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ARE WE IN FOR A LONG DROUGHT?

A look at the past provides the outlook for the future

by FRANKLIN THOMAS

PROBABLY IN no other area of comparable size in the world is the value of water so high when measured in terms of wealth it creates as in Southern California. During the period of residence here of most of the present population, there has not been much occasion to consider or question the availability of adequate water supplies. However, the 1947-48 season of low rainfall, while acute and damaging, is a period such as has occurred in Southern California at intervals in the past and must be anticipated in the future. In fact, this locality is fortunate that the current shortage of rain has not been experienced several years earlier than now, for a repetition of the severe eleven-year drought which occurred from 1893 to 1904 might be considered overdue.

The accepted rainfall record of Los Angeles extends for 71 years, since 1877, and is the longest available in the metropolitan area. That of Pasadena is continuous for the past 66 years.

The amount of rainfall is greater for inland locations than along the coast and increases with altitude toward the mountains. For instance, the seasonal aver-

Annual Rainfall in Inches for Los Angeles
Rainfall Season, July 1 to June 30

1877-78	21.26	1895-96	8.51	1913-14	23.65	1931-32	16.95
1878-79	11.35	1896-97	16.86	1914-15	17.05	1932-33	11.88
1879-80	20.34	1897-98	7.06	1915-16	19.92	1933-34	14.55
1880-81	13.13	1898-99	5.59	1916-17	15.26	1934-35	21.66
1881-82	10.40	1899-1900	7.91	1917-18	13.58	1935-36	12.07
1882-83	12.11	1900-01	16.29	1918-19	8.58	1936-37	22.41
1883-84	38.18	1901-02	10.68	1919-20	12.52	1937-38	23.43
1884-85	9.21	1942-03	19.32	1920-21	13.65	1938-39	13.07
1885-86	22.31	1903-04	8.72	1921-22	19.66	1939-40	19.21
1886-87	14.05	1904-05	19.52	1922-23	9.59	1940-41	32.76
1887-88	13.87	1905-06	18.65	1923-24	6.67	1941-42	11.18
1888-89	19.28	1906-07	19.30	1924-25	7.94	1942-43	18.17
1889-90	34.84	1907-08	11.72	1925-26	17.56	1943-44	19.22
1890-91	13.36	1908-09	19.18	1926-27	17.76	1944-45	11.59
1891-92	11.85	1909-10	12.63	1927-28	9.77	1945-46	11.65
1892-93	26.28	1910-11	16.18	1928-29	12.66	1946-47	12.66
1893-94	6.73	1911-12	11.60	1929-30	11.52	1947-48	7.22
1894-95	16.11	1912-13	13.42	1930-31	12.53	1948-49	?

Average of 71 years = 15.32 inches

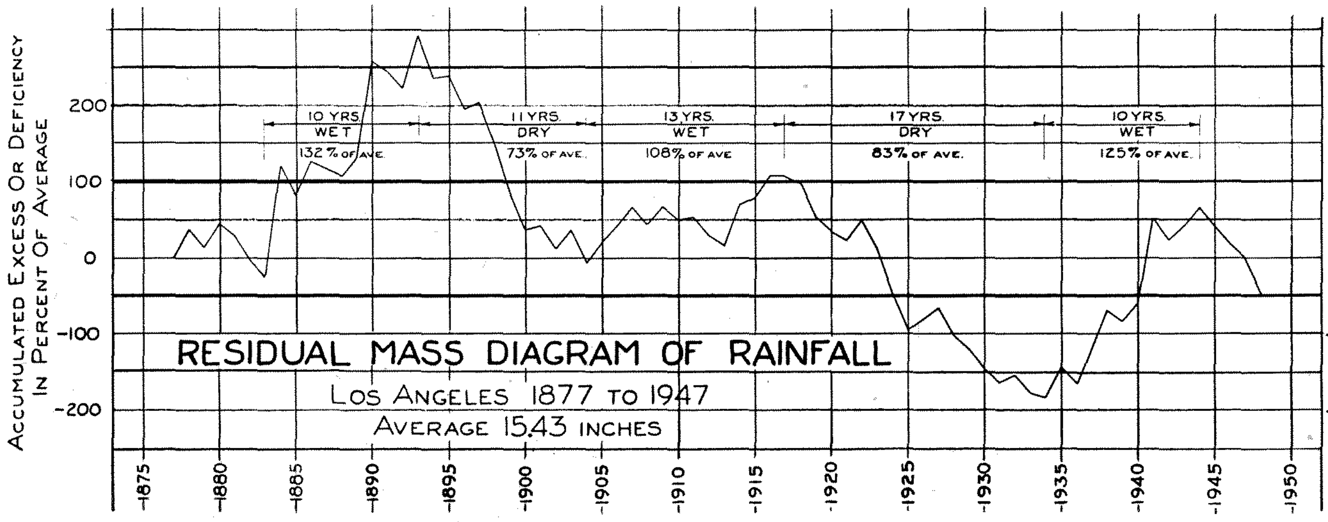


Diagram showing 71 years of rainfall for Los Angeles reveals alternating periods of above and below-average precipitation.

age for Pasadena, 20.63 inches, is slightly more than a third greater than 15.32 inches for Los Angeles. However, there is complete consistency between locations on the Coastal Plain in regard to the pattern of wet and dry periods.

While the fluctuations of rainfall as represented by the record of Los Angeles may not be sufficiently regular in extent and duration to be called cycles, there do seem to occur alternating periods of above-average and below-average precipitation. In the 71 years of rainfall record, there are three periods of above average rainfall alternating with three periods of below-average rainfall.

Identifying these wet and dry sequences is facilitated by constructing a chart called a residual mass diagram which represents an accumulation of seasonal excesses or deficits of rainfall in comparison to the average throughout the whole record. Such a chart appears above. It resembles the fluctuations of a savings bank account in which a surplus is built up by deposits larger than the average of all withdrawals over a period of time—a surplus that may later be depleted by withdrawals in excess of the average. The chart shows that there have been wet and dry periods following each other in succession and extending from ten to seventeen years in duration. The season of 1943-44 seems to have terminated a ten-year series of years providing considerably more rain than the average for Los Angeles, and the current season was the fourth consecutive season of sub-normal precipitation. Either a wet or a dry period may include one or more conflicting seasons with only a temporary interruption of the general trend.

The present marks the second time that four successive years of sub-normal precipitation appear in the record. They brought 70% of average. The other occurrence was from 1927-31 and represented 75% of average. On two other occasions three successive years of sub-normal precipitation occurred: 1897-00 at 45% of average, and 1922-25 at 53% of average. Such series of dry years occur in, and largely create, a below-average sequence. There seems to be less probability of the successive occurrence of above-average wet years. A succession of three wet years appears but twice: 1904-07 at 125% of average, and 1913-16 at 131% of average. On six occasions there are two successive wet years. All of the latter pairs of wet years occurred in wet sequences except one, 1925-27, which constituted a two-year interruption of, and minimized the severity of, a 17-year dry sequence.

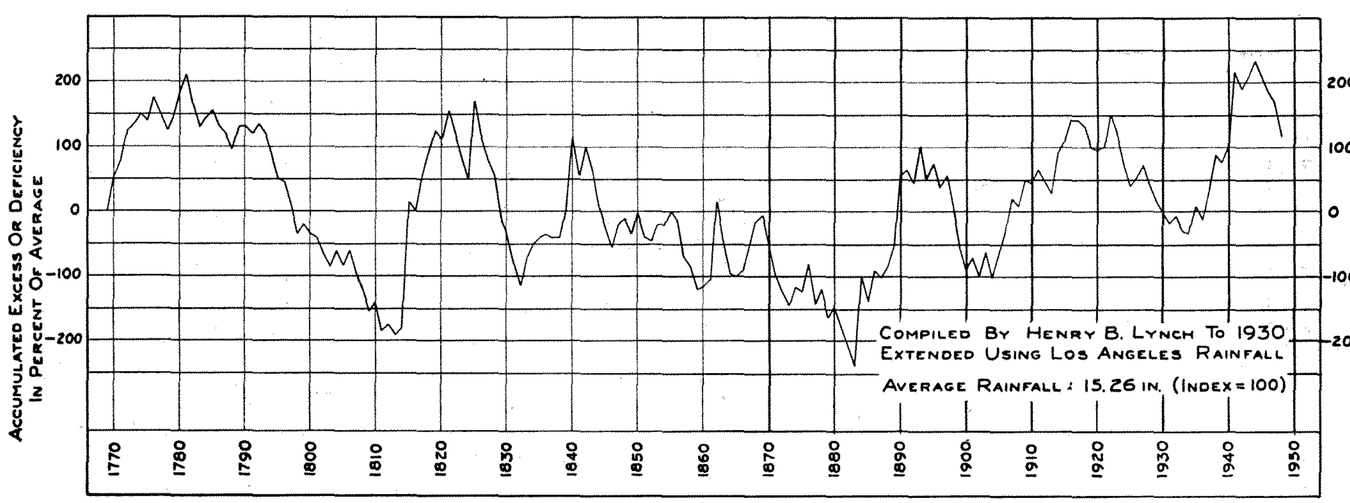


Diagram showing Los Angeles rainfall in years 1769-1930 reveals that alternating wet and dry pattern was set long ago.

On the basis of past indications then, there is good reason to expect that the season of 1948-49 will provide above-average rainfall to be followed by, in the aggregate, from five to ten years of less-than-average precipitation.

Historical rainfall indices

In a populous area where the water supply is so variable and so largely dependent upon that brought from distant sources, it is of great importance to have as much information as possible about conditions prior to the relatively recent date when the collection of official records of rainfall began. The best compilation available of such data is that accumulated through years of research by Mr. Henry B. Lynch, a Consulting Engineer who has made exhaustive search of crop records of the California Missions, reports of the Padres, diaries, journals, miscellaneous writings, court records and newspaper files, and from them assembled facts concerning rainfall, floods and droughts.

Mr. Lynch determined rainfall indices for successive seasons in relation to the record of recent years. The index of a season of average rainfall is taken as 100, then the indices of other years are expressed in per cent of the average.

His table of indices begins with the year of the founding of the San Diego Mission in 1769 and carries them through to 1930. The indices for the Los Angeles area are shown below, together with a residual mass diagram of the Lynch rainfall indices, on page 4.

The historical record shows alternating wet and dry trends similar to those which comprise the record of recent years. There are some aspects of the historical record, however, which are more ominous than the recent indications. California's most severe drought occurred in the period 1821-32; of the eleven years all but one had low rainfall indices ranging from 35 to 75. Following the conflicting season of 1824-25, notable for its great flood, there were seven consecutive and acutely dry years, including that of 1828-29, when the index dropped to the low of 35.

Aside from the drought just described, one extending twenty-eight years, from 1781-1809, is most pronounced, but more for its duration and lack of appreciable interruption than for its intesity. In contrast, during the century when California was being settled,

Rainfall Indices Los Angeles Area 1769 - 1930

1769-70	155	1810-11	155	1850-51	60	1890-91	109
1770-71	125	12	110	52	95	92	79
72	145	13	85	53	125	93	158
73	110	14	110	54	100	94	49
74	115	15	195	55	120	95	123
75	90	16	85	56	85	96	62
76	135	17	155	57	45	97	119
77	75	18	135	58	85	98	50
78	75	19	135	59	65	99	41
79	125	20	85	60	125	1900	64
80	135	1820-21	145	1860-61	90	1900-01	117
1780-81	125	22	65	62	220	02	72
82	55	23	65	63	40	03	137
83	65	24	65	64	50	04	61
84	115	25	220	65	95	05	137
85	110	26	45	66	110	06	134
86	75	27	65	67	135	07	152
87	90	28	75	68	140	08	88
88	75	29	35	69	110	09	140
89	135	30	75	70	55	10	95
90	100			1870-71	50	1910-11	121
1790-91	90	1830-31	55	72	75	12	82
92	115	32	45	73	80	13	81
93	85	33	165	74	129	14	163
94	65	34	120	75	92	15	120
95	65	35	110	76	143	16	131
96	95	36	105	77	38	17	100
97	65	37	95	78	124	18	92
98	55	38	100	79	54	19	66
99	115	39	145	80	118	20	97
1800	85	40	210	1880-81	71	1920-21	103
1800-01	95	1840-41	40	82	69	22	150
02	75	42	145	83	68	23	72
03	80	43	65	84	240	24	53
04	125	44	45	85	61	25	64
05	75	45	65	86	147	26	115
06	125	46	70	87	90	27	119
07	65	47	135	88	118	28	69
08	75	48	110	89	134	29	76
09	65	49	75	90	206	30	82
10	115	50	135				

Average rainfall season, 15.26 inches = 100.

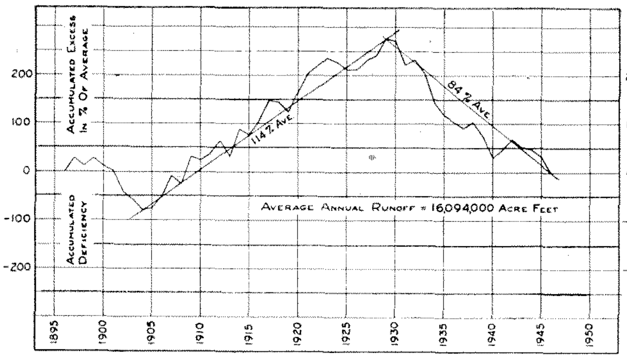


Diagram of Colorado River's flow shows longer wet and dry sequences than those in Los Angeles rainfall record on page 3

there were three seasons characterized by outstanding floods. They were 1824-25, 1861-62, and 1883-84. These floods are believed to have been on the order of that which occurred in March 1938.

Tree ring indications in Southern California

Studies of "Tree Ring Hydrology in Southern California", by Dr. Edmund Schulman, published by the University of Arizona, have identified tree ring records on Mt. San Bernardino back to 1350 A.D. For the period of historical and measured reports of rainfall, the years of poorest growth were 1864 and 1899. But Dr. Schulman notes that "In the last five centuries there were years of substantially greater severity for tree growth in A.D. 1492, 1542, 1580, 1585, 1590, 1613, 1633, 1654, 1670, 1782, and 1845, with many others of comparable deficiency." In contrast, growth in a number of years in previous centuries exceeded the greatest extremes of the last dozen years. Notwithstanding the recognition of evidence of alternating wet and dry periods in the distant past, no cycles of such regularity and dependence as to be usable in long range forecasting have as yet been identified from the study of tree rings.

Colorado River discharge

Those areas in Southern California which have had the foresight to protect their needs through arrangements for Colorado River water can view the current drought with moderate complacency. The question then arises whether shortages of rainfall in this part of the State would coincide with periods of low seasonal run-off in the Colorado River.

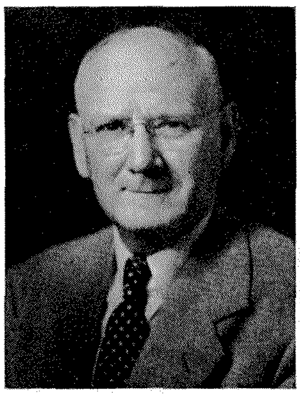
The most significant flow measurement station on the river is at Lee Ferry in Arizona, a few miles downstream from the southern Utah boundary. For this station, the flow record of measurements since 1921 has been adjusted by government engineers for upper river depletions for irrigation and projected backward to 1897.

A residual mass diagram of this record is shown above. The most conspicuous indication is that the sequences are of much longer duration on the Colorado River than are those of the Los Angeles rainfall record. Following the termination of the drought at the turn of the century when the two records were in phase, the flow of the river entered a 25-year trend, until 1929, of runoff above the average of 16,094,000 acre-feet per annum. Subsequently, for 19 years at least, until 1946, the long trend of deficiency persisted. Confirming favorable snowfall reports on the upper watershed of the Colorado during the past winter, the run-off prospects are about 10% above normal, constituting a fortunate contrast to local rainfall experience. It cannot be determined as yet how much longer this current downward trend will continue.

Tree ring indications on the Colorado

Studies of "Tree Ring Hydrology of the Colorado River Basin" have identified tree-ring records back to 1288 A.D. By determining departures both in excess and below-the-average growth, and plotting the diagram for trends, the indications of recent years correspond approximately with the rainfall indices. The longer record, however, shows more extreme conditions than those of the historical period. The severe drought of 1573-1601 was of such length and severity that it is believed to have caused the abandonment of the habitations which existed in considerable number in northern Arizona and southern Utah.

Fortunately, man's ingenuity has made it possible to extract water from underground accumulations with power machinery; such reserves would, in the future, do much to alleviate the deficiencies of surface water as they may occur. So long as local droughts do not coincide with periods of low flow in the Colorado water, needs on the Coastal Plain can be fairly well met. Heavy demands on the underground basins, however, should be relaxed by an extensive use of imported water so as to permit water to accumulate underground as a reserve supply against the contingency that a shortage in the Colorado might occur.



When Franklin Thomas talks about Southern California's rainfall and the habits of the Colorado River, he knows whereof he speaks, for probably no other single person has had more to do with obtaining Colorado River water for the region. In 1947, Professor Thomas was appointed to the Colorado River Board of California by Governor Earl Warren, and in 1948 he was made Chairman of the Board. He has served in a consulting capacity on flood control and sanitation projects for Los Angeles and Orange Counties, and for the City of Los Angeles; and from 1928-1947 he was vice-chairman of the Board of Directors of the Metropolitan Water District. From 1922-1933 he was a member of a special committee on Irrigation Hydraulics of the American Society of Civil Engineers. During the past summer, Professor Thomas' interest in such matters took him to Europe, where he attended the International Congress on Large Dams in Sweden.

These are some of Professor Thomas' activities outside academic circles. At the Institute, which he joined in 1913 as an Associate Professor of Civil Engineering, Professor Thomas has been full professor since 1915; from 1924-1944 he was chairman of the Division of Civil Engineering, Mechanical Engineering, Aeronautics and Meteorology; and since 1944, Dean of Students.

Professor Thomas grew up in Iowa, graduated from its University in 1908, and received his C.E. there in 1913. In 1910 he married Marie Planck, and they are the parents of six children, two of whom, Edward and Robert, were lost in World War II. The Thomases are active in many community affairs in Pasadena and have been influential in its cultural growth; Professor Thomas has been president of the Chamber of Commerce, and has headed up both the Community Chest and the Pasadena Civic Orchestra Association.