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Hydrological Studies of the Slims River, Yukon, June-August 1970

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ABSTRACT. Hydrological studies were conducted on the Slims River during the summer of 1970. The purpose was to determine factors causing diurnal and seasonal variations in discharge. Discharge measurements were taken during periods which displayed different climatological conditions; diurnal variations were measured within selected twenty-four hour periods. A continuous stage recorder was used to measure seasonal variations in stream flow. Tributary stream discharge was also measured.

Climatological data recorded at the nearby Kluane Lake Station were utilized for hydro-climatological analysis. Available measurements included temperature, wind direction and velocity, cloud cover and type, precipitation, atmospheric pressure, humidity, and incoming short-wave radiation.

Shifts of Kaskawulsh Glacier meltwater drainage from the Slims to the Kaskawulsh River are the major factor in intraseasonal variations of discharge. Otherwise, Slims River drainage was found to vary diurnally and seasonally in accordance with certain climatological and physiographic factors. These include glacier ablation, exposure direction and surface area of the watershed surface, ice-dammed lake drainage, short-wave radiation absorption, cloud cover, precipitation, and temperature. Discharge varied directly with the general increases and decreases in short-wave radiation and seasonal temperature. Intensity of rainfall does not always have a direct relationship to discharge.

Introduction

Hydrological studies were conducted on the Slims River during the summer of 1970. This river is important to an understanding of the regional environment because: (1) it is the major source of water for Kluane Lake, the largest lake in the Yukon Territoty; (2) it behaves anomalously from summer to summer, thus affecting lake levels and shoreline morphology; and (3) it is one of the two meltwater outlets of the Kaskawulsh Glacier.

Geomorphic studies have previously been conducted in the Slims River area. Fahnestock (1969) described characteristics and chronology of the Slims valley train, providing supporting evidence to Bostock's (1952; 1969) hypothesis that the Slims River has experienced drainage reversal in postglacial time.

The purpose of the study reported here was to determine factors causing diurnal and intraseasonal variations in discharge. To accomplish this, discharge measurements of the river were taken during periods which displayed different climatological conditions. In order to gain insights into diurnal variations, a series of measurements were taken within selected twenty-four hour periods; seasonal changes were compiled continuously by stage recorder. Discharge measurements of tributary streams were also taken to determine what percentage (or remainder) of the Slims' discharge was composed of Kaskawulsh Glacier meltwater.

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Climatological data from the Kluane Lake meteorological station utilized in this study included daily measurements of temperature, wind direction and velocity, cloud cover and type, precipitation, atmospheric pressure, humidity, and incoming short-wave radiation. Interpretation of the climatic data was useful in the identification of factors which influence discharge variations.

Study area. The Kaskawulsh Glacier in the Icefield Ranges of the St. Elias Mountains drains eastward a distance of 72 km to its end moraine (Plate 1)[1]. At this point two meltwater streams—the Kaskawulsh and Slims Rivers—emerge from the glacier snout and drain divergent valleys. The Slims River flows from the north edge of the Kaskawulsh Glacier's end moraine into Kluane Lake. It enters the lake at mile 1059.8 of the Alaska Highway, eventually draining to the Bering Sea via the Yukon River system. The Slims River stretches 22.5 km over a valley floor composed of glacial outwash. Its floodplain is about 1800 m wide, except in areas where tributaries have built alluvial fans which constrict the valley floor.

The Slims and Kaskawulsh Rivers share the runoff from a 2100 km^2 drainage basin in the Icefield Ranges. Approximately 1450 km^2 of this watershed is covered by Kaskawulsh Glacier ice (Richard Rangle, personal communication, in Fahnestock, 1969, p. 161).

Tributary streams (Fig. 1), which enter the river below the glacier terminus, supply the Slims with snowmelt as late as July, depending on both the amount of winter snow accumulation and climatic conditions. On the upper portions of fans, which are developed from the

[1] Plate 1 is a map inside the back cover of this volume.

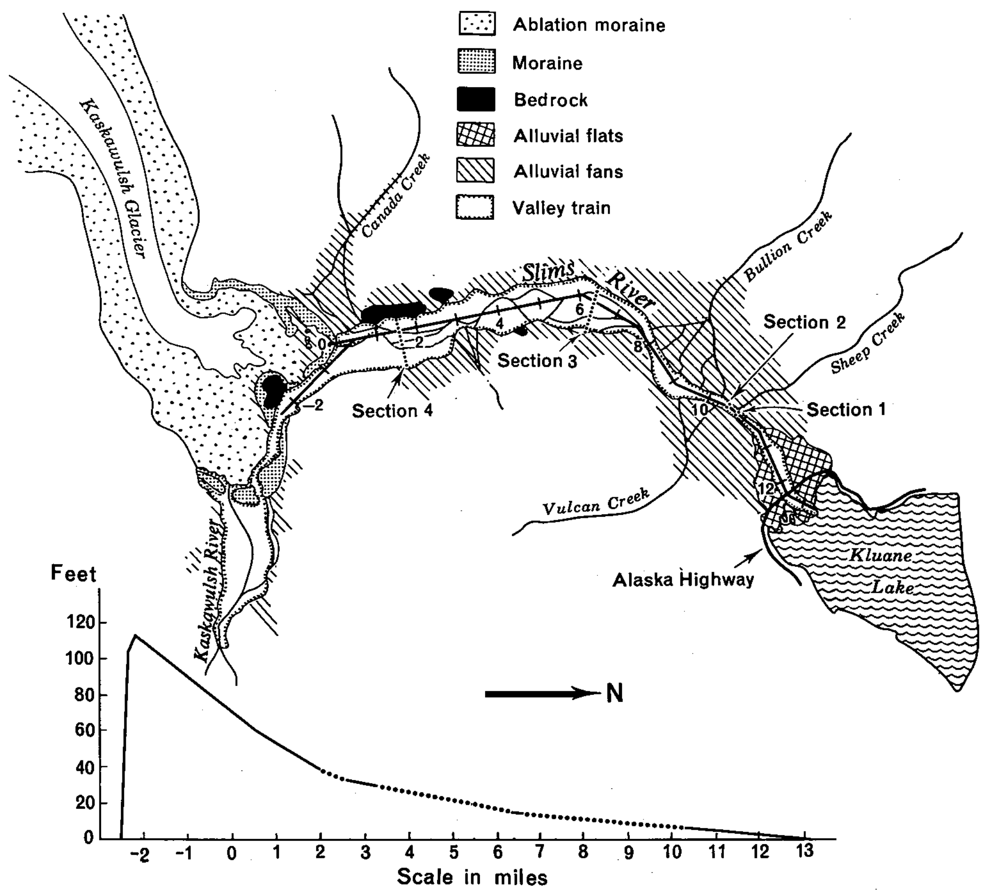

Fig. 1. The Slims River valley (from Fahnestock, 1969, p. 163; locations of cross sections discussed by Fahnestock should be disregarded).

tributaries, runoff infiltrates the fans but reappears at the edge of the river as small springs. Throughout the summer months the larger fans supply the Slims with snow and glacial melt. Of the larger tributaries, Canada and Bullion Creeks are glacially fed, whereas Vulcan and Sheep Creeks are supplied with snowmelt from high névé fields. The canyon walls of the lower segments of these streams exceed 30 m and large boulders cluster in their narrow flood plains.

Canada Creek, the largest of the tributaries, enters the Slims some 90 m downstream from the Kaskawulsh Glacier end moraine on the west slope of the valley. The upper portion of the fan is composed of coarse material; the lower two-thirds of the fan consists of gravel to silt-size material and has no vegetation cover.

Bullion and Sheep Creeks enter approximately 14 km and 13 km downstream on the west side of the valley. The upper two-thirds of their fans are wooded. The lower thirds are partially covered with thick grasses and muskeg.

On the Bullion Creek floodplain 15%–20% of the surface has been recently reworked by migrating, braided flow; major changes have occurred during peak runoff periods. Mining and road alterations across Bullion Creek have also modified its migration pattern.

Vulcan Creek, a snowmelt stream, drains the eastern slope of the Slims River and enters the main stream approximately 16 km below the Kaskawulsh Glacier terminus. On the upper portions of the Vulcan fan, stream flow infiltrates gravel-sized alluvium to reappear on grass and muskeg lower on the fan.

Field methods. Discharge and stage measurements were taken at the Slims River bridge. This is the most convenient location for discharge observations because a 122-m long bridge funnels all water into two narrow channels. Because there is a high permafrost table (less than 1 m below the surface) subsurface flow is negligible. Vertical markings painted on the downstream side of the bridge provided reference planes to measure the vertical angle created by the force of the water on a handline-suspended current meter and sounding weight. Starting at the west bank, depth readings were taken at 1.5-m intervals and velocity readings were taken at 3-m intervals. Water height was measured by stage recorder. Water temperature was also recorded prior to each discharge measurement.

Observations of tributary stream flow were made at Bullion, Sheep, and Vulcan Creeks. Steam discharge, water temperature, maximum and minimum air temperature, and precipitation were measured at these

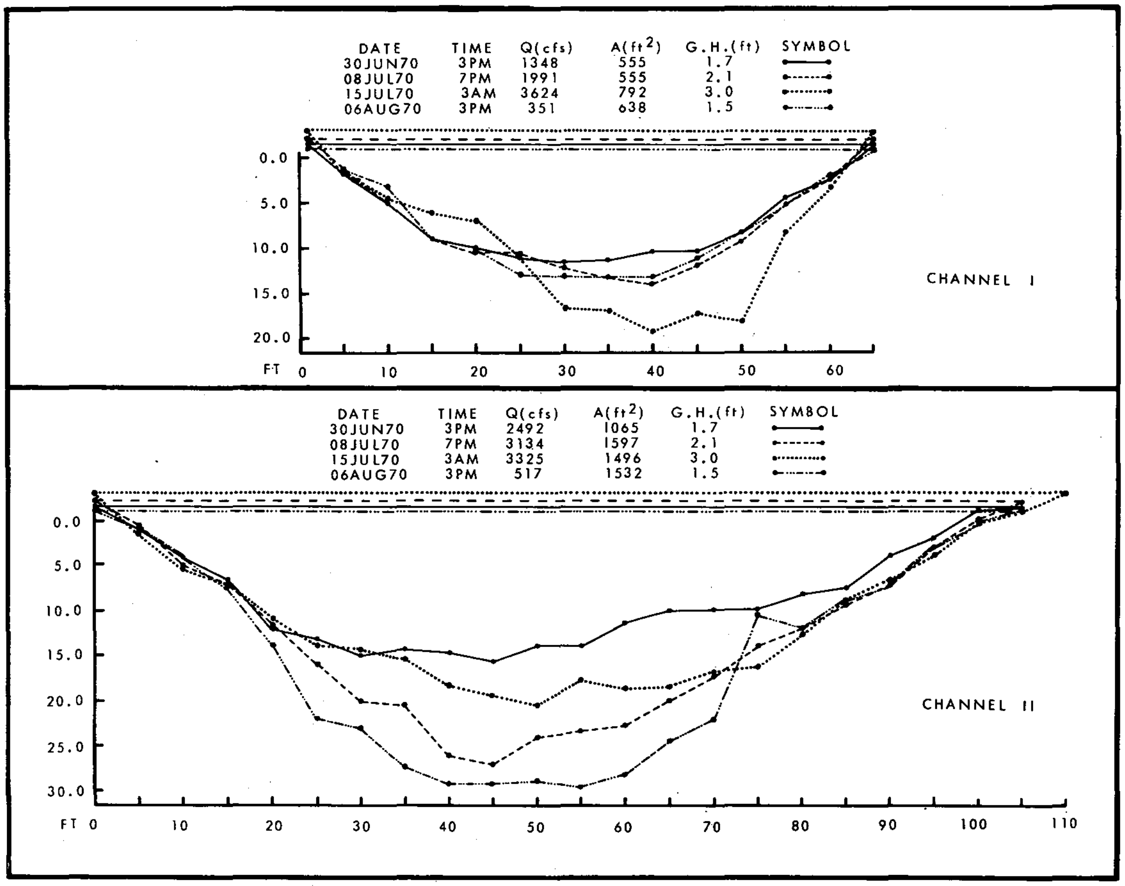

Fig. 2. Cross sections of the two Slims River channels showing depth variations throughout the two months of observation.

TABLE 1. Cross-Sectional Data, June 30 and August 6

CHANNEL I				CHANNEL II			
DIP*		Depth (m)		DIP*		Depth (m)	
(m)	(ft)	June 30	Aug. 6	(m)	(ft)	June 30	Aug. 6
24.7	81	0.00	0.00	12.2	40	0.00	0.00
25.9	85	0.94	0.82	13.7	45	0.73	0.76
27.4	90	1.88	1.28	15.2	50	1.74	1.71
29.0	95	3.08	2.87	16.8	55	2.44	2.62
30.5	100	3.38	3.41	18.3	60	4.08	4.57
32.0	105	3.78	4.30	19.8	65	4.42	5.49
33.5	110	3.96	4.36	21.3	70	4.97	5.94
35.1	115	3.93	4.27	22.9	75	4.82	7.19
36.6	120	3.63	4.30	24.4	80	4.88	7.68
38.1	125	3.63	3.69	25.9	85	5.18	7.68
39.6	130	2.96	2.83	27.4	90	4.60	7.62
41.1	135	1.80	1.98	29.0	95	4.60	7.77
42.7	140	1.16	1.01	30.5	100	3.87	7.07
44.2	145	0.00	0.00	32.0	105	3.44	6.31
				33.5	110	3.41	5.49
				35.1	115	3.41	3.51
				36.6	120	2.87	3.96
				38.1	125	2.71	3.11
				39.6	130	1.58	2.50
				41.1	135	0.98	1.22
				42.7	140	0.06	0.49
				44.2	145	0.00	0.00

*DIP = distance from initial point.

stations. All tributary stations were located above their alluvial fans to eliminate the complexities involved in braided stream measurements. Observations on Vulcan Creek were made 30 m above the head of the fan along a straight 15-m reach. Rod discharge measurements, using a number 622 Price pygmy current meter, were made at these stations.

Stream Geometry

The Slims River is divided into two separate channels by the center pile and foundation of the Alaska Highway bridge, mile 1059.8. Channel I has a width of 19.8 m from the west bank to the center pile and Channel II measures 32.0 m from the center pile to the east bank. The depths of both channels vary greatly (Fig. 2 and Table 1). The deepest point in Channel I varies from 3.3 to 5.8 m and in Channel II from 4.6 to 8.2 m.

Although the cross-sectional area of Channel II is greater than that of Channel I, the discharge of Channel II is often less than that of Channel I (Table 2). Channel I is located near the concave bank just downstream from the axis of bend in a meandering segment of the Slims River. This is the section in the meandering stream that experiences the greatest velocity (Leopold, Wolman, and Miller, 1964, p. 299).

It should be noted that although Channel I has higher velocities and discharge, Channel II experiences greater scouring and filling. Studies of hydraulic geometry have shown that the mean bed elevation at a river cross section depends not only on water discharge, but is related to changes in width, depth, velocity, and sediment load (Leopold, Wolman, and Miller, 1964, p. 230). During periods of low discharge and velocity (in August), the highest discharge shifts to the previously deepened Channel II.

Flow Characteristics

Diurnal discharge variations. Diurnal discharge measurements were taken on different days as the summer progressed. Table 2 summarizes the observations. The data reveal that peak discharges occur between 2100 and 0300 hours; lows occur in early afternoon. Given normal conditions the greatest ablation occurs when solar energy is most abundant; this generally occurs between the hours of 1300 and 1500 mean solar time. The time lag between peak ablation and peak discharge readings can be attributed to the combined length of the glacier ablation surface and the distance between the gauging station and the terminus of the glacier.

The magnitude of discharge during high flow periods is dependent on geomorphic factors such as glacier type, slope and exposure, surface area of the zone of ablation, glacier sediment cover, and drainage of ice-dammed lakes. Climatological factors include radiation absorption, cloud cover, precipitation, and temperature. Of these variables, only the climatological factors are considered in this paper.

It is found that although discharge varies during 24-hour periods, the factors causing these variations are due to the general tendency of the climatological variables during the period of observation rather than to their absolute value during measurement. A trend, to be effective, must extend a period of days prior to the discharge measurement. Exceptions to this are cases of intense precipitation and drainage of ice-dammed lakes which initiate major discharge fluctuations within twelve hours after occurrence.

Intraseasonal variations. Intraseasonal flow variations are given in Table 2. Measurements were taken at the same hours on different days in order to establish a better picture of seasonal progression. Measurements taken at 1400 and 1500 hours show gradual variations in discharge and cross-sectional area for three distinct periods. The first two periods are characterized by gradual increases in area and discharge, each followed by a decline.

The spring warming trend and associated snowmelt is the apparent cause for the increase in discharge for the first period (June 30-July 9). The invasion on July 5 of a storm system with associated precipitation contributed to the high runoff. By July 9, high barometric pressures and decreasing temperatures contributed to a decrease in runoff (Figs. 3 and 4). Subsequently, temperatures remained relatively low for the rest of the summer. This, and the reduction of snow available for melt, accounts for the discharge not reaching its previous level.

The second decrease (from Period II to Period III) was caused by a major shift to the Kaskawulsh Glacier meltwater from the Slims River to the Kaskawulsh River. This phenomenon is extraordinarily important to the regimen of the Slims River and has been observed on at least two other occasions during the 1960's (Melvin Marcus and Philip Lipton, personal communications). The subject is treated in a later section.

Effects of climate on discharge. Because the Slims River is located in a rain shadow on the leeward side of the St. Elias Mountains, the precipitation is low. On days when precipitation occurred, however, slight variations in discharge were recorded. On July 8, for example, there was 22.6 mm of precipitation. Two discharge measurements were taken on this day and one on the following day. Unfortunately, more measurements are not available for this period since the continuous stage recorder malfunctioned. In comparing measurements taken at 2200 hours on July 8 with measurements taken on July 5 at a corresponding time with no precipitation, a July 8 increase in discharge is apparent (Table 2).

Although on July 9, 2.8 mm of precipitation was recorded, reduction in discharge, cross-sectional area, and velocity were measured. Reduced short-wave radiation was received on July 8 and July 9. This, along with lower temperatures, reduced ablation and net water runoff into the Slims River. The amount of precipitation on July 8, however, was more than enough to compensate for the lost glacial meltwater discharge and thereby resulted in a

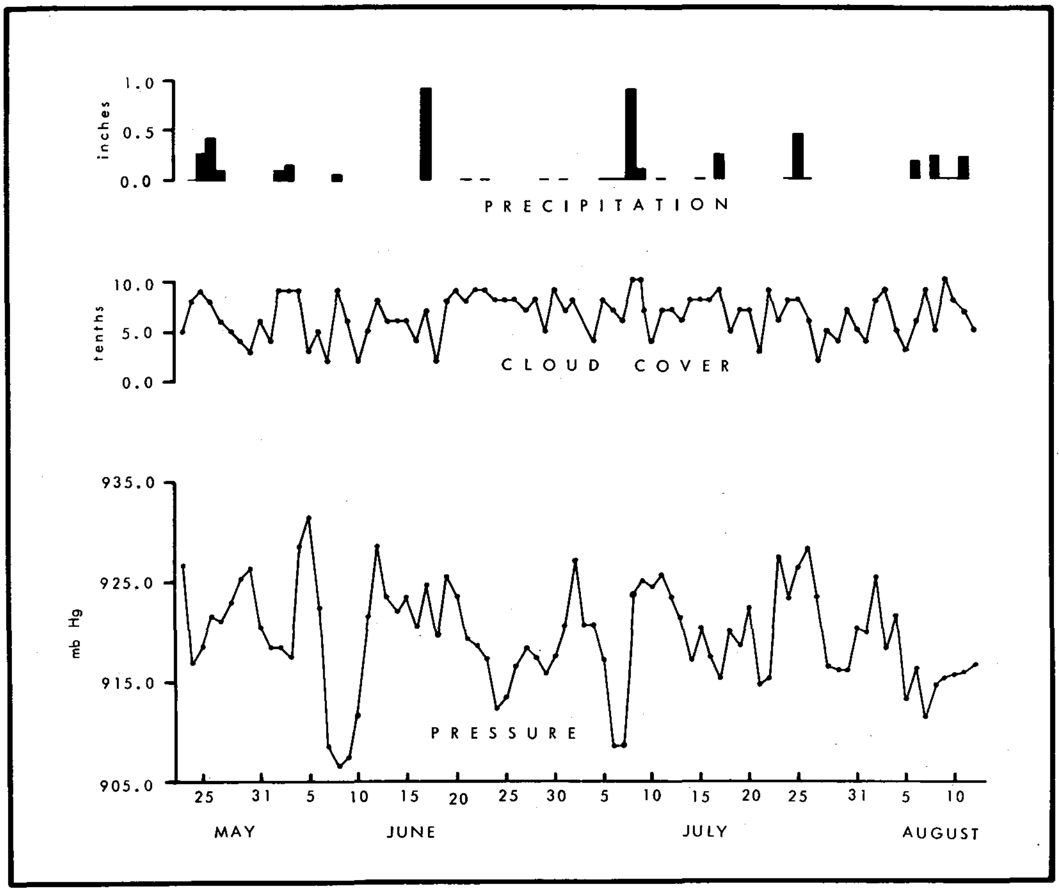

Fig. 3. Mean daily precipitation, cloud cover, and barometric pressure at Kluane Lake meteorological station, May-August 1970.

discharge increase. The amount falling on July 9 was not enough to compensate for reduced glacial melt, and therefore a reduction in discharge was experienced.

With the rise in stage accompanying flood passage through a gauging station, there is an increase in velocity and sheer stress on the stream bed. As a result there is a tendency for scouring to occur during high flow periods. Figure 2 shows the changes in cross section during passage of snowmelt increase for the Slims River. Observations began on June 30, 1970. It is seen that the bed level at this time was about 4.5 m below the gauging datum and the discharge was 38.2 and 70.2 m^3/sec, respectively, for Channels I and II. By July 8, the discharge increased to 68.2 and 92.8 m^3/sec and the bed level dropped 1.5 to 3.0 m. On July 10-11, a noticeable increase in stage (from 0.58 to 0.70 m) was recorded (Table 3). A diurnal variation from 0.64 to

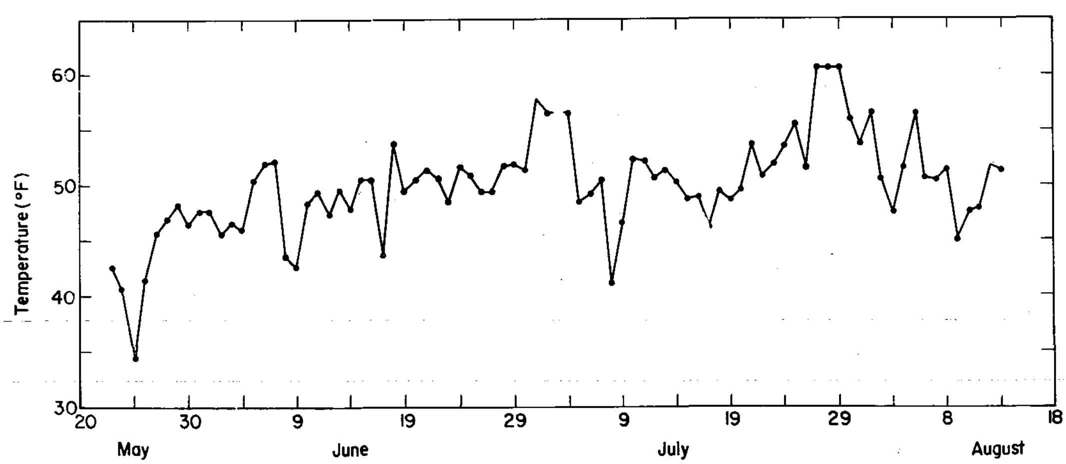

Fig. 4. Mean daily temperature at Kluane Lake meteorological station, May-August 1970.

TABLE 2. Slims River Discharge, Summer 1970

Period	Date	Time (Eastern Yukon Daylight)	Gauge height (m)	Channel I			Channel II			Both channels	
				Cross-section area (m^2)	Velocity (m/sec)	Discharge (m^3/sec)	Cross-section area (m^2)	Velocity (m/sec)	Discharge (m^3/sec)	Cross-section area (m^2)	Discharge (m^3/sec)
I	June										
	30	1500	0.52	51.6	0.74	38.2	98.9	0.71	70.2	150.5	108.4
	July										
	5	1400	0.67	39.9	1.21	48.3	107.9	0.63	68.0	147.8	116.3
	5	1800	0.67	39.9	1.12	44.7	107.9	0.67	71.8	147.8	116.5
	5	2100	0.67	39.9	1.25	49.9	107.9	0.82	88.1	147.8	138.0
	6	0001	0.70	62.3	1.14	71.0	137.6	0.46	63.3	199.9	134.3
	6	0700	0.70	62.3	0.96	59.8	137.6	0.45	62.4	199.9	122.2
	6	1300	0.70	58.2	1.01	58.8	150.2	0.58	87.1	208.4	145.8
	8	1900	0.64	58.1	0.97	56.4	149.6	0.43	64.3	207.7	110.7
	8	2200	0.64	58.1	1.17	68.2	149.6	0.62	92.8	207.7	161.0
	9	1400	0.55	56.1	0.81	45.9	146.4	0.39	57.1	202.5	103.0
II	July										
	15	0300	0.91	73.6	1.39	102.3	139.0	0.68	94.1	212.6	196.4
	19	1500	0.61	56.9	1.05	59.8	140.7	0.68	95.7	197.6	155.5
	19	1800	0.61	56.9	1.14	64.7	101.4	0.47	47.7	158.2	112.4
	19	2100	0.61	56.9	1.28	73.0	101.4	0.51	52.1	158.2	125.1
	20	0001	0.64	64.2	1.19	76.4	99.5	0.55	54.7	163.7	131.1
	20	0300	0.64	58.1	1.22	70.9	97.5	0.54	52.7	155.6	123.6
	20	0900	0.64	58.1	1.00	58.1	97.5	0.47	45.9	155.6	104.0
	30	1400	0.76	56.0	0.65	36.4	151.5	0.50	75.8	207.5	112.2
III	August										
	4	1500	0.49	54.8	0.14	7.7	142.9	0.09	12.9	197.7	20.6
	4	1800	0.49	54.8	0.14	7.4	142.9	0.08	11.1	197.7	18.5
	4	2100	0.49	54.8	0.17	9.4	142.9	0.09	13.0	197.7	22.4
	5	0001	0.49	54.8	0.18	10.1	142.9	0.11	15.9	197.7	26.0
	5	0300	0.49	54.2	0.16	8.7	140.7	0.11	15.5	194.9	24.2
	5	0900	0.49	54.2	0.18	9.6	140.7	0.09	13.4	194.9	23.0
	6	1500	0.46	59.3	0.17	10.1	142.9	0.10	14.3	202.2	24.4
	7	1200	0.43	52.8	0.18	9.5	138.7	0.10	13.9	191.5	23.4
	7	1500	0.43	52.8	0.15	7.7	138.7	0.07	9.6	191.5	17.3
	7	2100	0.43	52.8	0.15	7.7	138.7	0.09	12.6	191.5	20.3
	8	0001	0.43	52.8	0.19	10.0	138.7	0.10	14.3	191.5	24.3
	12	1500	0.37	51.3	0.15	7.7	137.7	0.07	9.6	189.0	17.3

TABLE 3. Slims River Gauge Height

Date	Gauge height in meters			
	0600 hr	1200 hr	1800 hr	Midnight
June 30	0.52	0.52	0.52	0.55
July 1	0.52	0.52	0.52	0.58
2	0.58	–	–	0.61
3	0.61	0.61	0.58	0.70
4	0.70	0.64	0.64	0.76
5	0.73	0.70	0.67	0.70
6	0.70	0.70	0.61	0.70
7	0.70	0.67	0.64	0.67
8	–	–	–	–
9	–	–	0.55	0.58
10	0.58	0.58	0.58	0.67
11	0.70	0.67	0.64	0.70
12	0.73	0.70	0.67	0.73
13	0.73	0.70	0.70	0.79
14	0.82	0.76	0.73	0.76
15	0.76	0.73	0.73	0.76
16	0.76	0.70	0.70	0.73
17	0.76	0.76	0.67	0.70
18	0.67	0.67	0.61	0.64
19	0.67	0.64	0.58	0.64
20	0.61	0.61	0.64	0.64
21	0.64	0.61	0.61	0.67
22	0.67	0.67	0.64	0.67
23	0.67	0.67	0.67	0.70
24	0.73	0.70	0.70	0.76
25	0.79	0.82	0.82	0.91
26	1.01	0.94	–	–
27	–	–	–	–
28	–	–	–	–
29	–	–	–	–
30	–	0.76	0.76	0.76
31	0.73	0.70	0.64	0.64
Aug. 1	0.64	0.61	0.61	0.61
2	0.61	0.58	0.55	0.55
3	0.55	0.55	0.52	0.52
4	0.49	0.49	0.49	0.49
5	0.49	0.49	0.49	0.46
6	0.46	0.46	0.43	0.43
7	0.43	0.43	0.40	0.40
8	0.37	0.40	0.43	0.40
9	0.37	0.40	0.37	0.37
10	0.37	0.37	0.37	0.37
11	0.37	0.37	0.37	0.37
12	0.37	0.37	0.37	0.37
13	0.37	0.37	0.37	0.37
14	0.37	0.37	0.37	0.37

Note: Time is Eastern Yukon Daylight.

0.73 m was maintained until July 13. A peak stage of 0.82 m above the gauge datum was achieved at 0600 hr on July 14, with a low stage of 0.73 m at 1800 hr. This level was maintained until July 17. The peak stage during this period occurred between midnight and 0300 hours and the low stage occurred between 1400 and 1700 hours.

Previous to July 10, a major storm system moved through the area, accompanied by heavy cloud cover and high precipitation. The lowest recorded incoming short-wave radiation occurred during this period. The stage increase on July 10 occurred in conjunction with clearing weather and a jump in insolation. The increase on July 14 was not due to intense insolation or precipitation. It is speculated that a draining ice-dammed lake supplied the Slims River with additional water in sufficient quantities to cause an increase in stage height. A number of small ice-dammed lakes are located along the lateral margin of the Kaskawulsh Glacier. These have been observed to drain in a matter of a few hours (Melvin Marcus, personal communication). One of these lakes apparently drained on July 14 as shown by an increase in stage from 64 to 76 mm within a period of 10 minutes. On July 17, the last day of the high flow period, precipitation created very small stage fluctuations.

The period July 18-20 experienced a reduction in stage. This was in part a response to the limited amount of incoming short-wave radiation (Fig. 5). Cross-sectional area reduction (filling) occurred with the decrease of velocity and discharge.

For the three-day period, July 24 to July 26, a total of 13.7 mm of precipitation fell, with 85% of this total occurring on July 25. Discharge measurements were not taken during this period, although stage records reveal an increase from 0.61 m on July 24 to 1.01 m on July 26. The accumulated precipitation for this period was not enough to cause such an increase in stage. This increase, therefore, must be attributed to some other cause. Temperature and radiation data show that the period in which the peak daily mean temperature occurred coincided with the period that received the greatest short-wave radiation (July 17 through August 1). The resulting increase of snowfield and glacier melting is the apparent cause of the stage increase for this period.

The Shift in Glacier Runoff

Between July 30 and August 4, 1970 the stage of the Slims River dropped from 0.76 to 0.49 m, cross-sectional area decreased from 207.5 to 197.7 m^2, and velocity in the two channels decreased from 0.65 to 0.14 m/sec (Channel I) and 0.50 to 0.09 m/sec (Channel II). This was the result of a major shift of Kaskawulsh Glacier meltwater into channels of the Kaskawulsh River, depriving the Slims River of more than three-quarters of its previous discharge. A gradual drop in stage continued for two weeks after the initial decline (Table 3). This event occurred at the end of the period that experienced the peak mean daily temperature (Fig. 4).

The diurnal discharge variations during August (Period III) were of smaller magnitude than those of the previous period. The August variation pattern more truly represents the diurnal pattern for tributary streams than do the June and July patterns. This is because approximately 50% of the Slims River flow after the shift at the end of July was composed of tributary meltwater, whereas only 10% of its earlier discharge consisted of tributary flow.

Peak flow in August occurred around midnight. This is similar to the discharge pattern in June and July before the drainage shift. However, it was observed that the high flow periods in August were somewhat more extended than high flows in the earlier period. Although

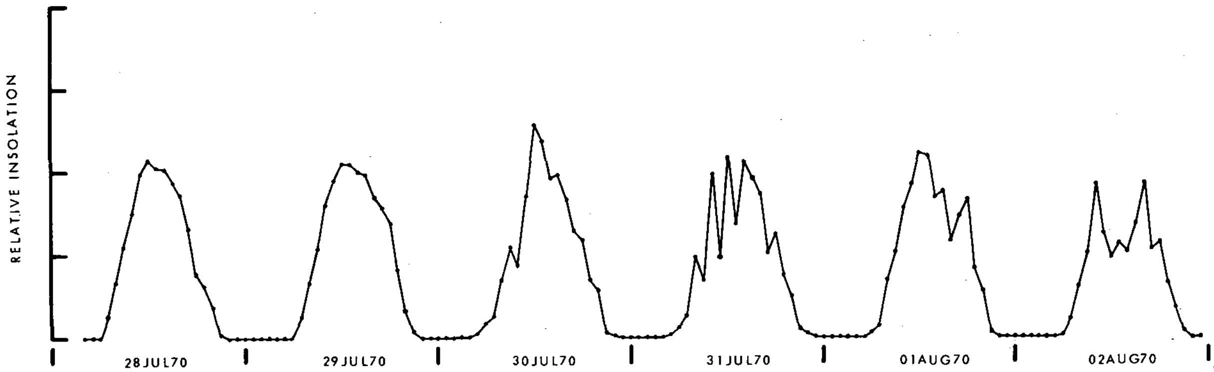

Fig. 5. Insolation at Kluane Lake meteorological station, July 28 through August 2, 1970. Each division on the vertical scale represents 0.5 langleys.

the time of day for peak ablation occurs simultaneously for tributary sources in the watershed, the differences in distances between tributary sources and the Slims River gauging station cause peak meltwater from each of the tributaries to reach the gauging station at different times. This lag effect results in extended high-flow periods that had been previously obscured by the Kaskawulsh Glacier runoff.

Conclusions

The most significant element in the summer 1970 regimen of the Slims River was the shift of Kaskawulsh Glacier meltwater runoff in early August. Deprived of its principal water source, the Slims River made only minimal contributions to Kluane Lake during a normally high flow period. The impact of the drainage shift was accentuated by climatic conditions during the summer and earlier 1969-1970 accumulation season.

The snowfield and glacier budget year 1969-1970 was exceptionally dry along the continental front of the Icefield Ranges (see Marcus, pp. 219–223, this volume). Thus less snow was accumulated to feed tributary streams during the summer ablation period. Most of the névé fields were exhausted by the time the Kaskawulsh Glacier drainage shift occurred. Counteracting this effect was the relative coolness and low insolation in June and July. This depression of incoming energy was insufficient to prevent the melting of the shallow snowfields in the tributary watersheds; however, it did reduce the usual rates of glacier ablation.

The combination of less glacier runoff and low tributary snow storage accounts for appreciably lower Slims River discharge in 1970 than in preceding years. Peak discharge values are, for example, less than half those recorded by Fahnestock in 1965 and Alford in earlier years (Fahnestock, 1969, Table 1). When the Kaskawulsh drainage shift occurred, extremely low discharges followed. Less than 25 m^3/sec flowed past the Slims River bridge in August 1970. In comparison, Fahnestock (1969) accounted for approximately 85 m^3/sec from tributary sources in late July 1965. Thus it seems that regional climatic events can also exert a major influence on year-to-year discharge of the Slims River. Because the Slims is the principal feeder source for Kluane Lake, these effects are inevitably significant to lake level and to shoreline development.

Acknowledgments

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