	M	6.77	5,220			
N	6.12	3,850						
6	6.77	5,220						
M	7.69	7,640						
	8 June							
6	7.99	8,480						
N	9.27	12,200						
6	10.77	17,100						
9	11.04	18,000						
M	10.91	17,500						
	9 June							
6	10.11	14,900						
N	9.13	11,800						
6	8.43	9,730						
M	7.90	8,230						

BELLY RIVER AT INTERNATIONAL BOUNDARY - STATION NO. 5AD32 (G9 on Fig. 1)
(International Gauging Station)

Location: Lat. 48° 59' 50", long. 113° 40' 50", Montana, in N.W. ¼ sec. 2, tp. 37N, rge. 16, W.P.M., approximately one mile west of Chief Mountain Customs Port on the Chief Mountain Highway, two hundred feet upstream from International Boundary and about three miles above confluence with North Fork. Drainage Area: 74.8 square miles. Gauge-Height record: Automatic stage recorder graph. Discharge Record: Stage-discharge relationship in 1964 defined by current-meter measurements below 1,150 cfs and extended to peak stage by logarithmic plotting. Period of Record: Continuous May 1947 to September 1957, and mainly open water 1958 to 1964. Station discontinued. Maxima: 12,000 cfs (estimated) at 1900 hrs., June 8, 1964 (g.h. 10.16). Remarks: Station maintained by the United States under agreement with Canada. All records at this station to 1960 inclusive have been reviewed in co-operation with the United States Geological Survey and summaries of the revised data can be obtained upon application to the District Engineer at Calgary.

Daily Mean Discharge in cfs, 1964

Date	Discharge	Date	Discharge	Date	Discharge
1 June	685	8 June	8,200	15 June	1,500
2 June	758	9 June	7,830	16 June	1,310
3 June	934	10 June	3,520	17 June	1,180
4 June	1,200	11 June	2,080	18 June	1,100
5 June	1,350	12 June	1,810	19 June	1,010
6 June	1,410	13 June	1,740	20 June	946
7 June	1,570	14 June	1,690	21 June	888

Gauge Height in feet and Discharge in cfs at indicated time, 1964

Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge
	6 June			9 June				
M	4.81	1,380	4	9.57	10,200			
			8	9.10	8,790			
	7 June		N	8.66	7,590			
N	-	-	4	8.26	6,590			
3	5.03	1,570	8	7.86	5,660			
6	5.18	1,700	M	7.51	4,920			
M	5.63	2,140						
				10 June				
	8 June		N	6.60	3,360			
2	6.00	2,570	6	6.23	2,860			
4	6.62	3,390	M	5.95	2,510			
6	7.29	4,490						
N	9.31	9,410						
3	9.92	11,200						
6	10.12	11,900						
7	10.16	12,000						
10	10.10	11,800						
M	9.97	11,400						

BELLY RIVER NEAR MOUNTAIN VIEW - STATION NO. 5AD5 (G10 on Fig. 1)

(International Gauging Station)

Location: Lat. 49° 06' 00", long. 113° 41' 48", Alberta, in N.E. ¼ sec. 5, tp. 2, rge. 28, W. 4th Mer., at John West's Ranch, six miles southwest of Mountain View, and about eight miles downstream from the International Boundary. Drainage Area: 121 square miles. Gauge-Height Record: Automatic stage recorder graph. Discharge Record: Stage-discharge relationship in 1964 defined by current-meter measurements below 11,200 cfs and extended to peak stage by logarithmic plotting. Period of Record: November 1911 to date. Maxima: 16,400 cfs at 1900 hrs., June 8, 1964 (g.h. 11.40). The flood of June 1908 is believed to have reached a stage about 0.5 feet higher than that of June 8, 1964. Remarks: This station is maintained by Canada under agreement with the United States. Water is diverted from the Belly River above this station to the Mountain View Irrigation District Canal. All of the records to 1960 inclusive at this station have been reviewed in co-operation with the United States Geological Survey and revised data can be obtained upon application to the District Engineer at Calgary.

Daily Mean Discharge in cfs, 1964

Date	Discharge	Date	Discharge	Date	Discharge
1 June	1,030	8 June	10,700	15 June	2,110
2 June	1,140	9 June	9,520	16 June	1,860
3 June	1,340	10 June	4,440	17 June	1,710
4 June	1,550	11 June	2,910	18 June	1,610
5 June	1,660	12 June	2,590	19 June	1,490
6 June	1,730	13 June	2,380	20 June	1,390
7 June	1,970	14 June	2,330	21 June	1,310

Gauge Height in feet and Discharge in cfs at indicated time, 1964

Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge
	6 June			9 June				
M	4.05	1,680	3	9.91	13,000			
			6	9.40	11,900			
	7 June		9	8.88	10,900			
N	4.12	1,760	N	7.85	8,850			
6	4.42	2,160	3	7.32	7,890			
M	4.89	2,900	6	6.82	7,010			
			9	6.47	6,430			
	8 June		M	6.15	5,900			
4	5.44	3,800						
7	6.71	6,000		10 June				
9	7.89	8,190	6	5.54	4,930			
10	8.49	9,490	N	5.16	4,350			
11	9.38	11,500	6	4.82	3,840			
N	10.12	13,300	M	4.49	3,340			
2	10.60	14,400						
5	11.10	15,700						
7	11.40	16,400						
10	10.89	15,200						
M	10.51	14,300						

BELLY RIVER NEAR STAND OFF - STATION NO. 5AD2 (G11 on Fig. 1)

Location: Lat. 49° 28' 40", long. 113° 18' 10", Alberta, in N.E. ¼ sec. 16, tp. 6, rge. 25, W. 4th Mer., six miles above the confluence with Waterton River. Drainage Area: 476 square miles. Gauge-Height Record: Automatic stage recorder graph. Gauge relocated April 1967 about one mile upstream from the former location. Discharge Record: Stage-discharge relationship in 1964 defined by current-meter measurements below 4,100 cfs and extended to peak stage by means of a logarithmic plot and a composite curve of high water measurements from various years. Period of Record: Periods of varying length, May 1909 to May 1931, and September 1935 to June 1936, and continuous from October 1948 to date. Maxima: 11,700 cfs at 8:00 a.m., June 9, 1964 (g.h. 11.56). Remarks: Discharge is affected by upstream diversions for irrigation purposes.

Daily Mean Discharge in cfs, 1964

Date	Discharge	Date	Discharge	Date	Discharge
1 June	905	8 June	2,920	15 June	910
2 June	952	9 June	10,300	16 June	868
3 June	1,090	10 June	7,990	17 June	2,060
4 June	1,350	11 June	4,410	18 June	1,900
5 June	1,470	12 June	3,120	19 June	1,780
6 June	1,600	13 June	2,770	20 June	1,640
7 June	1,640	14 June	1,480	21 June	1,540

Gauge Height in feet and Discharge in cfs at indicated time, 1964

Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge
	7 June			11 June				
M	5.84	3,460	6	7.13	4,980			
			N	6.46	4,110			
	8 June		M	5.90	3,520			
6	4.18	1,950						
N	4.81	2,520						
6	5.50	3,140						
M	6.91	4,670						
	9 June							
6	11.41	11,400						
N	11.49	11,600						
6	11.09	10,900						
M	10.64	10,200						
	10 June							
6	10.00	9,170						
N	9.17	7,900						
6	8.45	6,830						
M	7.80	5,920						

WATERTON RIVER NEAR INTERNATIONAL BOUNDARY - STATION NO. 5AD29 (G12 on Fig. 1)

(International Gauging Station)

Location: Lat. 48° 57' 20", long. 113° 54' 00", Montana, in N.W. ¼ sec. 23, tp. 37N, rge. 18, W.P.M., one hundred feet below mouth of Olson Creek, about three miles south of International Boundary and one-half mile upstream from outlet into south end of Waterton Lake. Drainage Area: 61.0 square miles. Gauge-Height Record: Automatic stage recorder graph. Discharge Record: Stage-discharge relationship in 1964 defined by current-meter measurements below 1,900 cfs and extended to peak stage by slope-area measurements and logarithmic plotting. Period of Record: Continuous May 1947 to September 1957, and open water 1958 to 1964. Station discontinued at end of 1964 water year. Maxima: 12,400 cfs at 5:00 p.m., June 8, 1964 (g.h. 11.55). Remarks: Station was maintained by the United States under agreement with Canada. All records at this station to 1960 inclusive have been reviewed in co-operation with the United States Geological Survey and summaries of the revised data are available from the District Engineer at Calgary.

Daily Mean Discharge in cfs, 1964

Date	Discharge	Date	Discharge	Date	Discharge
1 June	1,020	8 June	7,280	15 June	1,590
2 June	1,080	9 June	5,850	16 June	1,460
3 June	1,290	10 June	2,500	17 June	1,370
4 June	1,550	11 June	1,660	18 June	1,200
5 June	1,400	12 June	1,760	19 June	1,100
6 June	1,480	13 June	1,680	20 June	1,090
7 June	1,470	14 June	1,670	21 June	1,010

Gauge Height in feet and Discharge in cfs at indicated time, 1964

Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge
	6 June			9 June				
M	5.13	1,380	2	10.49	8,100			
			5	10.57	8,340			
	7 June		8	10.24	7,350			
10	5.18	1,420	N	9.48	5,580			
N	-	-	6	8.52	3,980			
4	5.19	1,430	M	8.07	3,370			
8	5.34	1,550						
M	5.67	1,820		10 June				
			6	7.70	2,880			
	8 June		N	7.36	2,430			
4	6.46	2,590	6	7.07	2,070			
8	8.69	5,510	M	6.89	1,870			
N	10.57	9,350						
2	11.09	10,800						
4	11.34	11,700						
5	11.55	12,400						
7	11.05	10,100						
9	10.63	8,540						
M	10.31	7,600						

WATERTON LAKE AT WATERTON PARK - STATION NO. 5AD25 (G13 on Fig. 1)

Location: Lat. 49° 03' 12", long. 113° 54' 18", Alberta, in N.E. ¼ sec. 23, tp. 1, rge. 30, W. 4th Mer., on retaining wall behind the National Park offices in the town of Waterton Park. Gauge-Height Record: Staff gauge readings taken one or more times daily. Period of Record: Periods of varying length during the water years 1950 to date. Maxima: 4,206.76 feet at 2:00 a.m., June 9, 1964 (from high water mark). Elevations are referred to Geodetic Survey of Canada datum, Publication No. 23, Supplement No. 1.

1964
Daily Elevations in Feet (G.S.C. Datum)

Day	April	May	June	July
1	4,193.3	4,193.8	4,197.0	
2	4,193.3	4,194.5 *e*	4,197.2	4,197.3
3	4,193.3	4,195.2 *e*	4,197.5	4,197.4
4		4,195.4 *e*	4,198.0	
5		4,195.4	4,198.2	
6	4,193.4	4,195.4	4,198.3 *e*	4,197.2
7	4,193.4	4,195.5 *e*	4,198.5 *e*	4,197.1
8	4,193.4	4,195.4 *e*	4,203.2 *e*	4,197.0
9	4,193.4	4,195.4 *e*	4,206.0 *e*	4,197.1
10	4,193.4	4,195.5 *e*	4,203.1 *e*	
11		4,195.5	4,200.9 *e*	
12		4,195.5	4,199.9 *e*	
13	4,193.5	4,195.6	4,199.4 *e*	4,196.7
14	4,193.5	4,195.8	4,199.1 *e*	4,196.5
15	4,193.5	4,195.9	4,199.0 *e*	4,196.5
16	4,193.5	4,195.9 *e*	4,198.7 *e*	4,196.4
17	4,193.5	4,196.1 *e*	4,198.5	4,196.2
18		4,196.5 *e*	4,198.1 *e*	
19		4,196.7	4,197.8 *e*	
20	4,193.5	4,197.2	4,197.6 *e*	4,196.0
21	4,193.6	4,197.8	4,197.4 *e*	4,195.7
22	4,193.6	4,197.9	4,197.7	4,195.6
23	4,193.6	4,197.5 *e*	4,197.7	4,195.6
24	4,193.7	4,197.0 *e*	4,198.0	
25		4,196.7	4,198.2	
26		4,196.4	4,198.3	
27	4,193.7	4,196.2	4,197.8 *e*	4,195.2
28	4,193.7	4,196.3	4,197.7 *e*	4,195.1
29	4,193.7	4,196.4	4,197.6	4,195.0
30	4,193.7	4,196.6 *e*	4,197.4	4,195.0
31		4,196.8 *e*		4,195.0

e - *Estimated from stream gauging station.*

WATERTON RIVER NEAR WATERTON PARK - STATION NO. 5AD3 (G14 on Fig. 1)

(International Gauging Station)

Location: Lat. 49° 06' 50", long. 113° 50' 20", Alberta, in N.E. ¼ sec. 8, tp. 2, rge. 29, W. 4th Mer., near Highway No. 5 crossing, immediately below Waterton Lakes and about one-half mile above the mouth of Crooked Creek. Drainage Area: 238 square miles. Gauge-Height Record: Automatic stage recorder graph. Discharge Record: Stage-discharge relationship in 1964 defined by current-meter measurements below 21,600 cfs and extended to peak stage by logarithmic plotting. Period of Record: Periods of varying length 1908 to 1933, and continuous March 1948 to date. Records prior to 1916 published under the title "at Waterton Mills." Maxima: 25,700 cfs at 4:00 a.m., June 9, 1964 (g.h. 9.22). Remarks: This station is maintained by Canada under agreement with the United States. All records to 1960 inclusive at this station have been reviewed in co-operation with the United States Geological Survey and revised data can be obtained upon application to the District Engineer at Calgary.

Daily Mean Discharge in cfs, 1964

Date	Discharge	Date	Discharge	Date	Discharge
1 June	2,340	8 June	13,700	15 June	4,710
2 June	2,620	9 June	22,700	16 June	4,320
3 June	2,940	10 June	13,400	17 June	3,940
4 June	3,370	11 June	8,220	18 June	3,540
5 June	3,690	12 June	6,230	19 June	3,210
6 June	3,870	13 June	5,450	20 June	2,970
7 June	4,130	14 June	5,030	21 June	2,790

Gauge Height in feet and Discharge in cfs at indicated time, 1964

Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge
	6 June			9 June				
M	3.91	3,870	4	9.22	25,700			
			6	9.20	25,600			
	7 June		N	8.83	23,700			
6	3.90	3,840	6	8.18	20,400			
N	3.94	3,940	M	7.60	17,600			
6	4.08	4,320						
M	4.32	5,000		10 June				
			6	7.05	15,100			
	8 June		N	6.57	13,100			
6	5.00	7,150	6	6.18	11,500			
9	5.68	9,550	M	5.83	10,100			
N	6.53	12,900						
3	7.39	16,700		11 June				
6	8.08	19,900	6	5.52	8,960			
9	8.66	22,800	N	5.28	8,110			
M	9.00	24,500	6	5.05	7,320			
			M	4.92	6,890			

WATERTON RIVER NEAR STAND OFF - STATION NO. 5AD8 (G15 on Fig. 1)

Location: Lat. 49° 30' 07", long. 113° 19' 34", Alberta, in N.E. ¼ sec. 29, tp. 6, rge. 25, W. 4th Mer., about three miles above confluence with Belly River. Drainage Area: 674 square miles. Gauge-Height Record: Graph based on once-daily wire-weight gauge readings. Discharge Record: Stage-discharge relationship in 1964 defined by current-meter measurements. Period of Record: Periods of varying length November 1915 to October 1947, and continuous March 1948 to 1966. Station discontinued at end of the 1966 water year. Maxima:

Daily Mean Discharge in cfs, 1964

Date	Discharge	Date	Discharge	Date	Discharge
1 June	3,390	8 June	9,110	15 June	7,160
2 June	3,750	9 June	16,000	16 June	6,480
3 June	4,420	10 June	16,500	17 June	6,040
4 June	5,160	11 June	15,500	18 June	4,970
5 June	5,260	12 June	13,800	19 June	4,250
6 June	5,370	13 June	10,900	20 June	4,090
7 June	5,570	14 June	8,080	21 June	3,970

STREET CREEK AT INTERNATIONAL BOUNDARY - STATION NO. 5AD31 (G16 on Fig. 1)

(International Gauging Station)

Location: Lat. 48° 59' 20", long. 113° 52' 40", in N.E. ¼ sec. 11, tp. 37N, rge. 18, W.P.M., Montana, one-half mile upstream from mouth on the east side of Waterton Lake and about one mile south of International Boundary. Drainage Area: 6 square miles. Gauge-Height Record: Automatic stage recorder graph. Discharge Record: Maximum discharge in 1964 obtained by slope-area measurement. Period of Record: October 1947 to November 1952, May to November 1953 and 1954, and May to October 1955. Station discontinued. Maxima: 5,740 cfs on June 8, 1964 (g.h. 13.60). Remarks: This station was maintained by the United States under agreement with Canada. Records prior to October 1948 were obtained and published by the United States Geological Survey.

BOUNDARY CREEK NEAR INTERNATIONAL BOUNDARY - STATION NO. 5AD30 (G17 on Fig. 1)

(International Gauging Station)

Location: Lat. 48° 59' 50", long. 113° 54' 20", Montana, in N.E. ¼ sec. 3, tp. 37N, rge. 18, W.P.M., in Glacier Park, about one-quarter mile upstream from its outlet into the west side of Waterton Lake. Drainage Area: 21.0 square miles. Gauge-Height Record: Automatic stage recorder graph. Discharge Record: Maximum discharge in 1964 determined by slope-area measurement. Period of Record: Continuous October 1947 to September 1957, and open water 1958 to 1964. Station discontinued. Maxima: 5,930 cfs on June 8, 1964. Remarks: This station was maintained by the United States under agreement with Canada.

DRYWOOD CREEK NEAR TWIN BUTTE - STATION NO. 5AD16 (G18 on Fig. 1)

Location: Lat. 49° 18' 00", long. 114° 00' 20", Alberta, in N.E. ¼ sec. 13. tp. 4, rge. 1, W. 5th Mer., about two miles above main stem, fifteen miles above confluence with Waterton River and about seven miles west of Twin Butte on Pincher Creek—Waterton Highway. Drainage Area: 11.8 square miles. Gauge Height Record: Automatic stage recorder graph. Discharge Record: Stage-discharge relationship in 1964 defined by current-meter measurements below 400 cfs and extended to peak stage by slope-area method. Period of Record: Mainly open water, 1935 to date. Records prior to 1962 were published under the title "North Branch Drywood River near Twin Butte." Maxima: 1,180 cfs at 11:30 a.m., June 8, 1964 (g.h. 5.99). Remarks: Prior to 1950, records were obtained from staff gauge near present location.

Daily Mean Discharge in cfs, 1964

Date	Discharge	Date	Discharge	Date	Discharge
1 June	111	8 June	892	15 June	161
2 June	130	9 June	414	16 June	145
3 June	176	10 June	215	17 June	137
4 June	173	11 June	170	18 June	128
5 June	178	12 June	181	19 June	117
6 June	169	13 June	179	20 June	112
7 June	225	14 June	175	21 June	105

Gauge Height in feet and Discharge in cfs at indicated time, 1964

Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge
	6 June							
M	3.69	158						
	7 June							
11	3.66	151						
N	—	—						
4	3.87	198						
7	4.36	326						
M	4.94	504						
	8 June							
3	5.04	572						
7	5.79	1,020						
N	5.96	1,160						
6	5.69	953						
M	5.29	707						
	9 June							
6	4.90	508						
N	4.58	391						
6	4.31	315						
M	4.10	266						

ST. MARY RIVER AT INTERNATIONAL BOUNDARY - STATION NO. 5AE27 (G19 on Fig. 1)
(International Gauging Station)

Location: Lat. 49° 00' 10", long. 113° 18' 50", Alberta, in S.W. ¼ sec. 5, tp. 1, rge. 25, W. 4th Mer., about one-quarter mile north of the International Boundary. Drainage Area: 469 square miles. Gauge-Height Record: Automatic stage recorder graph. Discharge Record: Stage-discharge relationship in 1964 defined by current-meter measurements below 17,100 cfs and extended to peak stage by logarithmic plotting. Period of Record: September 1902 to date. Records from 1902 to 1912 were published under the title "at Cook's Ranch near Cardston, Alberta." Records from 1913 to 1917 were published under the title "at" or "near Kimball," and from 1918 to 1955 "near International Boundary." Maxima: 40,000 cfs (estimated) on June 5, 1908 (g.h. 12.75 - from flood marks). For 1964, 21,000 cfs at 4:30 p.m., June 8 (g.h. 12.06). Remarks: This station is maintained jointly by Canada and the United States. Water is stored in Lake Sherburne above the station or diverted for irrigation purposes by the St. Mary Canal since 1917. All records to 1960 inclusive at this station have been reviewed in co-operation with the United States Geological Survey, and all revisions prior to 1951 are available upon request to the District Engineer at Calgary. No revisions were necessary from 1951 to 1960.

Daily Mean Discharge in cfs, 1964

Date	Discharge	Date	Discharge	Date	Discharge
1 June	1,590	8 June	12,700	15 June	7,250
2 June	1,760	9 June	17,000	16 June	6,610
3 June	2,110	10 June	14,300	17 June	6,190
4 June	2,480	11 June	11,600	18 June	5,720
5 June	2,710	12 June	10,100	19 June	4,840
6 June	2,920	13 June	8,960	20 June	4,000
7 June	3,320	14 June	8,190	21 June	3,580

Gauge Height in feet and Discharge in cfs at indicated time, 1964

Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge
	6 June			9 June				
M	6.31	2,980	6	11.09	17,000			
			N	11.16	17,300			
	7 June		6	11.31	17,800			
6	6.32	3,000	M	10.96	16,600			
N	6.38	3,140						
6	6.56	3,540		10 June				
M	6.87	4,260	6	10.51	15,200			
			N	10.22	14,300			
	8 June		6	9.89	13,300			
2	7.10	4,810	M	9.64	12,500			
4	7.52	5,920						
6	8.16	7,590						
8	8.99	9,950						
N	10.24	13,800						
2	10.73	15,600						
4	11.86	20,100						
4.5	12.06	21,000						
6	11.48	18,400						
8	11.08	17,000						
M	10.64	15,600						

ST. MARY RESERVOIR NEAR SPRING COULEE - STATION NO. 5AE25 (G20 on Fig. 1)

Location: Lat. 49° 21' 46", long. 113° 06' 58", Alberta, in N.W. ¼ sec. 1, tp. 5, rge. 24, W. 4th Mer., on St. Mary River, four miles northwest of Spring Coulee, and about forty miles by river below International Boundary. Gauge-Height Record: Automatic stage recorder graph. Period of Record: Water elevations and storage factors, April 1951 to date. Maxima: Maximum daily water elevation 3,619.99 feet on June 24, 1958 - contents of reservoir 320,700 acre-feet. For 1964, maximum daily water elevation 3,618.89 feet on July 9 - contents of reservoir 310,100 acre-feet. Remarks: Reservoir is operated by P.F.R.A. The total capacity is 320,800 acre-feet and live storage is 285,000 acre-feet. Water is impounded on the St. Mary River for diversion to the St. Mary and Milk Rivers Development irrigation system via the Canadian St. Mary Canal and the Magrath Irrigation District Canal.

Elevations in Feet and Total Contents in Acre-feet for the year 1964

Month	Elevation at End of Month	Contents at End of Month	Change in Contents During Month
January	3,606.60	217,700	
February	3,607.83	225,400	+ 7,700
March	3,608.92	232,500	+ 7,100
April	3,612.27	255,300	+ 22,800
May	3,608.21	227,900	- 27,400
June	3,618.03	302,100	+ 74,200
July	3,614.38	271,300	- 30,800
August	3,601.09	185,100	- 86,200
September	3,600.69	182,900	- 2,200
October	3,609.26	234,700	+ 51,800
November	3,612.01	253,400	+ 18,700
December	3,611.29	248,400	- 5,000

ST. MARY RIVER NEAR LETHBRIDGE - STATION NO. 5AE6 (G21 on Fig. 1)

Location: Lat. 49° 34' 10", long. 112° 50' 00", Alberta, in S.E. ¼ sec. 19, tp. 7, rge. 21, W. 4th Mer., at Russell's Ranch, immediately below mouth of Pothole Creek, nine miles south of Lethbridge, and six miles by river above confluence with Oldman River. Drainage Area: 1,410 square miles. Gauge-Height Record: Automatic stage recorder graph. Discharge Record: Stage-discharge relationship in 1964 defined by current-meter measurements. Period of Record: October 1911 to date. Prior to 1917, records were published under the title "at Whitney's Ranch." Maxima: 16,200 cfs at 4:00 a.m., June 11, 1964 (g.h. 8.52). Remarks: Discharge affected by storage and diversion for irrigation purposes upstream.

Daily Mean Discharge in cfs, 1964

Date	Discharge	Date	Discharge	Date	Discharge
1 June	527	8 June	401	15 June	7,540
2 June	560	9 June	9,920	16 June	5,720
3 June	595	10 June	15,100	17 June	5,920
4 June	622	11 June	15,800	18 June	6,090
5 June	656	12 June	14,200	19 June	3,240
6 June	382	13 June	8,570	20 June	3,180
7 June	227	14 June	8,010	21 June	3,160

Gauge Height in feet and Discharge in cfs at indicated time, 1964

Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge
	7 June			11 June				
M	1.48	266	6	8.51	16,100			
			N	8.48	16,000			
	8 June		6	8.41	15,600			
6	1.66	320	M	8.31	15,200			
N	1.88	388						
6	2.08	453		12 June				
M	2.45	622	6	8.19	14,600			
			N	8.18	14,500			
	9 June		6	8.07	14,000			
6	5.94	6,040	M	7.72	12,500			
9	7.25	10,600						
N	7.69	12,400						
6	7.92	13,300						
M	8.06	13,900						
	10 June							
6	8.17	14,400						
N	8.34	15,300						
6	8.44	15,800						
M	8.49	16,000						

SWIFTCURRENT CREEK AT MANY GLACIER - STATION NO. 5AE32 (G22 on Fig. 1)

(International Gauging Station)

Location: Lat. 48° 48' 10", long. 113° 39' 20", Montana, in S.E. ¼ sec. 11, tp. 35N, rge. 16, W.P.M., at outlet of Swiftcurrent Lake and about one-quarter mile above head of Lake Sherburne in Glacier Park. Drainage Area: 31.4 square miles. Gauge-Height Record: Automatic stage recorder graph. Discharge Record: Stage-discharge relationship in 1964 defined by current-meter measurements below 1,100 cfs and extended to peak stage by slope-area and other indirect measurements. Period of Record: Periods of varying length 1912 to 1957 and continuous March 1958 to September 1966. Station discontinued. Maxima: 6,700 cfs at 4:00 p.m., June 8, 1964 (g.h. 10.00). Remarks: This station is maintained jointly by Canada and the United States. All records to 1960 inclusive at this station have been reviewed in co-operation with the United States Geological Survey and revisions prior to 1951 are available upon request to the District Engineer at Calgary. No revisions were necessary from 1951 to 1960.

Daily Mean Discharge in cfs, 1964

Date	Discharge	Date	Discharge	Date	Discharge
1 June	514	8 June	4,130	15 June	633
2 June	571	9 June	2,480	16 June	567
3 June	686	10 June	970	17 June	525
4 June	808	11 June	682	18 June	484
5 June	779	12 June	720	19 June	447
6 June	783	13 June	766	20 June	444
7 June	820	14 June	728	21 June	440

Gauge Height in feet and Discharge in cfs at indicated time, 1964

Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge
	6 June			9 June				
M	4.02	753	6	7.75	3,120			
			N	6.90	2,260			
	7 June		6	6.06	1,680			
8	4.02	753	M	5.42	1,210			
N	4.08	779						
4	4.16	812		10 June				
8	4.39	909	6	5.09	1,070			
10	4.57	985	N	4.82	964			
M	4.83	1,100	6	4.54	854			
			M	4.33	774			
	8 June							
2	5.21	1,270						
4	5.80	1,550						
6	6.60	1,960						
8	7.52	2,880						
N	9.09	4,990						
2	9.74	6,200						
4	10.00	6,700						
6	9.84	6,390						
M	8.78	4,480						

SWIFTCURRENT CREEK AT SHERBURNE - STATION NO. 5AE33 (G23 on Fig. 1)

(International Gauging Station)

Location: Lat. 48° 50' 00", long. 113° 30' 50", Montana, in S.W. ¼ sec. 36, tp. 36N, rge. 15, W.P.M., at the outlet of Lake Sherburne and about six miles above the confluence with St. Mary River. Drainage Area: 64.3 square miles. Gauge-Height Record: Automatic stage recorder graph. Discharge Record: Stage-discharge relationship in 1964 defined by current-meter measurements. Period of Record: Continuous February 1916 to October 1923; mainly open water 1912 to 1915 and 1924 to date. Maxima: 2,360 cfs at 4:30 p.m., June 11, 1964 (g.h. 8.37). Remarks: This station is maintained jointly by the United States and Canada. The stream is controlled at Lake Sherburne above the station. All records to 1960 inclusive have been reviewed in co-operation with the United States Geological Survey and revised data can be obtained upon application to the District Engineer at Calgary.

Daily Mean Discharge in cfs, 1964

Date	Discharge	Date	Discharge	Date	Discharge
1 June	123	8 June	77	15 June	1,660
2 June	172	9 June	29	16 June	1,540
3 June	202	10 June	448	17 June	1,380
4 June	81	11 June	1,820	18 June	1,060
5 June	2.5	12 June	2,340	19 June	700
6 June	2.3	13 June	2,340	20 June	761
7 June	5.4	14 June	1,970	21 June	713

ROLPH CREEK NEAR KIMBALL - STATION NO. 5AE5 (G24 on Fig. 1)

Location: Lat. 49° 07' 30", long. 113° 08' 30", Alberta, in N.W. ¼ sec. 15, tp. 2, rge. 24, W. 4th Mer., about three miles above the confluence with St. Mary River. Drainage Area: 90.6 square miles. Gauge-Height Record: Graph based on one or more daily staff gauge readings. Discharge Record: Stage-discharge relationship in 1964 defined by current-meter measurements. Period of Record: Mainly March to October, 1911 to 1916 and 1935 to date; gauge heights only during April to July 1917. Maxima: 1,290 cfs at about 6:00 p.m., June 3, 1953 (g.h. 7.21 - from high water mark). For 1964, 630 cfs at 6:00 p.m., June 8 (g.h. 4.80).

Daily Mean Discharge in cfs, 1964

Date	Discharge	Date	Discharge	Date	Discharge
1 June	7.1	8 June	265	15 June	74.9
2 June	5.9	9 June	183	16 June	66.4
3 June	5.0	10 June	136	17 June	120
4 June	4.2	11 June	143	18 June	76.0
5 June	3.7	12 June	132	19 June	57.4
6 June	2.8	13 June	97.1	20 June	65.3
7 June	3.5	14 June	77.2	21 June	42.5

LEE CREEK AT CARDSTON - STATION NO. 5AE2 (G25 on Fig. 1)

Location: Lat. 49° 12' 00", long. 113° 17' 45", Alberta, in N.W. ¼ sec. 10, tp. 3, rge. 25, W. 4th Mer., upstream from St. Mary River Reservoir and two miles above confluence with St. Mary River. Drainage Area: 117 square miles. Gauge-Height Record: Automatic stage recorder graph. Discharge Record: Stage-discharge relationship in 1964 defined by current-meter measurements below 8,700 cfs and extended to peak stage by logarithmic plotting. Period of Record: Periods of varying length, 1909 to 1914; continuous, August 1920 to date. Maxima: 11,400 cfs at 5:00 p.m., June 8, 1964 (g.h. 12.59). Remarks: Recorder gauge was established in August, 1956. Former records were obtained by staff or chain gauges at various sites near present location.

Daily Mean Discharge in cfs, 1964

Date	Discharge	Date	Discharge	Date	Discharge
1 June	254	8 June	5,340	15 June	692
2 June	258	9 June	2,750	16 June	692
3 June	276	10 June	1,560	17 June	750
4 June	285	11 June	1,180	18 June	602
5 June	276	12 June	1,020	19 June	514
6 June	303	13 June	850	20 June	371
7 June	341	14 June	760	21 June	298

Gauge Height in feet and Discharge in cfs at indicated time, 1964

Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge
	6 June			9 June				
M	4.53	280	3	7.64	3,610			
			6	7.27	3,060			
	7 June		N	6.97	2,610			
8	4.57	298	6	6.61	2,100			
N	4.56	294	M	6.44	1,870			
4	4.62	321						
6	4.72	366						
10	5.05	492						
M	5.16	554						
	8 June							
2	5.34	663						
6	6.20	1,530						
9	7.48	3,370						
N	9.00	5,650						
5	12.59	11,400						
8	11.25	9,160						
10	9.96	7,100						
M	8.58	5,020						

RED DEER RIVER NEAR BINDLOSS - STATION NO. 5CK4 (G26 on Fig. 1)

Location: Lat. 50° 54' 10", long. 110° 17' 50", Alberta, in N.W. ¼ sec. 25, tp. 22, rge. 3, W. 4th Mer., about two miles northwest of Bindloss on road to Oyen. Drainage Area: 16,800 square miles. Gauge-Height Record: Automatic stage recorder graph. Discharge Record: Stage-discharge relationship in 1964 defined by current-meter measurements. Period of Record: October 1960 to date. Maxima: Maximum daily discharge, 24,700 cfs on April 16, 1965 (g.h. 11.02). For 1964, maximum daily discharge, 14,100 cfs on June 23 (g.h. 10.13).

Daily Mean Discharge in cfs, 1964

Date	Discharge	Date	Discharge	Date	Discharge
1 June	2,260	8 June	3,330	15 June	5,570
2 June	2,270	9 June	4,220	16 June	5,880
3 June	2,330	10 June	3,870	17 June	8,010
4 June	2,340	11 June	4,200	18 June	8,770
5 June	2,350	12 June	4,520	19 June	8,650
6 June	2,430	13 June	6,760	20 June	8,830
7 June	2,720	14 June	6,200	21 June	9,780

NORTH FORK MILK RIVER ABOVE ST. MARY CANAL - STATION NO. 11AA32 (G27 on Fig. 1)

(International Gauging Station)

Location: Lat. 48° 59', long. 113° 03', Montana, in N.E. ¼ sec. 16, tp. 37N, rge. 11, W.P.M., about two miles south of International Boundary and one and one-quarter miles above mouth of St. Mary Canal. Drainage Area: 61.8 square miles. Gauge-Height Record: Automatic stage recorder graph. Discharge Record: Stage-discharge relationship in 1964 defined by current-meter measurements. Period of Record: Part-year records 1911, 1912, and 1919 to date. Records were published under the title "near Browning" for 1911 and 1912. Maxima: 3,090 cfs at 7:00 p.m., May 8, 1967 (g.h. 7.95). For 1964, 653 cfs at 3:00 p.m., June 8 (g.h. 4.91). Remarks: This station is maintained jointly by Canada and the United States. All records to 1960 inclusive at this station have been reviewed in co-operation with the United States Geological Survey and revisions prior to 1951 are available upon request to the District Engineer at Calgary. No revisions were necessary from 1951 to 1960.

Daily Mean Discharge in cfs, 1964

Date	Discharge	Date	Discharge	Date	Discharge
1 June	17.8	8 June	391	15 June	44.6
2 June	17.3	9 June	148	16 June	54.3
3 June	16.8	10 June	59.0	17 June	57.0
4 June	16.3	11 June	46.2	18 June	37.6
5 June	16.3	12 June	41.4	19 June	34.8
6 June	16.3	13 June	43.0	20 June	33.4
7 June	22.6	14 June	36.9	21 June	33.4

Gauge Height in feet and Discharge in cfs at indicated times, 1964

Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge
	6 June			9 June				
M	1.14	16.3	3	3.14	247			
			6	2.54	156			
	7 June		N	2.14	105			
N	-	-	6	1.93	81.3			
2	1.16	17.3	M	1.82	70.0			
8	1.39	30.6						
M	1.66	51.6						
	8 June							
2	1.90	76.0						
5	2.51	149						
7	3.12	242						
9	3.43	296						
N	4.23	468						
3	4.91	653						
6	4.78	614						
8	4.36	500						
9	4.38	505						
11	4.68	585						
M	4.47	528						

NORTH MILK RIVER NEAR INTERNATIONAL BOUNDARY - STATION NO. 11AA1 (G28 on Fig. 1)

(International Gauging Station)

Location: Lat. 49° 01' 19", long. 112° 58' 18", Alberta, in N.E. ¼ sec. 11, tp.1, rge. 23, W. 4th Mer., two and one-half miles east of Whiskey Gap, two miles north of the International Boundary and about thirty miles above confluence with Milk River. Drainage Area: 91.8 square miles. Gauge-Height Record: Automatic stage recorder graph. Discharge Record: Stage-discharge relationship in 1964 defined by current-meter measurements below 700 cfs and extended to peak stage by slope-area measurement. Period of Record: Periods of varying length 1909 to date. Prior to 1917 records were published under the title "at Peters' Ranch." Records from 1917 to 1960 published under the title "North Branch of Milk River near International Boundary." Maxima: 2,950 cfs at 7:00 a.m. to 12:00 noon, June 17, 1948 (g.h. 6.47). For 1964, 1,940 cfs at 4:00 p.m., June 8 (g.h. 7.98). Note: the gauge was relocated in September 1962, one thousand feet upstream from the former location. Remarks: This station is maintained jointly by Canada and the United States. Since 1917, flows during the irrigation season have been augmented by water delivered to this stream from the St. Mary River via the St. Mary Canal, two miles above the station. Data to 1960 inclusive were reviewed in co-operation with the United States Geological Survey and revised data are available from the District Engineer at Calgary.

Daily Mean Discharge in cfs, 1964

Date	Discharge	Date	Discharge	Date	Discharge
1 June	680	8 June	1,360	15 June	57.5
2 June	680	9 June	697	16 June	70.1
3 June	687	10 June	172	17 June	79.6
4 June	691	11 June	86.9	18 June	50.6
5 June	691	12 June	60.0	19 June	46.2
6 June	696	13 June	58.7	20 June	118
7 June	724	14 June	51.7	21 June	474

Gauge Height in feet and Discharge in cfs at indicated time, 1964

Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge
	6 June			9 June				
M	5.94	696	6	6.37	934			
			N	5.68	605			
	7 June		6	5.18	412			
N	5.95	700	M	4.78	287			
6	6.06	751						
M	6.15	799		10 June				
			6	4.47	206			
	8 June		N	4.23	153			
6	6.50	988	M	4.00	111			
N	7.28	1,460						
4	7.98	1,940						
8	7.51	1,620						
M	7.16	1,390						

SOUTH FORK MILK RIVER NEAR BABB - STATION NO. 11AA33 (G29 on Fig. 1)

(International Gauging Station)

Location: Lat. 48° 45' 20", long. 113° 10' 00", Montana, in N.W.¼ sec. 34, tp. 35N, rge. 12, W.P.M., about fourteen and one-half miles southeast of Babb. Drainage Area: 68.6 square miles. Gauge-Height Record: Automatic stage recorder graph. Discharge Record: Stage-discharge relationship in 1964 defined by current-meter measurements below 250 cfs and extended to peak stage by slope-area measurement and logarithmic plotting. Period of Record: May to October 1961; March to October, 1962 to date. Maxima: 12,000 cfs at 1:00 p.m., June 8, 1964 (g.h. 6.61). Remarks: This station is maintained jointly by Canada and the United States. Daily discharge data for 1961 and 1962 are available in United States Geological Survey Water Supply Papers.

Daily Mean Discharge in cfs, 1964

Date	Discharge	Date	Discharge	Date	Discharge
1 June	86	8 June	4,940	15 June	218
2 June	78	9 June	734	16 June	244
3 June	76	10 June	355	17 June	244
4 June	82	11 June	288	18 June	189
5 June	82	12 June	248	19 June	167
6 June	88	13 June	230	20 June	151
7 June	130	14 June	206	21 June	141

Gauge Height in feet and Discharge in cfs at indicated time, 1964

Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge
	6 June			9 June				
M	3.01	92	6	4.72	834			
			N	4.46	578			
	7 June		6	4.29	460			
N	3.09	110	M	4.20	410			
3	3.13	120						
6	3.25	151						
9	3.37	186						
M	3.65	290						
	8 June							
4	4.08	518						
6	4.66	1,060						
8	5.32	2,560						
10	6.00	5,820						
N	6.48	10,000						
1	6.61	12,000						
2:30	6.59	11,600						
4	6.49	10,200						
6	6.20	6,800						
M	5.21	1,720						

MILK RIVER AT WESTERN CROSSING OF INTERNATIONAL BOUNDARY - STATION NO. 11AA25 (G30 on Fig.1)

(International Gauging Station)

Location: Lat. 49° 00' 30", long. 112° 32' 40", Alberta, in N.E. ¼ sec. 1, tp. 1, rge. 20, W. 4th Mer., one-half mile north of the International Boundary and about twelve miles above the confluence with North Milk River and twenty-four miles southwest of Milk River. Drainage Area: 397 square miles. Gauge-Height Record: Automatic stage recorder graph. Discharge Record: Stage-discharge relationship in 1964 defined by current-meter measurements below 5,000 cfs and extended to peak stage by logarithmic plotting. Period of Record: Mainly March to October 1931 to date. Records prior to 1961 were published under the title "South Branch of Milk River near the International Boundary." Maxima: 7,930 cfs at 6:00 a.m., June 9, 1964 (g.h. 9.77). Remarks: This station is maintained jointly by Canada and the United States. Discharge is affected by a few minor diversions for upstream irrigation purposes. All records to 1960 inclusive at this station have been reviewed in co-operation with the United States Geological Survey, and revisions prior to 1951 are available upon request to the District Engineer at Calgary. No revisions were necessary from 1951 to 1960.

Daily Mean Discharge in cfs, 1964

Date	Discharge	Date	Discharge	Date	Discharge
1 June	165	8 June	927	15 June	424
2 June	143	9 June	5,410	16 June	471
3 June	125	10 June	1,980	17 June	638
4 June	118	11 June	915	18 June	554
5 June	121	12 June	612	19 June	393
6 June	121	13 June	510	20 June	398
7 June	133	14 June	447	21 June	284

Gauge Height in feet and Discharge in cfs at indicated time, 1964

Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge
	6 June			9 June				
M	3.39	123	1	6.49	2,290			
			3	7.72	3,930			
	7 June		5	9.72	7,850			
N	3.38	121	6	9.77	7,930			
6	3.45	140	N	9.12	6,550			
M	3.57	178	5	8.40	5,110			
			M	7.28	3,240			
	8 June							
2	3.70	226		10 June				
6	4.16	443	6	6.54	2,310			
7	4.12	420	10	6.20	1,940			
9	4.31	519	N	-	-			
11	4.80	790	2	6.02	1,750			
N	4.89	848	6	5.83	1,560			
2	5.30	1,150	M	5.49	1,260			
5	5.59	1,400						
7	5.57	1,380		11 June				
9	5.76	1,550	6	5.15	988			
M	6.30	2,080	N	5.00	881			
			M	4.74	718			

MILK RIVER AT EASTERN CROSSING OF INTERNATIONAL BOUNDARY - STATION NO. 11AA31
(G31 on Fig. 1)

(International Gauging Station)

Location: Lat. 48° 59' 50", long. 110° 35' 30", Montana, in N.E. ¼ sec. 6, tp. 37N, rge. 9, E.P.M., about five hundred feet south of International Boundary and about twelve miles southeast of Comrey, Alberta. Drainage Area: 2,590 square miles. Gauge-Height Record: Automatic stage recorder graph. Discharge Record: Stage-discharge relationship in 1964 defined by current-meter measurements. Period of Record: Periods of varying length 1909 to date. Prior to 1917 records were published under the title "at Spencer's Lower Ranch." Maxima: 10,700 cfs at 6:30 a.m., April 9, 1965 (g.h. 9.53). For 1964, 7,770 cfs at 6:00 to 8:00 a.m., June 11 (g.h. 6.71). A greater flow may have occurred during ice conditions on March 28, 1952 (g.h. 13.65). Remarks: Station maintained jointly by Canada and the United States. Since July 1917 flows during the irrigation seasons have been augmented by water diverted from the St. Mary River via the St. Mary Canal. All records to 1960 inclusive have been reviewed in co-operation with the United States Geological Survey and revisions prior to 1951 are available upon request to the District Engineer at Calgary. No revisions were necessary from 1951 to 1960.

Daily Mean Discharge in cfs, 1964

Date	Discharge	Date	Discharge	Date	Discharge
1 June	903	8 June	897	15 June	864
2 June	941	9 June	1,120	16 June	752
3 June	861	10 June	3,820	17 June	630
4 June	843	11 June	5,790	18 June	650
5 June	837	12 June	2,220	19 June	720
6 June	825	13 June	1,300	20 June	778
7 June	831	14 June	974	21 June	645

Gauge Height in feet and Discharge in cfs at indicated time, 1964

Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge
	9 June			12 June				
M	2.23	1,220	6	3.47	2,500			
			N	3.23	2,220			
	10 June		6	2.88	1,840			
4	2.29	1,260	M	2.66	1,620			
6	2.74	1,700						
9	3.80	2,910						
N	4.56	3,990						
6	5.60	5,700						
M	6.18	6,760						
	11 June							
6	6.66	7,670						
8	6.71	7,770						
11	6.39	7,160						
N	-	-						
5	4.56	3,990						
M	3.87	3,000						

MILK RIVER AT MILK RIVER - STATION NO. 11AA5 (G32 on Fig. 1)

(International Gauging Station)

Location: Lat. 49° 08' 45", long. 112° 04' 44", Alberta, in S.E. ¼ sec. 28, tp. 2, rge. 16, W. 4th Mer., about fifteen miles below confluence with North Milk River. Drainage Area: 1,040 square miles. Gauge-Height Record: Automatic stage recorder graph. Discharge Record: Stage-discharge relationship in 1964 defined by current-meter measurements. Period of Record: Mainly open water 1909 to 1910, and continuous April 1911 to date. Maxima: 8,730 cfs on May 22, 1927 (g.h. 11.41). For 1964, 8,110 cfs at 11:00 p.m., June 9 (g.h. 10.40). Remarks: This station is maintained jointly by Canada and the United States. Since July 1917 flows during the irrigation season have been augmented by water diverted into the North Milk River from the St. Mary River via the St. Mary Canal. All records to 1960 inclusive at this station have been reviewed in co-operation with the United States Geological Survey and revisions prior to 1951 are available upon request to the District Engineer at Calgary. No revisions were necessary from 1951 to 1960.

Daily Mean Discharge in cfs, 1964

Date	Discharge	Date	Discharge	Date	Discharge
1 June	877	8 June	1,200	15 June	569
2 June	846	9 June	4,560	16 June	564
3 June	827	10 June	4,310	17 June	707
4 June	809	11 June	1,540	18 June	760
5 June	803	12 June	929	19 June	569
6 June	815	13 June	725	20 June	518
7 June	840	14 June	628	21 June	483

Gauge Height in feet and Discharge in cfs at indicated time, 1964

Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge	Hour	Gauge Height	Discharge
	7 June			10 June				
M	3.37	884	2	9.95	7,520			
			4	9.53	6,980			
	8 June		5	9.25	6,620			
2	3.41	910	6	8.77	5,990			
4	3.43	922	7	8.22	5,310			
10	3.63	1,060	8	7.78	4,790			
N	-	-	10	7.15	4,040			
2	3.75	1,150	N	6.68	3,560			
8	4.20	1,440	2	6.31	3,200			
M	5.03	2,060	8	5.52	2,480			
			M	5.18	2,180			
	9 June							
7	5.83	2,760		11 June				
8	5.77	2,700	6	4.72	1,810			
9	5.99	2,900	N	4.30	1,480			
11	6.73	3,610	6	3.98	1,240			
N	-	-	M	3.80	1,100			
1	7.30	4,210						
2	7.89	4,920						
4	8.50	5,650						
6	9.10	6,420						
7	9.75	7,260						
11	10.40	8,110						
M	10.30	7,980						

APPENDIX B

Meteorological Developments Contributing to the Flood

Meteorological Developments Contributing to the Flood

INTRODUCTION

Any attempt to describe the meteorology of a storm of sufficient magnitude to produce the extremely heavy rains observed June 7-8, 1964, along the north half of the Continental Divide in Montana, involves the problem of describing complex atmospheric motions and processes. Large-scale motions controlling the Montana storm covered large parts of the Northern Hemisphere. Medium-scale features included general orographic effects and wind patterns near the surface. Small-scale effects were local in extent (limited to small areas) and included effects of wind channeling in "dead-end" mountain valleys, local instability, and others. In view of the many-faceted importance of this storm and the resulting floods, these features will be treated in some detail.

The physical processes of the atmosphere that produce the upward air motion which finally causes precipitation are well known. They are summarized in some detail in a U.S. Weather Bureau (1960b) technical paper, and are covered in texts by Petterssen (1956), Haltiner and Martin (1957), and others. Accordingly, this summary of storm meteorology is limited to brief descriptions of some of the atmospheric processes involved, to their interrelationships and dimensions, and to an areal depiction of the resulting precipitation.

SYNOPTIC FEATURES

The climatic history of Montana (U.S. Weather Bureau, 1960a) points to an annual rainy season from about May 20 to June 30, during which nearly all the heavy east-slope rainstorms of record have occurred. Obviously then, it is during this 40-day period that general atmospheric conditions are most likely to be favorable for producing rains in central Montana. Seasonally, by early June, the southern half of the United States has warmed much more rapidly than has northern Canada. Circulations resulting from this annual thermal gradient have lost little of their late-winter and early-spring energy by early June, while airmasses from southern latitudes (Gulf of Mexico sources in particular) may carry larger quantities of water vapor than is possible earlier in the season at lower temperatures. Meteorological developments of early June 1964 fit this general pattern.

At the beginning of June 1964, moist air from the Gulf of Mexico was spreading north and north-northwest over the western plains and central Rocky Mountains, carried northward on generally southerly (from south quadrant) winds ahead of a series of low-pressure centers over and just east of the Continental Divide. This moist air, becoming involved in a series of slow-moving but quite energetic circulations, caused the first half of June to be very wet over much of the West. These and other larger scale features are discussed by Dickson (1964). By the afternoon of June 7 when rains associated directly with the flood disaster started, the airmass, still carrying much of its original Gulf of Mexico-source moisture, was entering the northeast quadrant of a low-pressure area which centered over Wyoming but covered most of the Rocky Mountain area of the United States. This cyclonic circulation extended vertically into the upper levels of the troposphere, with the vortex at 500 mb (millibar), about 18,000 ft msl (feet above mean sea level) and by 1700 hours, June 7, was centered just northeast of Boise, Idaho.

By 1700 hours, June 7, rain had become general over the affected area. Surface and 500-mb maps for that time are shown in Figure B1. The most important large-scale features are the circulations, shown by these two maps, involving the strong westward tilt of the vortex between surface (about 900 mb) and the 500-mb level; the tilt suggests flow from easterly directions over north-central Montana. This phenomenon was observed at this time at all levels, to well above 500-mb. Dewpoints near ground surface were very high for the season; they ranged from about 55°F in northeast Wyoming and the Dakotas and indicated the high water-vapor content of the airmass. Precipitable water (U.S. Weather Bureau, 1961) from the surface to 55-mb had reached 1.09 inches at Glasgow and probably exceeded one inch over most of northern Montana north and east of Great Falls—a very large amount for this altitude (3,000—4,000 ft msl), latitude, and season.

All the features described above were involved in the early phases of the storm and were magnified to a considerable extent by the fact that the observed easterly flow was travelling upslope in the affected area—sharply upslope the last 10 miles or so just east of the Rocky Mountain ridge. For 1700 hours, June 7, Figure B1 (bottom) shows a well-defined cold front at about 5° latitude north of the Canada-Montana border. This front entered the circulation system late in the storm (Figs. B2, B3) with significant effects, as will be noted. By 0500 hours, June 8, exceedingly heavy rain had become general

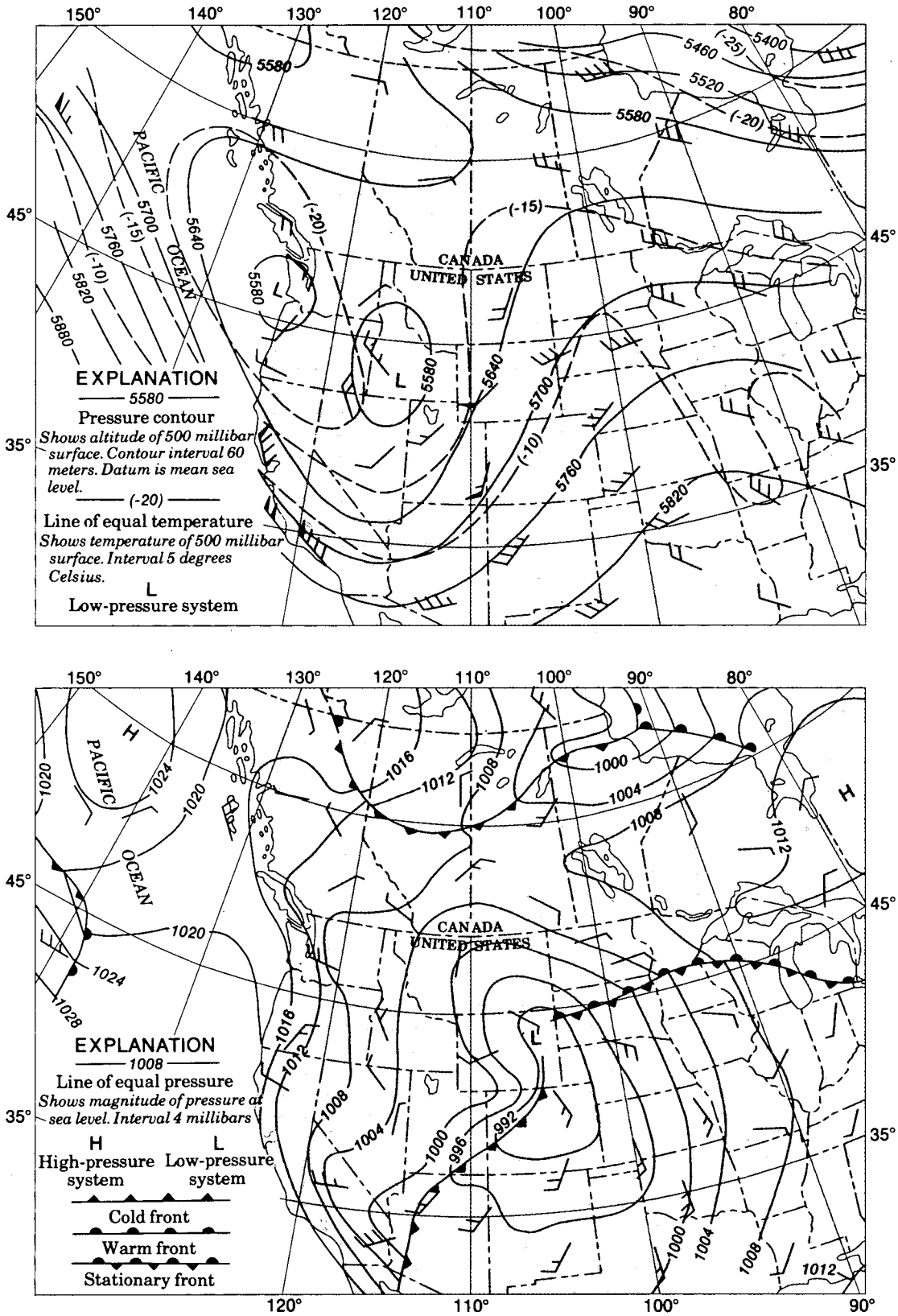


Figure B1. The 500-millibar surface (top) and sea-level pressure (bottom), 1700 hours, June 7, 1964. Note position of arctic front north of international boundary between Alberta and Montana. Note also the sea-level to 500-millibar westward tilt of vertex structure which is associated with a deep flow of moist air from the east over northern Montana. Wind-velocity symbol shafts are oriented with the wind direction: each flag represents 50 knots, each full barb represents 10 knots, and each half barb represents 5 knots.

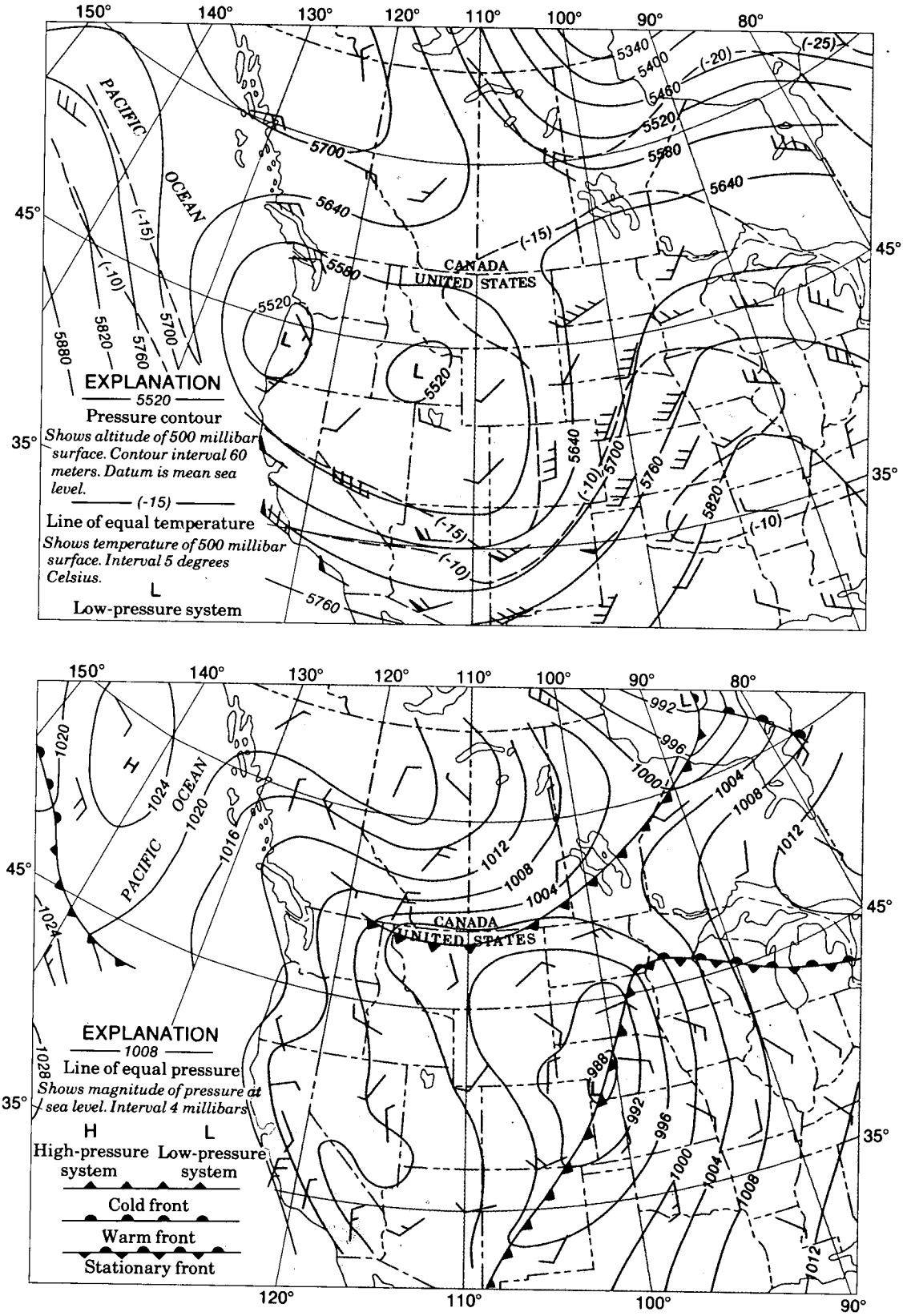


Figure B2. The 500-millibar surface (top) and sea-level pressure (bottom), 0500 hours, June 8, 1964, after heavy rain had persisted about 12-16 hours over flood headwaters. Note: (1) The advance to the arctic front into northern Montana, (2) The maintenance of depth and strength of the flow of moist air from the east. Wind-velocity symbol shafts are oriented with the wind direction; each flag represents 50 knots, each full barb represents 10 knots, and each half barb represents 5 knots.

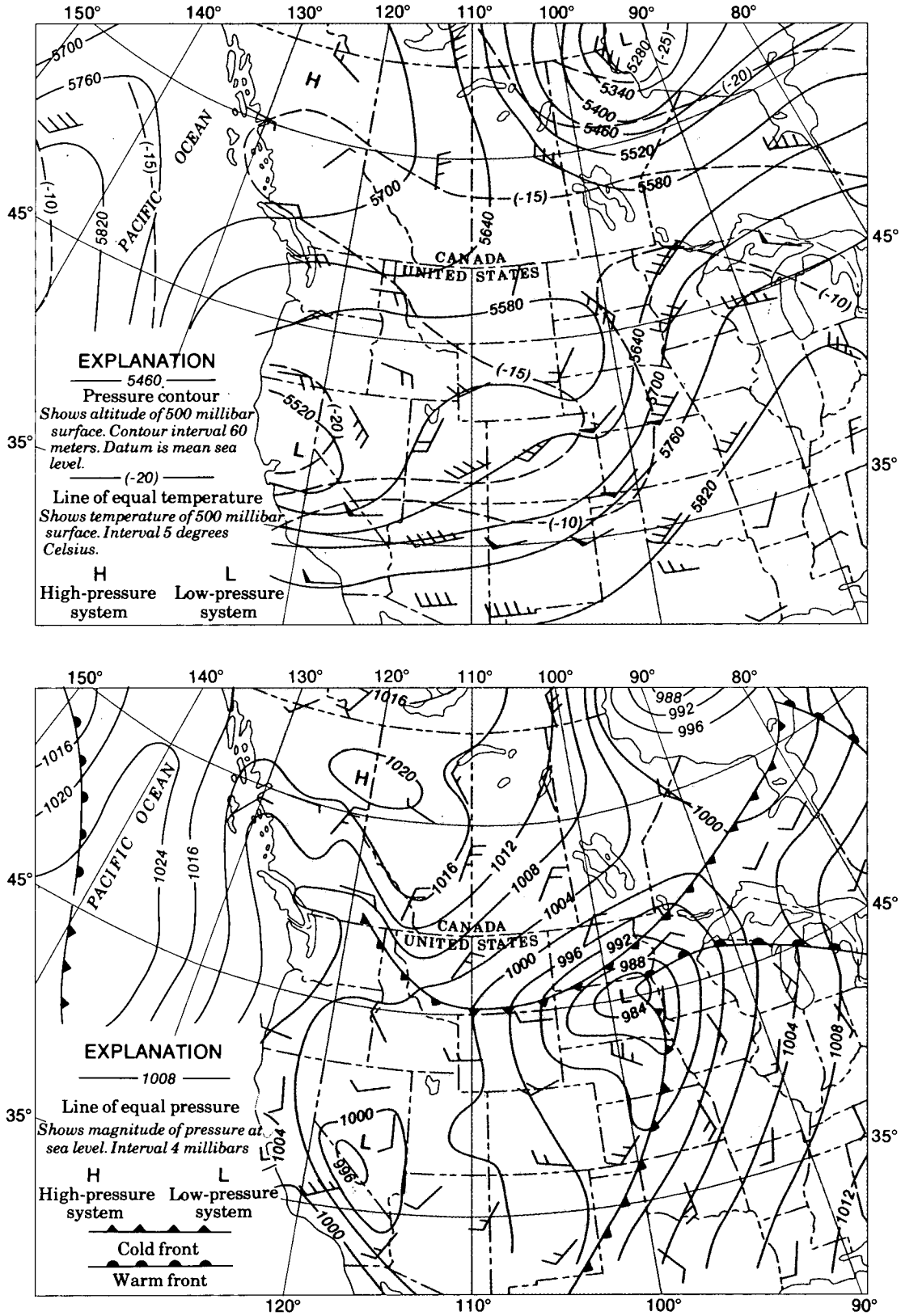


Figure B3. The 500-millibar surface (top) and sea-level pressure (bottom), 1700 hours, June 8, 1964. By this time, rains had either stopped or diminished to light as the cold-front wedge effectively cut off the low-level flow of moist air from the east. Wind-velocity symbol shafts are oriented with the wind direction: each flag represents 50 knots, each full barb represents 10 knots, and each half barb represents 5 knots.

on the high eastern slopes along the Continental Divide. In the very hard hit area between Browning and West Glacier, some of the heaviest rains reached into enough drainage area of the Middle Fork Flathead River to produce the highest discharge rates on record for the Flathead River at Columbia Falls and other points. The physical processes involved in the atmosphere had changed very little by the morning of June 8, but between sea level and the 500-mb level (Fig. B2) there was an even stronger westward tilt of the vortex than 12 hours earlier; this indicated that a deep and fairly strong easterly flow had persisted during the night. Figure B2 (bottom) shows the cold front from the north entering the northern edge of the area of heaviest rain. This cold front, as it moved southward, undoubtedly played a key role by imparting an important upward-motion component to the airmass during the last several hours of the storm, as well as sustaining the upward slope wind pattern. In general, the rain ended about 4 hours earlier in the northern part of the storm near Browning and East Glacier, than in southern areas about 100 miles away near Gibson Dam and Augusta.

By 1700 hours, June 8, rains had ended in the flood area except for a few light showers. By that time, the surface low-pressure center had moved to central South Dakota and Nebraska (Fig. B3, bottom). The primary circulation at 500 mb (Fig. B3, top) had also moved eastward, but with considerable weakening. A new 500-mb low had appeared to the southwest over northern California. These phenomena had reduced the effectiveness of the easterly flow over north-central Montana early in the day; but as the easterly flow diminished, the cold wedge from the north continued to supply storm winds from the northeast and continued vertical lifting of the airmass and thus extended the duration of heavy precipitation by about 4 hours.

All ingredients necessary for rain in the affected area were present: a large supply of relatively warm moist air lifting of this air by several methods, and large-scale atmospheric motions that sustained these overlapping effects for several hours. The sustained vertical motion necessary to produce the rates of precipitation observed in this storm may be estimated roughly by use of a method attributed to Fulks (1935), later modified and condensed by Petterssen (1956), Thompson and Collins (1953), and others. Assuming that (1) precipitation rates were 0.50–1.00 inch per hour (rates of 0.50–0.60 in. per hr were actually measured on recorders at Summit and Gibson Dam), (2) the precipitation layer was about 16,000 feet thick (4,000–20,000 ft msl), (3) the surface temperature was 50°F and decreased vertically at about 3.3° F per 1,000 feet (the saturated adiabatic rate at lower levels), and (4) the rate of condensation was approximately equal to the rate of precipitation, then vertical speeds from about 75 to 150 cm per sec (centimeters per second) would be required (Petterssen, 1956). If we assume that winds in the precipitation layer were easterly at about 30 knots, air involved would have to rise orographically from about 4,000 feet to the average altitude of the Continental Divide in this area, or to about 8,000 feet—a rise of about 4,000 feet in about 20 statute miles. The largest part of the lift could be expected at, or just east of, the ridge line; and this actually is the location of the centers of heaviest storm precipitation. If we use a lift of 200 feet per statute mile at a speed of 30 knots normal to the ridge line, by simple arithmetic, we arrive at an orographic component of 1.94 ft per sec (feet per second), or 59 cm per sec. Orographic lifting was probably most strong in the lower few thousand feet of the precipitating layer and was probably replaced, to an indeterminate extent, by convection in middle and upper parts of the layer.

Orographic lifting therefore appears to have been an extremely important factor. In the rugged areas in the northern center of heaviest rain (Fig. B4) where lifting of 1,000 feet is possible in less than 5 miles, the orographic lift component was undoubtedly greater than 59 cm per second and possibly exceeded 100 cm per sec by a considerable margin. Other factors contributing to upward motion include vertical variation of vorticity advection, the Laplacian of temperature advection, the Laplacian of the latent heat of condensation, and low-level friction effects. With an orographic lift of 60–100 cm per sec to build upon, these factors could account for the lifting necessary for rains with rates of up to an inch per hour in the heaviest rainfall areas (Fig. B4).

Many of the medium-scale atmospheric processes and motions of this storm have been touched upon in preceding paragraphs. Upslope, for example, sometimes is considered to be medium scale; but in this storm, it was part of large-scale motions on a front more than 100 miles wide. Vorticity, convergence, and instability also were important parts of the general circulation in the heavy-storm area. The general flow pattern of the atmosphere at lower levels is shown in Figure B5. The maps (depicting winds at about 2,000 feet above the surface and at 5,000 ft msl at 1700 hours, June 7) show very clearly the trajectory of the airmass involved in the storm. The airmass moved northward, then westward over northern Montana into the storm circulation. It was this moisture-laden air at the lower levels of the troposphere that fed the vertical motions in the storm centers. The flow of water vapor was strong and steady in the early stages of the storm, but was cut off by the action of the cold front (Figs. B1, B2) in the storm's later stages.

A few medium-scale features require comment. The channeling effect of mountain valleys, the angle of flow incidence to mountain ridges, and the effects of nearly parallel ridges almost normal to the general flow no doubt caused important local variations in rainfall rates. However, observations and measurements were not sensitive enough or were too sparse to detect such local variations with certainty. Mass rainfall curves for several

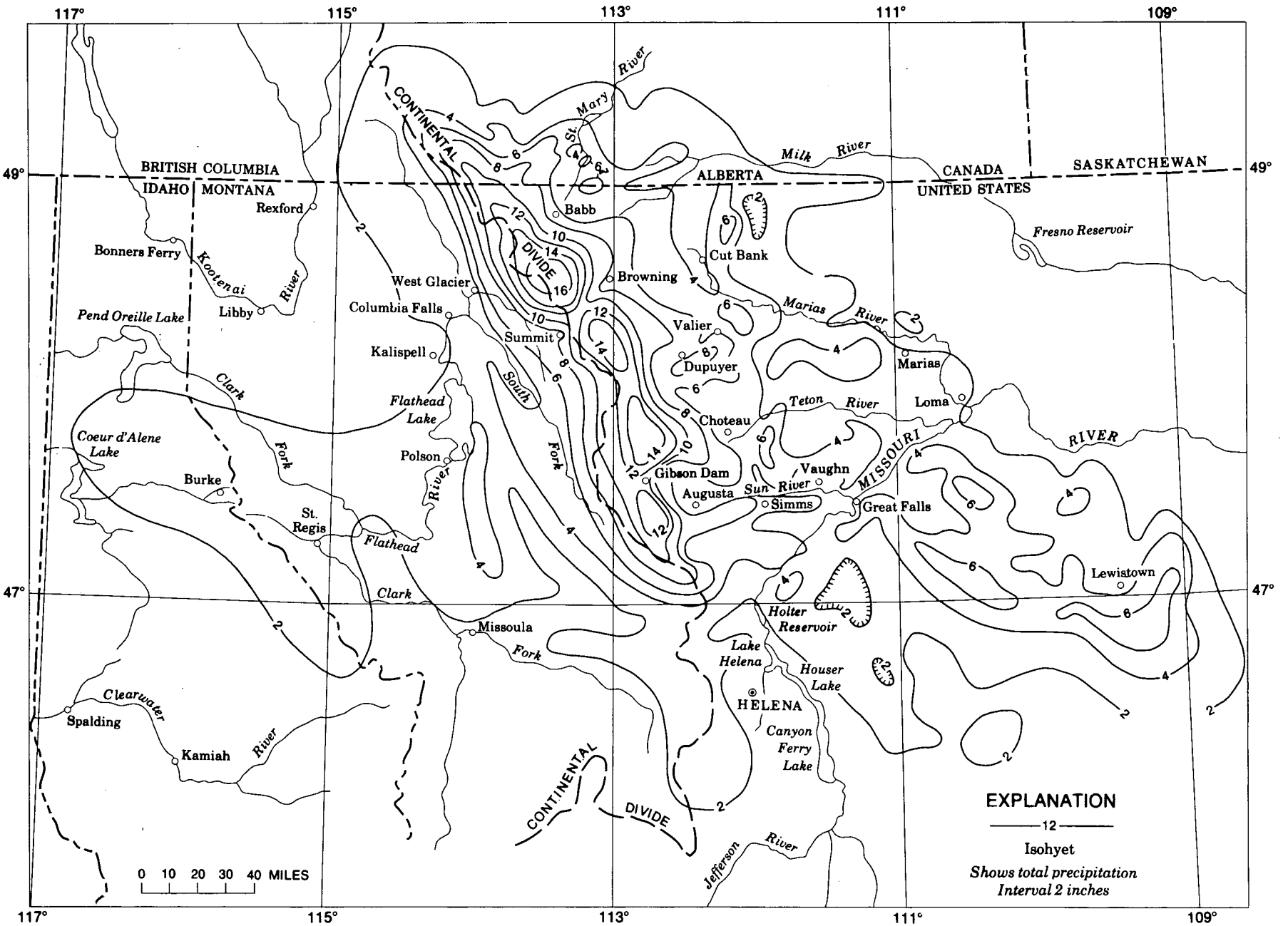
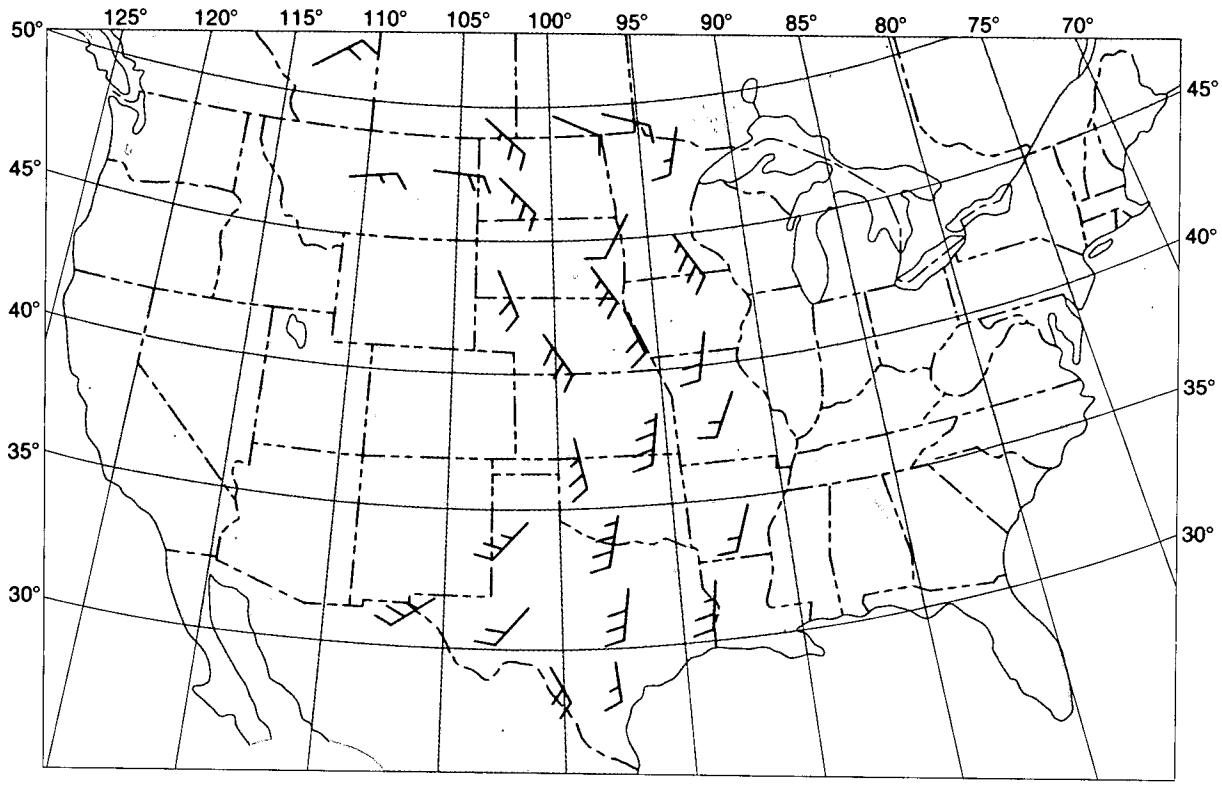


Figure B4. Total precipitation for June 7-8, 1964. Note centers of high intensity rainfall near crest of Continental Divide. Highest centers estimated because of lack of measurements in mountains. Owing to the natural variability of rainfall in rugged mountain country such as this, caution is recommended in interpolating from this chart.



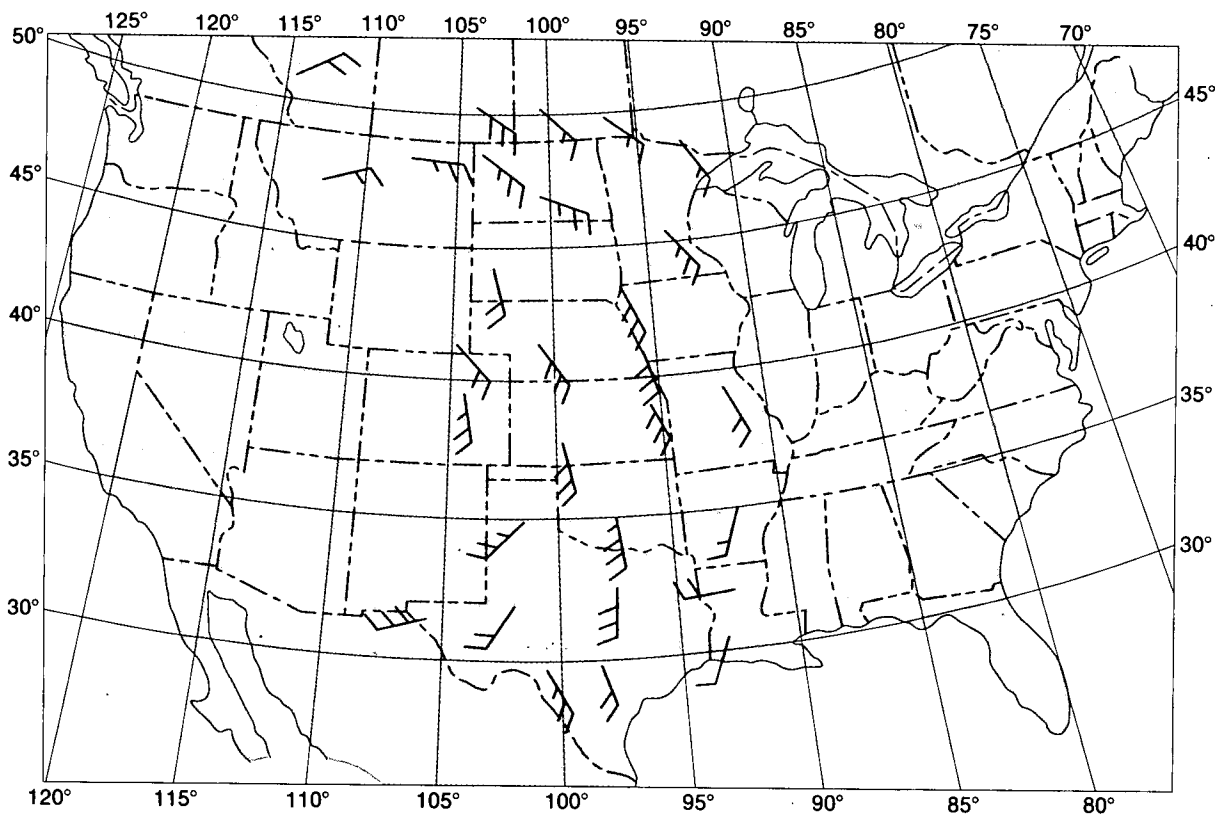


Figure B5. Windflow at about 5,000 feet above mean sea level (top) and 2,000 feet above land surface (bottom) into Montana from the Gulf of Mexico at 1700 hours, June 7, 1964. Wind-velocity symbol shafts are oriented with the wind direction; each full barb represents 10 knots; each half barb, 5 knots.

stations within the storm's boundaries, but still some distance from the heaviest centers, show a remarkable steadiness in the rates at which precipitation accumulated (Fig. B6). Thus, although the degree to which each factor acted to produce precipitation varied during the storm, the integrated effect changed little during the principal 30-hour storm period.

The flood-producing precipitation over the Flathead River basin and other basins to the west of the Continental Divide appears to have exceeded the magnitudes that can be accounted for by the drift, with the wind, of snow and rain formed in the rising air above the eastern slopes, though no calculations have been made to confirm this. It is surmised that this heavy lee-side precipitation was, in part, the result of convective cells, which were set off by the windward lift but which sloped with the wind and extended to the lee side. This concept is depicted schematically in Figure B7.

RAINFALL PATTERN

With the moist easterly flow impinging upon the eastern slopes along the Continental Divide where the orographic lift was large and steady, it should not be surprising that the area of heaviest rain was along or just east of the divide ridge for a north-south distance of more than 100 miles. The impact of the storm was staggering (the magnitude of the resulting flood disaster is covered elsewhere in this report); determination of precipitation amounts was delayed several days because of disrupted travel facilities and communications. With co-operation from U.S. Army Corps of Engineers, Bureau of Reclamation, U.S. Forest Service, U.S. Geological Survey, and U.S. Weather Bureau, a survey of the area was conducted during the week of June 15 to find sources of precipitation measurements which might help to reconstruct the storm and to outline the areas of heaviest rainfall. Hundreds of good-quality measurements were reported. However, the scarcity of observers severely limited information for the mountain areas where the heaviest precipitation occurred. Through the generous help of the Canada Department of Agriculture, Regina, Saskatchewan, about 200 measurements were made available for the southern Alberta area of the storm. All these measurements are listed in the United States Geological Survey Water-Supply Paper 1840-B, and were used in preparing the isohyetal chart for the storm (Fig. B4). Also given in that Paper is a comprehensive account of all rainfall gauging locations in the storm area in the United States.

The heavy-precipitation centers were very well located but their magnitude and extent are partly based upon peak stream discharges at 500 cfs per sq mi or more and several precipitation measurements of 10 inches or more. The altitude of the freezing level remained higher than mountain ridges throughout the storm area, and the effect upon snowmelt runoff was an important consideration. It appears that the snowmelt contribution to peak discharge was probably minor in the hardest hit areas.

MISCELLANEOUS NOTES

In connection with the strong upslope winds along the Continental Divide and the heavy spillover or lee-side precipitation (Fig. B7) previously described, it is worth noting that a large number of persons contacted for supplemental precipitation measurements commented upon the strength of the north to east windflow toward the storm's centers. At the Federal Aviation Agency station at the Cut Bank Airport (the nearest hourly observation station to any of the storm's heaviest rainfall centers), hourly wind readings confirm the strength of the northeast windflow from midnight until after noon June 8. The observations show that the wind direction ranged from northeast to east-northeast during the storm's heaviest period, with speeds frequently gusting to more than 40 mph (miles per hour). The same set of observations also confirms that the cold front from the north entered the northern parts of the affected area at about the time the map measurements were taken (0500 hr, June 8, Fig. B2).

Because Glasgow appears to have been near the center of the moist airstream flowing into the storm area, upper air observations made there just before the storm and during its early stages should reveal the general character of the airmass involved. The Glasgow radiosonde observation made at 1700 hours, June 7, is shown in Figure B8. It shows, among other things, very high mixing ratios—from nearly 12 grams of water vapor per kilogram of dry air at the surface to 2.6 g per kg (grams per kilogram) at 500 mb. The observed lapse was conditionally unstable up to 500 mb, but the greatest degree of conditional instability was between the surface and about 7,000 ft msl. This layer of greatest instability was at the bottom of the larger layer (reaching to higher than the 500-mb level) that appears to have been heading for the storm activity a few hundred miles to the west. The Glasgow sounding was used to calculate precipitable water (surface to 500 mb) content, which at that time was 1.09 inches, and the average relative humidity for the same layer was 84 percent.

An additional item of more than passing interest was the lack of thunderstorms in the heavy-precipitation areas. In view of the sparsely populated nature of the areas where the heaviest rains fell, it cannot be concluded that thunderstorms did not occur, but it is noteworthy that none was reported on June 7 or 8 by any regular Weather Bureau station near any of the storm's several centers. It seems likely that thunderstorms were widely scattered if they did occur, and that conditional instability release was mostly of a rather even intensity and fairly continuous. The steadiness of the rainfall rates shown in Figure B8 support, at least in part, such a hypothesis.

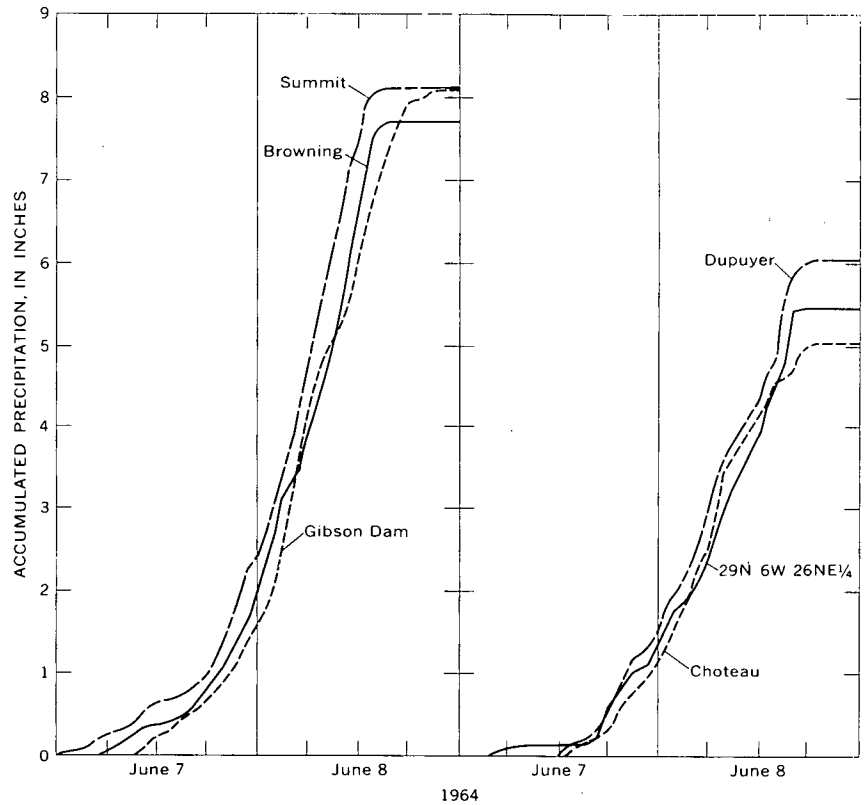


Figure B6. Mass curves of accumulation of precipitation with time from recording precipitation gages in (or on edge of) storm area, June 7-8, 1964.

METEOROLOGICAL COMPARISON WITH PREVIOUS FLOODS

The record-breaking floods of 1964 and most previous Montana floods occurred in June when seasonal large-scale meteorological conditions may have been similar. Heavy rainstorms along and near the eastern side of the Continental Divide in late May and early June are clearly associated with floods of 1894, 1906, 1908, 1916, 1927, 1938, 1948 and 1953. Mountain snowmelt has generally filled stream channels to near capacity in the same period, and the degree to which floods have been rain induced is rarely as clear as in 1964. The noteworthy Springbrook storm of 1921 was centered a considerable distance from the mountains although general rains appeared to have had some effect on mountain runoff as well.

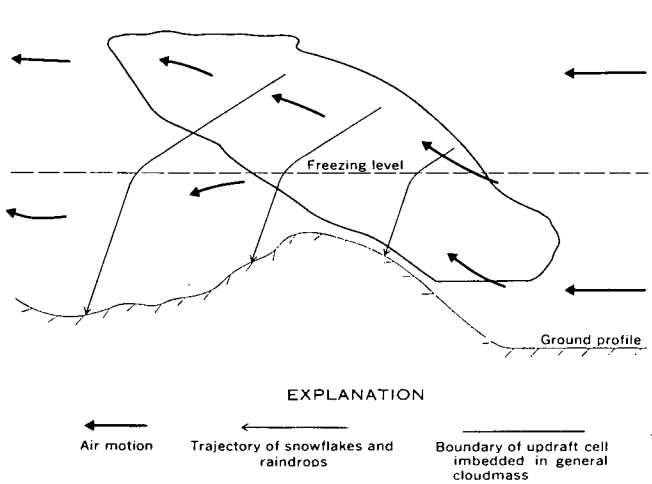


Figure B7. Concept of a precipitation-releasing updraft cell that is formed on a windward slope and leans with the wind. Upper part of cell lies above lee valley.

Precipitation data from regular stations for all these storms and a discussion of the flooding of June 1908 appear in the appropriate issues of the monthly publication "Climatological Data, Montana" by the U.S. Weather Bureau. Streamflow data, like precipitation data, are more complete in later years and may be found in the yearly reports of the U.S. Geological Survey entitled "Surface Water Supply of the United States." Studies of the 1921 (Springbrook), 1906 (Warrick) and 1938 (Big Timber and Chessman Reservoir) storms have been discussed by the U.S. Weather Bureau and Corps of Engineers (1945). Meteorological and hydrologic features of the Marias River flood of 1948 are discussed in the Monthly Weather Review (Dightman, 1950). The 1953 flood, which was felt particularly in Great Falls area, was documented in a report of the U.S. Geological Survey (1957). An examination of the data reveals a fairly strong climatological similarity in the

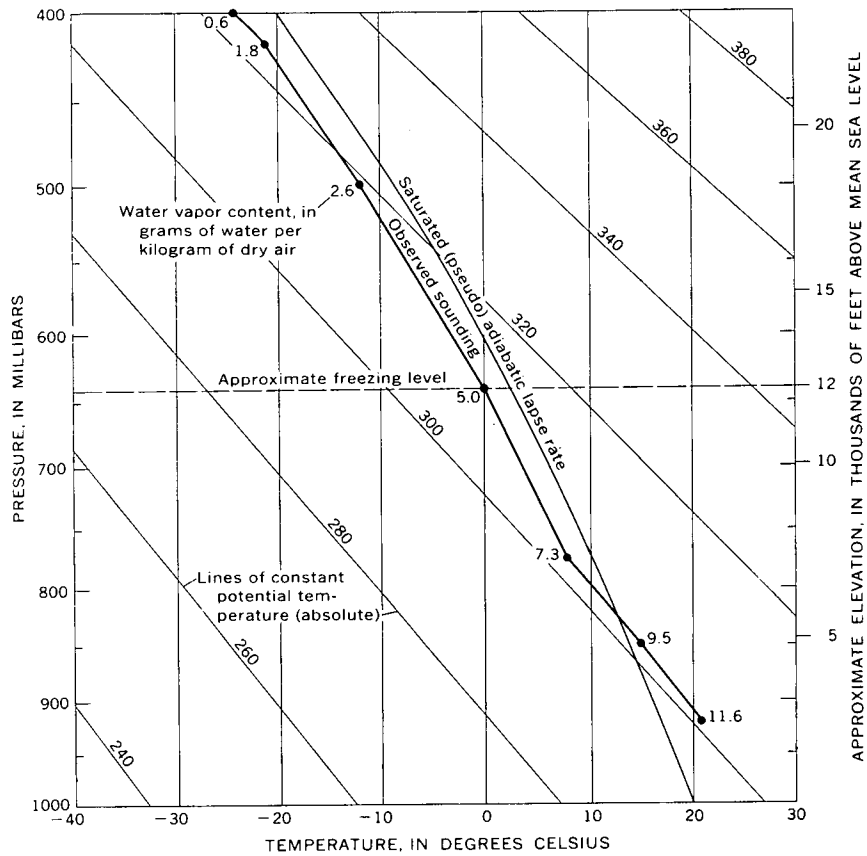


Figure B8. Glasgow radiosonde observation at 1700 hours, June 7, 1964, sampling moist air enroute westward into storm area. The airmass was conditionally unstable from the surface (about 920 mb) to nearly 400 mb.

rain-induced floods that generally occur in June, but which may begin to develop in late May. The major meteorological developments appear to be much the same. While vertical motion maxima may be located in any part of the upper Missouri River drainage basin, including the Yellowstone River, depending on the parts of the general area traversed by the storm structures, all the storms received their moist air supply from the Gulf of Mexico as a result of general flow northward, then northwestward over the western plains States.

The principal differences between previous storms and the 1964 storm were:

1. The maximum vertical motion centers in 1964 were apparently located above the steepest eastern slopes of the northern Rockies, and were reinforced by a larger orographic vertical-motion component than was possible in any of the earlier record floods.

2. The flow of moist air from the gulf was unusually direct, broad, and undisturbed until its arrival in the rain area.

3. The timing of the entry of the cold front from the north into the rain area was critical—its "wedging" and continued upslope flow effects probably caused a few hours more of heavy rain than otherwise would have occurred.

It would be difficult to design a combination of all factors more favorable for heavy rainfall than prevailed in this storm. The timing of the interacting physical forces and other parameters could hardly be improved, and it is therefore not surprising that the dimensions of this storm closely approximate those of probable maximum precipitation described by the U.S. Weather Bureau (1960b).

REFERENCES

Dickson, R.R. 1964. The weather and circulation of June 1964. U.S. Weather Bur., Monthly Weather Rev., v.92, no. 9, pp. 428-432.

Dightman, R.A. 1950. Montana Marias basin rainstorm, June 16-17, 1948. U.S. Weather Bur., Monthly Rev., v. 78, no. 1, pp. 6-12.

Fulks, J.R. 1935. Rate of precipitation from adiabatically ascending air. U.S. Weather Bur., Monthly Rev., v.63, no. 10.

Haltiner, G.J., and F.L. Martin. 1957. Dynamical and physical meteorology. McGraw-Hill Book Co., New York. 470 p.

Petterssen, S. 1956. Weather analysis and forecasting, v.2. McGraw-Hill Book Co., New York. 266 p.

Thompson, J.C., and G.O. Collins. 1963. A generalized study of precipitation forecasting. U.S. Weather Bur., Monthly Weather Rev., v.81, no. 4.

U.S. Geological Survey. 1957. Floods of May-June 1953 in Missouri River basin in Montana. U.S. Geol. Survey Water-Survey Paper 1320-B, p. 81-86.

U.S. Weather Bureau and U.S. Army Corps of Engineers. 1945. Storm rainfall in the United States, Depth – Area – Duration Data.

U.S. Weather Bureau. 1960a. Climates of the States. Montana. Climatography of the United States No. 60-24. 20 p.

U.S. Weather Bureau, 1960b. Generalized estimates of probable maximum precipitation for the United States west of the 105th meridian for areas to 400 square miles and durations to 24 hours. Tech. Paper 38. 66p.

U.S. Weather Bureau. 1961. Synoptic meteorology as practiced by the National Meteorological Center. The NAWAC Manual, pt. II. pp. 33-34.

INSERT

LARGE

FORMAT

PROJECT : ENVCAN 1-850

BOX : 2

FOLDER : BULLETIN # 73

OF DRWGS : 1

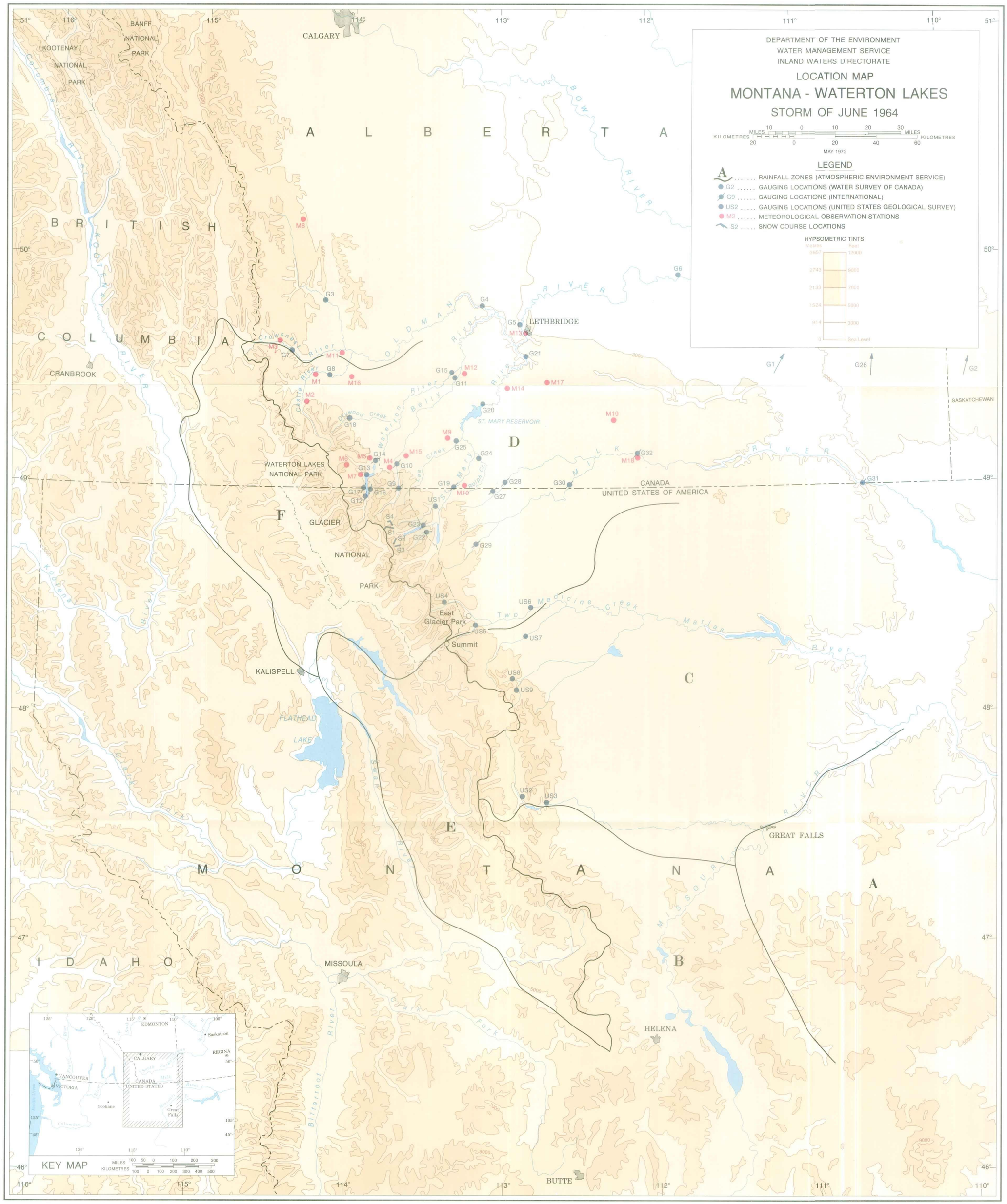

DEPARTMENT OF THE ENVIRONMENT
WATER MANAGEMENT SERVICE
INLAND WATERS DIRECTORATE
LOCATION MAP
MONTANA - WATERTON LAKES
STORM OF JUNE 1964
MAY 1972
LEGEND
RAINFALL ZONES (ATMOSPHERIC ENVIRONMENT SERVICE)
G2 GAUGING LOCATIONS (WATER SURVEY OF CANADA)
G9 GAUGING LOCATIONS (INTERNATIONAL)
US2 GAUGING LOCATIONS (UNITED STATES GEOLOGICAL SURVEY)
M2 METEOROLOGICAL OBSERVATION STATIONS
S2 SNOW COURSE LOCATIONS
HYPSOMETRIC TINTS
CALGARY
LETHBRIDGE
CRANBROOK
KALISPELL
MISSOULA
GREAT FALLS
HELENA
BUTTE
WATERTON LAKES NATIONAL PARK
GLACIER NATIONAL PARK
East Glacier Park
Summit
ST. MARY RESERVOIR
FLATHEAD LAKE
CANADA
UNITED STATES OF AMERICA
SASKATCHEWAN
A L B E R T A
B R I T I S H C O L U M B I A
M O N T A N A
I D A H O
KEY MAP

Table 3 (Cont.)

Map Index No.	Station No.	Gauging Station	D. A. mi.^{2}	Period of Record	Maximum Flood prior to 1964 (footnote *g*)			Maxima – Flood of June 1964					Remarks
					Date	G. H.	Discharge	Time hrs.	Date	G. H.	Discharge cfs	Discharge cfsm	
G14	5AD3	Waterton River near Waterton Park	238	1908-33 1948-68	June 1908	9.5 *(ef)*	24,000	0400	June 9	9.22	25,700*(a)*	108	International Gauging Station
G15	5AD8	Waterton River near Stand Off	674	1915-66	June 1942	8.21	15,750	–	June 10	9.68	16,500*(a)*	24.5	
G16	5AD31	Street Creek at International Boundary	6.0	1947-55	June 1953	4.5	437	–	June 8	13.6	5,740*(ad)*	957	Discontinued Station
G17	5AD30	Boundary Creek near International Boundary	21.0	1947-64	June 1953	5.24	904	–	June 8	–	5,930*(ad)*	282	International Gauging Station
G18	5AD16	Drywood Creek near Twin Butte	11.8	1935-68	June 1953	3.83	545	1130	June 8	5.99	1,180*(ad)*	100	
G19	5AE27	St. Mary River at International Boundary	469	1902-68	June 1908	12.75*(f)*	40,000*(e)*	1630	June 8	12.06	21,000*(c)*	44.8 *(c)*	International Gauging Station
G20	5AE25	St. Mary Reservoir near Spring Coulee	–	1951-68	June 1958	Elev. = 3,619.99 feet	Capacity = 320,700 acre-feet		July 9	Elev. = 3,618.89 feet	Capacity = 310,100 acre-feet	–	
G21	5AE6	St. Mary River near Lethbridge	1,410	1911-68	June 1953	8.60	15,600*(c)*	0400	June 11	8.52	16,200*(ac)*		
G22	5AE32	Swiftcurrent Creek at Many Glacier	31.4	1912-66	June 1937	6.89*(b)*	2,250	1600	June 8	10.00*(e)*	6,700*(ad)*	213	International Gauging Station
G23	5AE33	Swiftcurrent Creek at Sherburne	64.3	1912-68	June 1916	7.8	2,280*(c)*	1630	June 11	8.37	2,360*(ac)*		International Gauging Station
G24	5AE5	Rolph Creek near Kimball	90.6	1911-16 1935-68	June 1953	7.21	1,290	1800	June 8	4.80	630	6.95	
G25	5AE2	Lee Creek at Cardston	117	1909-14 1920-68	June 1951	10.49	7,820*(e)*	1700	June 8	12.59	11,400*(ad)*	97.4	
G26	5CK4	Red Deer River near Bindloss	16,800	1960-68	June 1963	8.13	7,140		June 23	10.13	14,100*(a)*	0.84	
G27	11AA32	North Fork Milk River above St. Mary Canal	61.8	1911-12 1919-68	April 1953	7.55	2,120	1500	June 8	4.91	653	10.6	International Gauging Station
G28	11AA1	North Milk River near International Boundary	91.8	1909-68	June 1948	6.47*(f)*	2,950*(c)*	1600	June 8	7.98	1,940*(cd)*		International Gauging Station
G29	11AA33	South Fork Milk River near Babb	68.6	1961-68	Feb. 1963	5.33	500*(e)*	1300	June 8	6.61	12,000*(ad)*	175	International Gauging Station

Photograph 5. Oldman River at Lethbridge on June 9, 1964 (photo by R. Terzi, Water Survey of Canada)

Table 3. Summary of Peak Gauge Heights and Discharges in the South Saskatchewan and Milk River Basins Flood of June 1964

Map Index No.	Station No.	Gauging Station	D. A. mi.^{2}	Period of Record	Maximum Flood prior to 1964 (footnote *g*)			Maxima – Flood of June 1964					Remarks
					Date	G. H.	Discharge	Time hrs.	Date	G. H.	Discharge cfs	Discharge cfsm	
G1	5AJ1	South Saskatchewan River at Medicine Hat	22,500	1911-68	June 1953	29.19	151,800*(c)*	1800	June 11	19.44	68,000*(c)*	3.06*(c)*	
G2	5HB1	South Saskatchewan River near Lemsford	45,000	1958-68	July 1963	16.20	62,500*(c)*	–	June 13	16.33	63,500*(c)*	1.41*(c)*	
G3	5AA23	Oldman River near Waldron's Corner	551	1949-68	June 1953	12.72	16,000	1200	June 8	6.81	4,950	8.98	
G4	5AD19	Oldman River near Monarch	3,450	1948-68	June 1953	23.82	67,450	2200	June 9	14.60	27,100*(d)*	7.86	
G5	5AD7	Oldman River near Lethbridge	6,630	1911-48 1957-68	June 1953	23.10	110,000*(ch)*	1300	June 10	18.55	73,800*(c)*	11.1*(c)*	
G6	5AG6	Oldman River near the Mouth	–	1964-68	–	–	–	0600	June 11	21.21	68,200*(ac)*	–	
G7	5AA8	Crowsnest River at Frank	162	1910-20 1949-68	June 1953	8.58	2,610	2000	June 7	7.58	1,780	11.0	
G8	5AA22	Castle River near Beaver Mines	319	1945-68	May 1948	–	12,780	2100	June 8	11.05	18,000*(ad)*	56.4	
G9	5AD32	Belly River at International Boundary	74.8	1947-64	June 1953	6.66	2,450	1900	June 8	10.16	12,000*(ad)*	160	International Gauging Station
G10	5AD5	Belly River near Mountain View	121	1911-68 1908	June 1953 1908	6.64 12.0 *(e)*	4,500 –	1900	June 8	11.40	16,400*(ad)*	136	International Gauging Station
G11	5AD2	Belly River near Stand Off	476	1909-31 1935-36 1948-68	June 1953	11.23	10,690	0800	June 9	11.56	11,700*(ad)*	24.6	
G12	5AD29	Waterton River near International Boundary	61.0	1947-64	May 1954	6.51	2,710	1700	June 8	11.55	12,400*(ad)*	203	International Gauging Station
G13	5AD25	Waterton Lake at Waterton Park	–	1950-68	June 1953	Elev. = 4,199.5 feet	–	0200	June 9	High Water Mark Elev. = 4,206.76 feet			

(a) New maximum for period of record.
(b) Backwater conditions from bridge.
(c) Discharge affected by significant upstream storage or diversion.
(d) Maximum discharge in 1964 determined by indirect methods.
(e) Estimated.
(f) Location and gauge datum then in use, not comparable to 1964 gauge datum.
(g) Gauge heights are referred to gauge datum in use in 1964 unless otherwise noted.
(h) Revised.