

MOUNTAIN VERSUS SEA LEVEL RAINFALL MEASUREMENTS
DURING STORMS AT JUNEAU, ALASKA

By

Thomas D. Murphy and Seymour Schamach^{1/}

Introduction

Southeastern Alaska is composed of a maze of islands and a narrow strip of continental land mass which lie along the northeastern perimeter of the Pacific Ocean. The region is mountainous and extremely glaciated. The topographic relief is in excess of 15,000 feet. Maritime influences prevail over this coastal area, and it is in the path of most storms that cross the Gulf of Alaska. Consequently, the area has little sunshine, generally moderate temperatures, and copious precipitation. Warm winds from the south-southwest carry moisture into this coastal area from the Pacific Ocean.

Precipitation occurs due to frontal systems, orographic effect, or combinations of both. Mean annual precipitation ranges from about 25 inches in the vicinity of Skagway in the northern part of the region to about 150 inches near Ketchikan in the southern part. The available precipitation data have been collected at or near sea level and do not reflect the precipitation increases with altitude which occur over the land mass. Runoff measured at low elevations on streams draining mountainous basins indicated that precipitation at higher elevations is substantially greater than the measured precipitation at sea level. No precipitation data have heretofore been available in southeastern Alaska to indicate the variation of rainfall intensities with altitude in individual storms. Knowledge of these variations is essential in resolving hydrologic problems associated with planning proposed projects in Alaska, such as determination of inflow design floods.

In 1961, the Bureau of Reclamation established a precipitation gage on Mount Juneau at an elevation of 3400 feet to study the orographic influence on precipitation in southeastern Alaska (Figure 1). The gage was a weighing-type recording instrument having a 12-inch capacity. The intensity and duration of the storms proved this gage to be inadequate. For example, in one 4-day storm period it was estimated that 27 inches of rain fell of which only 12 inches could be measured.

To overcome the limitations of the available instrumentation, the Bureau of Reclamation fabricated a rain gage with a capacity of 60 inches, a clock mechanism to run for 60 days unattended, and a means of recording the data on punched tape. This gage was installed in 1963 on Mount Juneau near the 1961 gage site (Figure 1).

To complete the system, a recording gage was required near sea level in proximity to the mountain station. A recording rain gage operated by the Weather Bureau at Juneau Airport, 8 miles northwest of Mount Juneau, was not considered suitable for comparative purposes because precipitation at the airport is estimated to be only 60 percent of that at the city of Juneau. Therefore, con-current with the installation on Mount Juneau, a weighing-type recording gage was installed on the roof of the state capitol building in Juneau (Figure 1). The Weather Bureau operates a nonrecording standard rain gage on the roof of the capitol building adjacent to the Bureau of Reclamation's recording gage.

Thus, the data collection system consists of sea level and mountain rain gage stations relatively close to each other, and separated by approximately 3300 feet of elevation. The sea level station is located in Juneau with the companion mountain gage located about 2.2 air miles northeast of Juneau on Mount Juneau. The purpose of this arrangement was to collect con-current rainfall data to determine the variation of rainfall intensities with altitude under storm conditions.

^{1/} Hydraulic Engineer and Meteorologist, respectively, Office of Chief Engineer, Bureau of Reclamation, Denver, Colorado.

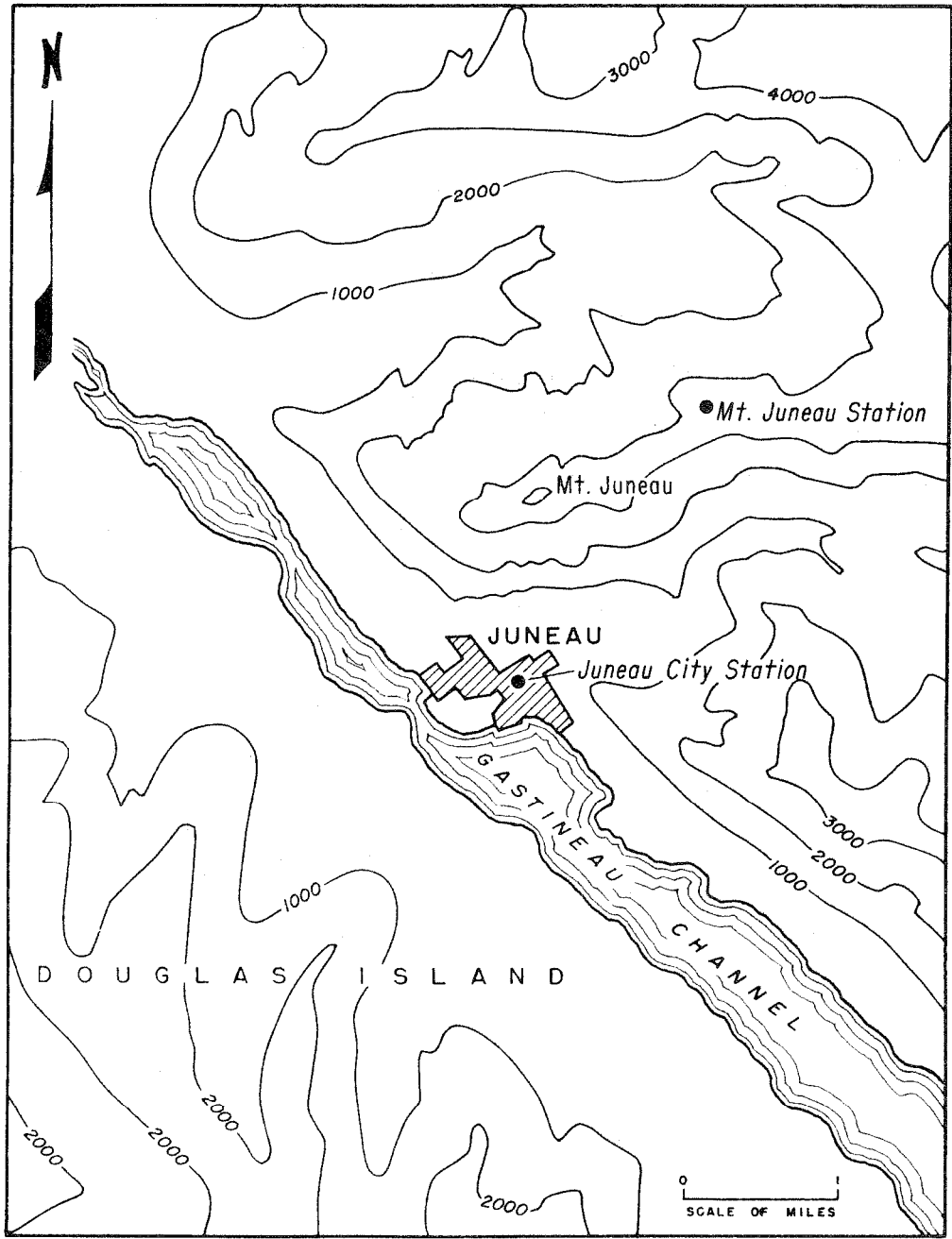


FIGURE I - LOCATION MAP

DESCRIPTION OF INSTRUMENTATION

Mount Juneau Rain Gage

The mountain rain gage was designed specifically for installation on Mount Juneau. The design criteria evolved from experience with the instrumentation of other type gages exposed to adverse conditions at the location and the maintenance necessary to economically operate a remote rain gage station. The basic requirements of the gage were: (1) that the gage storage capacity be capable of containing a storm of maximum probable intensity and duration plus additional capacity to eliminate the necessity of frequent maintenance; (2) that the recording mechanism runs for 60 days without servicing; (3) that the recording unit provides continuous records for periods up to 60 days without being affected by adverse storm conditions; and (4) that the gage installation withstands wind velocities of 150 miles per hour. The rain gage fabricated by the Bureau of Reclamation to meet these requirements is shown in Figure 2A.

The gage is designed so that the collector feeds the catchment of rainfall into a storage tube. A float, tape, and counterweight assembly adjusts with the liquid level in the storage tube and rotates the input shaft of a recording instrument by means of a pulley on the shaft. The recording instrument punches the relative positions of the input shaft into paper tape. Each row of punched holes in the tape represents the total amount of shaft rotation or rainfall accumulation in digital form at the time of punching. All readings are to the nearest tenth of an inch.

The recording instrument requires a 7-1/2 volt power supply which is provided by a dry cell battery. The battery power source is capable of running the recording unit in excess of 60 days of continual unattended operation. The recorder can store 60 days of continuous data on tape at a 15-minute readout interval or 96 readings per day.

The Alter windshield shown in Figure 2A was initially installed with the gage. This shield did not withstand the extreme wind velocities and was replaced in 1964 with a Modified Alter windshield. The modified shield consists of channel-shaped baffles in place of the flat baffles and does not use restraining chains along the bottom of the baffles. Baffle spacing is maintained by the use of spacers on the support ring.

The support tower was designed to withstand high wind velocities. Deck space was provided for the attachment of a windshield assembly and for adequate room to service the recording equipment.

The rain gage installation at the Mount Juneau location is shown in Figure 2B.

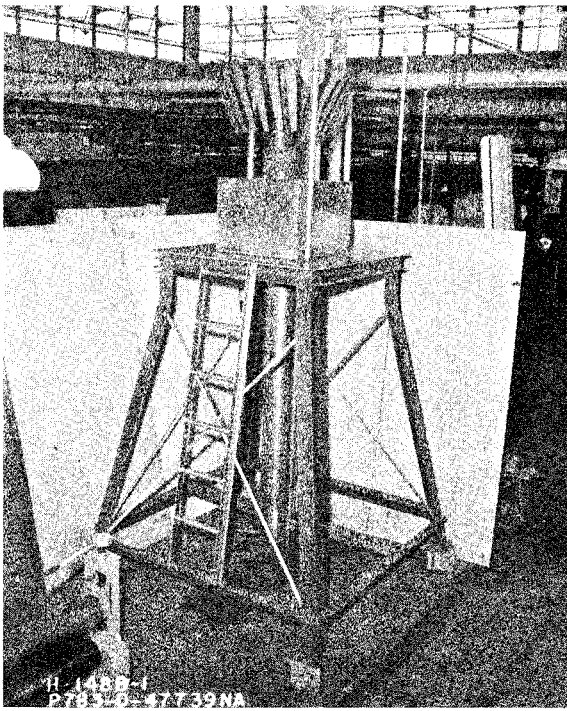
Juneau City Rain Gages

The Bureau of Reclamation's Juneau city station is equipped with a standard weighing-type recorder. The weight of the accumulated precipitation contained in the catch bucket of the recorder moves a pen to record inches of equivalent rainfall on a paper chart. The catch bucket has a nominal capacity of 24 inches of precipitation. An 8-day spring-driven clock movement revolves the chart drum one revolution in 192 hours. A Modified Alter windshield similar to the shield now used at the Mount Juneau gage was initially installed with the gage and is still in use.

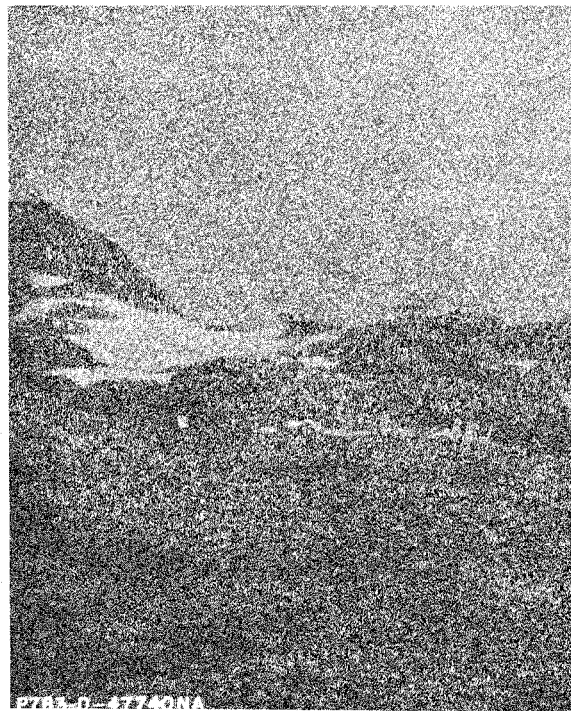
The recording rain gage installation at the Juneau location is shown in Figures 3A and 3B. Figure 3B shows the relationship of the recording gage to the Weather Bureau's non-recording standard gage. Note that the non-recording gage does not use a windshield.

ANALYSIS OF DATA

The collection of rainfall data on Mount Juneau can only be obtained during the period from about June 1 through October because of the limitation of the type of gage employed which is float operated and due to its inaccessibility because of deep snow during the remainder of the year. Con-current recording rainfall data at the city of Juneau and on nearby Mount Juneau were obtained for varying segments of record totaling 123 days during 1963 and 1964. During this period it was possible to examine about six storms of moderate magnitude. The available data were analyzed with the following questions in mind:



A - Rain gage fabricated for location on Mount Juneau.

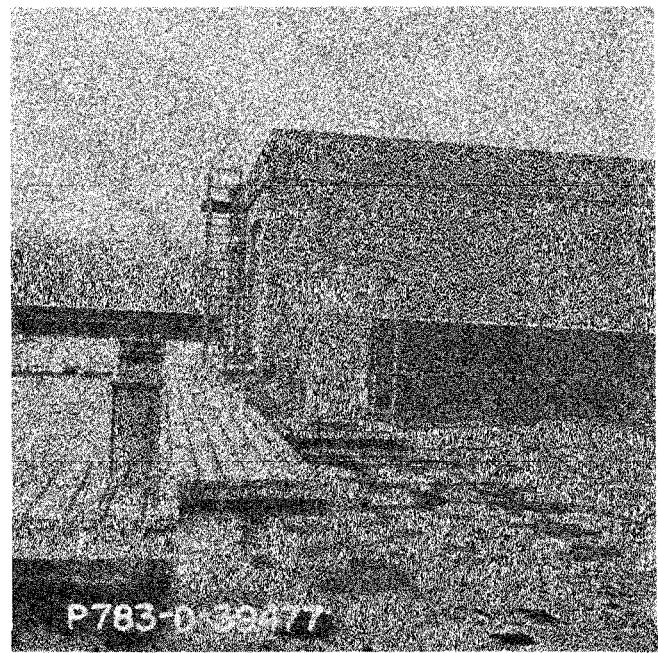


B - View looking east at the rain gage installation on Mount Juneau.

FIGURE 2.



A - View looking northeast at the Bureau of Reclamation's recording rain gage located on the roof of the Alaska State Capitol building in Juneau.



B - View looking west showing the relationship of the Bureau's non-recording standard rain gage (left foreground) and the Bureau of Reclamation's recording rain gage (center) on the roof of the Alaska State Capitol building in Juneau.

FIGURE 3.

1. In general storms producing large amounts of rainfall at the city of Juneau, how much larger are the con-current amounts of rainfall on Mount Juneau?
2. How do the greatest amounts of rainfall recorded on Mount Juneau in a given period compare with the greatest amounts of rainfall at the city of Juneau during the same period?

Con-current Amounts of Rainfall

Table 1 shows the six largest rainfall amounts recorded at the city of Juneau for each duration of 3, 6, 12, and 24 hours as compared with the con-current amounts recorded on Mount Juneau.^{2/} The relationships of these con-current values are plotted in Figure 4. The least squares method was used to determine the line of best fit for each duration. The slopes of these lines indicate the following ratios of Mount Juneau to city of Juneau con-current rainfall amounts:

<u>Duration in hours</u>	<u>Ratio of concurrent rainfall amounts.</u>
3	2.41
6	2.56
12	3.15
24	3.27

Greatest Amounts of Rainfall

Table 2 shows the greatest amount of rainfall on Mount Juneau and at the city of Juneau for each duration of 3, 6, 12 and 24 hours for the 123-day period of con-current recording rainfall data. The ratios of the Mount Juneau values to those at the city of Juneau are:

<u>Duration in hours</u>	<u>Ratio of greatest rainfall amounts</u>
3	3.00
6	3.06
12	3.43
24	3.27

Other Data

The above comparisons refer to the recording gages at Mount Juneau and city of Juneau and no mention has been made of the Weather Bureau's nonrecording standard rain gage located 10 feet from the recording gage at the city of Juneau. A comparison of cumulative precipitation data from these two gages at Juneau indicates the Weather Bureau gage averages about 16 percent higher catch. This relative deficiency of the recording gage was not taken into account in the foregoing comparisons with the Mount Juneau data, because it is considered likely that the catch at Mount Juneau is deficient to an even greater degree because of the much stronger winds existing at the top of the mountain.

The total precipitation measured on Mount Juneau during 5-1/2 months of operation was 128.10 inches as compared with a con-current amount of 40.95 inches at the Weather Bureau's nonrecording gage in the city of Juneau. Applying the resulting ratio of 3.13 to the normal annual precipitation of 90.98 inches at the Weather Bureau gage would produce a normal annual precipitation of at least 285 inches on Mount Juneau.

^{2/} Values of the Mount Juneau gage for durations of less than 3 hours were not considered accurate enough for comparison because the gage records in multiples of tenths of an inch every 15 minutes.

Table 1

Concurrent Amounts of Rainfall
 At Mount Juneau (El 3400 Ft) and City of Juneau (El 71 Ft)
 For Six Largest Events at City of Juneau
 For Each Duration of 3, 6, 12, and 24 Hours
 (Period of record 123 days in 1963 and 1964)

Date	Duration 3 hours		Date	Duration 6 hours		Date	Duration 12 hours		Date	Duration 24 hours	
	City of Juneau Amount (in.)	Mount Juneau Amount (in.)		City of Juneau Amount (in.)	Mount Juneau Amount (in.)		City of Juneau Amount (in.)	Mount Juneau Amount (in.)		City of Juneau Amount (in.)	Mount Juneau Amount (in.)
10-15-63	0.50	1.50	9-29-63	0.78	1.60	9-29-63	0.97	3.20	9-30-63	1.67	5.40
9- 7-63	.43	0.70	10-15-63	.65	2.20	9-30-63	.90	3.50	8-25-64	1.10	3.40
9- 7-63	.42	0.90	9-30-63	.63	2.30	10-10-63	.87	1.30	10- 1-63	0.92	3.70
10- 1-63	.38	0.90	10- 1-63	.55	1.50	10-16-63	.85	2.90	10-16-63	1.07	4.30
9-30-63	.32	1.30	9- 7-63	.55	0.90	8-28-64	.82	3.10	10-10-63	0.87	1.40
10-10-63	.32	0.40	10-10-63	.51	1.00	9- 7-63	.65	1.90	9- 7-63	0.74	2.50

Figure 4

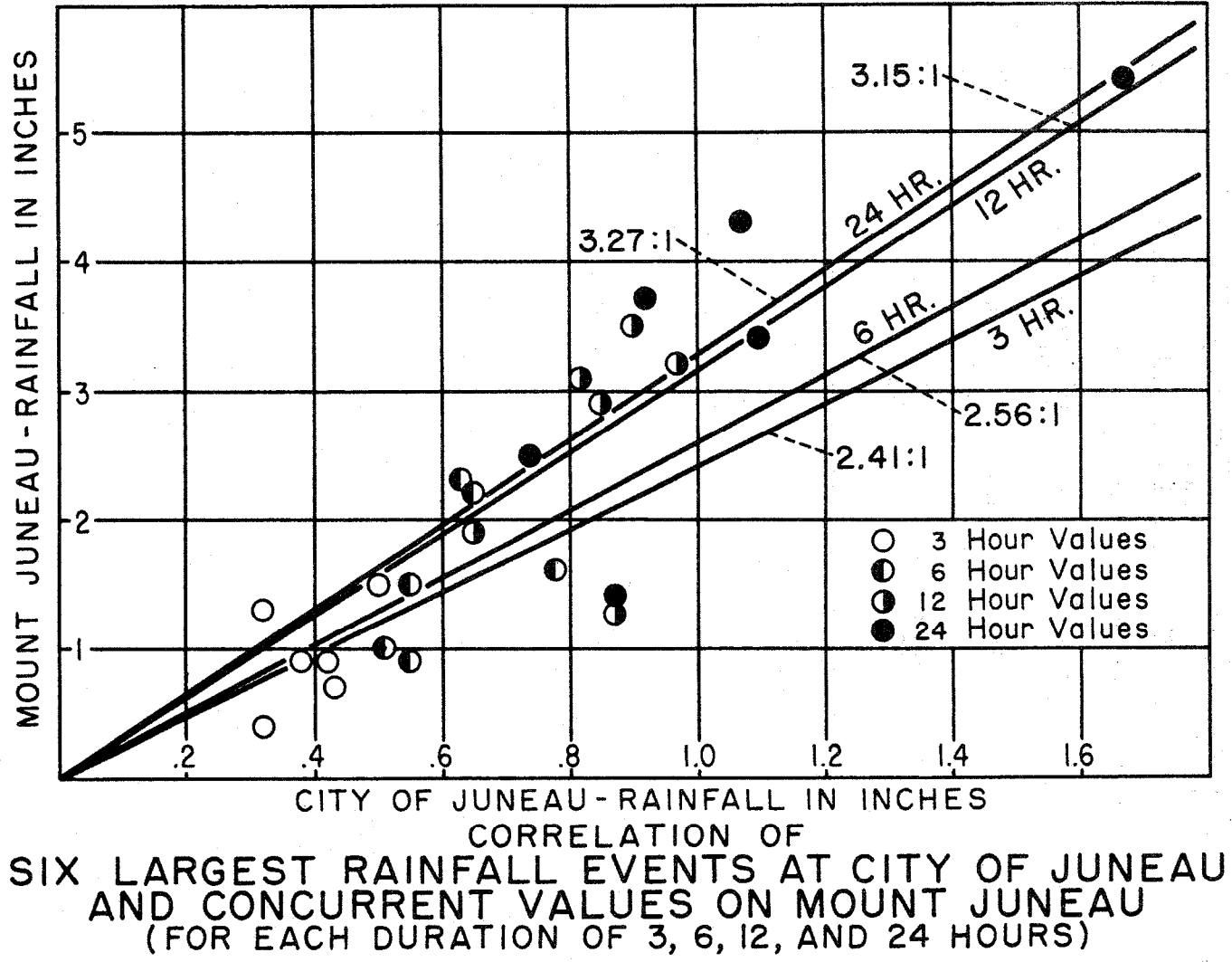


Table 2

Greatest Amounts of Rainfall
On Mount Juneau (E1 3400 Ft) and at City of Juneau (E1 71 Ft)
For Each Duration of 3, 6, 12, and 24 Hours
(During 123 days of concurrent recording data in 1963 and 1964)

Duration (hours)	City of Juneau		Mount Juneau		Ratio Mount Juneau to City
	Amount (in.)	Date	Amount (in.)	Date	
3	0.50	10-15-63	1.50	10-15-63	3.00
6	0.75	9-29-63	2.30	9-29-63 and 9-30-63	3.06
12	1.02	9-29-63	3.50	9-29-63 and 9-30-63	3.43
24	1.65	9-29-63 and 9-30-63	5.40	9-29-63 and 9-30-63	3.27

CONCLUSIONS

Based on recording rainfall records from a limited sample of storms, the following provisional conclusions have been reached:

1. Considering the six largest observed amounts of rainfall at the city of Juneau (near sea level) for each duration of 3, 6, 12 and 24 hours, the con-current amounts of rainfall measured on nearby Mount Juneau at the 3400-foot elevation are on the average 2.41, 2.56, 3.15 and 3.27 times as great, respectively. This indicates that the larger the duration, the greater the ratio.
2. The greatest amount of rainfall recorded on Mount Juneau for each duration of 3, 6, 12, and 24 hours was respectively 3.00, 3.06, 3.43, and 3.27 times the greatest amount recorded at the city of Juneau in the same period of record.
3. The normal annual precipitation on Mount Juneau at elevation 3400 feet is estimated to be at least 285 inches.

ACKNOWLEDGMENT

The authors express their appreciation to Mr. Richard Henry, formerly Hydrologist, District Manager's Office, Bureau of Reclamation, Juneau, Alaska, for his cooperation in providing necessary information and data used in this paper.

LIST OF FIGURES

- Figure 1 Location Map
- Figure 2A Rain Gage Fabricated for Location on Mount Juneau.
- Figure 2B View Looking East at the Rain Gage Installation on Mount Juneau.
- Figure 3A View Looking Northeast at the Bureau of Reclamation's Recording Rain Gage Located on the Roof of the Alaska State Capitol Building in Juneau.
- Figure 3B View Looking West Showing the relationship of the Bureau's Non-recording Standard Rain Gage (left foreground) and the Bureau of Reclamation's Recording Rain Gage (center) on the Roof of the Alaska State Capitol Building in Juneau.
- Figure 4 Six Largest Rainfall Events at City of Juneau and Concurrent Values on Mount Juneau (for each duration of 3, 6, 12, and 24 hours).

LIST OF TABLES

- Table 1 Concurrent Amounts of Rainfall at Mount Juneau (El. 3400 ft.) and City of Juneau (El. 71 ft.) for Six Largest Events at City of Juneau for each Duration of 3, 6, 12, and 24 Hours (Period of record 123 days in 1963 and 1964).
- Table 2 Greatest Amounts of Rainfall on Mount Juneau (El. 3400 ft.) and at City of Juneau (El. 71 ft.) for each Duration of 3, 6, 12, and 24 Hours (during 123 days of concurrent recording data in 1963 and 1964).