TABLE 1.—*Years of deficient rainfall (percent of normal) in order of relative dryness, Island of Puerto Rico, 1899 to 1932*

Section	Mean	1		2		3		4		5	
		Year	Percent	Year	Percent	Year	Percent	Year	Percent	Year	Percent
North	73.5	1930	76	1923	82	1925	84	1907	85	1918	87
East	75.28	1923	72	1907	74	1926	78	1915	85	1930	85
South	42.0	1929	70	1922	72	1930	72	1910	74	1923	75
West	76.9	1930	87	1923	88	1924	88	1919	89	1915	89
Island	67.4	1930	79	1923	80	1907	85	1929	88	1925	88

Section	Mean	6		7		8		9		10	
		Year	Percent	Year	Percent	Year	Percent	Year	Percent	Year	Percent
North		1929	88	1912	89	1926	89	1913	90	1920	90
East		1925	88	1917	89	1918	92	1914	94	1908	94
South		1907	80	1215	80	1917	81	1921	87	1926	88
West		1910	91	1900	91	1929	92	1905	92	1920	92
Island		1926	90	1918	91	1913	91	1921	92	1920	94

Note: Old Spanish records, San Juan, dating from 1868 show a dry period, approximating the record for 65 years in 1873, annual rainfall 68 percent of the normal and in 1893 67 percent of normal. Canovanas record 1890–98 also has record dry period, 1893 68 percent.

TABLE 2.—*Years of greater than normal rainfall (percent of normal) in order of relative depth, Island of Puerto Rico, 1899 to 1932*

Section	Mean	1		2		3		4		5	
		Year	Percent	Year	Percent	Year	Percent	Year	Percent	Year	Percent
North	73.5	1901	134	1927	132	1931	127	1916	122	1915	117
East	75.2	1931	143	1901	137	1909	125	1916	121	1932	121
South	42.0	1909	148	1931	143	1902	138	1916	134	1900	133
West	76.9	1928	129	1901	127	1927	114	1912	114	1931	111
Island	67.4	1901	131	1931	128	1916	121	1927	120	1902	118

Section	Mean	6		7		8		9		10	
		Year	Percent	Year	Percent	Year	Percent	Year	Percent	Year	Percent
North		1902	115	1899	110	1909	108	1932	108	1928	107
East		1902	120	1905	117	1927	117	1904	115	1924	110
South		1912	124	1932	124	1899	123	1928	122	1901	118
West		1932	110	1904	108	1899	108	1914	106	1902	106
Island		1909	116	1928	114	1932	112	1899	110	1911	107

TABLE 3.—*Percentage rainfall departure from normal by sections: Puerto Rico, 1899–1932*

Year	North	East	South	West	Island
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
1899	110	102	123	108	110
1900	101	109	133	91	104
1901	134	137	118	127	131
1902	115	120	138	106	118
1903	94	99	107	103	98
1904	93	115	109	108	101
1905	94	117	108	92	100
1906	96	96	97	98	96
1907	85	74	80	94	85
1908	93	94	96	93	94

TABLE 3.—*Percentage rainfall departure from normal by sections: Puerto Rico, 1899–1932*—Continued

Year	North	East	South	West	Island
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
1909	108	125	148	100	116
1910	101	98	74	91	95
1911	106	107	113	103	107
1912	89	96	124	114	103
1913	90	96	94	93	91
1914	93	94	91	106	89
1915	117	85	90	89	102
1916	122	121	134	97	121
1917	104	89	81	97	97
1918	87	92	93	99	91
1919	98	99	100	89	97
1920	90	96	104	92	94
1921	90	99	87	101	92
1922	91	95	72	106	88
1923	82	72	75	88	80
1924	104	110	111	88	105
1925	84	88	80	106	88
1926	89	78	88	99	90
1927	132	117	104	114	120
1928	107	109	122	129	114
1929	88	105	70	92	88
1930	76	85	72	87	79
1931	127	143	143	111	128
1932	108	121	124	110	112

TABLE 4.—*Percentage of the average precipitation in the 3 years of deficient and the 3 years of greatest precipitation in the groups of States, no. 1 to 4, and in Puerto Rico*

Groups	Least			Greatest			Range
	1	2	3	1	2	3	
No. 1	59	65	67	167	149	136	108
No. 2	64	72	77	143	133	129	79
No. 3	74	77	82	136	126	123	62
No. 4	78	83	84	127	120	116	49
Puerto Rico	79	80	85	131	128	121	52

TABLE 5.—*Comparative data on the rainfall in Puerto Rico during 1932, by sections, inches rainfall, and percent of normal*

	North		East		South		West		Island	
	Inches	*Percent*	*Inches*	*Percent*	*Inches*	*Percent*	*Inches*	*Percent*	*Inches*	*Percent*
January	6.36	131	4.62	121	1.02	71	2.60	111	4.26	121
February	.67	18	1.44	42	.48	26	.70	28	.71	24
March	2.71	66	3.40	103	1.63	97	2.29	63	2.44	72
April	4.34	87	6.89	181	2.60	107	5.04	85	4.30	97
May	11.70	175	10.02	149	10.60	283	14.23	180	11.96	188
June	8.26	145	10.65	148	6.98	190	5.02	68	7.58	134
July	5.90	81	11.13	153	2.25	60	8.79	107	6.07	92
August	6.46	94	9.17	128	7.58	164	11.76	129	7.96	117
September	11.57	155	9.58	104	6.69	118	17.11	182	11.28	149
October	7.21	103	9.63	102	4.20	65	9.75	100	7.21	94
November	6.80	84	7.82	88	4.85	104	5.11	69	6.11	85
December	6.38	104	6.46	131	3.14	174	2.23	68	4.83	109
Year	78.36	108	90.81	121	52.02	124	84.63	110	74.71	112

STORM TYPES AND RESULTANT PRECIPITATION IN THE SAN DIEGO AREA

DEAN BLAKE

[Weather Bureau, San Diego, Calif., 1933]

At the request of engineers and water conservationists of southern California, who are not satisfied with the rate and intensity alone of the rainfall but wish also to know something of its origin, tables were prepared which segregated storms in San Diego County into four groups according to their genesis. Weather maps of the north Pacific Ocean are available in San Diego for only the last 5 years, hence the data could not be carried back farther than 1929.

From available weather-reporting stations in San Diego County, 3 were selected, San Diego, 87 feet elevation, Cuyamaca, 4,677; and Warner Springs, 3,165. The criteria were length and dependability of record, elevation, and surrounding topography. San Diego was considered as representative of the coastal, Cuyamaca the mountain, and Warner Springs the intermediate rainfall regimes. Warner Springs in particular is well located for a rainfall study, for it is surrounded in all directions by moderately high mountains, and the effects of the dynamical or ascensional cooling of the rain-bearing winds here are nearly equal, regardless of the direction from which they come. On the other hand, the rain gage at Cuyamaca is exposed in a draw, and records very heavy rains when winds are from the southwest quadrant. In fact, it is located at one of the rainy spots of southern California.

From data of the three stations, three tables have been compiled: (1) The total number of days and amounts of rain from storms of each type; (2) the number of days, amounts and percentages of precipitation for each of the five seasons produced by storms of each type; (3) seasonal precipitation and departures from the mean. There is little difference in the number of rainy days at the stations, so the figures for San Diego are accepted as representative of all three. Other tables were prepared, among which was one showing the number of days with four arbitrarily fixed amounts. This afforded an index to the rainfall rate.

At the outset it was realized that the place of origin of many of the storms would be in doubt, lack of data preventing us from tracing their source or their movements in the early stages of their careers.

Four broadly generalized types or groups were immediately apparent. The first, designated the north Pacific type, includes all cases of low-pressure areas that approached the mainland from the Pacific Ocean north of San Francisco. The second, designated the south Pacific type, comprises all disturbances that came from the ocean south of San Francisco and north of the Tropic of Cancer. The third, designated the interior type, contains all active depressions that originated or developed over the plateau regions, the Colorado Valley, or the California interior. (An appreciable number of these were secondary disturbances to parent LOWS passing eastward near the Canadian border or through the Canadian Northwest.) The fourth, designated the Mexican type, consists of the tropical disturbances that occasionally moved northward to southern California from the west coast of Mexico, and also, not logically but as a matter of convenience, the few sporadic thunderstorms of the warmer months, known locally as "Sonoras."[1]

NORTH PACIFIC TYPE

This group ties in naturally with the recognized and fundamental types set forth by Thomas R. Reed.[2] As he states, his westerly types, which may be associated with the north Pacific type of this paper, and have the same characteristics, "run well to the south on many occasions" and when their paths are more southerly than usual, southern California is found within the precipitation area. This type is responsible for most of the rainy days, the largest falls, and the greatest number of days of any given intensity.

The general trend of norther storm tracks is southward with the approach of winter, but not until November is southern California within the precipitation area. The amount of precipitation and the number of days with rain increase until the maximum is reached in January, after which, with the return northward of the storm paths, both become less and end completely in May. It is worthy of note that days with rain are about equally frequent from February to May, while the catch falls off materially, denoting a decrease in energy rather than in the number of storms. This type appears to be the most dependable of the four. Large excesses and deficiencies in seasonal totals seem to be due more often to an unusual number of storms of the other types rather than to wide variations in the north Pacific group.

SOUTH PACIFIC TYPE

Apropos of his easterly type, Reed states:

> LOWS of like origin sometimes form over the southern California coast on the tropical side of an overrunning southwest high, or they may lodge there after running south along the eastern flank of a north-south HIGH which, after their passage, presses inland over the Pacific Northwest in a quasi-enveloping movement.

LOWS of this nature are responsible in the main for storms classified under the south Pacific type. At times, though, disturbances that are associated with Reed's southerly type take the form of a trough, and lie near enough to the coast to bring San Diego County under the domination of the secondary depressions that form in the lower end of the trough. This group is also classified under the south Pacific type.

The appearance of storms in this area is haphazard, and wide variations in number and rainfall amounts are found, but apparently conditions are most favorable for their formation during February, as they have proved to be the best rain producers during that month of any of the four types. They develop from November to March, move quickly, travel singly, and produce warm and not infrequently very heavy rains, particularly at stations where the mountain ranges parallel the coast.

INTERIOR TYPE

By far, the most interesting and complicated disturbances are of the interior type. Storms of this nature correspond to those which are the result of Reed's northerly type. While their breeding place appears to be the Great Basin most of the time, nevertheless they develop anywhere over the far western interior, Their growth and subsequent movements are erratic and hard to predict with any great degree of accuracy. Before the last decade the temptation was to ignore them as potential heavy rain producers. The tables show that in San Diego County 32 percent of the total number of rainy days and about 30 percent of the precipitation resulted from storms assignable to this type, and that 24-hour amounts greater than an inch were frequent. Because of the large high pressure area over the ocean off the coast of California at the time these LOWS form, too little weight usually is given to the drop in barometer that precedes their genesis, and before we are aware of it, general, and in many cases, heavy rain has begun over all of southern California. While interior storms are most active from February to May, they may form in any month of the year. During the last 5 years, however, none was tabulated during July or January.

MEXICAN TYPE

The fourth and last, the Mexican type, is responsible for only a small percent of the whole number, but the amounts of their precipitation at Cuyamaca and Warner Springs are much greater than at San Diego, and add materially to the season's totals. Only occasionally do they cross San Diego County. They originate in the tropics south and west of Baja California, and move northward, and only through chance radio reports from ships that happen to be in their path are we able to follow them. Occurring at a time when fruits and grapes are ripening or drying, they always are most unwelcome. Torrential rains often are the result, at which times damage to property is great, railways and highways suffering heavily. An example of particularly destructive rains of this type was the storm in the Tehachipi Mountains of September 28 to October 1, 1932, where the loss of life was 15 and the damage was estimated to be over $1,000,000.[3] Fortunately they are limited to the period from August to November, and years have passed without one of serious proportions reaching this part of the State.

[1] Sonora Storms, D. Blake. Monthly Weather Review, November 1923.

[2] Weather types of the northeast Pacific Ocean as related to the weather of the north Pacific coast. T. R. Reed. MO. WEA. REVIEW, December 1932, vol. 60, pp. 246–252.

[3] Destructive rains in the Tehachipi Mountains, Kern County, Calif. M. Sprague, in October 1932 Climatological Data, California section.

TABLE 1.—*Total number of days with rain from each type at San Diego, and total amounts from each type at San Diego, Cuyamaca, Warner Springs, during the last five seasons*

Month	North Pacific				South Pacific				Interior				Mexican			
	San Diego		Cuyamaca	Warner Springs	San Diego		Cuyamaca	Warner Springs	San Diego		Cuyamaca	Warner Springs	San Diego		Cuyamaca	Warner Springs
	Days	Amounts	Amounts	Amounts	Days	Amounts	Amounts	Amounts	Days	Amounts	Amounts	Amounts	Days	Amounts	Amounts	Amounts
July	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.24	0.38
August	0	0	0	0	0	0	0	0	4	.08	0	0	2	.03	3.03	5.17
September	0	0	0	0	0	0	0	0	1	.04	.05	.01	2	.22	5.30	1.94
October	0	0	0	0	0	0	0	0	3	.41	3.52	2.01	2	1.10	5.52	2.95
November	10	1.66	5.26	2.02	3	.37	1.03	.51	6	1.11	6.35	2.60	2	.78	.63	.41
December	17	5.85	22.97	6.78	5	1.68	2.97	1.52	3	.85	7.72	3.21	0	0	0	0
January	39	11.83	30.04	11.40	7	2.46	13.63	6.08	0	0	0	0	0	0	0	0
February	11	2.05	13.45	4.62	11	5.77	13.68	8.40	10	3.26	11.04	6.69	0	0	0	0
March	9	1.40	5.29	1.87	3	.34	2.09	.51	14	3.11	7.65	3.99	0	0	0	0
April	10	.96	7.99	3.32	0	0	0	0	13	4.30	12.07	4.03	0	0	0	0
May	10	.84	5.51	1.35	0	0	0	0	10	1.80	9.43	5.26	0	0	0	0
June	0	0	0	0	0	0	0	0	4	.12	.16	.06	0	0	.08	0
Total	106	24.59	90.51	31.36	29	10.62	33.40	17.02	68	15.08	57.99	27.86	8	2.13	15.80	10.85
Percent	50	47	46	36	14	20	17	20	32	29	29	32	4	4	8	12

TABLE 2.—*Total number of days with rain and percentages at San Diego, and total amounts and percentages from each type by seasons at San Diego, Cuyamaca, and Warner Springs*

Season	San Diego				Cuyamaca		Warner Springs	
	Days	Percent	Amounts	Percent	Amounts	Percent	Amounts	Percent
NORTH PACIFIC								
1928–29	25	60	5.12	73	25.05	70	8.78	71
1929–30	19	43	4.01	37	15.34	37	5.09	25
1930–31	14	39	4.47	41	8.48	32	3.25	27
1931–32	26	53	6.86	52	30.23	57	8.86	36
1932–33	22	55	4.13	39	11.41	28	5.38	32
SOUTH PACIFIC								
1928–29	1	2	0.10	1	0.73	2	0.28	2
1929–30	6	14	1.51	14	8.95	21	4.76	23
1930–31	11	30	4.42	41	7.40	28	4.87	41
1931–32	5	10	2.07	16	8.41	16	4.60	18
1932–33	6	15	2.52	24	7.91	20	2.51	14
INTERIOR								
1928–29	15	36	1.86	26	9.77	28	3.16	28
1929–30	17	39	4.99	47	12.30	30	6.89	33
1930–31	11	31	1.89	18	9.29	35	2.96	25
1931–32	15	31	3.46	26	11.38	21	8.66	34
1932–33	10	25	2.88	27	15.30	38	6.19	36

TABLE 2.—*Total number of days with rain and percentages at San Diego, and total amounts and percentages from each type by seasons at San Diego, Cuyamaca, and Warner Springs*—Continued

MEXICAN

Season	San Diego				Cuyamaca		Warner Springs	
	Days	Percent	Amounts	Percent	Amounts	Percent	Amounts	Percent
1928–29	1	2	0.02	0	0	0	0.08	1
1929–30	2	4	.22	2	5.06	12	3.87	19
1930–31	0	0	0	0	1.61	5	.78	7
1931–32	3	6	.79	6	3.61	6	3.02	12
1932–33	2	5	1.10	10	5.52	14	3.10	18

TABLE 3.—*Precipitation and departures from the mean at San Diego, Cuyamaca, and Warner Springs during the last five seasons*

Season	San Diego		Cuyamaca		Warner Springs	
	Precipitation	Departure	Precipitation	Departure	Precipitation	Departure
1928–29	7.10	−2.65	35.55	−3.25	12.30	−5.48
1929–30	10.73	+.98	41.65	+2.85	20.61	+2.83
1930–31	10.78	+1.03	26.78	−12.02	11.86	−5.92
1931–32	13.18	+3.43	53.58	+14.78	25.14	+7.36
1932–33	10.63	+.88	40.14	+1.34	17.18	−.60

HOURLY FREQUENCY AND INTENSITY OF RAINFALL AT SAN FRANCISCO, CALIF.

By R. C. COUNTS, Jr.

[Weather Bureau, San Francisco, Calif., August 1933]

[Compare: McDonald, W. F., Hourly Frequency and Intensity of Rainfall at New Orleans, La. MO. WEA. REV., January 1929, vol. 57, pp. 1-8]

The hourly rainfall data for San Francisco present several aspects, the most interesting of which is the decidedly greater frequency of rain during the late night and early morning hours than at midday or in the afternoon. This phase of the rainfall has long been a subject for comment, even by comparative newcomers to this area, but heretofore neither the exact facts nor their causes were known, and comment was based largely on conjecture. Data have been compiled for the 20-year period, 1911–30, which, it is believed, is of sufficient length to at least greatly reduce any effects resulting from pronounced abnormalities. The data were tabulated from the daily records of the local Weather Bureau office. These records contain not only the times of beginning and ending of precipitation but also the hourly amounts, which were extracted from the 24-hour record sheets of a self-recording rain gage of the tipping bucket type. Each 0.01 inch is registered on the sheets in the proper hour division, but occasionally this unit amount may be recorded in 1 hour yet be an accumulation of rain extending over several hours; especially is this true of a drizzle or heavy mist. It is reasonable to believe, however, that such cases are as numerous in any hour as another and that the relation of the total hours with a measurable amount, or the total hourly amounts, is unaffected.

In the first compilation the individual hours with 0.01 inch or more, by months, in the 20 years were counted. The sums obtained showed the trend of the hourly frequency for each of the calendar months but the sums for no month were strictly comparable with those of any other because of the variation in length of the months. To obviate this the sums were reduced to a percentage basis, shown in table 1, by dividing the total hours with a measurable quantity of rain by the total number of hours. In the 31-day months the possible hours for each of the 24 were 620, in the months of 30 days there were 600, and in February, 5 of which were in leap years, the divisor was 565. The annual hourly frequency percentages were found by dividing the number of rainy hours of the same name in all months by the possible 7,305 hours to obtain greater accuracy than the means of the monthly hourly percentages would have given.