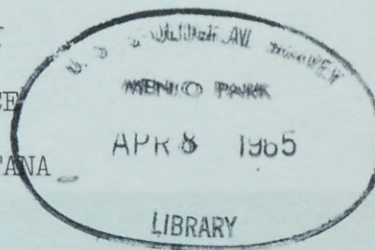


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UNITED STATES
DEPARTMENT OF THE INTERIOR
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U. S. GEOLOGICAL SURVEY
AND
U. S. NATIONAL PARK SERVICE
GLACIER OBSERVATIONS
GLACIER NATIONAL PARK, MONTANA
1964



by
Arthur Johnson

This report is distributed without editorial
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REPORT 15 OPEN FILE

February 1965

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1964 PROGRESS REPORT
GLACIER OBSERVATIONS
GLACIER NATIONAL PARK, MONTANA
INTRODUCTION

This report records the results obtained during the 1964 season in the continuing program of observations on the Grinnell and Sperry Glaciers in Glacier National Park, Montana. This is carried on cooperatively by the Geological Survey, the National Park Service, and the Weather Bureau. It includes the determination of annual changes in the surface elevation of the glaciers by the measurement of profiles; changes during the summer months by the establishment of and observations at ablation stakes; mapping the glacier termini in selected years to record advance or recession; determination of annual movement by the location of marked rocks; the operations of two storage-precipitation gages in the immediate vicinity of the Grinnell Glacier to record annual precipitation; the operation of two gaging stations, one just below the Grinnell Glacier during the summer months and one just below the outlet of Grinnell Lake on a year-round basis; the temperature data near the Grinnell Glacier and temperature and precipitation data at the Sperry Chalet near the Sperry Glacier during the summer months.

The program planned for the 1964 season was only partially accomplished due to adverse weather conditions during the latter one-third of August and much of September. These are described by Dightman

Mont. R. A., Climatological Data, Montana, September 1964,
No. 57, No. 8.

Most noteworthy of the month's August features were the persistent coolness of the last two weeks, and the very wet weather over all but the Northeastern Division beginning the 18th or 17th. The storm of the 19th along the Rocky Mountain section was both very cold and very wet for the season. Snow fell the 19th on most western mountain passes, and heavier snows occurred on northeastern mountains several times after that date. In many cases it was the coldest August in more than 20 years. In the southwest half the coolness of the last two weeks was sufficient to produce one of the coldest Augusts of record at many stations.

On August 31 there was a 3-to 4-inch accumulation of snow in the Grand Staircase.

Temperature data for the months of July, August, and September at West Glacier, Sperry Chalet, and Crinnell Glacier for the years 1961-64 are shown in table 1 along with the mean values at West Glacier based on the 30-year record 1931-1960. The 1961-64 period which as 1960 was the first year records were obtained at the Sperry Chalet. The mean temperatures at West Glacier for July, August, and September were 1.3°, 3.3°, and 4.4°, respectively, below the 30-year mean. On the assumption that conditions at West Glacier are representative for this section of the State, the summer temperatures at the areas of the Crinnell and Sperry Glaciers would also be well appreciably below normal. The mean August temperature at

Chert was more than 5° lower than any previous value during the 1952-54 period of record. The mean August temperature at Grinnell, however, was 5.1° lower than the average of 10 values: 1951, 1952, and 1953-1961.

Precipitation for the July-September period was appreciably above normal. The average total at West Harter for the 3-month period is 4.49 inches, whereas the July-September total for 1964 was 5.9 inches - 1.7 inches above the average amount. Precipitation at the average-precipitation gage at the end of the horse trail to Grinnell Station (Gage No. 1, table 4) totaled 6.0 inches from August 20 to September 16.

Table 1 - Temperature and precipitation data,
July, August, and September, 1960, 1961, 1962, 1963, and 1964

	West Glacier						Sperry Chalet					Grinnell Glacier					
	Mean ^{a/}	1960	1961	1962	1963	1964	1960	1961	1962	1963	1964	1960	1961	1962	1963	1964	
Temperature °F																	
Mean:																	
July	64.0	66.1	64.8	61.3	61.7	62.7	62.7	58.0	52.9	53.5	b/ 56.1	--	--	--	56.1	--	
August	62.0	57.9	66.4	60.6	63.2	56.7	50.7	61.9	51.0	56.6	45.5	51.1	61.7	54.5	57.5	49.1	
September	53.3	52.9	47.5	52.2	57.0	48.9	--	--	--	--	--	--	--	--	--	--	
Maximum:																	
July	--	93	89	88	90	88	84	75	74	76	79	--	--	--	79	--	
August	--	87	96	91	90	81	76	90	82	81	76	81	89	84	82	74	
September	--	80	76	79	89	72	--	--	--	--	--	--	--	--	--	--	
Mean Maximum:																	
July	80.6	84.4	81.1	77.4	77.5	78.7	73.0	67.8	61.2	62.0	66.4	--	--	--	66.4	--	
August	78.5	70.2	84.6	75.5	79.3	70.2	57.6	71.8	58.9	66.5	56.7	59.3	73.6	63.5	68.4	57.3	
September	67.2	67.8	59.7	67.7	71.3	60.3	--	--	--	--	--	--	--	--	--	--	
Minimum:																	
July	--	40	35	33	39	40	39	37	32	35	37	--	--	--	37	--	
August	--	34	39	37	37	32	30	36	31	36	33	31	33	35	38	31	
September	--	26	20	27	32	27	--	--	--	--	--	--	--	--	--	--	
Mean Minimum:																	
July	47.3	47.8	48.5	45.2	45.9	46.7	52.3	48.2	44.5	44.9	45.7	--	--	--	45.5	--	
August	45.5	45.5	48.1	45.7	47.1	43.1	43.7	51.9	43.1	46.7	42.3	42.8	49.8	45.2	--	40.8	
September	39.4	38.0	35.3	36.7	42.7	37.4	--	--	--	--	--	--	--	--	--	--	
Precipitation, inches:																	
July	1.27	0.00	2.20	0.58	1.70	3.50	0.15	3.27	0.76	2.30	2.69	--	--	--	--	--	
August	1.33	2.75	0.76	1.03	0.79	1.51	3.82	3.30	2.41	1.60	3.52	--	--	--	--	--	
September	1.89	0.59	3.33	1.65	1.80	2.71	--	--	--	--	--	--	--	--	--	--	

a/ From 30-year record, 1931-1960.

b/ No record July 1-3.

GRINNELL GLACIER

General

The compilation of maps of the Grinnell Glacier, based on aerial photographs taken in 1950 and 1960, will soon be completed. It is expected that these two maps, mounted on one sheet for easier comparison, will be published by June 1 or earlier. The 1950 map will supersede the map published in 1953 as it will be based on more adequate control than was available at the time of the previous compilation.

Surface Changes

Profiles

Profiles nos. 1 and 2 were remeasured on August 28, 29, and September 15, respectively. Profile no. 3 was not measured. The profiles for 1957, 1962, and 1963 are shown graphically in figure 1. The profiles for 1964 were not drawn in view of the comparatively small change since 1963. The mean elevations for subdivisions of profiles no. 1 and no. 2 are shown in tables 2 and 3 for all years in which measurements were made.

Profile no. 1 in 1964 was below or coincident with the 1963 profile throughout with two minor exceptions where for short distances the 1964 surface was slightly above that in 1963. As indicated in table 1 the most pronounced difference was in the first 400 feet of the profile with maximum difference of as much as 4 feet.

Profile no. 1 also showed a net decrease since 1963 but, as shown in table 2, not as pronounced as at profile no. 2. The most pronounced difference was in the first 400 feet of the profile where maximum differences were from 2 to 3 feet. From station 500 to 8000 the 1964 profile was much the same as the 1963 profile with minor variations both above and below.

Although profile no. 2 was measured 17 days later than profile no. 1 it is not likely that there was any appreciable change in the glacier surface during that period. During the period September 1-15 at West Glacier there were 5 days with measurable precipitation and 3 days with a trace. Precipitation in the glacier area is more frequent than at West Glacier. Also during this period precipitation in the glacier area would most likely have been snow.

The pronounced lowering of profile no. 2 from 1963 to 1964 is of particular interest in view of the summer season being earlier and wetter than normal. This may be partly due to the fact, as indicated on the 1963 report, that temperatures in September 1963 were among the highest on record for that month. The warm 1963 weather pattern in October 1963. Measurements at station 2700 on October 18, 1964, showed changes varying from 1.4 to 1.8 feet with an average of 1.6 feet since September 12, 1963. This could account for much of the difference observed between the 1963 and 1964 profile measurements.

Table 2. - Profile No. 1, Grinnell Glacier, Montana

Mean elevations, feet

Date	Distance from reference point, feet			
	100-500	500-1000	1000-1500	1500-2000
Sept. 14, 1950	6463.5	6510.3	--	--
Aug. 22, 1952	6463.6	6510.0	6529.5	--
Sept. 4, 1953	6460.2	6505.5	6523.6	--
Sept. 27, 1954	6461.1	6505.8	--	--
Sept. 8, 1955	6462.0	6505.1	6523.9	--
Aug. 30, 1956	6462.6	6504.4	6522.9	6515.4
Aug. 13, 1957	6461.6	6504.0	6522.0	6513.6
Sept. 10, 1957	6458.1	6500.7	6518.3	6508.3
Aug. 12, 1958	6454.8	6497.0	6513.2	6503.2
Sept. 14, 1958	6449.2	6491.1	6507.8	6497.6
Aug. 14, 1959	6454.9	6498.3	6514.4	6501.9
Sept. 12, 1959	6452.2	6495.7	6512.2	6500.3
Sept. 2, 1960	6453.0	6495.9	6511.1	6502.3
Sept. 19, 1961	6447.0	6489.2	--	--
Sept. 1, 1962	6446.6	6488.4	6505.0	6496.1
Sept. 12, 1963	6440.6	6484.2	6499.9	6492.4
Aug. 28,29, 1964	6437.3	6482.8	6499.3	6490.8

Table 3. - Profile No. 2, Grinnell Glacier, Montana

Mean elevations, feet

Date	Distance from reference point, feet				
	100-500	500-1000	1000-1500	1500-2000	2000-2500
Sept. 14, 1950	6460.1	6523.3	6564.8	--	--
Aug. 22, 1952	6460.3	6522.6	6563.8	6604.8	--
Sept. 4, 1953	6458.4	6519.5	--	--	--
Sept. 27, 1954	6459.5	6522.0	6564.4	--	--
Sept. 6, 1955	6460.6	6521.8	6563.9	--	--
Aug. 30, 1956	6461.7	6521.6	6563.8	6604.6	6659.9
Aug. 13, 1957	6460.2	6521.3	6563.2	6602.9	6657.2
Sept. 10, 1957	6456.6	6517.9	6560.6	6600.9	6654.9
Aug. 12, 1958	6452.5	6515.2	6557.1	6596.4	6649.6
Sept. 15, 1958	6446.4	6509.8	6551.6	6591.2	6642.7
Aug. 14, 1959	6453.0	6516.2	6558.6	6598.4	6651.6
Sept. 12, 1959	6449.9	6513.6	6555.7	6597.1	6649.5
Sept. 3, 4, 6, 1960	6449.9	6514.1	6555.5	6594.7	6646.7
Sept. 1, 2, 1962	6442.8	6506.4	6547.4	6586.9	6640.7
Sept. 12, 1963	6437.5	6499.2	6541.8	6582.4	6634.4
Sept. 15, 1964	6436.5	6499.1	6541.1	6581.4	--

Ablation

Five ablation stakes were placed on July 21, all in holes drilled to a depth of 9.9 feet, designated as S-1, S-3, S-4, S-7, and S-2. These were placed, by estimation, near stakes of the same number as shown on figure 2. The only stake visible on July 21 from the previous year was S-7. These 5 stakes were intended to provide a record from date of placement until late August or early September when it was planned to drill holes deep enough to serve for a 2-year period. Due to adverse weather conditions only 2 new holes were drilled. The results observed at the various stakes are summarized below:

S-1-64 Ablation July 21 to August 29 was 3.7 feet. Drilled new hole 19.7 feet deep, 2.2 feet downglacier from previous location and placed 4 stakes therein (6-foot stakes). This location was 25 feet upglacier from alignment of profile no. 1 and 200 feet closer to the initial point for the profile, BM 6425, then S-1-63.

S-1-63 No stakes left standing in the ice - all stakes lying on glacier surface. On October 15, 1963, a stake was imbedded 3.5 feet. This would indicate a change of at least 3.5 feet since October 15. This value is uncertain and seems inconsistent with other observations. The position of the stakes was about 75 feet downglacier from the alignment of profile no. 1 and showed a movement of 35 feet since September 1963.

S-2-63 Stake exposed 0.5 foot. Ablation since October 15, 1963, was 1.5 feet. Movement since September 1963 was 30 feet

- 5-3-64 Ablation July 21 to September 15 was 8.4 feet. This location about 350 feet southeast of position of 5-3-63.
- 5-4-64 On September 15 stakes placed on July 21 were all lying on the ice. This would indicate an ablation of more than 9.7 feet since July 21. At about this same location the change from July 9 to September 12, 1963, was more than 13 feet.
- 5-7-64 Ablation July 21 to September 13 was 7.4 feet. Ice was exposed on July 21. Stake placed within a few feet of previously used location. Stake placed in 1963 was found on July 21 and showed a change of only 0.3 foot since October 15, 1963.
- 5-8-64 Ablation July 21 to September 17 was 8.5 feet. This is an estimated value as stake was observed during a severe thunderstorm and reinstorm. This location was within 20 or 30 feet of a previously placed stake, probably placed in 1963 but markings not readable.
- 5-9-64 This stake exposed 1.6 feet on October 15, 1963, and 1.7 feet on September 17, 1963. In other words, glacier surface in this area was essentially the same on September 17, 1964, as on October 15, 1963. This stake showed a movement of almost 60 feet since September 1963.
- 5-9-64 Drilled hole 9.9 feet deep and placed stakes on September 17, 1964. This location was about 5 feet N, 7° W of 1963 location.

Movement

The results of the observations on movement since 1947 are shown on figure 2. In 1964 nine previously marked rocks were relocated: also three ablation stakes located in 1963 were relocated. The 1964 observations were consistent with those in previous years, indicating a movement of 35 to 50 feet per year. The greatest annual movement is in the southern part of the glacier.

One new rock, designated 64-1, was marked and located for future reference. This was in accordance with the recommendation in the 1963 progress report that one or two rocks near the original position of 50-2 but somewhat closer to the headwall be located for future determinations. The 1963 report also recommended that two or three suitable rocks about midway between 59-5 and the headwall be marked and located. This was not accomplished due to the adverse weather conditions. This should therefore be made a part of the 1965 field program.

Recession

The shore line of the lake at the end of the glacier was mapped. There were some minor changes since 1963 but no pronounced variations. No determinations were made of the position of the front or edge of the glacier, but it is believed that there were no significant changes since 1963.

Precipitation and Runoff

The two storage-precipitation gages, established and maintained by the Weather Bureau and the National Park Service, one in 1949 and one in 1955, were continued in operation. The gaging station at the outlet of Grinnell Lake, established in 1947, and the one just below the glacier, established in 1959, were also continued in operation. The results of the observations at the two precipitation gages, along with the runoff at the outlet of Grinnell Lake for corresponding periods, are shown in table 4. The time of observations at the precipitation gages varies from year to year so the observed results are not strictly comparable on an annual basis. However, summer precipitation is usually rather low so the difference between the observed values and the values if observed on the same date each year would not be an appreciable percentage of the total. The amounts listed are therefore close to true annual values. Considering the 16-year period, July 21, 1950, to July 30, 1964, the average at gage no. 1 was 106.6 inches. The average annual runoff at the gaging station below Grinnell Lake for the same period was 96.9 inches, or only 6.7 inches less than the observed precipitation at gage no. 1. This difference is probably low and as the runoff figures are more definite than the precipitation figures it would indicate that the catch at gage no. 1 is somewhat less than the average for the entire basin above the gaging station.

The measured precipitation at gage no. 2, as in previous years, was much greater than at gage no. 1. For the 9 years of record available at both gages the observed values for no. 2 average 50 percent greater than at no. 1. Year-to-year comparisons have varied from a minimum of 34 percent to a maximum of 65 percent. As stated in previous reports the differences in wind patterns, which in turn are influenced by the rugged mountain terrain are, no doubt, primarily responsible for the pronounced difference in catch at the two gages.

The relation between runoff at the gaging station below Grinnell Lake and the measured precipitation at the two gages varies appreciably from year to year. This relationship is strongly influenced by summer temperatures. High summer temperature following a winter of low snowfall could result in a high runoff value. Conversely, a summer of low temperatures could result in a low value of runoff even though the snowfall for the preceding winter had been high.

The gaging station immediately below the glacier (see figure 2) was placed in operation for the season on July 16. The recorder had continued in operation until December 5, following the last inspection on October 15, 1963. The stage discharge relation during portions of this period was affected by ice.

The results obtained thus far at this station are shown in table 1 and compared with the record for the corresponding months at the gaging station below the outlet of Grinnell Lake. The comparisons for the months of August and September are the most significant. The records for July, except for 1960 and 1963, are partly estimated as the

station was not placed in operation until after July 1. Records for October and subsequent months are affected by ice and based to some extent on estimations. For the six seasons of record the runoff at the station below the glacier for August and September averaged 84 and 73 percent respectively of the corresponding values at the station below the outlet of Grinnell Lake. The August ratios varied from 75 to 96 percent and the September ratios from 46 to 86 percent. The lowest September value, 46 percent, occurred in 1954. The area at the gaging station below the glacier is 32 percent of that at the gaging station below the outlet of Grinnell Lake.

As part of the record for the gaging station below the Grinnell Glacier a reference point was established by the small lake at the end of the glacier in September 1962, and the lake stage recorded at the time of each discharge measurement since then. There is a fairly definite relation between the stage of this lake and the discharge at the gaging station as shown by the rating curve in figure 3. This indicates that the conditions underneath the glacier must have remained fairly constant since the sudden 2-foot decrease in lake stage in August 1957.

Table 4. - Precipitation and runoff data in vicinity of Grinnell Glacier

Period	: Number of days	: Precipitation (inches) : : A : : Gage : : No. 1 a/	: B : : Gage : : No. 2 b/	: Percent : : B/A :	: Runoff : : (inches) : : c/
Aug. 27, 1949-July 20, 1950	327	125.1	-		87.0
July 21, 1950-July 24, 1951	369	117.5	-		109.8
July 25, 1951-July 15, 1952	357	108.3	-		90.4
July 16, 1952-July 31, 1953	381	106.9	-		101.9
Aug. 1, 1953-Aug. 5, 1954	370	138.2	-		107.3
Aug. 6, 1954-Aug. 10, 1955	370	109.2	-		105.2
Aug. 11, 1955-Aug. 7, 1956	363	100.7	152.8 d/	152	98.5
Aug. 8, 1956-July 16, 1957	342	88.7	137.2	155	81.4
Aug. 17, 1957-July 17, 1958	365	78.9	115.8	147	84.0
July 18, 1958-Aug. 4, 1959	383	111.6	184.6	165	108.8
Aug. 5, 1959-July 21, 1960	352	107.7	166.6	155	91.6
July 22, 1960-Aug. 8, 1961	383	98.3	131.8	134	106.1
Aug. 9, 1961-July 26, 1962	352	87.1	121.4	139	73.3
July 27, 1962-July 18, 1963	356	101.1	157.6	157	90.7
July 19, 1963-July 30, 1964	378	95.5	144.1	151	108.1

a/ Measured at storage precipitation gage near end of horse trail 0.4 mile from glacier.

b/ Measured at storage precipitation gage about $\frac{1}{2}$ mile southeast of gage described in footnote a/.

c/ Measured at gaging station at outlet of Grinnell Lake.

d/ August 15, 1955 to August 7, 1956.

Table 5. - Runoff Comparisons, Grinnell Creek
at Grinnell Glacier and Grinnell Creek
near Many Glacier (just below outlet
of Grinnell Lake)

Month	Grinnell Creek at Grinnell Glacier		Grinnell Creek near Many Glacier		Percent A/B
	Runoff		Runoff		
	Acre-feet	Inches	Acre-feet	Inches	
	A		B		
July 1959	2460	41.93	4310	23.27	57
August	1700	28.98	2260	12.21	75
September	1230	20.97	2280	12.29	54
October 1959	662	11.29	1500	8.09	44
July 1960	2770	47.30	4180	22.57	66
August	1700	28.98	2080	11.23	82
September	975	16.62	1190	6.44	82
October	351	5.98	599	3.24	59
November 1960	115	1.96	336	1.81	34
July 1961	2570	43.88	3500	18.90	73
August	2260	38.51	2360	12.75	96
September	666	11.35	944	5.10	71
October	1190	20.20	2530	13.65	47
November 1961	51	0.87	403	2.18	13
July 1962	2090	35.57	2820	15.25	74
August	1840	31.37	2170	11.74	85
September	729	12.42	935	5.05	78
October	529	9.01	1050	5.65	50
November	329	5.60	664	3.59	50
December 1962	113	1.93	403	2.18	28
July 1963	2310	39.39	3650	19.72	68
August	1860	31.78	2170	11.71	86
September	1350	23.09	1530	8.25	88
October	567	9.66	696	3.76	82
November 1963	213	3.63	345	1.86	62
July 1964	2790	47.56	4420	23.88	63
August	1550	26.42	2000	10.80	78
September 1964	600	10.22	1300	7.02	46
Drainage Areas					
	Square miles	Acres	Square miles	Acres	
	1.10	704	3.47	2221	

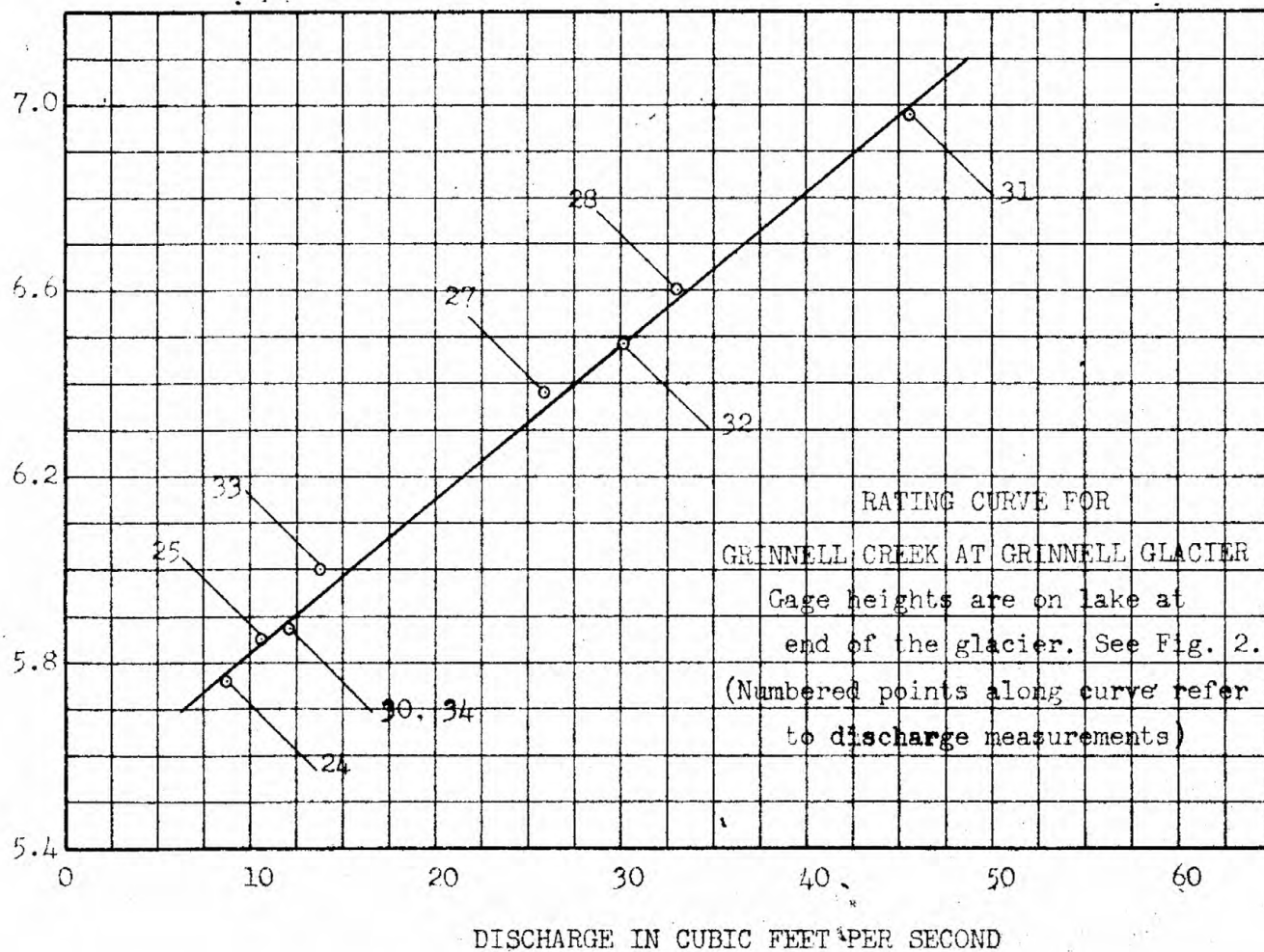


Figure 3

SPERRY GLACIER

General

The only work on the Sperry Glacier during the 1964 season was the placement of 5 ablation stakes on July 23. None of the stakes placed during the 1963 season were visible at that time. The profile measurements, usually made during late August or early September, were not made due to the adverse weather conditions during that period.

Maps of the Sperry Glacier, based on aerial photographs taken in 1950 and 1960, were completed and published in May 1964. The two maps are mounted on a single sheet for ease in comparison. The 1960 map supersedes the previously published (1953) map as it is based on more adequate control than was available at the time of the former compilation.

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