UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

EFFECT OF GLACIER ABLATION ON THE SNETTISHAM HYDROELECTRIC PROJECT, LONG LAKE AND CRATER LAKE BASINS, ALASKA

By Charles E. Sloan, Philip A. Emery, and Diana Fair

with a section on STREAMFLOW RECORDS

By Robert D. Lamke

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Multiply	by	to obtain
inch (in.)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square foot (ft^2)	0.09294	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
acre-foot (acre-ft)	1,233	cubic meter (m^3)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
degree Fahrenheit (°F)	°C=5/9 (°F-32)	degree Celsius (°C)

EFFECT OF GLACIER ABLATION ON THE SNETTISHAM HYDROELECTRIC PROJECT,

LONG LAKE AND CRATER LAKE BASINS, ALASKA

By Charles E. Sloan, Philip A. Emery, and Diana Fair

ABSTRACT

Long Lake basin in the Snettisham Project Area southeast of Juneau, Alaska, yields water used for the production of hydroelectric power. Development of adjacent Crater Lake is planned to increase the Project's generating capacity. Estimates of the hydroelectric potential of the lakes are based on streamflow records which are influenced by glaciers that cover 25 percent of the combined basins. Analysis of streamflow records shows that the quality and extent of records in the area are sufficient to predict flow from the Crater Creek basin with a fairly high degree of confidence. Comparison of aerial photographs indicates that glacier ablation and recession have been continuous since at least 1929. Estimates of ice-volume change from photogrammetric measurements indicate that less than 2.5 percent of the average runoff from the basins of Long and Crater Lakes has been from reduction in glacier-ice storage.

INTRODUCTION

Description and Location of Study Area

Long Lake and Crater Lake basins (fig. 1) are located about 30 mi southeast of Juneau, Alaska in the Tongass National Forest. Long Lake supplies water by means of a lake tap through a tunnel to the Snettisham hydroelectric power plant. The Corps of Engineers, Alaska District, plans to construct an additional lake tap and tunnel from Crater Lake in the near future to add to the capacity of Snettisham in order to meet the growing demand for electricity in the Juneau area.

Long Lake and Crater Lake occupy deep glacially scoured troughs surrounded by steep glacier-clad mountains. The lakes are in the maritime zone characterized by a wet, cool, and cloudy climate. The high divides of their respective basins form a barrier to storms from the North Pacific Ocean, providing an orographic effect and causing unusually high precipitation. Average annual precipitation is about 140 in/yr at the Snettisham power plant at sea level, and is estimated to be 230 in/yr in the Crater Lake drainage basin, only a mile away. Average monthly temperatures range from 25 °F in January to 55 °F in July at Snettisham (U.S. Department of Agriculture, 1979, map No. 30).

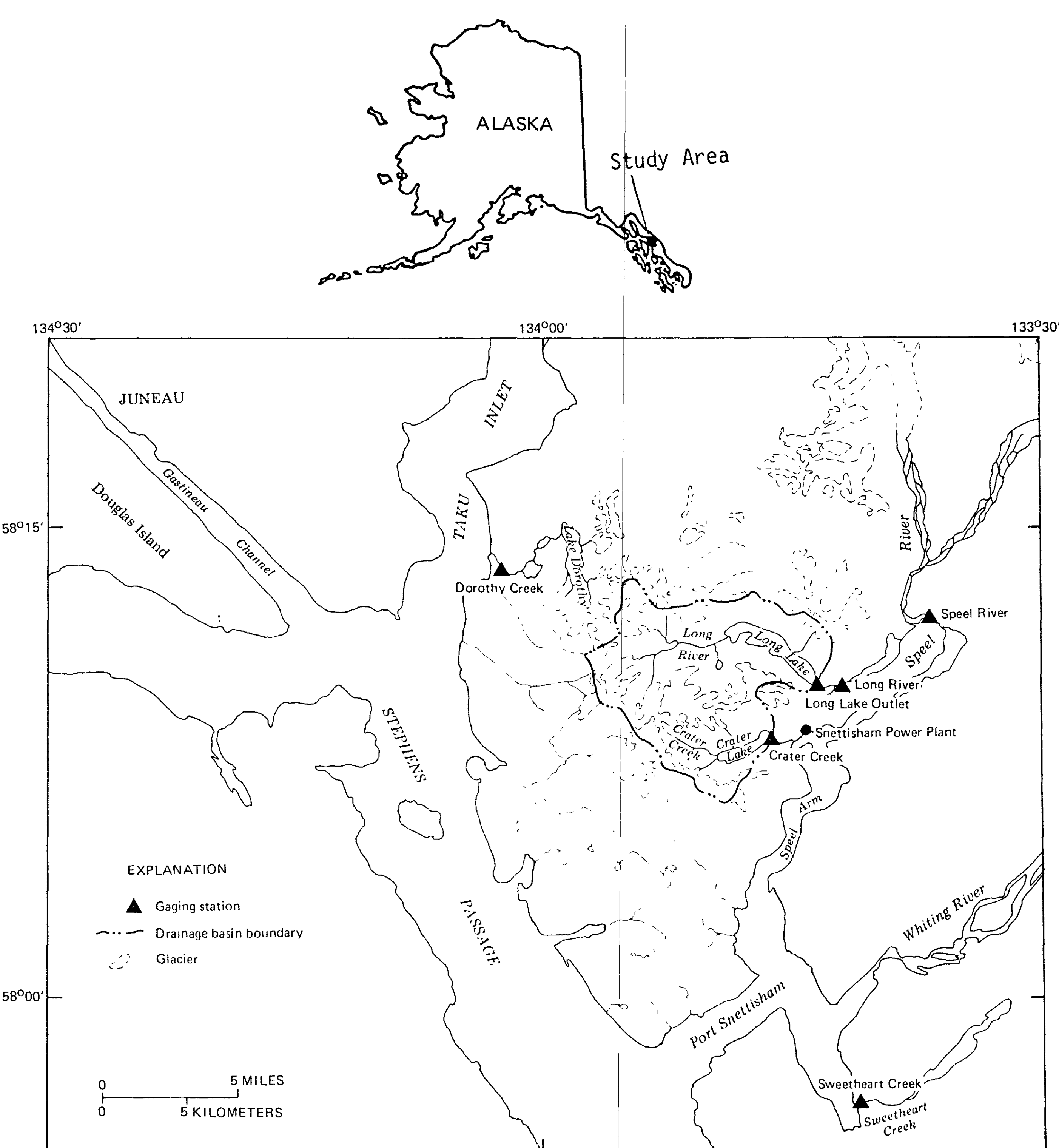

Figure 1.--Location of the study area and gaging stations.

Purpose of the Study

Design of the Snettisham Project is based, in part, on estimates of water yield from the drainage basins of Long and Crater Lakes. Owing to the absence of adequate precipitation data in the area, these estimates of water yield are based on gaging-station records for Crater Creek and Long River and by correlation with other nearby gaging stations. An analysis of the streamflow records to verify their accuracy and validity is described in a section of this report titled Streamflow Records.

Glacier ablation in the basins of Long and Crater Lakes has provided a previously unquantified component of the streamflow. Estimates of the contribution to the flow of Crater Creek and Long River by ice-volume reduction from glacial recession were required to see if this is a significant component. The purpose of this study was to estimate the magnitude of this component of runoff from the area. If ice melt is a large effect, then changes in long-term glacier dynamics and balance would be important to basin yield.

This report presents an analysis of glacier activity in the basins of Long and Crater Lakes and estimates of the contribution to streamflow from change in ice storage.

STUDY METHODS

The changes in glacier-ice volume within Long and Crater Lake basins were estimated by analyzing aerial photography (table 1).

Table 1.--Available aerial photography

Type	Approximate scale	Date
Black and white trimetragon	1:19,000	Summer 1929
Black and white vertical	1:40,000	August 1948
Black and white vertical	1:16,000	July 1962
Black and white vertical	1:30,000	August 1964
Color vertical	1:16,000	August 1977
Color infrared vertical	1:60,000	August 1979
Black and white vertical	1:120,000	August 1979
Color vertical	1:24,000	September 1984

Seasonal snow masked the boundaries of perennial snow and ice in some of the aerial photography. This effect was most pronounced in 1964, when Crater Lake was still ice covered at the time of the photography in August and there was extensive seasonal snow cover throughout the basin. The masking effects of seasonal snow cover were least in the trimetragon photography of 1929, the black and white vertical photography of 1948, and the color photography of September 1984.

Areas of perennial snow and ice and basin boundaries were delineated on the 1948, 1979 color-infrared, and 1984 aerial photographs. A base map (plate I) for compilation of the delineations was prepared by enlarging a portion of the Taku River A-6 quadrangle from a scale of 1:63,360 to 1:31,680. Attempts to transfer information from the photographs to the base map using a Bausch and Lomb ZT-3 Zoom Transfer Scope were unsuccessful because of the extreme distortion in the photographs caused by the high vertical relief in the area. The photogrammetry laboratory of the U.S. Geological Survey, Geologic Division, in Denver, Colorado used a high resolution, PG-2 precision plotting instrument to do the necessary plotting and measurements.

As an initial test of the methodology, delineated areas of snow and ice were transferred from the 1948 and 1979 photography to the base map. Nine selected glacier cross sections (plate I) also were measured on these photographs to determine change in ice thickness. The method used was efficient and practical in its application. A map of snow and ice was prepared from the September 1984 photography to show glacier conditions as they currently exist. Because the 1984 photography had less snow masking than the 1979 photography, the period 1948 to 1984 was selected to quantify the change in ice volume. The snow and ice shown on the 1929 trimetragon photography was also plotted in selected areas using a stereoscope for comparison of snow and ice extent earlier in time.

A reconnaissance field trip of the area was made in August 1984 to field check snow and ice conditions. Photographs of selected glaciers and glacial features (figs. 2-6) were taken on the ground and from a helicopter at the time.

GLACIER ACTIVITY

Accumulation to the valley glaciers in the Long and Crater Lake basins is mainly by snow and ice avalanches down the steep valley sides from the adjacent ridges. Glacier retreat is well exhibited at "New" lake (fig. 2), which was the site of a large continuous glacier in 1929 (see plate I). In 1948 "New" lake was about two-thirds occupied by a glacier that was cut off from its western tributary, "Bench" glacier (fig. 5). "Sideways" glacier (fig. 3) another example of glacier activity, is being supplied asymmetrically along its length by avalanches from the valley side and its movement is controlled by melting along the north side of the valley so that it is flowing at right angles to the axis of the valley. ("Sideways" and "Bench" glaciers, and "New" lake are informal names used in this report to identify unnamed features.)

The terminus of "Bench" glacier is in about the same position in 1984 as it was in 1948 because it rests at the brink of a very steep slope that causes ice-fall avalanches to the lower valley. Snow and ice boundaries in the accumulation areas along the high ridges also have the same approximate positions now as they have had since 1929 because the over-steepened valley walls cause the ice and snow to avalanche from the ridges.

Figure 2.--"New" lake near the upper end of Long Lake, and its tributary glaciers, August 23, 1984.

Figure 3.--"Sideways" glacier in tributary valley to Long River, August 23, 1984.

Figure 4.--A valley glacier at head of Crater Creek, August 23, 1984.

Figure 5.--Snow conditions on "Bench" glacier tributary to "New" lake, August 23, 1984.

Figure 6.--Late summer snow line approximating extent of glacier cover in Long Lake basin, August 23, 1984.

EFFECTS OF GLACIER ABLATION ON RUNOFF

The presence of glaciers in a watershed has several effects on runoff. First, glaciers usually have a moderating effect on runoff extremes. Glacier runoff tends to be greatest during sunny weather, whereas nonglacial runoff tends to be greatest during cloudy weather with rainfall. Basins with a mixture of glacier and nonglacier areas such as Long Lake and Crater Lake basins have lower variability of streamflow because of these opposite trends. Also, glaciers occupy areas with relatively high precipitation and thus are sources of higher runoff. Mayo (1984) estimates that runoff from glacier basins in the maritime regions of Alaska is about twice that of nonglacial basins. Finally, as glaciers grow or shrink, storage changes within the glaciers will affect runoff. The magnitude of the effect is a function of the volume of storage change over the period of time in which the change occurs. The glaciers within Long and Crater Lake basins have undergone recession and reduction in ice volume since they were first photographed from the air in 1929, and probably since the latter part of the 19th century if their behavior was similar to that of most glaciers in southeastern Alaska.

Glacier ice and perennial snow covered about 25 percent of the combined area of Crater Lake and Long Lake basins in September 1984, compared to 30 percent in August 1948 (table 2). This represents a reduction of snow and ice area of 2.19 mi^2 over a span of 36 years. Much of the reduction in area of snow and ice occurred at lower altitudes. The greatest change in ice thickness also occurred at altitudes below 2,500 ft. Above an altitude of about 2,500 ft, there have been comparatively small changes in area and thickness of snow and ice.

Table 2.--Area in square miles measured on maps compiled from aerial photographs

Basin and area	August 1948	September 1984
Crater Lake		
Drainage area	11.27	11.28
Snow and ice	3.19	2.81
Long Lake		
Drainage area	30.11	30.13
Snow and ice	9.38	7.57
Total snow and ice	12.57	10.38

The total area covered by perennial snow and ice in the two basins decreased from 12.57 mi^2 in 1948 to 10.38 mi^2 in 1984. Ice-thickness reduction at the cross sections (plate I) across the ice tongues and valley glaciers averaged about 140 ft during the same time span. Applying a thickness reduction of 140 ft to the area of permanent ice and snow below and altitude of 2,500 ft in 1948 (2.61 mi^2) results in ice loss from 1948 to 1984 equal to 1.12×10^{10} ft^3. The reduction in ice volume above 2,500 ft is estimated to be equal to that below 2,500 ft -- a lesser thickness change, but the area of higher altitude glaciers is about four times as great as that of lower valley glaciers. The loss of this much ice, 2.04×10^{10} ft^3, would contribute an average of 16 ft^3/s to streamflow over the 36-year period (1948-84). This amounts to an average annual yield of about 11,700 acre-ft of water, or a total yield for the period of record, 1948 to 1984, of about 421,000 acre-ft.

The combined average discharge from the two basins is about 650 ft^3/s (see tables 6 and 8 later in the text). The estimated runoff contributed by glacier recession is about 2.5 percent of the total runoff. This estimate is subject to an unquantified error in photogrammetric measurement that is probably small with regard to area, but may be large with regard to thickness. A larger factor of uncertainty rests in the judgment of how accurately the thickness reduction applies to the glacier area. Stereoscopic examination indicates that little thickness change has occurred in the higher altitude glaciers along the divides. The estimate of 2.5 percent of the average flow seems reasonable, and is probably on the large side, but should be considered only a "ballpark" figure. Even if twice the estimated amount of ice was lost, glacial melt would amount to only 5 percent of the average annual flow.

STREAMFLOW RECORDS

by Robert D. Lamke

Introduction

Streamflow data were collected at U.S. Geological Survey station 15038000, Crater Creek near Juneau, from February 1913 to December 1932 (records are fragmentary from January 1921 to June 1927). Streamflow data were collected also at five nearby stream-gaging stations at various times within the 1913-32 period (table 3). Data are also available for some of the sites after 1932. Analysis of the quality of the data collected in the 1913-32 period was made and the discharge records were entered in the U.S. Geological Survey's WATSTORE Daily Values File. These records can be used to estimate discharges to fill in the fragmentary record of Crater Creek during 1913-32 and to extend the Crater Creek record during the 1933-68 period.

Table 3.--Gaging stations and periods of record in the Daily Values File of WATSTORE

Station number	Station name	Period of record in WATSTORE [Water years, or partial (f) water years]
15030000	Sweetheart Creek near Juneau	1915f, 1916, 1917f, 1918f, and 1919-27
15032000	Long Lake Outlet near Juneau	1913f, 1914-15, 1916f
15034000	Long River near Juneau	1916-24, 1927f, 1928-32, 1933f, 1951-73
15036000	Speel River near Juneau	1916f, 1917-18, 1960f, and 1961-75
15038000	Crater Creek near Juneau	1913f, 1914-20, 1921f, 1923f, 1924f, 1927f, 1928-32, 1933f
15040000	Dorothy Creek near Juneau	1930-41, 1942f, 1943, 1944f, 1945-67, 1968f

History

Gaging stations were established in January 1913 at the outlets of Long and Crater Lakes by FPC (Federal Power Commission) applicants. These stations were operated until 1921 by the Speel River Project, in cooperation with the U.S. Geological Survey and U.S. Forest Service. Station 15032000, Long Lake outlet, was moved downstream on November 10, 1915 and established as Station 15034000, Long River. During water years 1914-33, discharge data were sporadically collected at three other sites in the vicinity of Long and Crater Lakes. The USGS established Station 15030000, Sweetheart Creek, in August 1915. Station 15036000, Speel River, was operated from July 1916 to September 1918 by the Speel River Project. The Geological Survey discontinued its participation in the operation of these stations in April 1921. The Forest Service continued to operate these stations at a reduced level of effort for the FPC until 1927.

In 1927, another FPC applicant, George T. Cameron, applied for a power license on Crater and Long Lakes, and the stations on Crater Creek and Long River were operated in conjunction with the Forest Service until 1933. During this same period, Mr. Cameron applied for a power license on Dorothy Creek, a stream adjacent to the Long River drainage. Station 15040000, Dorothy Creek, was established in October 1929. This station was operated by the Forest Service until 1946 and subsequently, through December 1967 by the Geological Survey. The USGS reactivated Stations 15034000, Long River, and 15036000, Speel River, in October 1951 and May 1960, respectively. Discharge data have been published in various reports of the Geological Survey of which Bulletin 836-C, "Surface Water Supply of Southern Alaska, 1909-30" (Henshaw, 1933) and Wate-Supply Paper (WSP) 1372, "Compilation of Records of Quantity and Quality of Surface Waters of Alaska through September 1950" (U.S. Geological Survey, 1957) are of principal interest. Additional information is included in "Report to Federal Power Commission on Water Powers of Southeastern Alaska" (Dort, 1924) and in "Water Powers Southeast Alaska" (Federal Power Commission and U.S. Forest Service, 1947).

Streamflow Analysis

Streamflow records collected prior to 1946 in Alaska are summarized as monthly mean flows in WSP 1372. Prior to publication of WSP 1372, the original data and computations of discharge at all stream-gaging stations in Alaska were reviewed and some computations were revised. If the quality of the record seemed poor and if revision of the discharges was not feasible or practical, the data were not included in WSP 1372. For some stations, discharges were estimated to complete the record for a month or a water year. Streamflow data for these years were published as monthly summaries in WSP 1372.

The WATSTORE system (Hutchinson, 1975) of the Geological Survey will store only daily values and has no provision for entry of monthly summaries. Many daily discharges for years prior to 1946 were never entered into the Daily Values File, although the daily discharge values were available from the original worksheets and from notes made during the 1950 compilation analysis. Some discharges for the periods of missing daily record in the original computations were estimated as totals for the period or the monthly totals were estimated. These totals were estimated by comparison with daily discharge records at nearby stations, if available.

In the process of determining daily flows for periods of missing record, least-squares regression equations for each month were computed using available daily discharge values for the station record being analyzed as a function of the actual record at a nearby station (or stations) (Lamke, 1984, p. 37-45). These equations were then used as guides in estimating daily discharges for the station of interest. If daily discharges during a period of missing record did not vary greatly or if records were not available for the nearby stations, average values for the missing record periods were entered into the WATSTORE Daily Values File. Daily discharge values for all the months shown in table 3 and in WSP 1372 are now stored in WATSTORE.

Discharge values for periods of missing record at Crater Creek were estimated by comparing with records at Long River and conversely, Crater Creek records were used to estimate missing records of daily discharge at Long River. The daily discharges at these stations in adjacent basins have a cross-correlation coefficient of 0.78. For concurrent periods of missing record at Crater Creek and Long River, the record at Sweetheart Creek was used to estimate discharges at those stations. Crater Creek and Long River daily discharges have cross-correlation coefficients of 0.55 and 0.74, respectively, with daily discharges at Sweetheart Creek. The Sweetheart Creek station had less missing record than the stations at Crater Creek and Long River.

A correlation coefficient is a measure of how well the data fit the linear relation between variables. The term "cross" correlation coefficient is used herein to denote that the daily discharges were transformed to remove seasonal trends before the linear relation was calculated (see Lamke, 1984, p. 52-53). The daily flows for each day of the year were standardized by subtracting the mean for that day of the year and dividing by the standard deviation for that day of the year. If the daily discharges were not transformed, the resultant correlation coefficient for Crater Creek and Long River is 0.96 and the resultant correlation coefficients of Crater Creek and Long River with Sweetheart Creek are 0.82 and 0.86, respectively.

Seasonal flow characteristics of Sweetheart Creek differ from those of the other two streams because only one-tenth of the Sweetheart Creek basin is covered by glaciers while glacier ice covers one-fourth of the basins of Crater Creek and Long River. The percentages of lake area in the three basins are comparable. Crater Creek's drainage area is about one-third that of Long River and Sweetheart Creek. Crater Creek has a more rapid runoff response to rainfall, larger values of peak runoff per unit area, and less storage to support low flows than either Sweetheart Creek or Long River.

Correlations between flows at Long River and at Crater Creek versus flows at other nearby stations were also examined. Daily discharge values at Speel River correlate poorly with values for other nearby stations, probably because the drainage area of Speel River is much larger than the other streams.

The cross-correlation coefficients of daily discharges at Crater Creek and Long River with Dorothy Creek are 0.61 and 0.68, respectively. Because of the relatively higher altitudes and the series of lakes in the Dorothy Creek drainage basin, the cross-correlation coefficient improves to 0.71 if daily discharges at Dorothy Creek are compared to the previous day's discharge at Crater Creek. Dorothy and Crater Creeks have only 3 years of concurrent record and the Dorothy Creek gage was moved upstream 0.8 mi in 1937. For these reasons, any extension of the Crater Creek record based on the Dorothy Creek record should be done with caution.

Results

The results of the analysis of the six stations' records are summarized in tabulations of monthly discharges for the period of record (tables 4-9). The months with record shown in these tables for the periods prior to 1950 are the same as those in WSP 1372. Discharges given in this report are generally the same as those shown in WSP 1372, except for minor differences due to rounding procedures. Significant differences in monthly averages are footnoted in the tables for months for which there were arithmetical errors in the original records or an incorrect value was inadvertently shown in WSP 1372.

The tables contain statements about the estimated accuracy of the daily discharge records. "Excellent" means that about 95 percent of the daily discharge values are estimated to be within 5 percent of the true discharge, "good" within 10 percent, and "fair" within 15 percent. "Poor" means that daily discharges have less than "fair" accuracy.

Footnotes are shown in the tables for periods of estimated record. The mean discharges for any month have been designated as "estimated" if data are available for fewer than 6 days during the month, and "partly estimated" if data are available for 6 to 25 days. No footnote is used if fewer than 6 days of record are missing. The accuracy of streamflow records depends on the stability of the stage-discharge relation, on the accuracy (and frequency) of stage observation and measurements of flow, and on the interpretation of those data.

Table 4.--Sweetheart Creek near Juneau (15030000)

(Formerly published as Sweetheart Falls Creek near Juneau and
Sweetheart Falls Creek at Port Snettisham)

LOCATION: (REVISED).--Lat 57°56'35", long 133°40'55", in NE¼NW¼ sec. 25, T.45S., R.73E., City and Borough of Juneau, Hydrologic Unit 19060000, in Tongass National Forest, 300 ft upstream from mouth, 2.0 mi downstream from Lower Sweetheart Lake, and 37 mi southeast of Juneau.

DRAINAGE AREA.--36.8 mi^2, revised.

PERIOD OF RECORD.--August 1915 to March 1917 and June 1918 to September 1927.

GAGE.--Water-stage recorder. Altitude of gage is 50 ft, from topographic map.

AVERAGE DISCHARGE.--10 years (water years 1916, 1919-27), 335 ft^3/s, 125 in/yr, 242,700 acre-feet/yr.

COOPERATION.--Records subsequent to 1920 furnished by U.S. Forest Service.

REMARKS.--Stage-discharge relation permanent, but occasionally affected by ice. Records considered excellent except those for periods of missing record or when discharges are greater than 1,300 ft^3/s, which are fair.

CORRECTIONS.--Minor differences in monthly discharges between those shown herein and those published in WSP 1372 occur because of changes in rounding. However, other monthly and annual discharges have been corrected because of arithmetical errors in the original records; the corrected values are footnoted in the following table.

MONTHLY AND ANNUAL MEAN DISCHARGE, IN CUBIC FEET PER SECOND, BY WATER YEAR

YEAR	OCT	NOV	DEC	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	YEAR
1915	*	*	*	*	*	*	*	*	*	*	a501	a524	-
1916	a412	a168	101	38.3	38.1	a43.0	a156	368	787	a501	a582	636	319
1917	621	194	87.7	56.5	127	a49.5	*	*	*	*	*	*	-
1918	*	*	*	*	*	*	*	*	753	623	666	619	-
1919	376	393	193	256	53.9	42.2	147	342	535	613	577	604	346
1920	489	154	136	a227	93.4	a39.3	50.9	237	622	568	640	418	308
1921	349	275	53.0	a63.0	a95.0	a64.0	115	395	630	a479	428	425	282
1922	598	a163	292	91.0	b30.0	b25.0	b115	419	677	574	552	b525	341
1923	a346	403	116	57.9	a93.6	133	230	475	626	483	362	710	336
1924	b495	a488	203	a67.3	b40.0	b74.4	a115	586	829	774	585	821	424
1925	c458	287	a163	b38.5	b30.0	44.8	84.1	a477	692	637	372	423	311
1926	304	353	491	a574	144	263.0	422	363	451	344	301	238	355
1927	489	b313	a223	b108	b37.3	77.3	97.3	396	767	481	342	592	328
AVERAGE	448	290	187	143	71.0	77.7	153	406	670	552	492	545	335
PERCENT	11.1	7.2	4.6	3.5	1.8	1.9	3.8	10.1	16.6	13.7	12.2	13.5	100

* No data for part or all of the month.
\- No data for part of the year.
a Partly estimated.
b Estimated
c Corrected.

Table 5.--Long Lake Outlet near Juneau (15032000)

(Formerly published as Long Lake Outlet at Port Snettisham)

LOCATION.--Lat 58°10'00", long 133°43'30", in W½SE¼ sec.1, T.43S., R.71E., City and Borough of Juneau, Hydrologic Unit 19060000, in Tongass National Forest, 30 ft upstream from outlet of Long Lake, 1.3 mi upstream from Indian Lake, 5 mi upstream from mouth, and 26 mi southeast of Juneau.

DRAINAGE AREA.--30.2 mi^2.

PERIOD OF RECORD.--February 1913 to October 1916.

GAGE.--Water-stage recorder. Altitude of gage is 800 ft, from topographic map. No gage prior to January 1914.

COOPERATION.--Current-meter and float measurements obtained by Kennedy and Lass, a Federal Power Commission applicant during 1913. Records for 1913-15 furnished by Speel River Project.

REMARKS.--Stage-discharge relation permanent and unaffected by ice. Records for calendar year 1913 are poor and are fair thereafter (except for periods of missing record. Records for 1913 were computed from current-meter and float measurements and short periods were estimated. Minor differences in monthly discharges between those shown herein and those published in WSP 1372 occur because of changes in rounding.

MONTHLY AND ANNUAL MEAN DISCHARGE, IN CUBIC FEET PER SECOND, BY WATER YEAR

YEAR	OCT	NOV	DEC	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	YEAR
1913	*	*	*	*	120	143	131	449	1125	1895	1761	1267	-
1914	1155	375	163	50.0	67.8	83.3	111	338	724	1207	1063	629	501
1915	554	273	121	a96.0	a46.0	a125	202	529	841	1097	1256	1002	515
1916	507	*	*	*	*	*	*	*	*	*	*	*	-
AVERAGE	739	324	142	73.0	78.0	117	148	439	897	1400	1360	966	508
PERCENT	11.1	4.8	2.1	1.1	1.2	1.7	2.2	6.6	13.4	20.9	20.4	14.5	100

* No data for part or all of the month.
\- No data for part of the year.
a Estimated.

Table 6.--Long River near Juneau (15034000)

(Formerly published as Long River below Second Lake, at Port Snettisham)

LOCATION.--Lat 58°10'00", long 133°41'50", in W½SE¼ sec.6, T.43S., R.72E., City and Borough of Juneau, HydrologicUnit 19060000, in Tongass National Forest, on right bank 0.4 mi upstream from Indian Lake, 1 mi down-stream from Long Lake, and 27 mi southeast of Juneau.

DRAINAGE AREA.--32.5 mi^2.

PERIOD OF RECORD.--October 1915 to September 1924, October to December 1926, June 1927 to May 1933, and October 1951 to September 1973.

GAGE.--Water-stage recorder. Altitude of gage is 183 ft, from topographic map. Prior to Oct. 1 1929, at site 600 ft upstream.

AVERAGE DISCHARGE.--31 years (water years 1916-24, 1928-32, 1952-68), 464 ft^3/s, 192 in/yr, 335,900 acre-ft/yr, prior to regulation at Long Lake and diversion for Snettisham Power Project. Discharges for water years 1969-73 are not included in the figure above.

COOPERATION.--Records for 1921-33 furnished by U.S. Forest Service.

REMARKS.--Stage-discharge relation is permanent; generally affected by ice during winter months, December to April. Records for 1916-22 and 1928-33 are good except those for periods of missing record which are fair. Records for 1923-27 are fair. Records good for 1951-73 except those for winter periods and periods of missing record, which are poor. Flow has been regulated at Long Lake since July 16, 1969.

CORRECTIONS.--Minor differences in monthly discharges between those shown herein and those published in WSP 1372 occur because of changes in rounding. However, other monthly and annual discharges have been corrected because of arithmetical errors in the original records; the corrected values are footnoted in the following table.

MONTHLY AND ANNUAL DISCHARGE, IN CUBIC FEET PER SECOND, BY WATER YEAR

YEAR	OCT	NOV	DEC	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	YEAR
1916	b527	a136	a98.2	a49.9	b49.4	b50.0	129	253	864	855	1069	1043	428
1917	605	145	86.4	87.5	a130	51.8	a66.5	335	695	995	1293	923	454
1918	652	660	a94.6	a97.5	b41.0	b26.0	b71.1	a300	744	1065	1219	1062	505
1919	503	343	181	a209	b55.0	b50.0	b125	a309	a545	b864	b1050	b1000	439
1920	a526	a192	b128	b180	94.7	a45.6	b52.0	a235	580	918	1198	641	401
1921	381	262	b60.0	b68.0	b95.0	b69.0	a110	388	715	851	857	c702	381
1922	688	a208	278	b91.0	b30.0	b25.0	ac120	a405	704	913	1046	829	448
1923	476	a523	b104	b62.0	b85.0	b117	ac240	436	724	929	a973	bc1132	485
1924	b563	521	b221	b78.0	b50.0	b90.0	b135	575	910	1169	a1053	b1080	538
1927	a495	ac333	a280	*	*	*	*	*	893	960	965	960	-
1928	347	a126	b49.8	a186	a137	a121	219	554	815	1076	a887	a831	447
1929	525	364	315	a197	42.8	105	83.1	348	826	884	bc841	a754	443
1930	1079	486	a144	b20.0	b45.0	b60.0	a137	317	712	900	1079	820	486
1931	548	560	329.0	152	265	a51.6	a124	a489	961	955	1093	821	530
1932	689	181	a84.4	a55.0	b55.0	b60.0	a108	a357	a757	821	877	975	419
1933	c669	122	a73.6	45.0	40.0	41.2	301	539	*	*	*	*	-
1952	a310	129	a90.9	b38.0	b38.0	b49.7	a150	439	733	1043	958	1103	425
1953	a1124	445	121	a57.8	a67.2	a48.3	a84.8	572	943	a929	1018	881	527
1954	909	143	139	a70.9	a275	b59.7	b50.0	a321	754	816	631	909	424
1955	466	470	366	a88.7	55.0	60.0	67.1	286	670	1036	1145	845	466
1956	338	212	b55	b30.0	b30.0	b40.0	b70.0	489	591	1021	1353	668	410
1957	374	435	a347	a122	b45.0	b35.0	87.1	472	801	830	807	1024	450
1958	587	449	a119	b193	b70.0	b50.0	a150	549	1043	979	989	530	478
1959	748	254	b143	b70.0	b70.0	b60.0	a99.3	427	905	a1210	a895	583	458
1960	566	274	201	a91.1	b54.6	71.8	147	472	705	1044	973	979	466
1961	818	336	292	130	127	100	202	507	1017	1358	1482	719	595
1962	959	205	55.7	183	78.2	91.6	85.1	305	797	901	833	1103	469
1963	592	406	301	145	215	109	a115	b388	740	945	757	1237	497
1964	a751	a127	b218	b125	b108	e69.5	156	312	992	1201	852	489	452
1965	692	272	a204	b226	b119	b125	b109	b250	b691	a868	b877	588	421
1966	924	155	112	a52.2	b45.2	b65.2	a130	383	799	929	1056	1113	483
1967	710	228	55.0	a50.9	b55.4	b45.5	b47.8	a386	1159	865	1099	1322	504
1968	398	362	122	59.1	134	221	110	434	654	902	b673	b1278	446
1969	401	178	92.5	26.4	b24.7	b55.7	112	490	1165	d1197	d1849	d1911	d628
1970	d1017	d200	d21.9	d5.85	d3.9	d8.4	d18.8	d980	d1291	d920	d934	d706	d513
1971	d899	d293	d38.1	d59.5	d42.0	d26.3	d68.1	d282	d724	d990	d1195	d840	d458
1972	d435	d157	ad66	bd17.0	bd10.0	bd19.5	bd12.8	ad96.9	d57.3	d31.6	d603	d769	d190
1973	d615	d150	d63.9	d49.1	bd59.3	bd43.9	bd88.5	d348	d616	d884	d1117	d676	d395
AVERAGE #	622	305	166	103	87.5	70.8	121	401	795	970	997	904	464
PERCENT #	11.2	5.5	3.0	1.9	1.6	1.3	2.2	7.2	14.3	17.5	18.0	16.3	100

* No data for part or all of the month.
\- No data for part of the year.
\# Does not include water years 1969-73.
a Partly estimated.
b Estimated.
c Corrected.
d Flow regulated since July 16, 1969.

Table 7.--Speel River near Juneau (15036000)

(Formerly published as Speel River at Port Snettisham)

LOCATION.--Lat 58°12'10", long 133°36'40", in SE¼NE¼ sec. 27, T.42S., R.72E., City and Borough of Juneau, Hydrologic Unit 19060000, on right bank 0.8 mi downstream from Long River, 8 mi upstream from mouth at Speel Arm of Port Snettisham, and 30 mi southeast of Juneau.

DRAINAGE AREA.--226 mi^2.

PERIOD OF RECORD.--July 1916 to September 1918, May 1960 to September 1975.

GAGE.--Water-stage recorder. Altitude of gage is 140 ft, from topographic map. Prior to September 1918, at site 0.2 mi upstream. May 25 to Sept. 28, 1960, nonrecording gage.

AVERAGE DISCHARGE.--17 years (water years 1917-18, 1961-75), 2,585 ft^3/s, 155 in/yr, 1,873,000 acre-ft/yr; average not corrected for Long Lake diversion.

REMARKS.--Records generally fair (and occasionally good) for entire period except those for periods of no gage-height record and for winter periods, which are poor. Monthly and annual flows not corrected for regulation at Long Lake, since July 16, 1969, and for subsequent diversion from Long River.

CORRECTIONS.--Minor differences in monthly discharges between those shown herein and those published in WSP 1372 occur because of changes in rounding. However, other monthly and annual discharges have been corrected because of arithmetical errors in the original records; the corrected values are footnoted in the following table.

MONTHLY AND ANNUAL MEAN DISCHARGE, IN CUBIC FEET PER SECOND, BY WATER YEAR

YEAR	OCT	NOV	DEC	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	YEAR
1916	*	*	*	*	*	*	*	*	*	a5423	7047	a6220	-
1917	a2890	760	b420	b356	b500	a170	ac347	1697	a3572	a5671	b8500	ac5449	2544
1918	a4226	a3548	b500	a378	c175	ac138	357	1570	b3963	a6281	a7420	b7152	2990
1960	*	*	*	*	*	*	*	*	4062	6320	6306	5596	-
1961	b4117	a1599	1294	551	554	375	891	3477	6576	8488	9951	5271	3620
1962	4565	859	a324	b1002	b511	b430	b418	b1525	4283	5931	5611	6070	2642
1963	3065	1867	1152	b657	b936	b479	b492	b1710	4630	6242	5371	6773	2789
1964	3786	a605	b1104	b669	b619	a419	a772	b1644	b5867	b7103	b5281	b2520	2544
1965	3282	1347	a987	b908	a356	430	568	a1470	b4583	5901	5780	3770	2464
1966	4100	769	441	b171	b154	275	680	1408	3901	b4990	a5475	b5767	2358
1967	b3890	b1003	b214	b207	b201	a175	310	2034	6455	5248	6717	a6825	2785
1968	a1996	b1468	a420	208	582	960	482	2779	3812	5659	a3965	b5717	2341
1969	1309	b514	b286	b68.9	b45.9	a125	530	3114	7006	6645	7173	4876	2656
1970	2813	2204	669	159	368	338	458	2612	5622	5607	6060	5300	2695
1971	a2727	b1143	b148	b237	b259	91.7	279	1659	5034	6337	6441	3990	2377
1972	2089	683	239	105	100	263	183	1902	3709	5775	6596	b3938	2143
1973	a3289	b1020	b351	b261	b323	b227	b439	b1706	b3330	b4887	a6233	4088	2194
1974	2050	317	97.4	71.0	79.8	93.5	310	1925	3856	a5004	a5600	5343	2074
1975	5736	2063	734	264	103	63.4	283	1780	4026	7220	4586	5587	2722
AVERAGE	3290	1281	552	369	345	297	459	2001	4683	6039	6322	5276	2585
PERCENT	10.6	4.1	1.8	1.2	1.1	1.0	1.5	6.5	15.1	19.5	20.5	17.1	100

* No data for all or part of the month.
\- No data for part of the year.
a Partly estimated.
b Estimated.
c Corrected.

Table 8.--Crater Creek near Juneau (15038000)

(Formerly published as Crater Lake Outlet at Port Snettisham)

LOCATION.--Lat 58°08'15", long 133°46'15", in SE¼SE¼ sec. 15, T.43S., R.71E., City and Borough of Juneau Hydrologic Unit 19060000, in Tongass National Forest, 100 ft upstream from outlet of Crater Lake, 1 mi upstream from mouth, and 26 mi southeast of Juneau.

DRAINAGE AREA.--11.4 mi^2.

PERIOD OF RECORD.--February 1913 to December 1920, June to August 1921, October to December 1922, June to September 1923, June to September 1924, and June 1927 to December 1932.

GAGE.--Water-stage recorder. Altitude of gage is 1,010 ft, from topographic map. No gage prior to January 1914. Prior to March 1929, staff gages at the beach at various sites were generally read at frequencies ranging from once a day to once weekly during the winter. Supplemental water-stage recorder at the beach, March 1929 until May 1932, operated during winter periods.

AVERAGE DISCHARGE.--12 years (water years 1914-20, 1928-32) 193 ft^3/s, 230 in/yr, 139,800 acre-ft/yr.

COOPERATION.--Current-meter and float measurements obtained by Kennedy and Lass, a Federal Power Commission applicant, during 1913. Records for 1913-15 furnished by Speel River Project and records for 1921-33 furnished by U.S. Forest Service.

REMARKS.--The stage-discharge relation at the lake outlet is permanent. The records that were computed using this relationship for water years 1916-20, and 1928-32, are good to excellent and those for other periods are fair to good. Records are poor for periods of missing record and calendar year 1913. Because of inaccessible location and deep snow, the gage at the lake could not be operated during the winter. The records for several winter periods were computed using stage-discharge ratings for various sites on the beach. The record obtained at the beach is fair. Prior to December 1929, discharges at the beach were not adjusted for the extra square mile of low-altitude drainage area between the bench and the outlet. Based on the corrections used in water years 1930-32, the annual discharge values for the other years when the gages at the beach were used to compute winter records should be reduced by about 2 percent. This reduction would only lower the average discharge for the period of record from 193 to 190 ft^3/s. No further attempt has been made to adjust the individual monthly means prior to December 1930. The months during which gages at the beach were used are shown in the accompanying table.

CORRECTIONS.--Minor differences in monthly discharges between those shown herein and those published in WSP 1372 occur because of changes in rounding. However, other monthly and annual discharges have been corrected because of arithmetical errors in original records; corrected values are footnoted in the following table.

MONTHLY AND ANNUAL MEAN DISCHARGE, IN CUBIC FEET PER SECOND, BY WATER YEAR

YEAR	OCT	NOV	DEC	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	YEAR
1913	*	*	*	*	47.0	48.3	57.3	203	531	a830	858	491	-
1914	260	a108	38.2	d20.9	d45.0	d36.7	d52.8	144	272	517	409	266	182
1915	313	104	d23.9	d36.1	d17.2	d44.6	d74.0	235	414	497	469	389	219
1916	185	44.9	b33.0	b18.0	b18.0	b19.0	b44.0	b90.0	b370	370	464	b470	178
1917	270	a51.2	ad32.7	d34.9	d44.5	d22.5	d23.8	d142	305	441	539	a361	190
1918	251	b250	b35.0	ad33.2	cd16.4	d12.7	d20.7	ad129	c359	482	591	a411	c217
1919	202	133	65.4	68.4	a14.6	b12.0	b47.0	a118	217	417	a511	b420	187
1920	a209	a66.8	b45.0	b100.0	b35.0	b16.0	b20.0	a53.3	177	406	532	262	161
1921	b140	a91.8	a24.7	*	*	*	*	*	b305	399	a360	*	-
1923	202	158.0	a40.7	*	*	*	*	*	297	452	483	a502	-
1924	*	*	*	*	*	*	*	*	a400	584	566	581	-
1927	*	*	*	*	*	*	*	*	a350	377	357	a352	-
1928	b135	b48.0	b25.0	d88.7	d30.7	d40.0	d42.3	d193	a381	528	a377	343	187
1929	194	113	81.9	ad76.0	ad19.1	d49.4	d29.3	a91.9	382	419	404	347	185
1930	463	222	ae60.2	b4.9	b9.0	b14.7	ae34.4	e104	308	420	484	359	208
1931	225	257	e146	e68.2	ae102	e22.3	e45.3	e211	402	417	474	c357	228
1932	334	ae72.7	e27.5	b20.0	b20.0	b15.0	e32.9	ae105	a284	362	366	429	173
1933	c307	42.2	26.5	*	*	*	*	*	*	*	*	*	-
AVERAGE	246	117	47.1	47.4	32.2	27.2	40.3	140	338	466	485	396	193
PERCENT	10.3	4.9	2.0	2.0	1.4	1.1	1.7	5.9	14.2	19.5	20.4	16.6	100

* No data for part or all of the month.
\- No data for part of the year.
a Partly estimated.
b Estimated.
c Corrected.
d Record obtained at beach for part or all of the month.
e Record obtained at beach for part or all of the month. Correction used to account for difference in drainage areas at the beach and at outlet of Crater Lake.

Table 9.--Dorothy Creek near Juneau (15040000)

(Formerly published as Dorothy Creek at Taku Inlet)

LOCATION.--Lat 58°13'40", long 134°02'25", in NW¼SW¼ sec. 18, T.42S., R.70E., City and Borough of Juneau, Hydrologic Unit 19060000, in Tongass National Forest, on left bank 0.7 mi downstream from Lake Bart, 0.8 mi upstream from mouth at Taku Inlet, 3 mi downstream from Lake Dorothy, and 14 mi southeast of Juneau.

DRAINAGE AREA.--15.2 mi^2.

PERIOD OF RECORD.--October 1929 to October 1941, September 1942 to December 1943, and June 1944 to December 1967.

GAGE.--Water-stage recorder. Altitude of gage is 350 ft, from topographic map. Prior to Sept. 14, 1937, at site 100 ft upstream from mouth.

AVERAGE DISCHARGE.--36 years (water years 1930-41, 1943, and 1945-67), 143 ft^3/s, 128 in/yr, 103,600 acre-ft/yr.

COOPERATION.--Records prior to water year 1946 furnished by U.S. Forest Service and George T. Cameron, a Federal Power Commission applicant.

REMARKS.--The stage-discharge relation is permanent for all practical purposes. Stage-discharge relation affected by ice only in extremely cold weather at the most recent location; however, it was difficult to obtain winter records at the former site. Records good to excellent except those for periods of no gage-height record and winter periods, which are poor to fair.

CORRECTIONS.--Minor differences in monthly discharges between those shown herein and those published in WSP 1372 occur because of changes in rounding. However, other monthly and annual discharges have been corrected because of arithmetical errors in the original records; the corrected values are footnoted in the following table.

MONTHLY AND ANNUAL MEAN DISCHARGES, IN CUBIC FEET PER SECOND, BY WATER YEAR

YEAR	OCT	NOV	DEC	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	YEAR
1930	342	152	64.4	10.6	13.2	20.8	48.1	75.2	197	330	373	283	160
1931	195	194	100	47.0	70.9	a22.3	a34.0	117	329	311	361	300	174
1932	209	64.1	17.0	18.4	a13.9	13.4	26.8	70.6	250	290	281	274	128
1933	214	42.6	a22.6	a19.4	15.6	c10.2	21.8	86.7	150	251	269	184	108
1934	169	158	b32.0	a10.0	12.0	15.0	b20.0	b60.0	b250	277	406	250	139
1935	c210	82.5	53.9	c18.5	b10.0	a18.0	19.1	54.4	a164	396	a304	202	129
1936	202	57.7	a82.5	b18.0	b13.0	a19.0	b35.7	109	317	299	272	357	149
1937	455	284	a113	a25.0	a15.0	22.7	26.1	66.5	298	b250	b300	a340	184
1938	384	85.9	48.9	ac39.4	a37.6	c68.7	21.2	125	205	279	245	391	162
1939	232	74.7	55.0	32.2	23.8	17.4	23.4	72.8	225	342	436	258	150
1940	258	141	74.9	26.7	33.3	16.6	37.4	115	216	320	403	316	164
1941	223	70.0	31.8	17.4	23.4	b23.0	53.6	94.9	251	323	217	148	124
1942	204	*	*	*	*	*	*	*	*	*	*	a287	-
1943	a252	a53.4	31.2	a37.3	b20.0	b40.0	a62.3	95.1	226	383	338	383	161
1944	394	158	110	*	*	*	*	*	a336	298	290	213	-
1945	320	140	84.2	20.2	14.3	24.8	27.1	117	a243	b330	a262	a310	159
1946	398	a47.1	b19.6	b15.3	b14.9	a17.2	a19.0	b140	b282	b266	332	231	149
1947	193	130	26.0	22.9	18.2	85.9	47.4	118	278	266	243	b384	151
1948	b212	a89.7	62.8	36.4	19.2	16.1	13.1	134	320	a304	a273	387	156
1949	162	123	b36.7	b31.0	b15.1	18.5	28.9	116	206	271	307	277	133
1950	172	355	a36.6	b12.9	b10.0	b11.1	13.6	72.5	216	287	250	302	145
1951	97.5	a31.7	14.3	18.5	14.6	16.8	23.4	91.6	280	322	216	227	113
1952	144	45.9	22.1	a17.3	17.4	15.1	22.4	80.5	180	306	289	334	123
1953	327	159.0	32.7	a19.1	b19.5	21.2	22.6	118	249	317	a333	284	159
1954	236	92.5	30.5	25.8	b65.0	b25.4	16.5	64.5	198	241	198	241	120
1955	a135	114.0	72.4	28.4	18.6	19.4	20.3	61.5	167	325	340	253	130
1956	118.0	53.0	21.4	11.3	10.0	14.1	20.2	111	171	302	440	240	127
1957	121	a82.9	b101	59.3	17.3	14.3	17.4	101	240	258	249	288	130
1958	222	170	33.8	39.1	16.0	14.1	23.3	a103	314	282	332	169	144
1959	183	103	37.0	a23.3	a18.0	a23.4	22.7	83.0	249	375	318	160	134
1960	149	72.8	46.5	26.6	18.3	15.5	29.2	103	197	350	309	297	135
1961	259	117	65.1	49.2	33.4	25.4	42.1	120	318	419	465	238	181
1962	272	61.3	22.1	34.5	27.0	18.8	22.7	55.9	241	307	288	358	143
1963	153	164	107	49.7	58.2	37.5	22.7	96.5	204	298	251	380	152
1964	252	49.6	41.6	37.1	29.4	23.2	27.7	51.8	284	359	273	142	131
1965	201	85.7	48.5	58.0	32.3	26.6	22.1	62.5	200	265	225	225	122
1966	238	94.0	31.2	a14.4	b10.9	a16.7	25.9	96.7	236	271	327	319	141
1967	240	79.7	a15.7	13.9	16.1	15.5	13.0	83.9	290	271	334	432	151
1968	145	88.7	44.5	*	*	*	*	*	*	*	*	*	-
AVERAGE	228	110	49.7	27.3	22.6	22.9	27.0	92.3	243	306	307	281	143
PERCENT	13.3	6.4	2.9	1.6	1.3	1.3	1.6	5.4	14.1	17.9	17.9	16.3	100

* No data for part or all of the month.
\- No data for part of the year.
a Partly estimated.
b Estimated.
c Corrected.

CONCLUSIONS

Water supply to the Snettisham hydroelectric project in southeast Alaska near Juneau is assured in spite of glacier recession in the basins of Long and Crater Lakes. Ablation of the glaciers during this century gave rise to speculation that runoff would be significantly reduced as the glaciers became smaller. Comparative studies of aerial photographs of the area spanning the period 1929 to 1984 indicate that glacier recession has been relatively minor. Estimates of ice-volume change based on photogrammetric measurements indicate that less that 2.5 percent of the average runoff in the area has been contributed by loss of glacier-ice storage. Analysis of streamflow records for the area shows that the quality and extent of the data are sufficient to predict flow from the Crater Creek basin with a fairly high degree of confidence.

REFERENCES CITED

Dort, J. C., 1924, Report to the Federal Power Commission on water powers of Southeastern Alaska: Washington, Government Printing Office, 172 p.

Federal Power Commission and U.S. Forest Service, 1947, Water powers Southeast Alaska: Federal Power Commission P-9, 168 p.

Henshaw, F. F., 1933, Surface water supply of Southeastern Alaska, 1909-30: U.S. Geological Survey Bulletin 836-C, p. 137-218.

Hutchinson, N. E., 1975, WATSTORE--National water data storage and retrieval system of the U.S. Geological Survey--User's guide: U.S. Geological Survey Open-File Report 75-426, 791 p.

Lamke, R. D., 1984, Cost-effectiveness of the stream-gaging program in Alaska: U.S. Geological Survey Water-Resources Investigations Report 84-4096, 100 p.

Mayo, Larry R., 1984, Glacier mass balance and runoff research in the U.S.A: Geografiska Annaler, v. 66A, no. 3, p. 215-227.

U.S. Department of Agriculture, 1979, Water-resources atlas: Prepared by Forest Service Region 10, Juneau, Alaska, 7 p.

U.S. Geological Survey, 1957, Compilation of records of quantity and quality of surface waters in Alaska through September 1950: U.S. Geological Survey Water-Supply Paper 1372, 262 p.