STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF ENGINEERING AND IRRIGATION
EDWARD HYATT, State Engineer

BULLETIN No. 14

The Control of Floods by Reservoirs

By
PAUL BAILEY

AN APPENDIX

to the

SUMMARY REPORT
TO THE LEGISLATURE OF 1927

on the

WATER RESOURCES OF CALIFORNIA

and a

Coordinated Plan for Their Development

CALIFORNIA STATE PRINTING OFFICE
SACRAMENTO, 1928

52411

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TABLE OF CONTENTS

TABLE OF CONTENTS—Continued

CHAPTER VI.

CHAPTER VII.

CHAPTER VIII.

FOREWORD.

This bulletin is one of a series appended to the "Summary Report on the Water Resources of California and a Coordinated Plan for their Development" that was presented to the Legislature of 1927. It is part of the investigation of the water resources of the state commenced in 1921. This investigation has comprised a survey of water supplies and flood flows throughout the state, a determination of their characteristics, an estimate of the present and future needs for water, and the formulation of a comprehensive and coordinated plan for future development in order to insure adequate water supplies for all purposes. The 1927 report concludes this investigation. The entire series of bulletins pertaining to the 1927 report are:

- Bul. 12—"Summary Report on the Water Resources of California and a Coordinated Plan for their Development." (A report to the Legislature of 1927.)
- Bul. 13—"The Development of the Upper Sacramento River."
- Bul. 14—"THE CONTROL OF FLOODS BY RESERVOIRS."
- Bul. 15—"The Coordinated Plan of Water Development in the Sacramento Valley."
- Bul. 16—"The Coordinated Plan of Water Development in the San Joaquin Valley."
- Bul. 17—"The Coordinated Plan of Water Development in Southern California."

Other bulletins pertaining to these investigations published prior to the 1927 report are:

- Bul. 4—"Water Resources of California." (A report to the Legislature of 1923 on the first two years of investigation.)
- Bul. 5—"Flow in California Streams."
- Bul. 6—"Water Requirements of California Lands."
- Bul. 9—"A Supplemental Report on the Water Resources of California." (A report to the Legislature of 1925.)
- Bul. 11—"Ground Water Resources of the Southern San Joaquin Valley."

The first appropriation for the investigation of the water resources of California was made by Chapter 889 of the 1921 Statutes, in the amount of $200,000. This resulted in the publication of Bulletins Nos. 4, 5, and 6. These contain a complete inventory of all the waters within the State's boundaries, an estimate of the future needs of water for all purposes, and a preliminary comprehensive plan for ultimate development that will secure the greatest public service from the State's limited water supply.

No provision was made for the continuance of the investigations by the 1923 legislature but at the urgent request of the farmers of the southern San Joaquin Valley, the Chambers of Commerce of San Francisco and Los Angeles advanced $90,000 for the study of a first unit of the comprehensive plan that would relieve the stress in a section of the State most in need of an imported water supply. With this money, works were planned that would transport the surplus waters of the Sacramento drainage basin into the San Joaquin Valley and make a new supply available for the southern half of the valley. An account of this work is published in Bulletin No. 9, a report to the Legislature of 1925.

Chapter 477 of the 1925 Statutes made $150,000 available to the Division for completion of the work. This money was spent in perfecting the "Coordinated Plan" of development requested in the appropriation bill. Heretofore, in looking to the future, the problems of flood control and of conservation have been given separate consideration. Expensive construction programs are known to be necessary in both fields of endeavor to provide habitable conditions for the increasing population. The investigation of the possibility of coordinating these two necessary programs has assumed such large proportions that this entire volume has been given over to the presentation of this phase of the "Water Resources Investigation."

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LIST OF PLATES

LIST OF TABLES

YEARLY SUMMARIES OF RESERVOIR YIELDS COMPUTED ON A DAILY BASIS

LIST OF TABLES—Continued

MONTHLY SUMMARIES OF RESERVOIR YIELDS COMPUTED ON A DAILY BASIS

CHAPTER I.

OPPORTUNITY FOR CONTROLLING FLOODS BY RESERVOIRS.

Past consideration given to control of floods by reservoirs.

The control of floods by reservoirs has been regarded in the past, generally, as an uneconomic system of protection. However, knowledge of reservoir sites in California and of the extent to which they will have to be employed in order that the State's latent resources may be utilized, is comparatively recent. The report of the Conservation Commission* of 1912, although mentioning the necessity of storage, does not list more than a couple of dozen reservoir sites. Not until the water resources investigations were initiated in 1921 has there been general public knowledge of the part reservoirs will play in the future development of this state. It has been pointed out in this work, that a construction program adequate for the State's potentialities will eventually total 50,000,000 acre-feet or more of reservoir capacity. This will involve the construction of several hundred large reservoirs. More than a thousand sites are now known to exist, more than will be required for a complete development of available waters.

Such study as has been given previously to the control of floods by reservoirs indicates that their cost, when constructed for flood control purposes alone, exceeds so far the cost of equivalent protection by leveed channels and by-passes, that only in instances of unusually cheap construction or in the vicinity of metropolitan areas of high property values, can reservoirs be utilized for flood control purposes. In all these studies, either the entire space in the reservoir or some fraction of it, has been allotted to flood control for use only in the temporary detention of flood flows and to be held empty at all times other than during large floods. Under this mode of operation, the entire cost of the storage space allotted to flood control is chargeable to the protective system. Because this required space is large on important streams, the cost of flood control by reservoirs usually has been found prohibitive. The only instances of reservoir construction for flood control purposes in California are the current undertakings of the Los Angeles County Flood Control District and of the City of Stockton. In both of these instances bonds have been voted. Several reservoirs have been constructed by the Los Angeles District.

It has been considered by some, without much study, that the construction of large reservoirs for irrigation and power purposes will diminish the size of floods. A careful analysis, however, discloses that, unless these reservoirs are operated especially for flood control purposes, they are apt to be fairly well filled upon the arrival of large floods, because large floods do not occur in seasons of small run-off. While they may absorb many medium and small floods, dependence can not be placed upon their absorption of large floods. Therefore the vast program of reservoir construction that will be necessary for domestic supply, irrigation and power, has no particular bearing upon flood

* The State Conservation Commission was appointed in 1911 to investigate and report, among other things, on water, the use of water, water power, irrigation and reclamation.

control, unless a special program is devised for its employment for this purpose.

That the engineering profession has held the belief that reservoirs would come into more general use in controlling floods, is shown by the report of the California Debris Commission of June 29, 1911. The report of this commission is one of the most extended studies of flood control that has been made in California. The plan of leveed channels and by-passes for carrying off maximum flood flows proposed in this report was adopted by both the California Legislature and the National Congress and is being followed in reclaiming a million acres of overflow land in the Sacramento Valley. The works are now two-thirds complete. In planning and recommending the construction of these works, consideration was given by the California Debris Commission to the reduction of floods by reservoirs. Its conclusions were expressed in the 1911 report as follows:

> "While favoring the use of reservoirs as far as possible, and considering that one of the advantages of the project herein proposed is that it lends itself to future storage possibilities, the commission believes that it is not economical to construct reservoirs for flood control, but that such construction should be deferred until these reservoirs prove desirable for power and irrigation purposes."

Future conditions favorable for use of reservoirs in controlling floods.

The time has arrived when reservoir construction is necessary for both power and irrigation purposes. California now stands with a full measure of development of the summer flow in its streams. Further progress involves the storage of winter and spring storm water and its retention for summer use. The employment of these reservoirs for flood control, that necessarily will be constructed in succeeding years for irrigation, power and domestic supplies, is a matter of great public interest. Its accomplishment would be of inestimable public benefit. The water resources investigation, therefore, has undertaken the intensive study of the problem of how flood control might benefit from the construction of reservoirs for other purposes.

The attempt to use reservoirs for both flood control and conservation seems at first like a contradictory effort. To be useful for regulating floods, reservoirs should be held empty during the period of heavy run-off in order to be able to absorb an excessive flood flow if it should occur, while for conservation purposes, they should be allowed to fill during this same period in order that the run-off season may end with a full reservoir. However, a detailed analysis of the time of occurrence and volume of flood flows discloses a procedure for filling reservoirs that will hold in reserve sufficient capacity to absorb floods during the time in which they are likely to occur, and progressively release this space for filling as the end of the flood season approaches. This bulletin is devoted to the presentation of these matters.

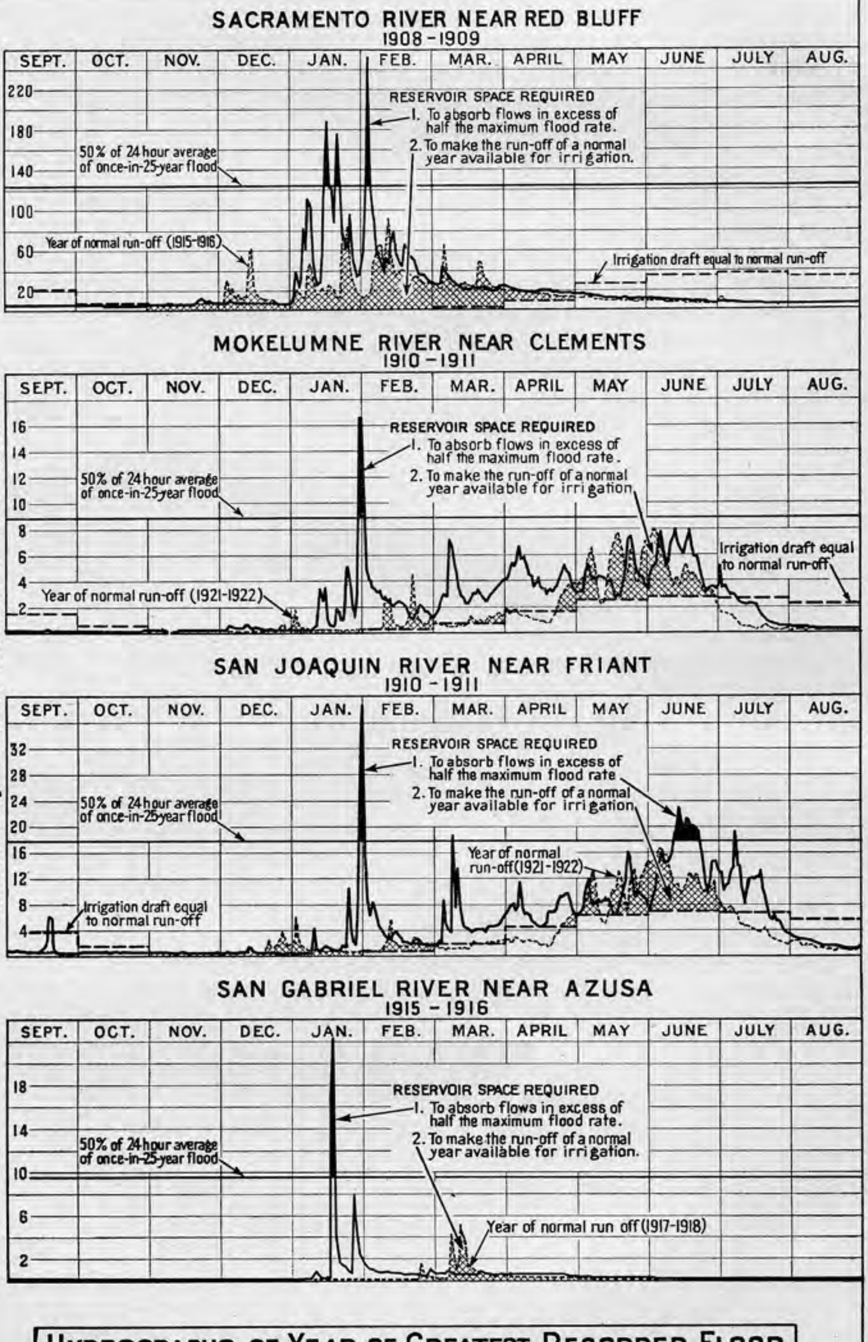
Physical opportunity to combine conservation and flood control in same reservoir.

That a combination program of conservation and flood control should be possible seems evident from an examination of the hydrographs of California streams. This discloses that excessive rates of flood flow are of comparatively short duration, that they occur in the middle or fore part of the period of heavy run-off, and that the volume of water discharged at the extremely high rates is relatively small. The reservoir capacity required to absorb these high rates of flood flow, although large in itself, is still very much less than will be required to equalize any great part of the seasonal run-off for irrigation use. These general observations are illustrated by the hydrographs of four typical streams, the Sacramento, Mokelumne, San Joaquin and San Gabriel rivers, drafted on Plate I, "Hydrographs of Year of Greatest Recorded Flood."*

On this plate, full-line hydrographs portray the run-off throughout the year of the greatest flood on record on each of the four streams. A heavy horizontal line crosses each hydrograph plotted at half the rate of discharge of a large flood which is here taken as one estimated to be exceeded at average intervals of 25 years. (The frequency of flood occurrence is taken up in detail in the second chapter.) The areas within the full-line hydrographs above the heavy horizontal line, shaded in solid black, represent the total volume of water that would have had to be detained by reservoirs in that season in order to limit the downstream flow to half the rate of a once-in-25-year flood. Superimposed on these full-line hydrographs of the flood years are hydrographs of seasons of normal run-off shown by dotted lines. The cross-hatched areas within these dotted-line hydrographs represent the volume of winter and spring run-off that would have to be stored to make the entire run-off of a normal season available for irrigation use. A comparison of the solid black with the cross-hatched area on each figure of Plate I, shows the relative reservoir capacity needed to limit the largest flood of record to half the rate of a once-in-25-year flood and to equalize the entire run-off of a normal season for irrigation use. It may be observed that the reservoir capacity required to cut large flood flows in half is small compared to that required to equalize the entire run-off of a normal season for irrigation use. On the Sacramento, Mokelumne and San Joaquin rivers the one is from 5 to 15 times larger than the other, while on the San Gabriel, a very flashy stream, the reservoir capacity required to equalize the entire run-off of a normal season for irrigation purposes is about twice that needed to absorb the top half of a large flood. Since it will be necessary in coming years, on most of the streams of the State, to make the entire flow of normal years available for use in order that deficient water supply may not limit the growth of California, it is seen that the reservoir capacity necessary for conservation purposes is very much greater than that needed to limit the high rates of flood flow to half that of a once-in-25-year flood, except on streams like the San Gabriel River that have exceedingly flashy run-off. Any reservoir or group of reservoirs that have sufficient capacity to store a considerable fraction of the winter and spring run-off of a normal year, if not already well filled, could easily absorb the volume of flood water which

* Water Supply Paper No. 551 of the United States Geological Survey, recently published, places the maximum discharge of the Mokelumne River at Clements at 25,500 second feet. This is obtained by applying the rating curve of the 1911 flood to the gage heights of 1907. The crest discharge of the 1907 flood has been published as 17,000 second feet in former publications including Water Supply Paper No. 299 in which are printed the daily discharges of the 1907 flood. The figures contained in Water Supply Paper No. 299 have been used in preparing this volume. Should the daily discharges of the 1907 flood be revised by application of the 1907 gage heights to the 1911 rating curve, the increase in their values would be so substantial as to require a complete revision of the analyses of floods on the Mokelumne River contained in this volume in order to make the analyses harmonize with the increased discharge values.

PLATE I.



HYDROGRAPHS OF YEAR OF GREATEST RECORDED FLOOD otherwise would be discharged at rates in excess of half that of a once-in-25-year flood.

Although the volume of flood water discharged at rates in excess of half that of a large flood is relatively small, an inspection of the general shape of the hydrographs on Plate I reveals that the volume of flood water discharging at rates less than half that of a large flood increases quite rapidly with the lower rates of discharge. This is indicated by the increasingly greater widths of the peaks on the hydrographs as they descend below the heavy horizontal lines drawn at rates half that of a once-in-25-year flood. At about the quarter points, except on the San Gabriel River, these peaks merge more or less into one another on account of their increasing width. This greater width of the peaks on the hydrographs represents increasing duration of flow at the lower rates.

The flows delineated by the thin width of the peaks on their upper part are high rates of discharge, the direct result of intense rainfall on saturated or snow-covered areas. Since high rates of rainfall do not continue over long periods of time, the duration of these excessively large rates of run-off is brief and the peaks on the hydrographs have a narrow width. As lesser flows are considered, the run-off from medium and low rates of rainfall, which continue much longer, as well as the tardy waters draining off the catchment area in the wake of heavy storms, are included to a greater extent and the peaks on the hydrographs have a greater width. The duration of the lower rates of rainfall is so much longer than the duration of the higher rates that much greater volumes of water would have to be detained by reservoirs if floods were to be reduced to as much as a quarter or less of the rate of a large flood than to only a half.

A further increase in the volume of water that would have to be detained in order to limit flood flows to much less than half that of a once-in-25-year flood comes from melting snow on those streams a considerable part of whose drainage areas extends into high altitudes. As illustrated by the hydrographs of the Mokelumne and San Joaquin on Plate I, fairly high rates of discharge occur from melting snow during May, June and July. The Sacramento and the San Gabriel, the two other illustrative streams, do not have snow-water floods. Unlike the flood discharge from rainfall, that from melting snow continues over rather long periods of time. However, their greatest rate seldom exceeds half that of a once-in-25-year flood, so that they concern flood control only if floods are to be reduced to less than this rate of flow.

While the foregoing considerations are very general and are principally illustrative of the characteristics of stream flow to be analyzed in detail in later chapters, nevertheless, they indicate that the volume of water to be detained by reservoirs would increase very rapidly if an attempt were made to reduce floods to much less than half a once-in-25-year flood. The capacity required to do this would be much larger than probably will be constructed on most of the State's streams for many years to come. The relatively small space required to reduce floods to half the rate of a once-in-25-year flood or thereabouts makes it appear, in general, that this would be the possible present utility of conservation reservoirs for controlling floods. A coordinated program of operation for both conservation and flood control would be necessary for this accomplishment.

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CHAPTER II.

SYSTEMS OF FLOOD CONTROL.

Leveed channel system.

There are, in general, two systems of flood control: one that leads flood flows to the ocean in specially prepared channels without diminution in volume, the other that reduces the volume of flow to a harmless amount by detention of excess water in storage reservoirs. The first is the system in common use, for it is usually least in cost. The reasonable cost of this system is attained by constructing the greater part of the flood channels above the ground surface. The banks of the channels are formed by earthen levees excavated from adjacent borrow pits. The capacity of the channels is fixed by the spacing and height of the levees. Seldom does the borrow pit from which the levee material is excavated constitute a very large part of the waterway. Even where the leveed channels follow natural water courses, their increased capacity, due to the construction of the levees, is largely in the cross-sectional area above the ground surface. Thus, the safety of the system rests upon the strength of the levees to withstand the water pressure and the sufficiency of the carrying capacity of the flood channels. Should the levees fail or be breached by over-topping, a large part of the entire flood volume might run through the breach over the adjacent land.

One of the principal reasons for success in this system of protection is the infrequent occurrence and short duration of large floods that tax the strength of the levees and the capacity of the channels. On the other hand, one of the principal dangers in this system is the neglect of maintenance of the levees and channels through a false sense of security that develops during the ten-or-more-year average intervals between large floods. The levees that form the channel banks may settle, crack or be holed by burrowing animals during the long periods of only partial use. Also, the channel capacity may deteriorate through the growth of trees, brush or tule or the deposit of silt by the lesser floods. The intermittent wettings from smaller floods encourage channel growths. The usually fertile soil and the favorable moisture conditions on the low land that flood channels naturally occupy often produce obstructive growths that occupy considerable parts of the waterway areas. The maintenance of these channels in condition to safely carry off the infrequently occurring large floods requires constant attention and very considerable expense.

Reservoir system.

The second system of flood control, that which reduces the volume of flood flow by detention of excess water in storage reservoirs, is a recent innovation in California. The Los Angeles County Flood Control District now has a $40,000,000 program under way. This provides for the construction of thirteen reservoirs for flood control purposes on Los Angeles County streams. The City of Stockton has undertaken the construction of a reservoir on the Calaveras River solely for flood control purposes. The reservoir system has been adopted in these instances because the high property values and close settlement of some of the territory protected permits greater expenditures than have been customary in the past.

The high cost of constructing reservoirs for flood control alone and the large size required to reduce floods to harmless amounts limits the usefulness of the reservoir system of protection. To be effective with certainty, liberal reservoir capacity has to be provided and the rules of operation rigidly adhered to so that this space will surely be empty at the time needed for detaining flood waters. The system is attractive, however, where the cost is justified, because of the shorter traffic crossings on the smaller channels needed, the elimination of the bother and expense of maintaining large waterways in expectancy of a great flood through years of use to but a small part of their total capacity, and the possibility of utilizing areas that would otherwise be occupied by flood channels.

Combined reservoir and leveed channel system.

It was pointed out in the first chapter that there is a physical opportunity to obtain joint use of the same space in reservoirs for both conservation and flood control purposes. It was pointed out also that the present possibility for economical joint use of the same reservoir space will, in general, be limited to a reduction of flood flows to a half or a third of that of a large flood. On many streams in California, leveed channels will be required to carry off even a half or a third the volume of a large flood, although, of course, the size of these channels need not be nearly as large. Therefore, leveed channels will probably remain part of most of our flood protection systems until either the close settlement of the overflow areas warrants the great expense of their complete elimination, or the demand for additional water supplies forces the construction of much greater reservoir capacity than will be required for a good many years at the present rate of growth. Thus, the combination of the reservoir and the leveed channel system of protection will probably be most suitable to conditions on many California streams for some time to come.

The suitability of the combined system to the immediate future is fortunate, because often much of the work first constructed under the leveed channel system may be utilized in the combined system to afford an increased degree of protection. Also, the combined system of protection removes the most unsatisfactory features of the leveed channel system. In California, the leveed channels take up much room and form awkward obstacles to traffic and communication. This public inconvenience rapidly gains importance as territory becomes more thickly populated. The cost of bridges alone over wide channels is a large item of expense and increases greatly as denser population demands more convenient routes of communication.

In southern California, whose rapid growth has already brought 20 per cent of available flat lands into incorporated cities and towns, and where their extent is limited, the occupation of large areas by flood channels is a serious impediment to community expansion. Although the extent of flat lands is greater in northern California, the area occupied by flood channels is nevertheless a considerable item in the inventory of lands favorable for intensive human occupation. One of the channels of the flood control project in the Sacramento Valley is as much as three miles in width, and in total all the channels of this project occupy 250 square miles of territory that can be put to only partial use.

The channels of the combined system would be of moderate size and capacity. Such channels could be more easily maintained, both because they would be smaller in size and because a larger part of their total capacity would be used oftener. The elimination by reservoir control of the excessively high rates of run-off that are particularly dangerous by surcharging the present large channels at very infrequent intervals would add to the safety of occupying adjacent lands. The smaller channels would leave greater areas to be reclaimed and would not constitute unduly awkward barriers to traffic and communication under the conditions of the near future. Thus, the combined reservoir and leveed channel system of protection has distinct advantages. If a satisfactory program could be devised for the joint use of the same reservoir space for both conservation and flood control, it will come into use on many California streams. On those streams where leveed channels are already constructed, the safety of protection would be increased, and on other streams the cost of building the leveed channels would be reduced. All localities would be benefited.

The Sacramento Valley has progressed further than any other section of California in perfecting a leveed channel system of flood protection. Here a very extensive program is about two-thirds complete. The levees along the main river channel are constructed to grade and cross-section for practically the entire length and a substantial part of the large by-passes is already built. The principal unfinished work lies along the tributary streams. The control of floods by reservoirs could not affect the works already constructed except to increase their efficiency in protecting the reclaimed lands. It would reduce somewhat the volume of unfinished work, but the greatest benefit would accrue by the attainment of a higher degree of protection than is afforded by the present system of leveed channels alone whose planned degree of safety is inadequate for the intensive development and close settlement of the future. Other benefits would accrue in the reduced project maintenance and in the greater reclaimed areas and shorter traffic crossings attending the use of narrower channels than are at present planned along the tributary streams. Thus, the combined reservoir and leveed channel system of flood protection would have great value even in the Sacramento Valley, where the leveed channel system is largely completed.

Degree of protection in flood control systems.

In estimating the future, while witnessing the present rapid growth of population and expansion in property values, it would seem that public policy may require a higher degree of protection than present economy would dictate in order to preserve public confidence in the safety of residing and doing business in areas subject to flood hazard. From this viewpoint, the degree of protection rendered by flood control works becomes an important subject, for about a fifth of all the agricultural area in its natural condition is subject to flood menace.

In examining the essential characteristics of the two systems of flood protection, there does not seem to be any inherent difference in the degree of protection afforded by either one. Although there is a danger in transporting large volumes of water above the ground surface between parallel leveees because of the dependence for safety upon the integrity of many miles of earth dike, nevertheless this system could be constructed to offer the same degree of protection that is contained in the reservoir system. The levees would have to be built with heavy cross-section and protected on their face from wave wash and sloughing and the channels would have to be properly maintained.

The degree of protection offered by either system or their combination, if sound physical works are constructed with equal safety factors, is essentially dependent upon the possibility of occurrence of floods greater than the capacity for which the system is designed. Under either system, should a flood exceed the design capacity, the channels would be surcharged, with the consequent flooding of the adjacent lands. Inquiry into the possibility of occurrence of floods greater than the design capacity of protective systems, therefore, must be the principal feature of a general discussion of the degree of protection offered by flood control systems.

Frequency of flood occurrence.

A discussion of the occurrence of floods in California streams and the probable frequency with which floods of various sizes might be expected to occur has been presented in the 1923 report* on the water resources of the State. Here it is shown that stream flow closely follows the characteristics of precipitation, the volume of which is the resultant of the vicissitudes of weather so complex that they defy analysis.

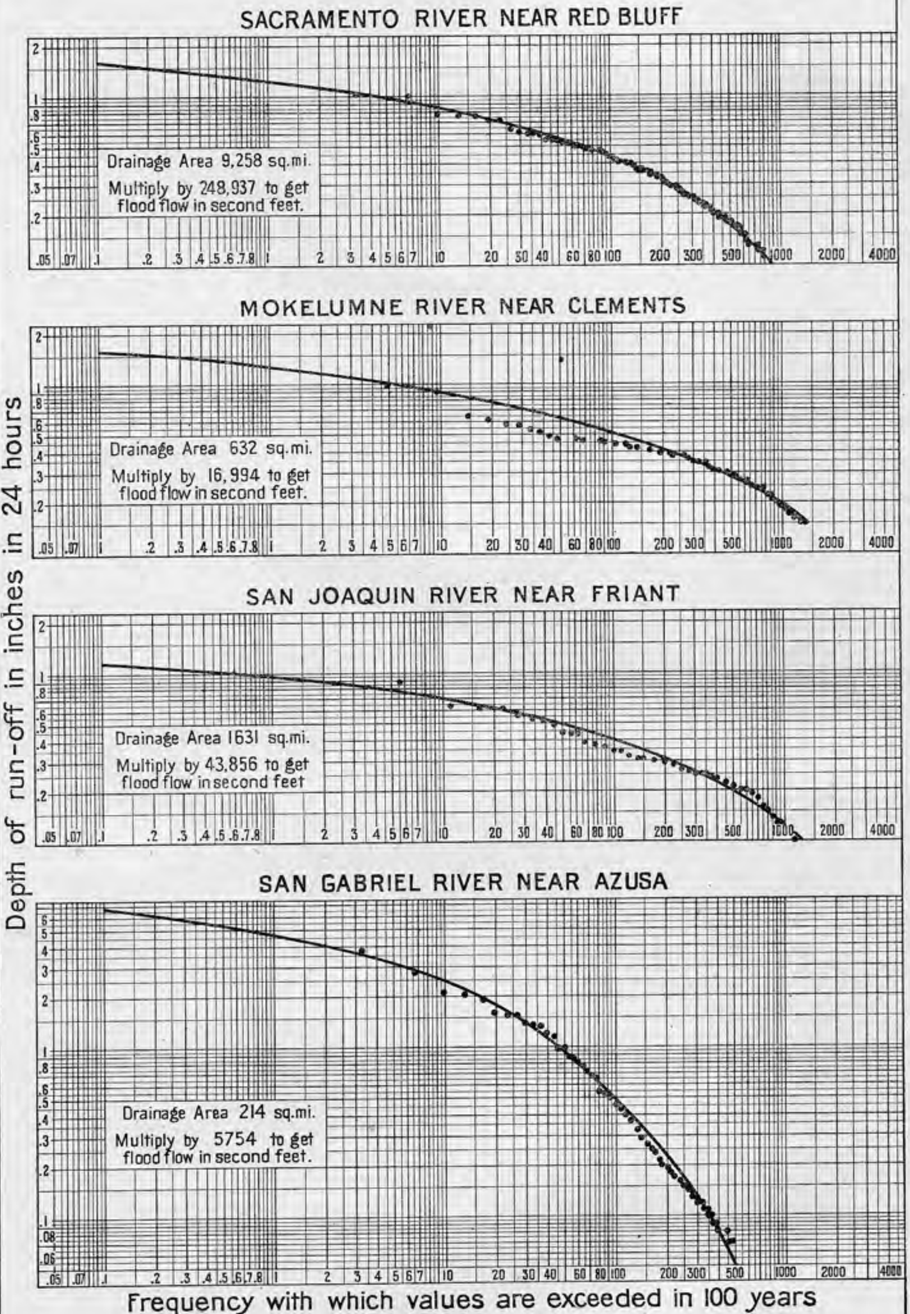
Precipitation records show that extremely high rates of rainfall are rather infrequent and invariably occur in the winter months only. The record at San Francisco,** centrally located and one of the longest in the State, shows that more than four inches of rain in twenty-four hours occurred but once in the sixty-one years of record, while from three to four inches of rain in twenty-four hours occurred nine times in sixty-one years, from two to three inches twenty-nine times, and from one to two inches one hundred and sixty times. Thus, it is seen that the highest rates of rainfall occur only at long average intervals of time, while the lower rates occur oftener and with increasing frequency as the rate becomes less.

The duration of rainstorms follows a similar behavior. The San Francisco record shows that eight consecutive days of rain averaging more than one inch in twenty-four hours occurred but four times in the sixty-one years of record, while it occurred for four consecutive days twenty-nine times, for three consecutive days fifty-three times, two consecutive days one hundred and nine times, and one day three hundred and eight times. Since it is the combination of extended storms and high rates of precipitation that furnish flood run-off, the frequency of flood occurrence in the stream channels of California may be expected

* Chap. V, Bul. No. 5, "Flow in California Streams," of the Division of Engineering and Irrigation, State Department of Public Works.

** U. S. Weather Bureau Record 1897 to 1926. Private Record of John Petee 1865 to 1897.

PLATE II.



PROBABLE FREQUENCY OF FLOOD DISCHARGE

to have characteristics similar to the frequency and duration of the higher rates of precipitation.

An extended comparison of all the stream-gaging records in the State* reveals this to be true. Although this study does not disclose the sequence with which floods of various sizes follow one another, it does indicate that there is a rather fixed relation between the size of floods and the average interval of time between their occurrence. In general, it indicates that, on an average of once in four years, floods may occur double or more the size that is exceeded but once a year; that on an average of once in twenty years floods may occur three or more times this volume; that once in two hundred years they may occur over four times this volume; and at intervals of a few thousand years a flood may be expected surpassing five times the volume that is exceeded on an average but once a year. It thus appears that the largest possible flood may not have occurred on any California stream since white man has resided here, and that the greatest flood yet observed on any of the streams may be exceeded at any time, but only at average intervals that increase in length as the magnitude of the excess is greater.

The relation of the size of floods to the average interval of time between their occurrence disclosed by the stream flow records on four typical streams, the Sacramento, the Mokelumne, the San Joaquin and the San Gabriel rivers, is set forth on Plate II, "Probable Frequency of Flood Discharge." For convenience of comparison, the rate of flood run-off is here expressed as inches depth of run-off in twenty-four hours on the tributary drainage area. A multiplying factor is given on each chart to convert the values of depth of run-off on the drainage area into mean rate of run-off for twenty-four hours in second-feet. The horizontal scale expresses the frequency with which values are exceeded in 100 years. The dots plotted on the charts are the floods on the respective streams taken from the records of measured stream flow that have been maintained for the past twenty to thirty years. The actual occurrences counted from the records have been expanded by proportion to obtain the probable number that would have occurred had the record been 100 years in length. Double logarithmic scales were used in plotting these charts because of the convenience in shape of the resulting curves.

To illustrate the interpretation of Plate II, reference is made to the upper diagram portraying the probable frequency of flood occurrence on the Sacramento River near Red Bluff. On this diagram the horizontal scale represents frequency. The whole figure 1 represents one flood crest in 100 years. One-tenth represents one-tenth of a flood in 100 years or one flood in 1000 years. Similarly 4 represents four flood crests in 100 years or one each 25 years. Following up the vertical line labeled 4 on the horizontal frequency scale, to intersection with the curve, it will be noted that the value opposite the intersection on the vertical scale of run-off on the left is one. This means that, on an average, four flood crests in 100 years, or one in twenty-five years, will probably exceed one inch in depth of run-off in twenty-four hours on the tributary drainage area. This rate of flood run-off is converted into second-feet by multiplying by the factor 248,937 (shown on the face of the diagram). Thus 249,000 second-feet mean daily flow may be

* Chap. V, Bul. No. 5, "Flow in California Streams," of the Division of Engineering and Irrigation, State Department of Public Works.

exceeded on an average of once in 25 years. For convenience, this value has been referred to in Chapter I as the "once-in-25-year flood." It approximates the flood called "maximum" in the usual engineering parlance of this locality.

It may be observed on Plate II that the plotted data fairly define curves of regular shape that may be extended beyond the limits of the observations. By so doing, some comprehension may be gained of the frequency with which floods might occur greater than those appearing in the comparatively short period of observation. The following table, obtained by scaling the charts, shows how rarely the excessively large floods occur. It also shows how the size of flood, that may be expected at increasing intervals, grows larger quite rapidly up to those occurring on an average of once in twenty-five years. For longer intervals the size grows larger less rapidly.

DEPTH OF FLOOD RUN-OFF ON DRAINAGE AREA OF FOUR ILLUSTRATIVE STREAMS IN INCHES PER 24 HOURS.

River	Frequency with which values are exceeded					
	Once a year	Once in 10 years	Once in 25 years	Once in 50 years	Once in 100 years	Once in 1000 years
Sacramento	0.44	0.85	1.00	1.15	1.25	1.65
Mokelumne*	0.51	0.89	1.05	1.15	1.25	1.61
San Joaquin	0.40	0.71	0.81	0.89	0.96	1.22
San Gabriel	0.49	2.49	3.34	4.00	4.62	6.74

It is seen that the depth of flood run-off from the drainage areas of the three streams north of Tehachapi Pass is much alike for large floods, except that it is slightly smaller on the San Joaquin River. The depth of flood run-off on the San Gabriel, a typical stream of southern California, is several times as great for large floods as on the northern streams. It shows how much larger floods in proportion to the size of their drainage areas develop on the southern streams.

The foregoing table of frequency of flood flows on the four illustrative streams, in expressing the rate of run-off in inches depth on the drainage area per twenty-four hours, does not show the actual magnitude of the flood values. The following table expresses the values parallel to the former table in second-feet. These are the estimated quantities at the gaging station on each stream near the edge of the valley floor.

* Water Supply Paper No. 551 of the United States Geological Survey, recently published, places the maximum discharge of the Mokelumne River at Clements at 25,500 second feet. This is obtained by applying the rating curve of the 1911 flood to the gage heights of 1907. The crest discharge of the 1907 flood has been published as 17,000 second feet in former publications including Water Supply Paper No. 299 in which are printed the daily discharges of the 1907 flood. The figures contained in Water Supply Paper No. 299 have been used in preparing this volume. Should the daily discharges of the 1907 flood be revised by application of the 1907 gage heights to the 1911 rating curve, the increase in their values would be so substantial as to require a complete revision of the analyses of floods on the Mokelumne River contained in this volume in order to make the analyses harmonize with the increased discharge values.

FLOOD RUN-OFF OF THE FOUR ILLUSTRATIVE STREAMS IN SECOND-FEET.

River	Frequency with which values are exceeded					
	Once a year	Once in 10 years	Once in 25 years	Once in 50 years	Once in 100 years	Once in 1000 years
Sacramento	109,000	212,000	249,000	286,000	311,000	411,000
Mokelumne*	8,700	15,100	17,800	19,500	21,200	27,400
San Joaquin	17,500	31,200	35,600	39,000	42,100	53,500
San Gabriel	2,800	14,300	19,200	23,000	26,600	38,800

It is interesting to note in examining the charts of Plate II that, even with the continued extension of these curves to intervals of time thousands of years long, the size of floods still grows larger with the increasing length of the interval. This indicates that there probably is no limit to the size of floods that may occur, but that the very largest ones occur only at intervals of many thousands of years. It would appear, therefore, that absolute protection from floods is impossible and that the degree of protection desired should be carefully considered in laying out protective systems.

Because of the unlimited size in which floods may occur, flood control embodies an economic question as to the size for which protective works should be designed. The engineering profession has generally accepted designs based upon the greatest flood of record or upon a more or less arbitrary increase to it resulting from a study of high water marks or the memory of old inhabitants. The foregoing analysis, however, shows that all of these may be exceeded at long intervals of time. The design floods used in the adopted flood control plan ** for the Sacramento Valley, the greatest work in flood control consummated in California, are found to closely approximate the mean daily values that may be exceeded on an average of once in twenty-five years. The design quantities adopted by the California Debris Commission in 1911 were revised in 1925 after further study. Both the original and revised quantities are compared to the once-in-25-year values in the following table:

* Water Supply Paper No. 551 of the United States Geological Survey, recently published, places the maximum discharge of the Mokelumne River at Clements at 25,500 second feet. This is obtained by applying the rating curve of the 1911 flood to the gage heights of 1907. The crest discharge of the 1907 flood has been published as 17,000 second feet in former publications including Water Supply Paper No. 299 in which are printed the daily discharges of the 1907 flood. The figures contained in Water Supply Paper No. 299 have been used in preparing this volume. Should the daily discharges of the 1907 flood be revised by application of the 1907 gage heights to the 1911 rating curve, the increase in their values would be so substantial as to require a complete revision of the analyses of floods on the Mokelumne River contained in this volume in order to make the analyses harmonize with the increased discharge values.

** Report of California Debris Commission, June 29, 1911.

COMPARISON OF DESIGN FLOOD FLOW USED BY CALIFORNIA DEBRIS COMMISSION IN SACRAMENTO VALLEY FLOOD CONTROL PROJECT WITH THE ONCE-IN-25-YEAR VALUES OF THE WATER RESOURCES INVESTIGATION.

Stream	Design flood flows of California Debris Commission in second-feet		Flood flows (av. 24 hrs.) exceeded once in 25 years Water Resources Investigation in second-feet
	1911 Report	1925 Report	
Sacramento River near Red Bluff	250,000	260,000	249,000
Feather River	150,000	180,000	171,000
Yuba River	110,000	120,000	128,000
Bear River	30,000	30,000	29,000
American River	120,000	128,000	119,000
Stony Creek	30,000	30,000	45,000
Cache Creek	20,000	20,000	20,000
Putah Creek	25,000	25,000	46,000

In the Sacramento Valley the crest discharge of large floods is approximately 10 per cent greater than the average flow for twenty-four hours. Therefore, the crest of the once-in-25-year flood would encroach upon the freeboard of the levees of the Debris Commission plan to the extent of about 10 per cent of the channel capacity. Since this encroachment on the freeboard would be of only a few hours' duration, with usual maintenance, the works as planned should protect the project against floods that will not be exceeded on an average oftener than once in twenty-five years. Because of the difficulty in parts of the project, not intensively cultivated, of meeting assessments for the work from the sale of products of the land, it is believed that this protection is greater than these lands can now afford. On the other hand, perhaps it is not a sufficient degree of protection for the intensively cultivated sections and the thickly populated areas about the City of Sacramento. It would seem that at least the design flood for the American River, which directly menaces the City of Sacramento, should be relatively larger than for other parts of the project. Thus, the degree of protection employed in designing flood control projects should be governed by the class of territory to be protected. Logically, it should be increased from time to time as the territory becomes more thickly populated and property values become larger. The analysis here presented offers a convenient means of expressing the degree of protection of any project in terms of the average interval of time in which the design flood may be expected to be exceeded.

CHAPTER III.

THE PRINCIPAL CHARACTERISTICS OF FLOOD OCCURRENCE.

Regularity of flood occurrence.

It has been pointed out in Chapter II, that the records of stream flow in California disclose a relation between the size of floods and the average frequency of their occurrence. Floods occur in their varying sizes at regular average intervals throughout long periods of time. Although floods happen almost every year, only the smaller ones are at all frequent. Extremely large floods occur at such long average intervals that several generations may pass without witnessing one of greatest magnitude. This relation disregards the sequence with which the various sizes follow one another and expresses only the average frequency of their occurrence. A glance at the records is conclusive that the actual sequence is most irregular although the average occurrence seems to follow a regular behavior.

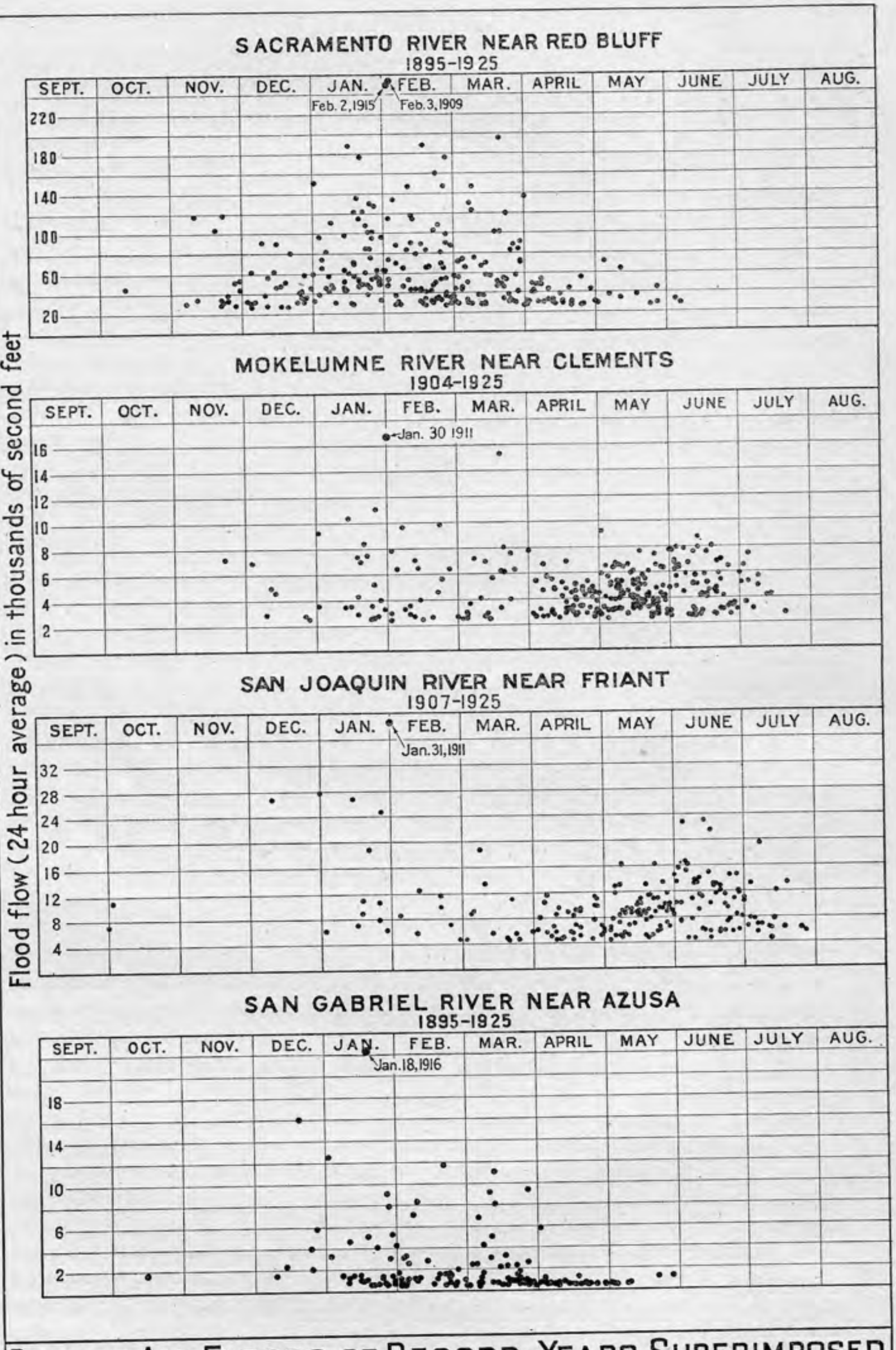
The combination of this irregularity in sequence of the various size floods and the long average intervals between the large ones, creates an impression of erratic behavior in flood occurrence that is not indicated by a close analysis of the records. A study of the records shows that a degree of systematic behavior exists sufficient to determine within useful limits certain characteristics as to the time of year and the amount of previous precipitation in the season with which they occur. However, this behavior is not so systematic that the relations may be discussed by directly plotting the quantities on coordinate paper in the usual manner; rather they must be approached by determining limiting values within which all events occur. The limiting values to these relations found to characterize floods by these investigations, are presented herewith. They concern the time of year, the previous seasonal rainfall, and the seasonal run-off subsequent to flood occurrence.

Time of year of flood occurrence.

The sharp division of the California year into a wet and dry season is of common knowledge.* Precipitation in any quantity is confined to the six months period from November 1st to May 1st while the remaining six months are for the most part warm and dry. Except in the desert sections of the State and on streams fed by extensive snow fields, floods occur only during the rainy season; however, the extent to which the flood season varies through the six months in which rains occur, is not generally appreciated. Stream flow records indicate that the time of year in which the largest floods occur is limited to mid-winter and, during the remainder of the six months period of rain, only lesser floods occur in sizes that become smaller toward either extremity of the season until a date is disclosed before and after which floods do not occur. On streams fed by extensive snow fields, floods of

* For full exposition see Chap. II, Bul. No. 6, "Irrigation Requirements of California Lands," of Division of Engineering and Irrigation. State Department of Public Works.

PLATE III.



PLOT OF ALL FLOODS OF RECORD-YEARS SUPERIMPOSED medium size occur in the early summer after the close of the precipitation season. These floods, fed by melting snow, are not as large but are of longer duration than those fed from rainfall. They have their special characteristics. An extended investigation of the time of year of flood occurrence was made on streams having the longest record of measurements. In order to avoid a tiresome review of similar data, those of four typical streams only are presented, the Sacramento, Mokelumne, San Joaquin and San Gabriel rivers. These data are displayed on Plate III, "Plot of All Floods of Record—Years Superimposed." A dot is plotted on this plate for every flood of record both large and small, at the day of its occurrence indicated on the horizontal time scale. The size of each flood in second-feet is shown on the vertical scale.

The great preponderance of small floods and the apparent irregularity in occurrence of the larger ones may be observed at once by the relative position of the dots. The manner of their clustering also illustrates how the larger floods occur during the midwinter months and how their magnitude decreases towards the fore and latter part of the season.

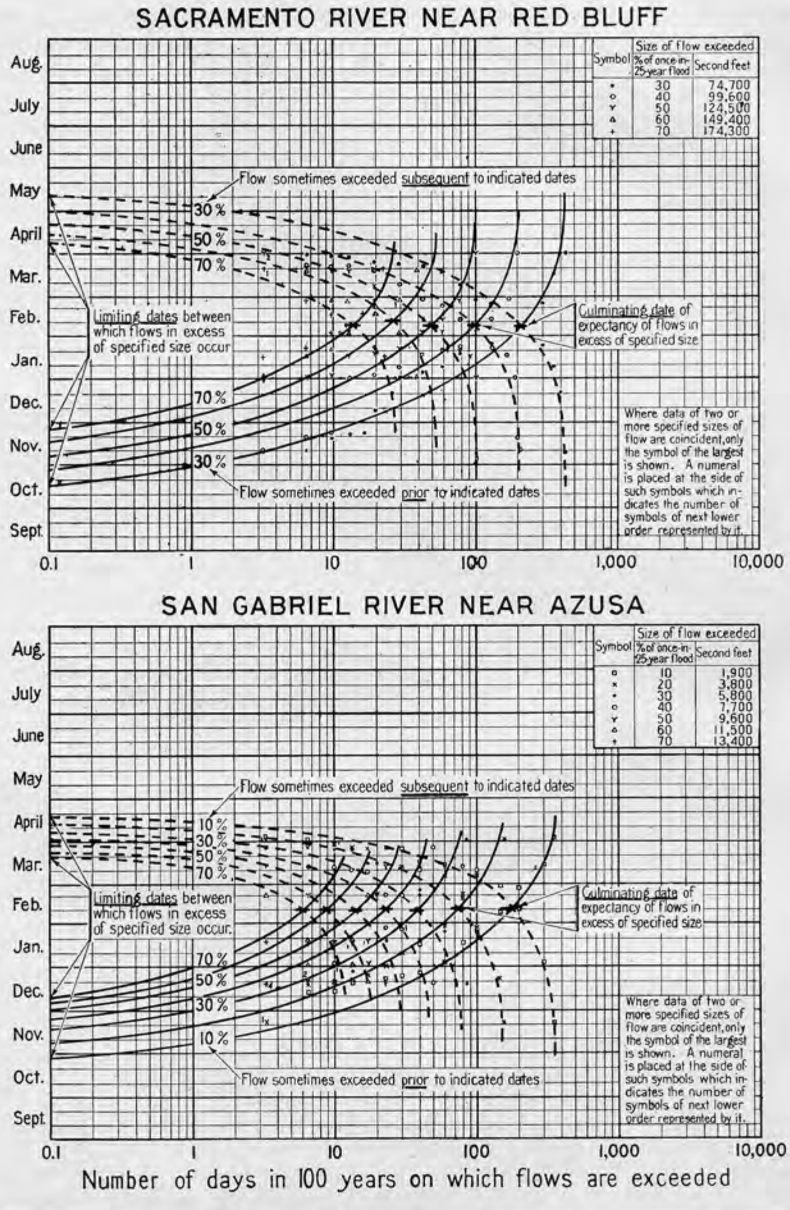
The dots of greatest height on the graphs are in the midwinter months for all four streams. These represent rain-water floods. The dots on the plots for the Mokelumne and San Joaquin rivers forming a distinct cluster in the early summer months, but of lesser height, represent floods resulting from rapidly melting snow on the high mountainous parts of their drainage areas. The Sacramento and San Gabriel drainage areas do not have sufficient precipitation as snow to cause floods during the melting season. Most of the snow that falls on these drainage areas melts in the early spring and augments the run-off from rainfall. It is interesting to note from the manner in which the two groups of dots cluster, that floods from melting snow occur with greater frequency and regularity than those from rainfall but, in general, do not attain much more than half the size of the large midwinter rain-water floods.

The position of the dots, in relation to the time scale of the diagram, indicates dates before and after which floods of much size have not occurred within the 20 to 30 years of record on these streams. These dates vary somewhat on the several streams but, in general, floods resulting from rainfall occur between November 1st and May 1st with the largest ones in the months of January, February and March. The snow-water floods occur between May 1st and August 1st with the greatest ones in the first half of June.

Limiting dates to the flood season.

While Plate III, "Plot of All Floods of Record—Years Superimposed," furnishes a perspective of the time of year during which floods of the various sizes occur, a closer analysis is desirable for working purposes. It may be observed on Plate III that the relation between the size of floods and the time of their occurrence is rather broad in its character. There appears, however, to be certain limiting dates for the medium and large floods before and after which the many records of daily run-off disclose neither an instance of nor a tendency toward floods of that size occurring. For a close valuation of these limiting dates, it is not enough to enter the records of occurrence and select the dates

PLATE IV.



RELATION OF TIME OF YEAR TO FLOOD OCCURRENCE

CURVES SHOW NUMBER OF DAYS IN 100 YEARS ON WHICH FLOWS OCCUR IN EXCESS OF SPECIFIED SIZE PRIOR AND SUBSEQUENT TO INDICATED DATES

Flows expressed in per cent of greatest daily rate of flow of once-in-25-year flood

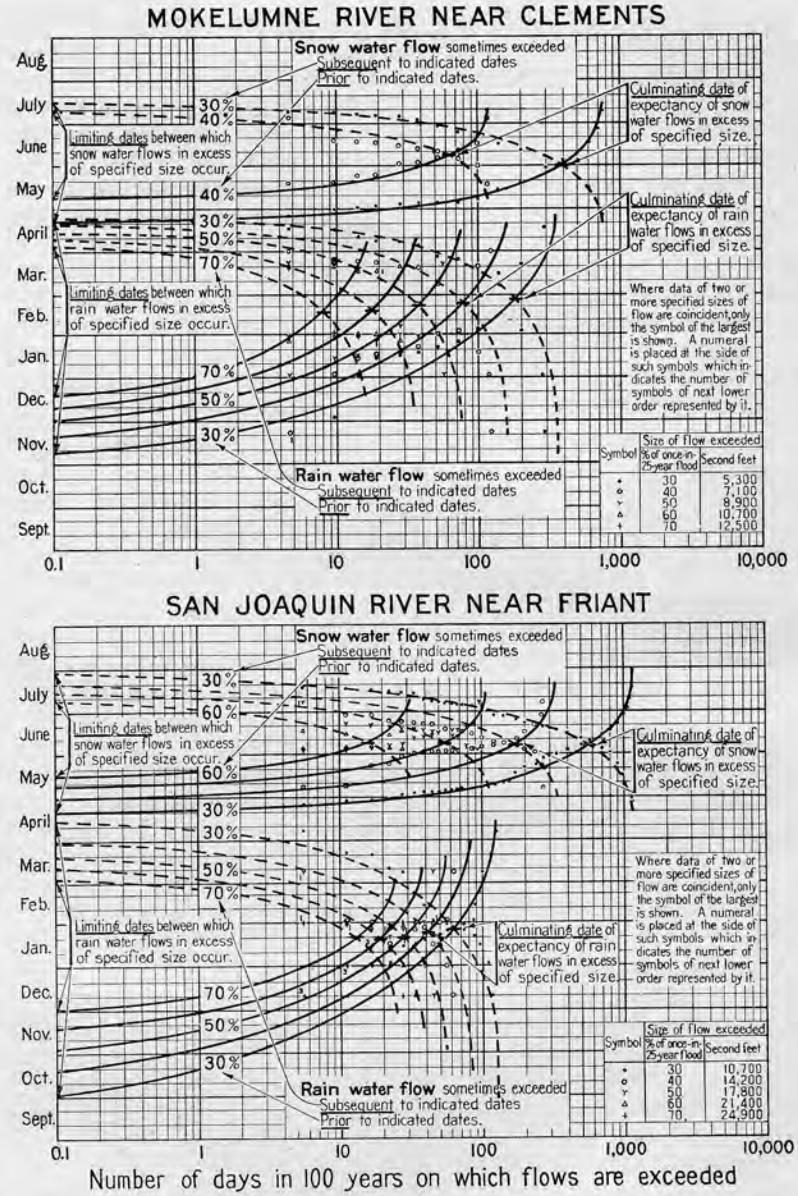
before and after which large floods have not occurred. In so doing, no conception would be gained of the reliance that could be placed upon their future occurrence within the dates selected.

In order to determine as well as may be, the reliance that may be placed on selected limiting dates, the daily stream flow records of twenty streams were analyzed in regard to the frequency with which specified flows were exceeded both prior and subsequent to various dates during the season. The analysis tabulated the occurrences within the period of record so that their frequency could be counted. The frequencies counted from the records of the four illustrative streams, are plotted on Plates IV and V, "Relation of Time of Year to Flood Occurrence." Plate IV presents the data for the Sacramento and San Gabriel rivers and Plate V for the Mokelumne and San Joaquin rivers. The rates of flow are expressed in relation to that of a once-in-25-year flood for convenience of comparison between streams. A conversion table to second feet is given on each diagram. Cross-section paper ruled to logarithmic scale in one direction was used, since it was found by trial that more satisfactory graphs could be obtained by so doing.

Smooth curves were drawn approximating the trend of these data and labeled with the rate of flow for which the computations were made. There are two curves in each diagram for the same rate of flow, one full-line and one dotted-line curve. The full-line curve shows the probable frequency with which the specified flow is exceeded prior to the date indicated on the vertical scale. The dotted-line curve shows the probable frequency with which it is exceeded subsequent to the date indicated on the vertical scale. While it is evident that the data do not disclose exact relationships, it may be noted that the curves representing the smaller flows are fairly well defined. More data are available concerning small flows than large ones for they appear a greater number of times in the records. The short term of the records relative to the infrequent occurrence of large flood flows prevents their containing adequate data for displaying the relations plainly. Were there as many data contained in the comparatively short records concerning the larger flows as there are for the smaller ones, it seems probable that their curves would be equally well defined. However, the curves for the larger values take logical positions in relation to available data when drafted by comparison with the data for the smaller flows.

The advantage of the analysis delineated on Plates IV and V is that the curves of relationship developed from the data collected during a quarter century, may be extended to indicate expectancies, had the records covered much longer periods of time. For instance, by extending these curves to intersect the 0.1 line on the frequency scale, the time of the year before and after which greater flows than the specified sizes do not occur oftener than one day in a thousand years (0.1 day in 100 years) is indicated on the vertical time scale by the points of intersection. Intercepts of the full and dotted-line curves on other verticals than the 0.1 line, indicate on the vertical time scale, the period of the year before and after which the specified flows are exceeded more frequently than one day in a thousand years. The frequency with which they are exceeded is shown by the position of the vertical line intersected by the two curves on the horizontal frequency scale.

PLATE V.



RELATION OF TIME OF YEAR TO FLOOD OCCURRENCE

CURVES SHOW NUMBER OF DAYS IN 100 YEARS ON WHICH FLOWS OCCUR IN EXCESS OF SPECIFIED SIZE PRIOR AND SUBSEQUENT TO INDICATED DATES.

Flows expressed in per cent of greatest daily rate of flow of a once-in-25-year flood.

By way of illustration of the interpretation of these plates, reference is made to the upper chart on Plate IV, showing the relation of the time of year to flood occurrence on the Sacramento River near Red Bluff. Selecting the vertical ordinate that passes through the figure 1 on the horizontal frequency scale, it is seen to intersect the full-line curve labeled 50 per cent, opposite November 22d on the vertical time scale to the left. This means that on an average of one day in 100 years there probably will be a flow exceeding 50 per cent of a once-in-25-year flood prior to November 22d. Following the same vertical ordinate to intersection with the dotted-line curve labeled 50 per cent, it is seen that the intersection is opposite April 12th on the time scale to the left. This means that on an average of one day in 100 years, a flow exceeding 50 per cent of a once-in-25-year flood will probably occur subsequent to April 12th. Thus, November 22d and April 12th are the limiting dates of the season for floods greater than half the size of the once-in-25-year value with the probability that either limit may not be exceeded oftener on an average than one day in 100 years.

The information taken from Plates IV and V is expressed in the following tables. Here are given in the several columns the probable dates before and after which greater flows than the several specified sizes do not occur oftener on the average than one day in a thousand, one day in a hundred, one day in fifty, one day in twenty-five and one day in ten years. It is interesting to observe in reviewing these tables, that, of the 365 days in the year, the season for the occurrence of rain-water floods of corresponding size (equal per cent of once-in-25-year flood) opens and closes on the four illustrative streams with the greatest variance in dates of 47 days. It opens from 40 to 72 days earlier for the smaller floods than for the large ones and closes from 20 to 57 days later. For decreasing the probability from one day in 10 years to one day in 1000 years that flows in excess of those specified will not occur either before or after these opening and closing dates, the season opens as much as 65 days earlier and closes as much as 49 days later.

The season for the occurrence of floods from rapidly melting snow is seen to be less variable than that for rain-water floods. Of the two illustrative streams having snow-water floods, the season for floods of corresponding size opens and closes within 14 days of the same dates and these dates do not change more than 23 days for decreasing the probability from one day in 10 years to one day in 1000 years that flows in excess of those specified will not occur either before or after the opening or closing dates.

LIMITING DATES OF FLOOD SEASON ON SACRAMENTO RIVER.

Size of flood near Red Bluff—greatest daily rate of flow		Opening dates					Closing dates				
		Frequency with which greater flows occur **prior** to tabulated date					Frequency with which greater flows occur **subsequent** to tabulated date				
In per cent of once-in-25-year flood	In second-feet	One day in 1000 years	One day in 100 years	One day in 50 years	One day in 25 years	One day in 10 years	One day in 1000 years	One day in 100 years	One day in 50 years	One day in 25 years	One day in 10 years
30	74,700	Oct. 15	Oct. 29	Nov. 4	Nov. 11	Nov. 23	May 12	May 4	Apr. 30	Apr. 25	Apr. 15
40	99,600	Oct. 27	Nov. 11	Nov. 17	Nov. 25	Dec. 9	Apr. 30	Apr. 21	Apr. 17	Apr. 10	Mar. 31
50	124,500	Nov. 7	Nov. 22	Nov. 29	Dec. 8	Dec. 24	Apr. 21	Apr. 12	Apr. 7	Mar. 31	Mar. 19
60	149,400	Nov. 16	Dec. 2	Dec. 11	Dec. 21	Jan. 10	Apr. 13	Apr. 3	Mar. 29	Mar. 21	Mar. 7
70	174,300	Nov. 24	Dec. 11	Dec. 22	Jan. 4	Jan. 28	Apr. 7	Mar. 27	Mar. 19	Mar. 9	Feb. 17

LIMITING DATES OF FLOOD SEASON ON MOKELUMNE RIVER.

Size of flood near Clements—greatest daily rate of flow		Opening dates					Closing dates				
		Frequency with which greater flows occur **prior** to tabulated date					Frequency with which greater flows occur **subsequent** to tabulated date				
In per cent of once-in-25-year flood	In second-feet	One day in 1000 years	One day in 100 years	One day in 50 years	One day in 25 years	One day in 10 years	One day in 1000 years	One day in 100 years	One day in 50 years	One day in 25 years	One day in 10 years
					Rain-Water Floods.						
30	5,300	Nov. 7	Nov. 18	Nov. 24	Dec. 1	Dec. 12	Apr. 24	Apr. 22	Apr. 20	Apr. 18	Apr. 14
40	7,100	Nov. 20	Dec. 1	Dec. 7	Dec. 14	Dec. 28	Apr. 19	Apr. 16	Apr. 14	Apr. 11	Apr. 5
50	8,900	Dec. 1	Dec. 12	Dec. 18	Dec. 27	Jan. 11	Apr. 14	Apr. 10	Apr. 8	Apr. 4	Mar. 25
60	10,700	Dec. 10	Dec. 22	Dec. 30	Jan. 9	Jan. 30	Apr. 9	Apr. 3	Mar. 30	Mar. 23	Mar. 8
70	12,500	Dec. 18	Dec. 31	Jan. 10	Jan. 25	....	Apr. 4	Mar. 26	Mar. 19	Mar. 8	....
					Snow-Water Floods.						
30	5,300	Apr. 22	Apr. 24	Apr. 25	Apr. 26	Apr. 27	July 15	July 13	July 12	July 10	July 7
40	7,100	May 8	May 10	May 12	May 14	May 19	July 9	July 5	July 3	June 30	June 25

LIMITING DATES OF FLOOD SEASON ON SAN JOAQUIN RIVER.

Size of flood near Friant—greatest daily rate of flow		Opening dates					Closing dates				
		Frequency with which greater flows occur **prior** to tabulated date					Frequency with which greater flows occur **subsequent** to tabulated date				
In per cent of once-in-25-year flood	In second-feet	One day in 1000 years	One day in 100 years	One day in 50 years	One day in 25 years	One day in 10 years	One day in 1000 years	One day in 100 years	One day in 50 years	One day in 25 years	One day in 10 years
					Rain-Water Floods.						
30	10,700	Oct. 1	Oct. 20	Oct. 29	Nov. 9	Nov. 28	Apr. 14	Apr. 8	Apr. 4	Mar. 30	Mar. 19
40	14,200	Oct. 18	Nov. 3	Nov. 11	Nov. 21	Dec. 8	Mar. 30	Mar. 23	Mar. 19	Mar. 14	Mar. 2
50	17,800	Nov. 3	Nov. 16	Nov. 23	Dec. 2	Dec. 19	Mar. 19	Mar. 12	Mar. 7	Mar. 2	Feb. 17
60	21,400	Nov. 17	Nov. 29	Dec. 5	Dec. 13	Dec. 31	Mar. 11	Mar. 4	Feb. 27	Feb. 21	Feb. 7
70	24,900	Nov. 30	Dec. 11	Dec. 17	Dec. 25	Jan. 13	Mar. 4	Feb. 24	Feb. 20	Feb. 12	Jan. 27
					Snow-Water Floods.						
30	10,700	Apr. 20	Apr. 22	Apr. 23	Apr. 24	Apr. 27	July 29	July 25	July 23	July 21	July 18
40	14,200	Apr. 30	May 2	May 3	May 5	May 8	July 20	July 16	July 14	July 12	July 8
50	17,800	May 8	May 10	May 12	May 15	May 20	July 13	July 9	July 7	July 4	June 30
60	21,400	May 15	May 19	May 22	May 25	June 1	July 8	July 2	June 29	June 24	June 15

LIMITING DATES OF FLOOD SEASON ON SAN GABRIEL RIVER.

Size of flood near Azusa—greatest daily rate of flow		Opening dates					Closing dates				
		Frequency with which greater flows occur **prior** to tabulated date					Frequency with which greater flows occur **subsequent** to tabulated date				
In per cent of once-in-25-year flood	In second-feet	One day in 1000 years	One day in 100 years	One day in 50 years	One day in 25 years	One day in 10 years	One day in 1000 years	One day in 100 years	One day in 50 years	One day in 25 years	One day in 10 years
10	1,900	Oct. 28	Nov. 6	Nov. 11	Nov. 18	Nov. 29	Apr. 18	Apr. 14	Apr. 11	Apr. 8	Apr. 3
20	3,800	Nov. 8	Nov. 19	Nov. 25	Dec. 3	Dec. 17	Apr. 12	Apr. 7	Apr. 4	Apr. 1	Mar. 25
30	5,800	Nov. 17	Nov. 30	Dec. 7	Dec. 15	Dec. 31	Apr. 6	Apr. 2	Mar. 30	Mar. 26	Mar. 17
40	7,700	Nov. 25	Dec. 8	Dec. 16	Dec. 26	Jan. 14	Apr. 1	Mar. 28	Mar. 25	Mar. 19	Mar. 6
50	9,600	Dec. 1	Dec. 17	Dec. 25	Jan. 6	Jan. 28	Mar. 28	Mar. 23	Mar. 19	Mar. 12	Feb. 22
60	11,500	Dec. 6	Dec. 23	Jan. 2	Jan. 16	....	Mar. 23	Mar. 17	Mar. 12	Mar. 3	....
70	13,400	Dec. 10	Dec. 30	Jan. 11	Jan. 28	....	Mar. 19	Mar. 12	Mar. 5	Feb. 22	....

Date of greatest flood expectancy.

Since the analysis of flood occurrence as disclosed by the records of the last quarter century shows definite limiting dates to the flood season before and after which the probability of their occurrence is exceedingly remote, it is reasonable that the flood expectancy should increase toward some culminating date and then decrease as the end of the season is approached. The data plotted on Plate III, "Plot of All Floods of Record—Years Superimposed," indicate such culminating dates for the several streams.

On Plates IV and V, "Relation of the Time of Year to Flood Occurrence," pairs of curves are drafted, one dotted and one full-line, each pair representing a flow of a specified size. The dotted curves show the probable frequency with which flows greater than specified occur subsequent to the dates indicated on the vertical time scale. The full-line curves show in a similar way, the probable frequency of greater flows prior to the date indicated on the time scale. As the two curves of a pair, one dotted and one full-line, approach each other, flows greater than the specified size occur more frequently until the central day of the flood season is reached at their intersection. On this day, flows greater than the specified size occur both before and after with equal frequency. It is the central day of occurrence for flows greater than the specified size.

The dates of the intersection of the several pairs of curves on each stream are nearly the same. On the San Gabriel they are within one day of being the same, on the Sacramento three days, on the San Joaquin seven days, and on the Mokelumne nine days. These dates are so nearly alike for the several size flows on each stream that they may be taken as the culminating dates of flood expectancy. They vary on the four illustrative streams from January 20 to February 26 for rain-water floods and, on the two illustrative streams having snow-water floods, from May 31 to June 8. These dates are listed in the following table:

CULMINATING DATES OF FLOOD EXPECTANCY.

Size of flood	Date					
In per cent of greatest daily rate of flow of once-in-25-year flood	Sacramento River	Mokelumne River		San Joaquin River		San Gabriel River
		Rain-water floods	Snow-water floods	Rain-water floods	Snow-water floods	
10	....	....	....	....	....	Feb. 11
20	....	....	....	....	....	Feb. 11
30	Feb. 8	Feb. 26	May 31	Jan. 27	June 6	Feb. 10
40	Feb. 7	Feb. 23	June 7	Jan. 24	June 7	Feb. 10
50	Feb. 8	Feb. 21	....	Jan. 21	June 8	Feb. 10
60	Feb. 10	Feb. 18	....	Jan. 20	June 8	Feb. 10
70	Feb. 7	Feb. 17	....	Jan. 20	....	Feb. 10

Preparatory precipitation for flood occurrence.

While the records of stream flow show that there is a definite season within which floods occur and that the expectancy of floods within this season increases toward culmination at some mid-season date, nevertheless, the expectancy on the successive days of each season is not identical in every year. Floods can not occur without preparatory precipitation to wet the earth's surface. If dry, this surface is so absorbent that even the heaviest rains are insufficient to produce large run-off. With the drainage area already saturated from previous precipitation, the same high intensities produce run-off that concentrates in the stream channels to form excessive floods. Sometimes, snow from previous storms, melting in contact with warm rains, augments the run-off from the later storm. For these reasons, the precipitation that has taken place prior to any date in a season markedly influences the expectancy of floods, and, since each season has its own peculiar number, intensity and sequence of storms, the flood expectancy varies on like dates of different seasons.

These investigations have searched for an index of the degree of preparedness of drainage areas necessary for turning off large floods. Since the varying intervals between storms dry up the ground surface to a different extent, the amount of precipitation that precedes floods is variable. An examination of the records shows that large floods have occurred only with very substantial preparatory precipitation. The following table shows the seasonal precipitation at the stations* used in conjunction with the analysis of run-off records, prior to the date of the largest floods on each of the four illustrative streams. The rainfall is expressed both in inches depth and in per cent of that of a normal season up to the date of the flood. (Season commencing on July 1.)

* These are the principal rainfall stations in the precipitation divisions in which the drainage areas lie. See Chap. II, Bul. No. 5, "Flow in California Streams." Here the State was divided into twenty-six areas, called "precipitation divisions," in each of which the rainfall at the various stations has approximately like characteristics when expressed in relation to its normal although the actual rain in inches at the several stations may be very different. The rain in inches at the selected stations is much less than on the drainage areas for they are all at accessible locations of low elevation.

PRECIPITATION PRIOR TO FLOOD OCCURRENCE.

Sacramento River					Mokelumne River									
					Rain-water floods					Snow-water floods				
Size of flood near Red Bluff—greatest daily rate of flow		Date of flood	Precipitation prior to flood,[1] Red Bluff rainfall station		Size of flood near Clements—greatest daily rate of flow		Date of flood	Precipitation prior to flood,[1] Electra rainfall station		Size of flood near Clements—greatest daily rate of flow		Date of flood	Precipitation prior to flood,[1] Electra rainfall station	
In per cent of once-in-25-year flood	In second-feet		In inches	In per cent of normal	In per cent of once-in-25-year flood	In second-feet		In inches	In per cent of normal	In per cent of once-in-25-year flood	In second-feet		In inches	In per cent of normal
102	254,000	Feb. 3, 1909	18.58	128	94	16,700	Jan. 30, 1911	21.94	132	49	8,740	June 12, 1906	42.28	130
100	249,000	Feb. 2, 1915	17.05	119	86	15,310	Mar. 19, 1907	37.39	142	45	8,030	June 18, 1911	47.78	146
79	196,000	Mar. 20, 1907	23.05	114	62	11,100	Jan. 26, 1914	23.79	151	45	7,970	June 3, 1922	31.29	97
76	188,000	Jan. 16, 1909	11.47	97	58	10,400	Jan. 14, 1909	10.32	79	45	7,960	June 12, 1911	47.78	147
76	188,000	Feb. 16, 1904	15.99	98	55	9,850	Feb. 21, 1914	28.59	134	44	7,880	June 6, 1911	47.75	147
71	177,000	Jan. 21, 1909	13.05	104	54	9,700	Feb. 6, 1925	13.87	76	44	7,770	May 31, 1922	31.29	97
71	176,000	Feb. 25, 1917	12.43	71	52	9,250	Jan. 1, 1914	9.35	94	44	7,750	June 1, 1915	34.43	106
64	160,000	Feb. 21, 1914	26.83	158	47	8,400	Jan. 21, 1909	19.47	133	43	7,670	May 18, 1922	30.81	97
61	151,000	Jan. 1, 1914	14.76	157	45	8,040	Mar. 20, 1916	30.54	115	43	7,600	June 16, 1906	42.28	130
61	151,000	Feb. 24, 1902	18.54	107	44	7,860	Feb. 2, 1907	24.01	139	42	7,550	June 10, 1917	29.14	89
59	147,000	Mar. 8, 1904	20.86	110	43	7,750	Mar. 31, 1906	31.89	112	42	7,500	May 24, 1911	47.71	149
56	140,000	Feb. 10, 1902	13.88	90	43	7,610	Mar. 23, 1907	44.05	163	42	7,480	July 4, 1906	[2]42.60	130
55	137,000	Mar. 31, 1906	25.53	120	42	7,470	Jan. 22, 1914	20.22	137	39	6,960	June 22, 1906	42.58	130
55	136,000	Jan. 19, 1906	8.71	71	41	7,350	Jan. 18, 1921	17.42	125	39	6,960	June 2, 1907	49.41	152
54	134,000	Feb. 4, 1907	16.82	115	41	7,210	Mar. 7, 1911	37.12	153	38	6,850	June 20, 1906	42.58	130
53	131,000	Jan. 25, 1903	14.81	112	40	7,200	Nov. 21, 1909	6.75	188	38	6,800	June 2, 1909	38.95	120
52	130,000	Mar. 7, 1911	19.62	104	40	7,060	Feb. 11, 1919	13.47	70	38	6,750	May 7, 1906	37.71	120
51	128,000	Jan. 27, 1896	11.79	87	39	6,960	Jan. 19, 1906	12.60	89	38	6,700	June 8, 1915	34.43	106
49	123,000	Mar. 8, 1900	17.84	94	39	6,940	Mar. 12, 1918	16.60	66	37	6,640	May 9, 1906	37.71	120
49	122,000	Jan. 22, 1914	21.32	168	39	6,910	Apr. 16, 1925	30.28	101	37	6,630	May 13, 1915	32.13	102

[1]Precipitation includes all rainfall from July 1st to morning of the day before the flood.

PRECIPITATION PRIOR TO FLOOD OCCURRENCE.

San Joaquin River										San Gabriel River				
Rain-water floods					Snow-water floods									
Size of flood near Friant—greatest daily rate of flow		Date of flood	Precipitation prior to flood,[1] Fresno rainfall station		Size of flood near Friant—greatest daily rate of flow		Date of flood	Precipitation prior to flood,[1] Fresno rainfall station		Size of flood near Azusa—greatest daily rate of flow		Date of flood	Precipitation prior to flood,[1] Claremont rainfall station	
In per cent of once-in-25-year flood	In second-feet		In inches	In per cent of normal	In per cent of once-in-25-year flood	In second-feet		In inches	In per cent of normal	In per cent of once-in-25-year flood	In second-feet		In inches	In per cent of normal
109	38,800	Jan. 31, 1911	4.67	97	65	23,100	June 13, 1911	11.80	123	116	22,300	Jan. 18, 1916	11.73	156
78	27,900	Dec. 31, 1909	23.58	[3]155	64	22,800	June 4, 1909	9.79	103	83	16,000	Dec. 19, 1921	2.84	71
75	26,800	Jan. 14, 1909	3.09	79	60	21,500	June 16, 1911	11.80	123	65	12,500	Jan. 1, 1910	8.15	157
75	26,800	Dec. 10, 1909	17.53	[3]167	55	19,500	July 7, 1911	[2]11.80	123	61	11,800	Feb. 20, 1914	17.05	146
69	24,700	Jan. 26, 1914	7.05	157	47	16,700	June 5, 1922	10.71	113	58	11,130	Mar. 12, 1905	12.29	85
53	18,900	Jan. 21, 1909	3.70	88	46	16,200	May 22, 1911	11.80	126	49	9,430	Mar. 26, 1906	16.58	102
53	18,800	Mar. 8, 1911	8.24	119	46	16,200	June 6, 1911	11.80	124	48	9,160	Mar. 10, 1911	17.74	126
38	13,600	May 10, 1911	9.91	142	46	16,200	May 8, 1909	9.79	108	48	9,150	Jan. 26, 1914	9.94	118
35	12,500	Feb. 12, 1909	8.04	146	44	15,700	June 2, 1914	10.81	114	43	8,200	Feb. 9, 1922	18.71	180
33	11,700	Feb. 21, 1917	5.73	96	43	15,300	June 5, 1912	7.34	77	42	8,020	Mar. 12, 1906	9.50	66
33	11,600	Apr. 6, 1911	10.83	130	42	14,900	June 15, 1909	9.79	102	41	7,940	Jan. 27, 1916	18.15	209
31	11,000	Jan. 18, 1916	5.66	138	41	14,700	June 27, 1911	11.80	123	37	7,100	Feb. 7, 1909	13.26	133
31	11,000	Mar. 21, 1916	11.12	146	41	14,700	May 31, 1922	10.71	113	35	6,810	Mar. 5, 1907	19.97	148
31	10,900	Oct. 2, 1918	0.53	177	41	14,600	June 24, 1909	9.87	103	31	5,920	Apr. 1, 1903	19.78	[4]88
30	10,700	Jan. 25, 1911	3.06	68	39	14,000	June 11, 1909	9.79	102	31	5,900	Dec. 27, 1921	12.36	263
29	10,400	Apr. 5, 1914	10.22	125	39	13,800	June 9, 1915	10.92	114	27	5,260	Jan. 29, 1911	6.07	69
28	9,910	Feb. 21, 1914	9.04	151	38	13,500	June 1, 1915	10.92	115	27	5,110	Jan. 18, 1914	7.90	107
26	9,150	Mar. 5, 1916	10.23	153	38	13,400	June 10, 1917	7.25	76	26	5,030	Mar. 11, 1918	9.44	66
25	8,900	Jan. 18, 1914	4.90	120	38	13,400	May 25, 1922	10.71	114	24	4,670	Jan. 10, 1907	12.12	189
24	8,720	Mar. 4, 1911	7.93	120	37	13,300	July 18, 1911	[2]11.80	123	22	4,220	Jan. 31, 1911	9.26	102

[1] Precipitation includes all rainfall from July 1st to morning of the day before the flood.
[2] Precipitation from July 1st of previous year.
[3] Rainfall records at Summerdale.
[4] Rainfall records at Sierra Madre.

The foregoing tables show that the largest floods of record on the four illustrative streams occurred with the per cent of normal rainfall up to the day of the flood, varying from 97 to 156, and the second largest floods from 71 to 155. Of the twenty largest floods of record, those on the Sacramento occurred with rainfall varying from 71 to 168 per cent of normal; those on the Mokelumne, from 76 to 163 per cent of normal; those on the San Joaquin, from 77 to 167 per cent of normal; and those on the San Gabriel, from 66 to 263 per cent of normal. Therefore, it is seen that precipitation, at least in amount equivalent to a substantial part of that for a normal season, preceded all the large floods of record on the four illustrative streams. In 71 per cent of the instances tabulated above, the seasonal precipitation up to the date of the flood was larger than that for a normal season up to the same date. Although it is evident from these figures that the per cent of normal rainfall up to any date in a season is an extremely approximate indication of the degree of preparedness of a drainage area for turning off floods, nevertheless, in conjunction with another element of the analysis, it was found to have a practical value greater than any other index of a simple nature. This other element is the approach, in any part of a season, to the limit of rain-producing capacity of weather sequences.

It is a matter of common observation that sunshine, clouds, winds and rain follow one another in various complicated sequences. The state of the weather on any day is known to be the result of preceding atmospheric events over a large territory combining with the seasonal cycles peculiar to each geographic location. Many actions and reactions have followed one another in finally producing the resulting weather on any particular day. The intensity and duration of rain storms are a product of these intricate sequences. They are limited in value by the reactions to their occurrence which induce succeeding states of weather other than rain.

An inspection of precipitation records is convincing that these reactions are effective in limiting both the intensity and duration of storms, for the large values appear in the records only occasionally, less often as they become larger. A conception of the capacity of weather sequences to produce precipitation in unusual amounts may be gained by comparing the total season's precipitation of the largest years with that of a normal season. If these sequences had unlimited capacity to produce precipitation it would show in correspondingly large departures from normal in the season's rain. The following tabulation of the five seasons of greatest precipitation at the rainfall stations used in conjunction with the run-off records of the four illustrative streams shows only two instances of the seasonal precipitation exceeding twice the normal. Therefore, it would seem reasonable that the approach toward the limit of precipitation producing capacity at any time during the season might be measured approximately by the degree of normalcy of the precipitation at that time. Thus, when the precipitation at any time approaches, say, twice that of a normal season up to the same date, it would seem reasonable that there would be small likelihood of additional heavy storms because of the exceptionally large amount of precipitation that must have already occurred to place the season so far ahead of normal. Such a measure would necessarily lack accuracy during the first few months of the rainy season while the value of normal precipitation is a small quantity. Until the season progresses sufficiently for normal precipitation to date to become a substantial quantity, it is a poor base for comparison because the relative value is considerably affected by small amounts of additional precipitation. For the greater part of the season, however, normal precipitation to date affords a convenient base with which to compare the precipitation of the current season.

FIVE SEASONS OF LARGEST PRECIPITATION AT U. S. WEATHER BUREAU STATIONS.

Red Bluff, 1877-1921		Electra, 1904-1921		Fresno, 1881-1921		Claremont, 1891-1921	
Season	Precipitation in per cent of normal	Season	Precipitation in per cent of normal	Season	Precipitation in per cent of normal	Season	Precipitation in per cent of normal
1877-78	215	1906-07	156	1885-86	202	1913-14	160
1889-90	169	1910-11	146	1883-84	194	1906-07	136
1885-86	142	1905-06	130	1894-95	152	1915-16	135
1914-15	141	1908-09	119	1905-06	140	1892-93	131
1905-06	140	1913-14	117	1889-90	135	1894-95	127

For convenience, the ratio of the actual precipitation up to any date in a season to the normal amount up to the same date (season commencing July 1), has been named the "Progressive Rainfall Index" because its value changes daily as the season progresses. Plate VI, "Progressive Rainfall Index at Time of Flood Flow," displays the values* of this index at the time of every recorded flood on the four illustrative streams. Each dot on the graph represents one flood and shows its greatest 24-hour rate of discharge on the vertical scale and the value of the "progressive rainfall index" on the other. All floods of record are plotted.

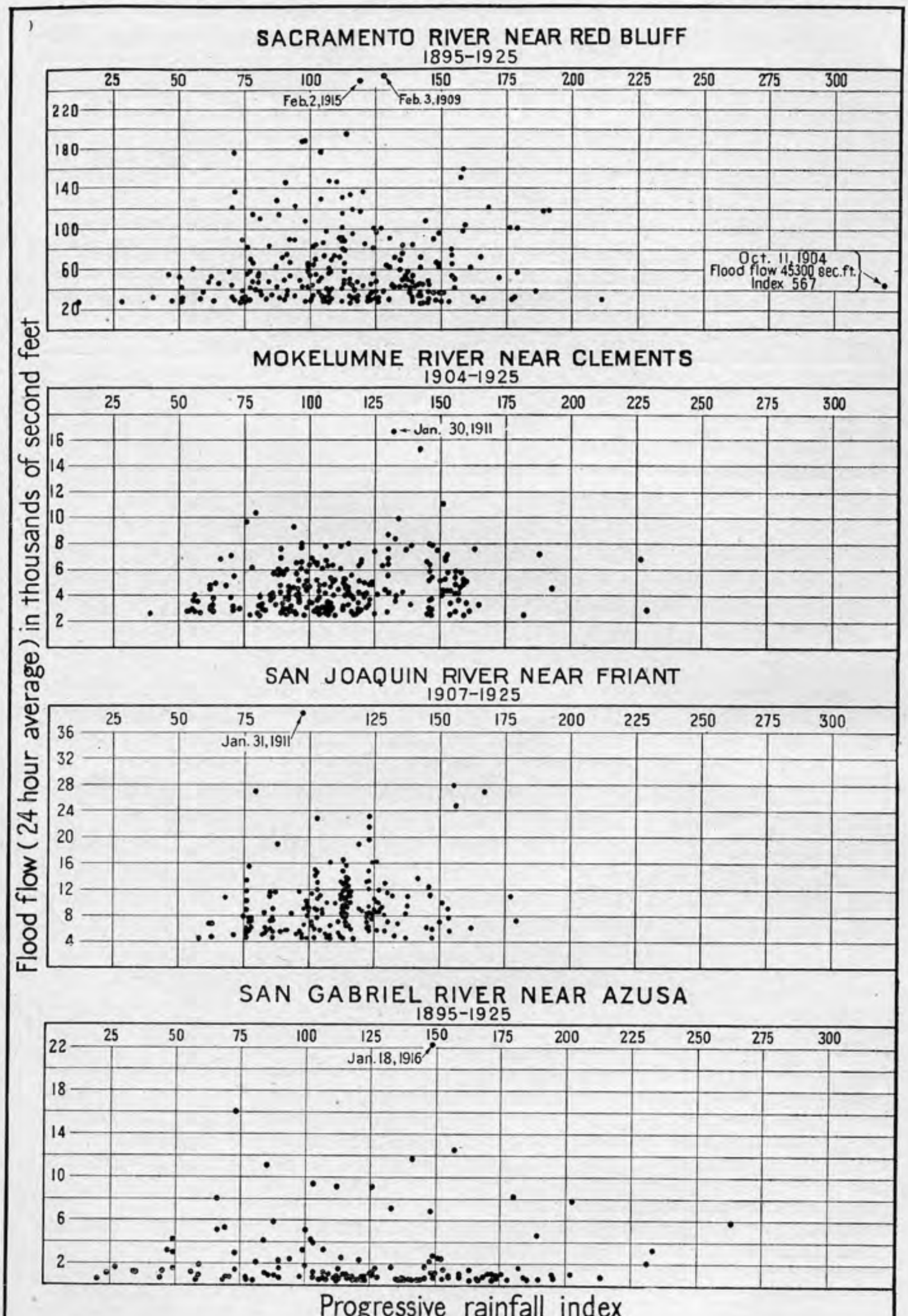
It may be observed on this plate that, of all the floods of record on these four typical streams, those within the highest quarter on the discharge scale occurred with values of the progressive rainfall index lying between 90 and 150; those within the third quarter occurred with indices between 70 and 180; those within the second quarter with indices between 50 and 270; and those within the lowest quarter on the discharge scale with indices between values of 10 and 567. Thus, it is seen that the great floods do not occur with either small or large values of the progressive rainfall index. On the one hand, the small index values witness lack of preparatory precipitation, while, on the other hand, the large index values witness that the heavy rains for that part of the season have already taken place.

Limiting values of progressive rainfall index between which floods occur.

Although the progressive rainfall index, by its nature, can be neither an accurate index of conditions on the drainage area nor of the temporary approach in any part of the season to the limit of the rain-

* The values of the index for each stream were computed from the records at the principal rainfall station in the precipitation division in which the drainage area lies. These precipitation divisions are defined by the analysis of precipitation in California contained in Chap. II of Bul. No. 5, "Flow in California Streams." Here the state was divided into twenty-six areas, called "precipitation divisions," in each of which the rainfall at the various stations has approximately like characistics when expressed in relation to its normal although the actual rain in inches at the several stations may be very different.

PLATE VI.



PROGRESSIVE RAINFALL INDEX AT TIME OF FLOOD FLOW

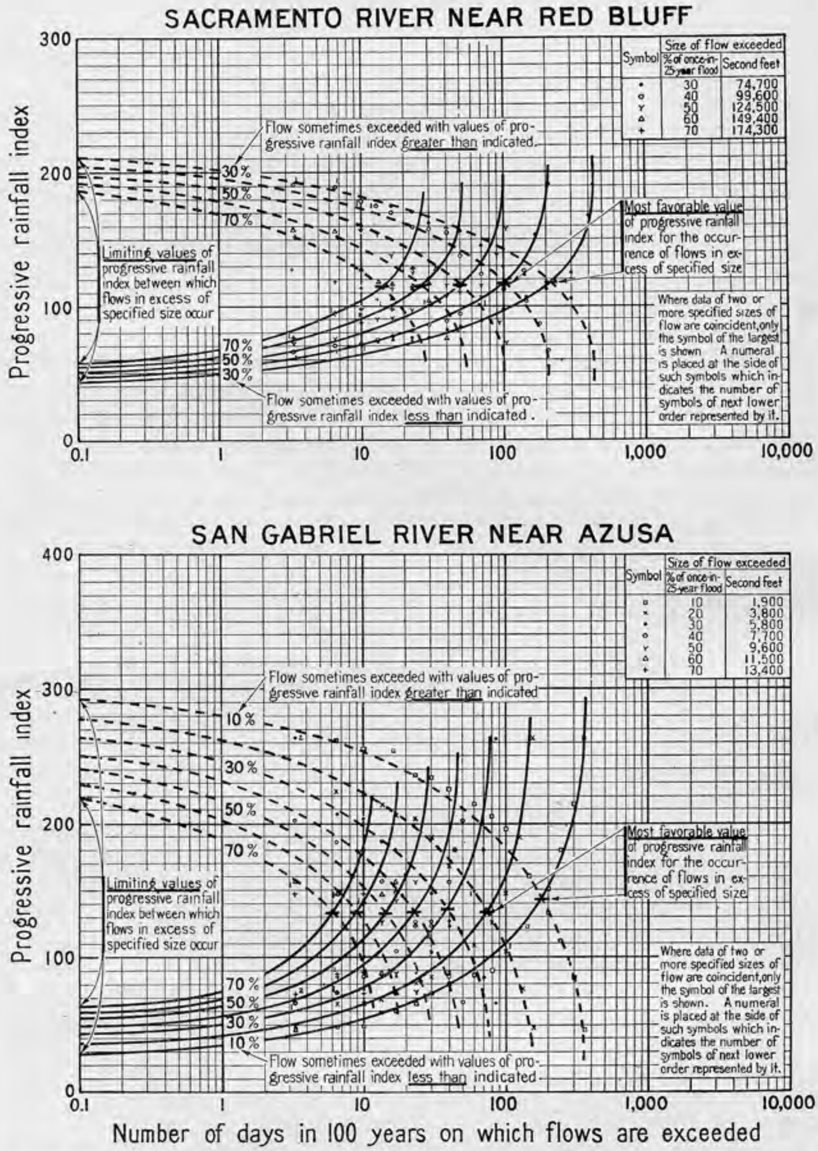
ALL FLOODS OF RECORD PLOTTED

producing capacity of weather sequences, nevertheless, it was found that there are limiting values with which flows of the various sizes occur and that the probability of their occurrence with values beyond these limits is too remote for practical considerations. To define these limiting values of index for the various size flows, an analysis was made of the frequency with which flows of greater-than-specified sizes have occurred in the past with varying index values. The results of this analysis for the four illustrative streams are drafted on Plates VII, VIII and IX, "Relation of Progressive Rainfall Index to Flood Occurrence." The construction of these plates, as well as the analyses upon which they are based, is identical to that of Plates IV and V, "Relation of Time of Year to Flood Occurrence," except that values of the progressive rainfall index are substituted for days of the year.

On the diagrams of Plates VII, VIII and IX, each pair of curves, one dotted and one full-line, represents a specified rate of flow. For convenience in comparison between streams, the rate of flow is expressed in relation to that of a once-in-25-year flood. A conversion table to second-feet is in the upper right corner of each diagram. The full-line curves approximate the trend of the data expressing the probable frequency of flows in excess of their size that occur with smaller values of the progressive rainfall index than indicated on the vertical scale. The dotted-line curves express the probable frequency of flows in excess of their size that occur with greater values of the index than indicated on the vertical scale. As in the diagrams constructed in a corresponding way to determine the limiting dates of the flood season (Plates IV and V), the curves are well defined by the data only for the smaller flows for which more data are contained in the stream flow records. The curves for the larger flows were drafted largely by comparison with the better defined curves for the smaller ones. Although the analysis delineated on Plates VII, VIII, and IX can not be said to be exact because of the limited amount of information relating to the larger floods, an examination of the similar trend of the data on the several streams investigated, is convincing that the results are substantially correct to the extent that the future will repeat the past.

By way of illustrating the interpretation of these plates, reference is made to the upper figure on Plate VII which shows the relation of the progressive rainfall index to flood occurrence in the Sacramento River near Red Bluff. Following up the vertical line labeled 1 on the horizontal frequency scale to intersection with the pair of 50 per cent curves, it is seen that the intersection with the full-line curve is opposite a value of 58 on the scale of progressive rainfall index to the left. This means that, on one day in 100 years, flows will probably occur in excess of 50 per cent of a once-in-25-year flood with a progressive rainfall index value smaller than 58. Following the vertical line labeled 1 on the horizontal scale to intersection with the dotted-line curve, it is seen that the intersection lies opposite 188 on the scale of progressive rainfall index to the left. This means that, on one day in 100 years, flows will probably occur in excess of 50 per cent of a once-in-25-year flood with a progressive rainfall index value greater than 188. The values 58 and 188 are then the limiting values with which such floods occur with a probability of exceptional behavior of one day in a hundred years.

PLATE VII.



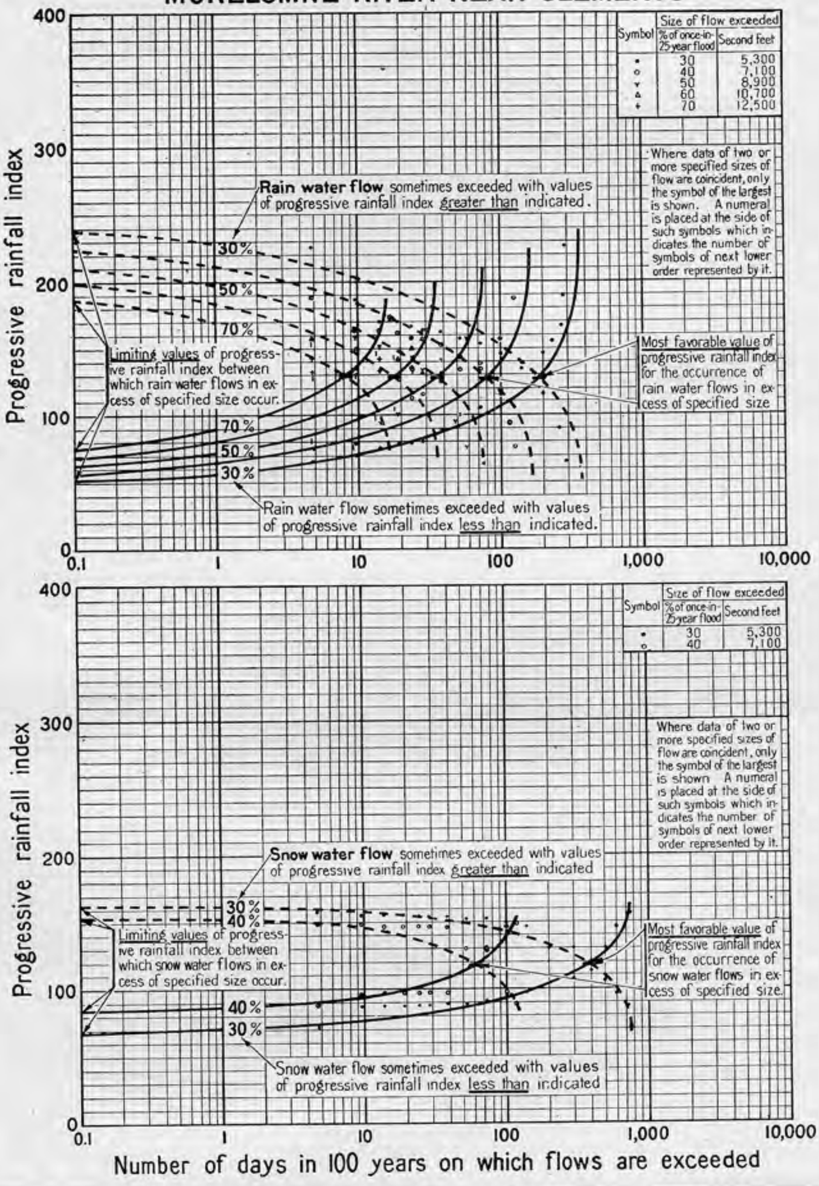
RELATION OF PROGRESSIVE RAINFALL INDEX TO FLOOD OCCURRENCE

CURVES SHOW NUMBER OF DAYS IN 100 YEARS ON WHICH FLOWS OCCUR IN EXCESS OF SPECIFIED SIZE WITH VALUES OF PROGRESSIVE RAINFALL INDEX GREATER AND LESS THAN INDICATED.

Flows expressed in per cent of greatest daily rate of flow of once-in-25-year flood

PLATE VIII.

MOKELUMNE RIVER NEAR CLEMENTS

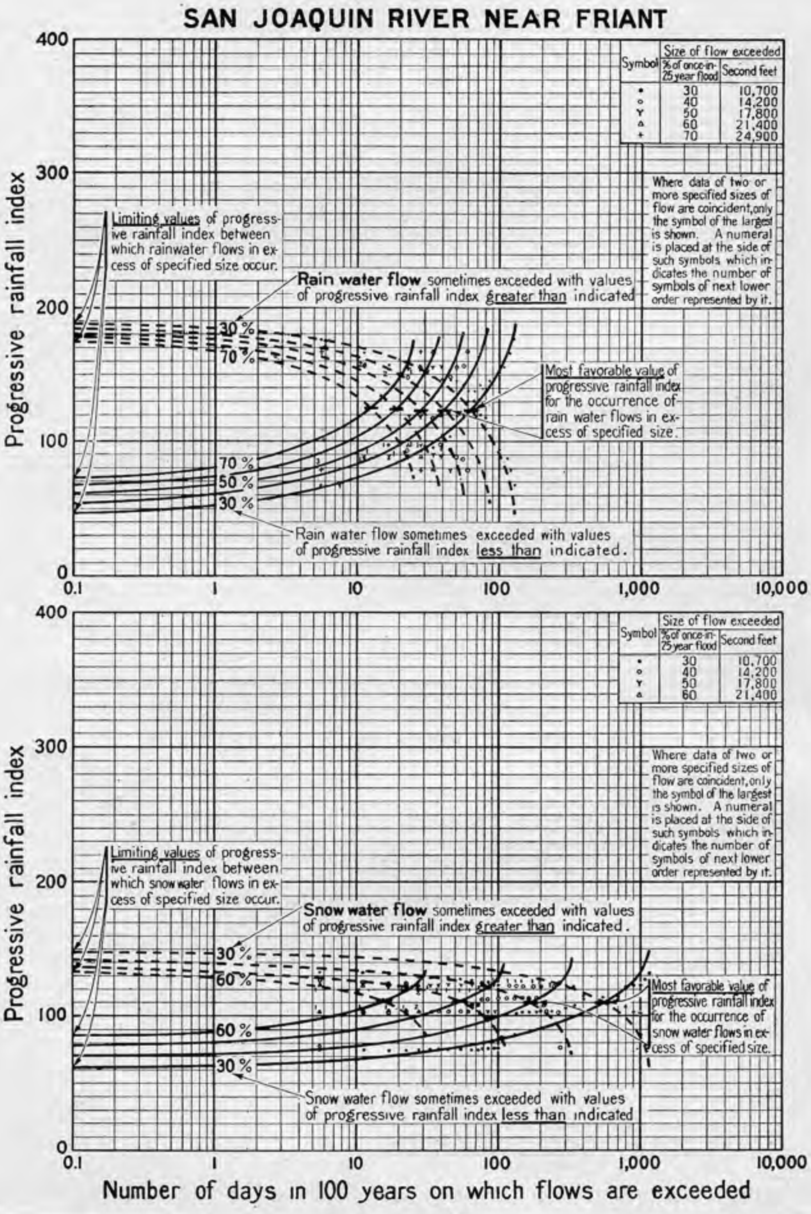


RELATION OF PROGRESSIVE RAINFALL INDEX TO FLOOD OCCURRENCE

CURVES SHOW NUMBER OF DAYS IN 100 YEARS ON WHICH FLOWS OCCUR IN EXCESS OF SPECIFIED SIZE WITH VALUES OF PROGRESSIVE RAINFALL INDEX GREATER AND LESS THAN INDICATED.

Flows expressed in per cent of greatest daily rate of flow of once-in-25-year flood

PLATE IX.



RELATION OF PROGRESSIVE RAINFALL INDEX TO FLOOD OCCURRENCE

CURVES SHOW NUMBER OF DAYS IN 100 YEARS ON WHICH FLOWS OCCUR IN EXCESS OF SPECIFIED SIZE WITH VALUES OF PROGRESSIVE RAINFALL INDEX GREATER AND LESS THAN INDICATED.

Flows expressed in per cent of greatest daily rate of flow of once-in-25-year flood

The data from which these curves (Plates VII, VIII and IX) were constructed are largely included within frequencies greater than four days in a hundred years. The frequency of four days in a hundred years represents one occurrence during the period of 25 years of measurement, the length of the longer records. Knowledge of expectancies had records been kept for greater lengths of time, may be obtained by extending these curves into the zones of smaller frequencies. In so doing, information is gained of the probability of flood occurrence with indices greater or less than the limiting values shown in the records themselves. The limiting values between which any specific flow occurs are indicated on the diagrams by the extremities of the intercept on any vertical line made by the two curves of the pair representing that specific flow. The limiting values of the index are read on the index scale to the left, opposite the extremities of the intercept. The frequency of greater flows occurring with larger or smaller values of the index than there indicated, is read on the horizontal frequency scale where it is cut by the vertical intercepted by the pair of curves. The intercept on the vertical at the extreme left of the diagrams, labeled 0.1 on the frequency scale, gives the limiting values of indices with which flows greater than specified will probably occur either with an index greater than the upper limit or with an index smaller than the lower limit except on one day in a thousand years. The intercepts on verticals representing greater frequencies of exceptional behavior become smaller as the frequencies become larger. These smaller intercepts indicate a lesser range of index values with which flows occur greater than specified.

The following tables set forth the range of index values indicated by Plates VII, VIII and IX, within which floods greater than various specific sizes will probably occur on the four illustrative streams. The maximum and minimum values are tabulated for several different frequencies of exceptional occurrence.

It may be observed, on reviewing these tables, that the smallest limiting value of the progressive rainfall index therein is 28 and the largest is 293, both for the San Gabriel River. The extreme values for the other streams are 51 and 239 on the Mokelumne, 43 and 211 on the Sacramento, and 46 and 189 on the San Joaquin River. The least values with which rain-water floods of corresponding size (equal per cent of once-in-25-year flood) occur, differ not more than 33 points on the four illustrative streams while the maximum values differ not more than 75 points. The smallest floods tabulated occur with minimum indices from 15 to 66 points smaller than the minimum indices for the largest floods and with maximum indices from 14 to 115 points larger than the maximum indices for the largest floods. For decreasing the probability from one day in 10 years to one day in 1000 years that flows in excess of those specified will not occur with either smaller or larger values of the index than indicated, the minimum value of the index may be reduced as much as 58 points and the maximum value increased as much as 87 points. The range of index values with which floods occur from rapidly melting snow is seen to be less variable than for rain-water floods. Of the two illustrative streams having snow-water floods, the smallest value of the index with which they occur is 61 and the largest is 163. The minimum values on the two streams differ not more than 16 points and the maximum not more than 15 points.

SACRAMENTO RIVER.

LIMITING VALUES OF PROGRESSIVE RAINFALL INDEX BETWEEN WHICH FLOODS OCCUR.

Size of flood near Red Bluff—greatest daily rate of flow		Minimum index values					Maximum index values				
		Frequency with which flows occur with progressive rainfall index* **less** than values tabulated					Frequency with which flows occur with progressive rainfall index* **greater** than values tabulated				
In per cent of once-in-25-year flood	In second-feet	One day in 1000 years	One day in 100 years	One day in 50 years	One day in 25 years	One day in 10 years	One day in 1000 years	One day in 100 years	One day in 50 years	One day in 25 years	One day in 10 years
30	74,700	43	48	52	57	64	211	203	198	192	183
40	99,600	47	53	57	62	71	204	196	191	185	173
50	124,500	51	58	62	69	80	198	188	182	174	160
60	149,400	55	63	69	77	91	192	179	171	161	143
70	174,300	58	69	76	86	103	187	169	160	148	125

*At Red Bluff rainfall station.

MOKELUMNE RIVER.

LIMITING VALUES OF PROGRESSIVE RAINFALL INDEX BETWEEN WHICH FLOODS OCCUR.

Size of flood near Clements—greatest daily rate of flow		Minimum index values					Maximum index values				
		Frequency with which flows occur with progressive rainfall index* **less** than values tabulated					Frequency with which flows occur with progressive rainfall index* **greater** than values tabulated				
In per cent of once-in-25-year flood	In second-feet	One day in 1000 years	One day in 100 years	One day in 50 years	One day in 25 years	One day in 10 years	One day in 1000 years	One day in 100 years	One day in 50 years	One day in 25 years	One day in 10 years
						Rain-Water Floods.					
30	5,300	51	56	59	64	71	239	227	221	214	202
40	7,100	57	65	69	75	84	225	212	205	197	183
50	8,900	63	72	78	85	98	211	197	190	180	164
60	10,700	69	80	88	97	113	199	184	176	165	146
70	12,500	75	90	100	112	....	187	169	160	147	....
						Snow-Water Floods.					
30	5,300	68	71	72	74	77	163	162	161	160	158
40	7,100	84	87	89	90	94	154	153	152	150	146

*At Electra rainfall station.

SAN JOAQUIN RIVER.

LIMITING VALUES OF PROGRESSIVE RAINFALL INDEX BETWEEN WHICH FLOODS OCCUR.

Size of flood near Friant—greatest daily rate of flow		Minimum index values					Maximum index values				
		Frequency with which flows occur with progressive rainfall index* **less** than values tabulated					Frequency with which flows occur with progressive rainfall index* **greater** than values tabulated				
In per cent of once-in-25-year flood	In second-feet	One day in 1000 years	One day in 100 years	One day in 50 years	One day in 25 years	One day in 10 years	One day in 1000 years	One day in 100 years	One day in 50 years	One day in 25 years	One day in 10 years
						Rain-Water Floods.					
30	10,700	46	53	58	63	73	189	185	182	178	170
40	14,200	54	61	66	72	83	185	180	177	173	162
50	17,800	61	68	73	79	93	181	176	173	167	154
60	21,400	67	75	80	87	103	178	172	168	161	144
70	24,900	72	81	87	96	117	175	168	162	153	133
						Snow-Water Floods.					
30	10,700	61	63	64	66	69	149	147	146	145	143
40	14,200	70	72	73	75	79	142	139	138	136	134
50	17,800	78	81	83	85	90	137	133	132	130	126
60	21,400	85	89	92	96	105	133	128	126	123	116

*At Fresno rainfall station.

SAN GABRIEL RIVER.

LIMITING VALUES OF PROGRESSIVE RAINFALL INDEX BETWEEN WHICH FLOODS OCCUR.

Size of flood near Azusa—greatest daily rate of flow		Minimum index values					Maximum index values				
		Frequency with which flows occur with progressive rainfall index* **less** than values tabulated					Frequency with which flows occur with progressive rainfall index* **greater** than values tabulated				
In per cent of once-in-25-year flood	In second-feet	One day in 1000 years	One day in 100 years	One day in 50 years	One day in 25 years	One day in 10 years	One day in 1000 years	One day in 100 years	One day in 50 years	One day in 25 years	One day in 10 years
10	1,900	28	35	39	45	55	293	280	274	266	253
20	3,800	36	43	48	53	64	278	261	253	242	222
30	5,800	43	50	56	63	77	264	246	235	222	198
40	7,700	49	57	62	72	93	251	231	219	204	177
50	9,600	55	63	71	83	113	240	217	203	186	153
60	11,500	59	69	78	95	....	229	202	188	169	....
70	13,400	64	75	86	111	....	220	188	172	151	....

*At Claremont rainfall station.

Most favorable value of progressive rainfall index for flood occurrence.

It has been observed that there are limiting values of the progressive rainfall index with which floods occur. Plates VII, VIII and IX, "Relation of Progressive Rainfall Index to Flood Occurrence," delineate the frequency of the exceptional occurrence of flows outside of either of these limits. Pairs of curves are drafted on these plates, one dotted and one full-line, representing this exceptional behavior of flows exceeding specified amounts. The full-line curves show the probable frequency of occurrence of greater-than-specified flows with index values smaller than indicated, while the dotted-line curves show the probable frequency of occurrence with index values larger than indicated on the vertical scale. The two curves of each pair approach each other as these frequencies increase, until their intersection indicates a value of the progressive rainfall index with which greater-than-specified flows occur equally frequent with either smaller or larger values of the index. This is the index value with which flows greater than specified occur most frequently since the frequency of occurrence with either smaller or larger values is the same. Therefore, the values of the progressive rainfall index indicated by the intersections of these pairs of curves, are the most favorable values for flood occurrence.

The following table contains the most favorable index values for the occurrence of flows of greater-than-specified sizes on the Sacramento, Mokelumne, San Joaquin and San Gabriel rivers as taken from Plates VII, VIII and IX. It may be noted that the values range from 114 to 143 for rain-water floods, being least for the Sacramento River and largest for the San Gabriel. On the San Joaquin River the values for the several sizes vary only one point while on the Mokelumne the variance is two, on the Sacramento four and on the San Gabriel twelve points. The most favorable values for snow-water flows on the Mokelumne and San Joaquin rivers, are smaller than for rain-water flows. On the Mokelumne this value is 118, while on the San Joaquin it is 110-111.

MOST FAVORABLE VALUE OF PROGRESSIVE RAINFALL INDEX FOR FLOOD OCCURRENCE.

Size of flood	Sacramento River	Mokelumne River		San Joaquin River		San Gabriel River
In per cent of greatest daily rate of flow of once-in-25-year flood		Rain-water floods	Snow-water floods	Rain-water floods	Snow-water floods	
10	....	....	....	....	....	143
20	....	....	....	....	....	136
30	118	127	118	124	110	137
40	117	128	118	124	110	134
50	117	129	....	124	110	134
60	114	129	....	124	111	134
70	114	129	....	125	....	133

Relation of flood occurrence to season's run-off.

It has been pointed out through analyses of stream flow records, that the most favorable time for flood occurrence, except from melting snow, is in mid-winter. Thus, it would be expected that the largest and heaviest floods occur during the middle of the rainy season followed by a considerable part of the season's total precipitation and hence a considerable part of the season's run-off. Therefore, since large floods usually occur in seasons of greater than normal run-off, the stream flow subsequent to them should be a substantial fraction of that for a normal season.

The following table presents the run-off in the Sacramento, Mokelumne, San Joaquin and San Gabriel rivers subsequent to the largest floods on record. The run-off is expressed in per cent of the total run-off for an average season. It may be noted that the run-off subsequent to the largest floods of record on the Sacramento River averaged 80 per cent of the total for a normal season, on the Mokelumne and San Joaquin, following rain-water floods, 106 and 120 per cent, respectively, and on the San Gabriel 129 per cent of the total run-off of a normal season. The run-off subsequent to the largest snow-water floods on the Mokelumne and San Joaquin rivers was 44 and 48 per cent, respectively, of the total for a normal season. These values varied considerably with the different floods. On the Sacramento, Mokelumne and San Joaquin rivers the minimums were about half the average values, but on the San Gabriel it was about a third of the average. It is seen that, for the most part, a very substantial amount of run-off follows large floods, even the snow-water floods that occur late in the season.

RUN-OFF SUBSEQUENT TO LARGEST FLOODS OF RECORD.

Sacramento River			Mokelumne River					
			Rain-water floods			Snow-water floods		
Mean daily flow in second-feet	Date of flood	Subsequent run-off in per cent of mean seasonal[1]	Mean daily flow in second-feet	Date of flood	Subsequent run-off in per cent of mean seasonal[2]	Mean daily flow in second-feet	Date of flood	Subsequent run-off in per cent of mean seasonal[2]
254,000	Feb. 3, 1909	79.9	16,700	Jan. 30, 1911	*149.1	8,740	June 12, 1906	*50.9
249,000	Feb. 2, 1915	93.1	15,310	Mar. 19, 1907	136.9	8,030	June 18, 1911	27.4
196,000	Mar. 20, 1907	63.3	11,100	Jan. 26, 1914	101.3	7,970	June 3, 1922	*30.8
188,000	Jan. 16, 1909	114.7	10,400	Jan. 14, 1909	*118.3	7,960	June 12, 1911	36.5
188,000	Feb. 16, 1904	121.7	9,850	Feb. 21, 1914	90.3	7,880	June 6, 1911	45.2
177,000	Jan. 21, 1909	101.5	9,700	Feb. 6, 1925	80.8	7,770	May 31, 1922	37.5
176,000	Feb. 25, 1917	44.9	9,250	Jan. 1, 1914	114.6	7,750	June 1, 1915	30.3
160,000	Feb. 21, 1914	65.4	8,400	Jan. 21, 1909	110.9	7,670	May 18, 1922	53.9
151,000	Jan. 1, 1914	*113.1	8,040	Mar. 20, 1916	79.5	7,600	June 16, 1906	*45.0
151,000	Feb. 24, 1902	x58.4	7,860	Feb. 2, 1907	167.2	7,550	June 10, 1917	24.0
147,000	Mar. 8, 1904	91.3	7,750	Mar. 31, 1906	119.6	7,500	May 24, 1911	*58.3
140,000	Feb. 10, 1902	x80.9	7,610	Mar. 23, 1907	*127.0	7,480	July 4, 1906	22.4
137,000	Mar. 31, 1906	50.0	7,470	Jan. 22, 1914	106.8	6,960	June 22, 1906	37.6
136,000	Jan. 19, 1906	93.5	7,350	Jan. 18, 1921	85.1	6,960	June 2, 1907	57.6
134,000	Feb. 4, 1907	99.5	7,210	Mar. 7, 1911	*126.9	6,850	June 20, 1906	40.6
131,000	Jan. 25, 1903	63.6	7,200	Nov. 21, 1909	97.4	6,800	June 2, 1909	32.6
130,000	Mar. 7, 1911	56.6	7,060	Feb. 11, 1919	57.8	6,750	May 7, 1906	92.4
128,000	Jan. 27, 1896	77.7	6,960	Jan. 19, 1906	143.9	6,700	June 8, 1915	x19.2
123,000	Mar. 8, 1900	34.6	6,940	Mar. 12, 1918	50.1	6,640	May 9, 1906	x89.5
122,000	Jan. 22, 1914	89.6	6,910	Apr. 16, 1925	*51.8	6,630	May 13, 1915	48.7
Average value		79.6			105.8			44.0

San Joaquin River						San Gabriel River		
Rain-water floods			Snow-water floods					
Mean daily flow in second-feet	Date of flood	Subsequent run-off in per cent of mean seasonal[3]	Mean daily flow in second-feet	Date of flood	Subsequent run-off in per cent of mean seasonal[3]	Mean daily flow in second-feet	Date of flood	Subsequent run-off in per cent of mean seasonal[4]
38,800	Jan. 31, 1911	157.5	23,100	June 13, 1911	63.9	22,300	Jan. 18, 1916	125.3
27,900	Dec. 31, 1909	84.6	22,800	June 4, 1909	*51.0	16,000	Dec. 19, 1921	253.6
26,800	Jan. 14, 1909	*132.4	21,500	June 16, 1911	*56.0	12,500	Jan. 1, 1910	60.0
26,800	Dec. 10, 1909	91.2	19,500	July 7, 1911	27.8	11,800	Feb. 20, 1914	119.9
24,700	Jan. 26, 1914	126.7	16,700	June 5, 1922	45.9	11,130	Mar. 12, 1905	70.7
18,900	Jan. 21, 1909	*127.5	16,200	May 22, 1911	*90.1	9,430	Mar. 26, 1906	83.4
18,800	Mar. 8, 1911	142.9	16,200	June 6, 1911	75.8	9,160	Mar. 10, 1911	86.5
13,600	Mar. 10, 1911	*140.2	16,200	May 8, 1909	*80.5	9,150	Jan. 26, 1914	165.2
12,500	Feb. 12, 1909	*119.9	15,700	June 2, 1914	55.1	8,200	Feb. 9, 1922	135.6
11,700	Feb. 21, 1917	82.1	15,300	June 5, 1912	19.4	8,020	Mar. 12, 1906	*127.4
11,600	Apr. 6, 1911	126.2	14,900	June 15, 1909	*35.4	7,940	Jan. 27, 1916	96.7
11,000	Jan. 18, 1916	126.7	14,700	June 27, 1911	*39.2	7,100	Feb. 7, 1909	88.6
11,000	Mar. 21, 1916	104.0	14,700	May 31, 1922	54.9	6,810	Mar. 5, 1907	142.5
10,900	Oct. 2, 1918	62.5	14,600	June 24, 1909	*26.1	5,920	Apr. 1, 1903	41.1
10,700	Jan. 25, 1911	165.8	14,000	June 11, 1909	42.1	5,900	Dec. 27, 1921	208.2
10,400	Apr. 5, 1914	103.1	13,800	June 9, 1915	*36.9	5,260	Jan. 29, 1911	164.8
9,910	Feb. 21, 1914	119.0	13,500	June 1, 1915	x44.5	5,110	Jan. 18, 1914	187.8
9,150	Mar. 5, 1916	112.8	13,400	June 10, 1917	34.2	5,030	Mar. 11, 1918	58.0
8,900	Jan. 18, 1914	132.2	13,400	May 25, 1922	62.2	4,670	Jan. 10, 1907	214.1
8,720	Mar. 4, 1911	146.0	13,300	July 18, 1911	15.2	4,220	Jan. 31, 1911	156.8
		120.2			47.8			129.3

[1] Mean seasonal run-off of Sacramento River near Red Bluff (50 yr. mean) 9,929,000 acre-feet.
[2] Mean seasonal run-off of Mokelumne River near Clements (50 yr. mean) 898,000 acre-feet.
[3] Mean seasonal run-off of San Joaquin River near Friant (50 yr. mean) 2,057,000 acre-feet.
[4] Mean seasonal run-off of San Gabriel River near Azusa (50 yr. mean) 147,000 acre-feet.
*Second day after flood to October 1.
xThird day after flood to October 1.
All other values of run-off subsequent to flood are from first day after flood to October 1.

CHAPTER IV.

RESERVOIR SPACE REQUIRED TO DETAIN EXCESS FLOOD FLOWS.

Source of information.

Of all information concerning floods, that most important to their control by reservoirs is the volume of water contained in the excessive rates of flow. This is the volume that must be detained in reservoirs if the downstream flow is to be limited to reasonable rates. Information concerning the volume that must be so detained is contained in the records of stream measurement. Although the period of measurement in California is too brief for direct disclosure of either the largest floods that may occur or the length of the intervals between them, nevertheless, within these records is the sum total of accurate knowledge of the volume of flood flow. Other information, at best, is indirect and very approximate. Flood estimates based on high-water marks, on the memory of old inhabitants or rates of rainfall that have occurred in other localities, contain many elements of uncertainty. The stream-flow measurements themselves are the only direct and definite information on the volume of flood flow. This study, therefore, is confined to their analysis.

Continuous stream measurement in California was started with the establishment of the first gaging station at Jelly's Ferry on the Sacramento River in 1895. Since then many other stations have been established on the larger streams. At present, about 250 stations are maintained by the United States Geological Survey and the State of California in cooperation. From the continuous records kept at these stations, the United States Geological Survey publishes in its water-supply papers, tables of the average daily stream flow past each one of these points of measurement. The published tables, together with those in preparation for publication, have been used in the computations of this bulletin.

Method of analysis.

Since the stream-flow records cover too short a time to include the maximum flood that might occur, it is desirable to ascertain the relation between the volume of flow and frequency of its occurrence as disclosed by the many smaller floods observed during the period of record. To ascertain the volume of water contained in the excessive rates of flood flow, the records on twenty streams of the State that have been measured from seventeen to thirty years were assembled and the volume of water contained in every flood in excess of certain specified rates of flow was computed. These are the volumes of water that would have had to be detained in reservoirs to have reduced the floods of record to the specified rates of maximum flow through reservoir control. The following table enumerates the streams whose records were analysed, the names of the stream-gaging stations and the period of record:

LIST OF STREAM FLOW RECORDS ANALYZED FOR FLOOD CHARACTERISTICS.

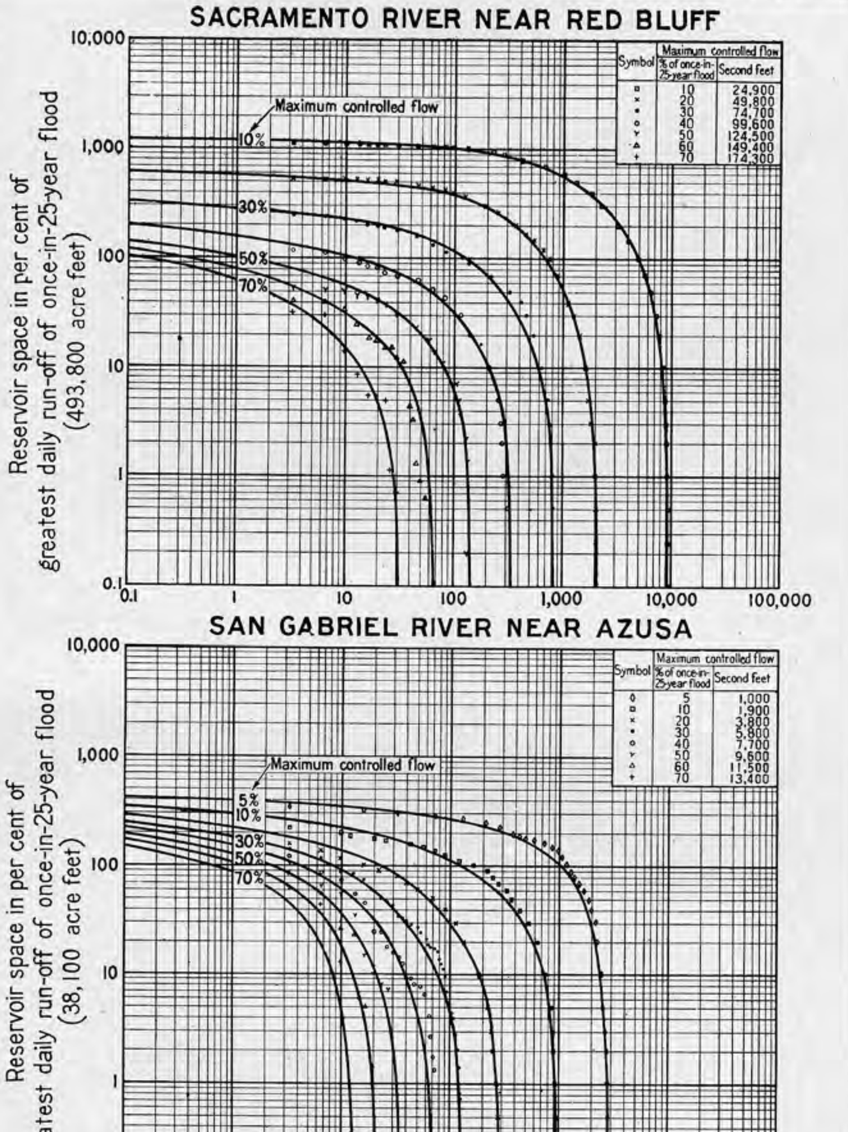
Stream	Gaging station	Drainage area in square miles	Period of record	Number of years of record
Sacramento River	Jelly's Ferry	9,093	Apr. 29, 1895-Jan. 31, 1902	30.4
Sacramento River	Red Bluff	9,258	Feb. 1, 1902-Oct. 1, 1925	
Feather River	Oroville	3,627	Jan. 1, 1902-Oct. 1, 1925	23.7
Yuba River	Smartsville	1,200	July 1, 1903-Oct. 1, 1925	22.3
Bear River	Van Trent	262	Oct. 8, 1904-Oct. 1, 1925	21.0
American River	Fair Oaks	1,919	Nov. 4, 1904-Oct. 1, 1925	20.9
Cosumnes River	Michigan Bar	534	Oct. 20, 1907-Oct. 1, 1925	17.9
Mokelumne River	Clements	632	Oct. 28, 1904-Oct. 1, 1925	20.9
Calaveras River	Jenny Lind	394	Jan. 1, 1907-Oct. 1, 1925	18.7
Stanislaus River	At Knights Ferry	983	May 19, 1903-May 1, 1916	22.4
Stanislaus River	Near Knights Ferry	973	May 1, 1916-Oct. 1, 1925	
Tuolumne River	La Grange	1,543	Aug. 30, 1895-Oct. 1, 1925	30.1
Merced River	Merced Falls	1,054	Apr. 6, 1901-Nov. 30, 1913	22.5
Merced River	Exchequer	1,020	Nov. 28, 1915-Nov., 1922	
Merced River	Exchequer	1,034	Nov., 1922-Oct. 1, 1925	
San Joaquin River	Friant	1,631	Oct. 18, 1907-Oct. 1, 1925	18.0
Kings River	Sanger	1,694	Sept. 3, 1895-Oct. 1, 1925	30.1
Kaweah River	Three Rivers	514	Apr. 29, 1903-Oct. 1, 1925	22.4
Tule River	Porterville	264	May 1, 1901-Oct. 1, 1925	24.4
Kern River	Bakersfield	2,410	Jan. 1, 1896-Oct. 1, 1925	29.8
Stony Creek	Fruto	577	Jan. 30, 1901-Oct. 5, 1912	17.4
Stony Creek	Orland	636	Jan. 1, 1920-Oct. 1, 1925	
Putah Creek	Winters	655	Oct. 1, 1905-Oct. 1, 1925	20.0
San Gabriel River	Azusa	214	Aug. 1, 1895-Oct. 1, 1925	30.2
Santa Ana River	Mentone	189	July 1, 1896-Oct. 1, 1914	29.3
Santa Ana River	Mentone	199	Oct. 1, 1914-Oct. 1, 1925	

After computing the volume of water in all flows exceeding certain specified rates, determination was made for each successive day of every flood of the empty reservoir space that would have been needed to have absorbed, through the remainder of the flood, all water in excess of the several specified rates of flow. Counts were made in each set of computations pertaining to a specified rate of controlled flow of the number of times empty space in excess of various values was needed. These counts were expanded by proportion to obtain the number of occurrences had the records been a hundred years in length. The relations disclosed by the data on the Sacramento, Mokelumne, San Joaquin and San Gabriel rivers, the four streams selected for illustration, are shown on Plates X, XI and XII, "Reservoir Space Required to Control Floods."* These present the relations established from the data between reservoir space and the frequency with which it would be surcharged if used to detain excess flood flows.

The horizontal scale on these three plates shows the number of days in a hundred years that reservoir space in excess of the values indicated on the vertical scale would be required in a reservoir to reduce floods to the maximum rate of flow specified on the curves. For convenience of comparison between the twenty streams for which these computa-

* Water Supply Paper No. 551 of the United States Geological Survey, recently published, places the maximum discharge of the Mokelumne River at Clements at 25,500 second feet. This is obtained by applying the rating curve of the 1911 flood to the gage heights of 1907. The crest discharge of the 1907 flood has been published as 17,000 second feet in former publications including Water Supply Paper No. 299 in which are printed the daily discharges of the 1907 flood. The figures contained in Water Supply Paper No. 299 have been used in preparing this volume. Should the daily discharges of the 1907 flood be revised by application of the 1907 gage heights to the 1911 rating curve, the increase in their values would be so substantial as to require a complete revision of the analyses of floods on the Mokelumne River contained in this volume in order to make the analyses harmonize with the increased discharge values.

PLATE X.

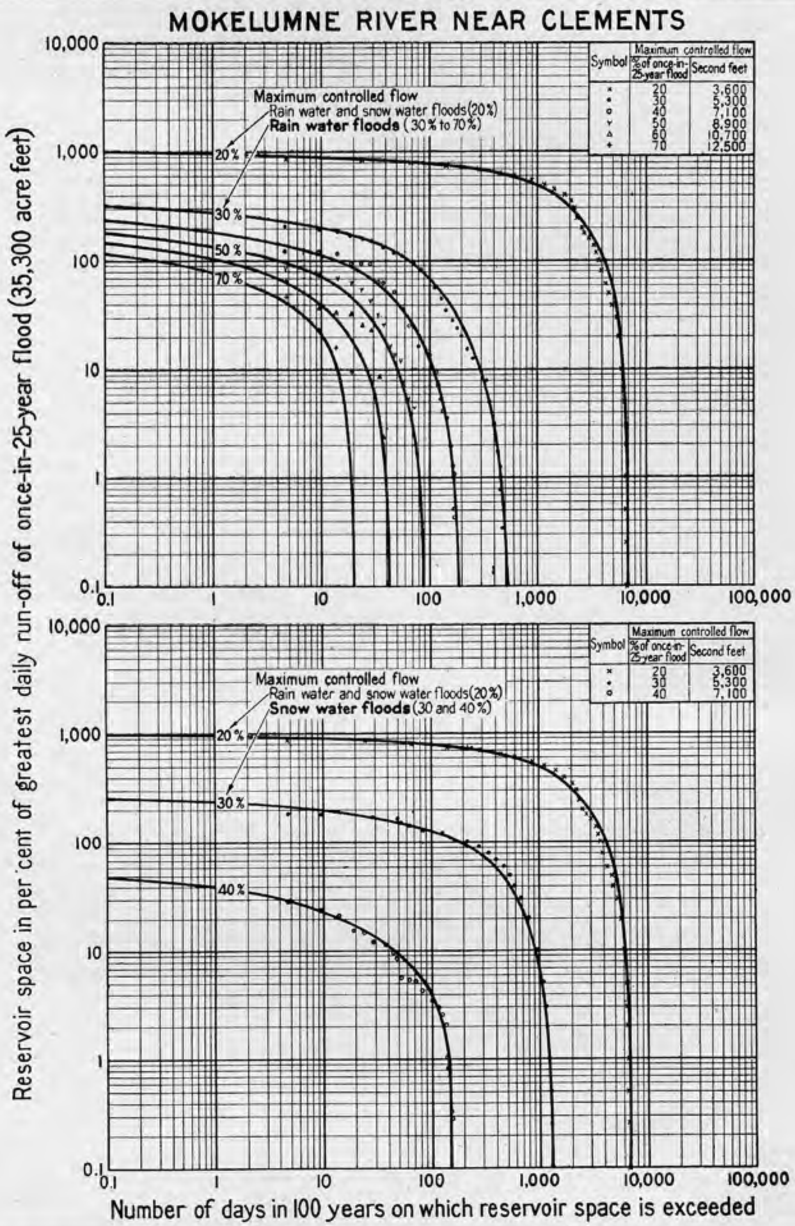


RESERVOIR SPACE REQUIRED TO CONTROL FLOODS

CURVES SHOW NUMBER OF DAYS IN 100 YEARS ON WHICH RESERVOIR SPACE GREATER THAN INDICATED IS NEEDED TO CONTROL FLOODS TO SPECIFIED MAXIMUM FLOW.

Maximum controlled flow expressed in per cent of greatest daily rate of flow of a once-in-25-year flood

PLATE XI.



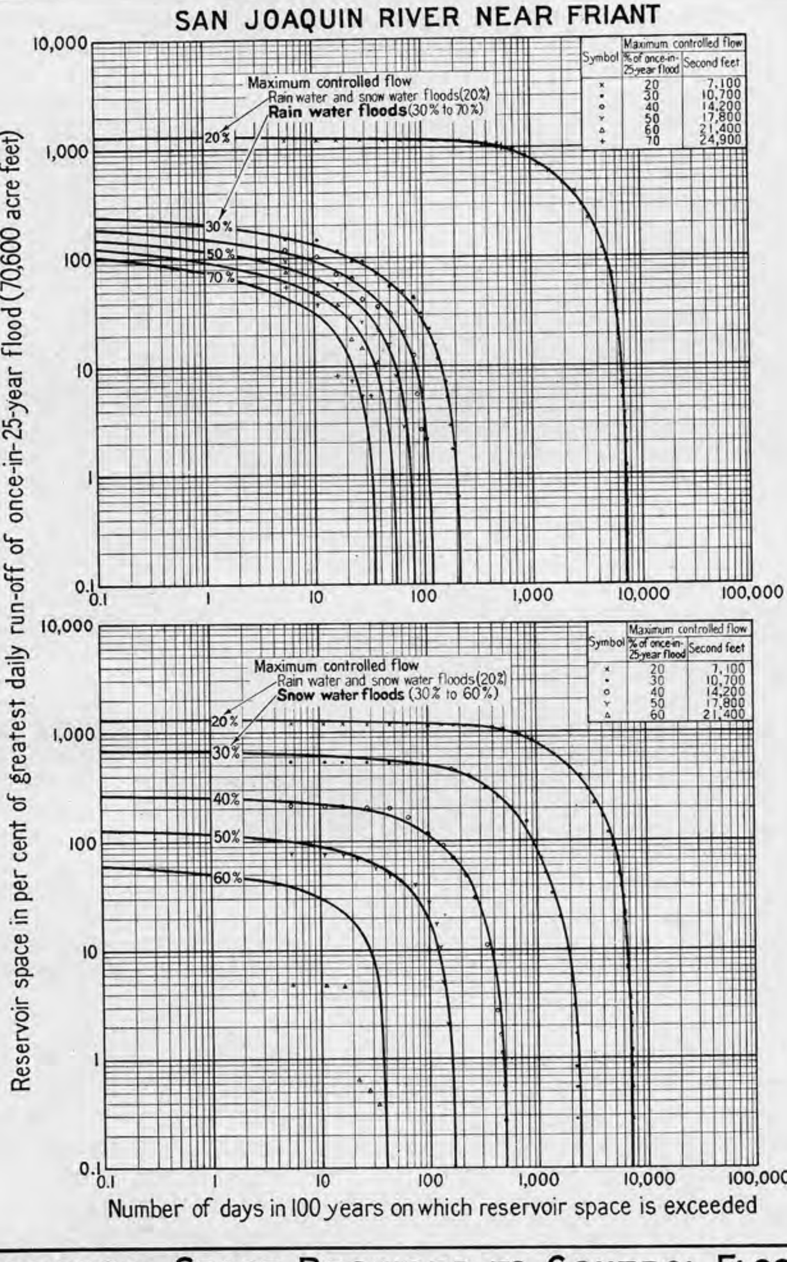
RESERVOIR SPACE REQUIRED TO CONTROL FLOODS

CURVES SHOW NUMBER OF DAYS IN 100 YEARS ON WHICH RESERVOIR SPACE GREATER THAN INDICATED IS NEEDED TO CONTROL FLOODS TO SPECIFIED MAXIMUM FLOW

Maximum controlled flow expressed in per cent of greatest daily rate of flow of a once-in-25-year flood

PLATE XII.

SAN JOAQUIN RIVER NEAR FRIANT



RESERVOIR SPACE REQUIRED TO CONTROL FLOODS

CURVES SHOW NUMBER OF DAYS IN 100 YEARS ON WHICH RESERVOIR SPACE GREATER THAN INDICATED IS NEEDED TO CONTROL FLOODS TO SPECIFIED MAXIMUM FLOW.

Maximum controlled flow expressed in per cent of greatest daily rate of flow of a once-in-25-year flood.

tions were made, the values of reservoir space were expressed in per cent of the greatest daily run-off of a once-in-25-year flood. The rates of flow were expressed in per cent of the greatest daily rate of flow of a once-in-25-year flood. The use of these units eliminates the dimensions of the drainage area and permits the ready comparison of data pertaining to all drainage areas, irrespective of their size.

The curves are drawn to express the trend of the plotted data. Because of the greater mass of statistics pertaining to the smaller flows, the curves relating to them are the most clearly defined by the plotted points. The curves for the larger flows are drafted by comparison with those for the smaller ones as well as with those on other streams, while at the same time conforming to the plotted points. The data on some streams plot closer to regular curves than on others. In determining the general shape of the curves greater weight was given to these data, believing that the greater regularity indicates fewer departures from a general relation.

It may be observed that the plotted data determining the parts of the curves in zones of greater frequencies on the right of the graphs depart less from the smooth curves than in the zones of smaller frequencies on the left, where the points are determined by a less number of floods. The point in each series farthest to the left is computed from the largest flood during the period of record. Although it has been regarded as having an average frequency of once in the period of record, it might well be a flood of some other frequency that happened to occur within this group of years, since the relation expressed by the curves does not take the sequence of flood sizes into account, but only the average interval of time between their occurrence. For this reason the period of record may contain single floods or even groups of floods that have actual frequencies different from those indicated by their chance occurrence within the period of record. Points representing such floods on the graphs would be expected to depart from smooth curves. The departure of points in the zones of smaller frequencies toward the left on the graphs is believed to be from this cause. Therefore, in drafting the series of curves to represent the average tendency of occurrence, they were drafted neither to average the points nor to pass through as many as possible, but rather they were drafted as curves of regular shape taking the most reasonable position relative one to the other and to the plotted points and commensurate with the indications of the data on all the other streams studied.

Relations established.

The curves of Plates X, XI, and XII show the relation between reservoir space and the probable frequency with which specific values would be surcharged if used to detain excess flood flows. They yield information upon the degree of certainty with which floods may be controlled by reservoirs and the reserve space needed for this purpose. Intersections of the curves on the extreme left vertical, indicate the reserve space that would be sufficient to detain flows in excess of the values specified on the curves for all except one day of flood in a thousand years. On this one day, the indicated reserve space would fill and water in excess of the specified maximum flow would have to be disposed of. This day may be one of either small or large flow following close upon the great flood that filled the reserve space in the reservoir. The only information yielded by the analysis is that the reserve space would be filled to overflowing. The amount of the overflow in excess of the specified maximum discharge might take any value greater than zero with the greatest likelihood of its being among the smaller values.

Intersections of the curves with verticals other than the one on the

RESERVOIR SPACE REQUIRED TO CONTROL FLOODS.

Stream	Maximum controlled flow		Reservoir space in per cent of greatest daily run-off of once-in-25-year flood				
	In per cent of greatest daily rate of flow of once-in-25-year flood	In second-feet	Exceeded one day in 1000 years	Exceeded one day in 100 years	Exceeded one day in 50 years	Exceeded one day in 25 years	Exceeded one day in 10 years
Sacramento River near Red Bluff .	10	24,900	1,200	1.190	1,180	1,165	1,135
	20	49,800	620	580	563	548	519
	30	74,700	320	282	267	249	223
	40	99,600	198	154	140	126	104
	50	124,500	148	105	92	78	58
	60	149,400	121	80	66	51	32
	70	174,300	102	62	48	33	16
Mokelumne River near Clements**			Rain-Water Floods.				
	20	*3,600	*1,000	*960	*940	*920	*900
	30	5,300	322	278	260	237	203
	40	7,100	240	189	172	151	119
	50	8,900	191	141	122	102	72
	60	10,700	153	104	87	69	42
	70	12,500	122	76	62	46	21
			Snow-Water Floods.				
	30	5,300	250	230	220	211	195
	40	7,100	50	40	36	30	23
San Joaquin River near Friant....			Rain-Water Floods.				
	20	*7,100	*1,320	*1,310	*1,300	*1,280	*1,260
	30	10,700	243	209	188	168	131
	40	14,200	188	154	138	122	94
	50	17,800	150	120	106	90	67
	60	21,400	123	94	81	68	48
	70	24,900	101	74	62	50	32
			Snow-Water Floods.				
	30	10,700	700	678	660	645	622
	40	14,200	270	260	250	240	222
	50	17,800	130	117	110	102	88
	60	21,400	60	51	46	40	30
San Gabriel River near Azusa.....	5	1,000	419	390	380	370	350
	10	1,900	344	295	277	254	225
	20	3,800	287	225	200	170	134
	30	5,800	243	180	154	131	93
	40	7,700	220	150	127	102	62
	50	9,600	197	128	104	79	37
	60	11,500	173	107	85	59	19
	70	13,400	153	88	67	40	5

*Rain-water and snow-water floods.

** Water Supply Paper No. 551 of the United States Geological Survey, recently published, places the maximum discharge of the Mokelumne River at Clements at 25,500 second feet. This is obtained by applying the rating curve of the 1911 flood to the gage heights of 1907. The crest discharge of the 1907 flood has been published as 17,000 second feet in former publications including Water Supply Paper No. 299 in which are printed the daily discharges of the 1907 flood. The figures contained in Water Supply Paper No. 299 have been used in preparing this volume. Should the daily discharges of the 1907 flood be revised by application of the 1907 gage heights to the 1911 rating curve, the increase in their values would be so substantial as to require a complete revision of the analyses of floods on the Mokelumne River contained in this volume in order to make the analyses harmonize with the increased discharge values.

extreme left, indicate the probable frequency with which smaller values of reservoir space would fill to overflowing while regulating to the maximum flows specified on the curves. These smaller values of reservoir space are indicated on the vertical scale opposite the intersections while the frequencies are indicated on the horizontal scale where cut by the verticals intersected.

Values determined.

The values of reserve reservoir space and the probable frequencies with which they would be filled to overflowing while controlling floods to the several specified rates are contained in the foregoing table for the four illustrative streams. The units employed are relative to a once-in-25-year flood and are identical to those used on Plates X, XI and XII.

It may be observed in the foregoing table that the relative space required to control floods is not extremely different on the several streams for control between 40 and 70 per cent of the once-in-25-year flood. For control to less than 30 or 40 per cent of the once-in-25-year flood, there is a sharp increase in the reservoir space required on the three northerly streams. On the San Gabriel, however, this sharp increase occurs for control to less than 10 or 20 per cent of the once-in-25-year flood.

On all four streams, for rain-water floods, very much greater space is required if the probability of control is raised from an average exceptional behavior of one day in 10 years to one day in 1000 years. For control to 70 per cent of the once-in-25-year flood, the space increases from 5 to 32 per cent for an average exceptional behavior on one day in 10 years to 101 to 153 per cent for average exceptional behavior on one day in 1000 years. For control to 40 per cent of the once-in-25-year flood the space increases from 62 to 119 per cent for exceptional behavior on one day in 10 years to 188 to 240 per cent for exceptional behavior on one day in 1000 years. These values increase to over 1000 per cent for control to less than 10 or 20 per cent of the once-in-25-year flood on the three northerly streams and to over 400 per cent for control to less than 5 per cent of the once-in-25-year flood on the San Gabriel.

The space required to control snow-water floods on the two illustrative streams on which they occur is less than that required to control rain-water floods except for reductions to less than 50 per cent of the once-in-25-year flood. Larger space is required to reduce the snow-water floods to these smaller rates of flow than to correspondingly reduce the rain-water floods. In general, the increase in space for gaining greater probability in control is less for snow-water floods than for those from rain.

While there is much similarity on the four illustrative streams in the relative reservoir space required for flood control, the actual space in acre-feet is very different due to the great variance in the size of the four streams. This variance in size is shown by the following table:

SIZE OF THE FOUR ILLUSTRATIVE STREAMS.

River	*Drainage area in square miles*	*Mean seasonal run-off in acre-feet*	*Maximum flood of record—mean daily flow in second-feet*
Sacramento	9,258	9,929,000	254,000
Mokelumne	632	898,000	16,700
San Joaquin	1,631	2,057,000	38,800
San Gabriel	214	147,000	22,300

The actual reservoir space in acre-feet required to control floods, corresponding to the relative values heretofore presented, are given in the following table. The maximum controlled flows are expressed in second-feet:

RESERVOIR SPACE REQUIRED TO CONTROL FLOODS.

Stream	Maximum controlled flow		Reservoir space in acre-feet				
	In per cent of greatest daily rate of flow of once-in-25-year flood	In second-feet	Exceeded one day in 1000 years	Exceeded one day in 100 years	Exceeded one day in 50 years	Exceeded one day in 25 years	Exceeded one day in 10 years
Sacramento River near Red Bluff..	10	24,900	5,926,000	5,876,000	5,827,000	5,753,000	5,605,000
	20	49,800	3,062,000	2,864,000	2,780,000	2,706,000	2,563,000
	30	74,700	1,580,000	1,393,000	1,318,000	1,230,000	1,101.000
	40	99,600	978,000	760,000	691,000	622,000	514,000
	50	124,500	731,000	518,000	454,000	385,000	286,000
	60	149,400	597,000	395,000	326,000	252,000	158,000
	70	174,300	504,000	306,000	237,000	163,000	79,000
Mokelumne River near Clements**			Rain-Water Floods.				
	*20	3,600	353,000	339,000	332,000	325,000	318,000
	30	5,300	114,000	98,000	92,000	84,000	72,000
	40	7,100	85,000	67,000	61,000	53,000	42,000
	50	8,900	67,000	50,000	43,000	36,000	25,000
	60	10,700	54,000	37,000	31,000	24,000	15,000
	70	12,500	43,000	27,000	22,000	16,000	7,000
			Snow-Water Floods.				
	30	5,300	88,000	81,000	78,000	74,000	69,000
	40	7,100	18,000	14,000	13,000	11,000	8,000
San Joaquin River near Friant....			Rain-Water Floods.				
	*20	7,100	932,000	925,000	918,000	904,000	890,000
	30	10,700	172,000	148,000	133,000	119,000	92,000
	40	14,200	133,000	109,000	97,000	86,000	66,000
	50	17,800	106,000	85,000	75,000	64,000	47,000
	60	21,400	87,000	66,000	57,000	48,000	34,000
	70	24,900	71,000	52,000	44,000	35,000	23,000
			Snow-Water Floods.				
	30	10,700	494,000	479,000	466,000	455,000	439,000
	40	14,200	191,000	184,000	177,000	169,000	157,000
	50	17,800	92,000	83,000	78,000	72,000	62,000
	60	21,400	42,000	36,000	32,000	28,000	21,000
San Gabriel River near Azusa.....	5	1,000	160,000	149,000	145,000	141,000	133,000
	10	1,900	131,000	112,000	106,000	97,000	86,000
	20	3,800	109,000	86,000	76,000	65,000	51,000
	30	5,800	93,000	69,000	59,000	50,000	35,000
	40	7,700	84,000	57,000	48,000	39,000	24,000
	50	9,600	75,000	49,000	40,000	30,000	14,000
	60	11,500	66,000	41,000	32,000	22,000	7,000
	70	13,400	58,000	34,000	26,000	15,000	2,000

*Rain-water and snow-water floods.

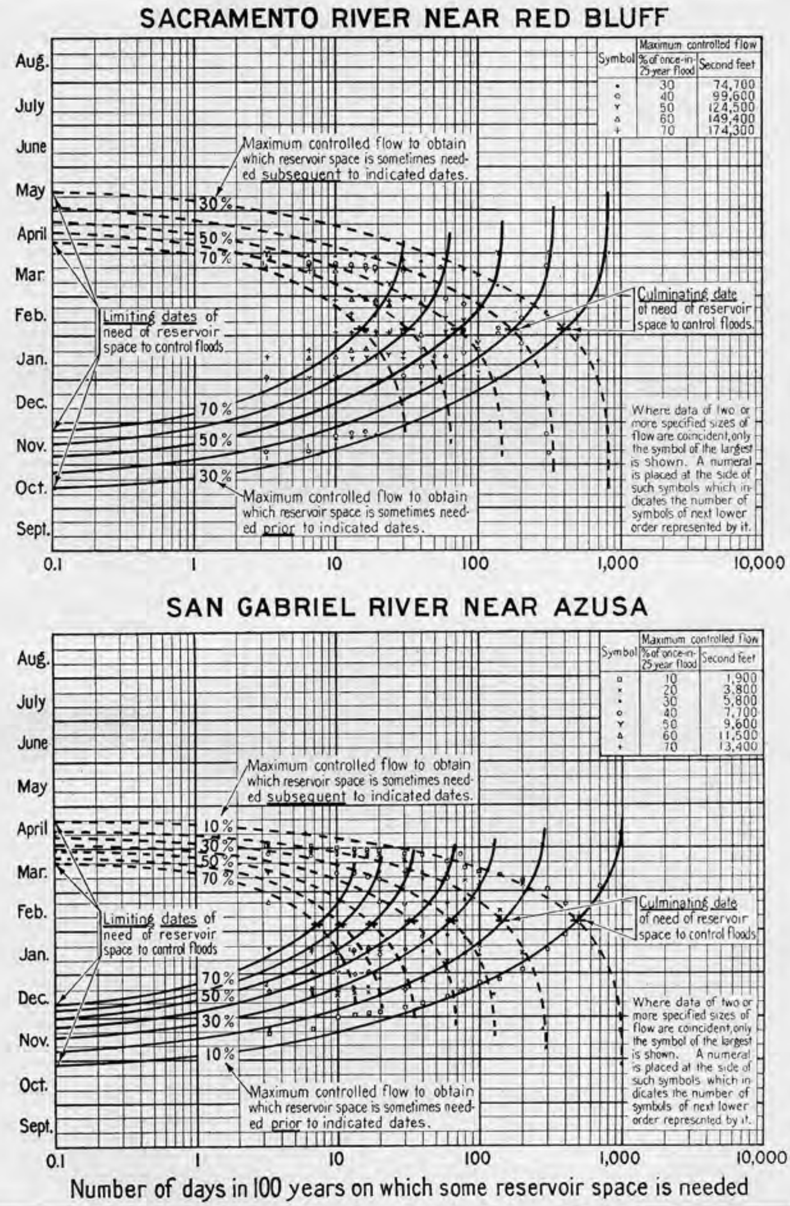
** Water Supply Paper No. 551 of the United States Geological Survey, recently published, places the maximum discharge of the Mokelumne River at Clements at 25,500 second feet. This is obtained by applying the rating curve of the 1911 flood to the gage heights of 1907. The crest discharge of the 1907 flood has been published as 17,000 second feet in former publications including Water Supply Paper No. 299 in which are printed the daily discharges of the 1907 flood. The figures contained in Water Supply Paper No. 299 have been used in preparing this volume. Should the daily discharges of the 1907 flood be revised by application of the 1907 gage heights to the 1911 rating curve, the increase in their values would be so substantial as to require a complete revision of the analyses of floods on the Mokelumne River contained in this volume in order to make the analyses harmonize with the increased discharge values.

Variation in values with time of year and progressive rainfall index.

The reservoir space required to control floods deduced by the foregoing analysis is the largest that may be needed under the many circumstances of flood occurrence. It was derived from a discussion of all recorded floods regardless of the time of year or the value of progressive rainfall index with which they occurred. The reservoir space required to control floods necessarily will vary with the time of year and value of the progressive rainfall index in a way similar to the size of floods of which it is a function. This relation of reservoir space required to control floods to the time of year and value of progressive rainfall index parallels so closely that of the size of floods which is fully presented in Chapter III, pages 29 to 50, that the plates setting forth the corresponding analysis in respect to reservoir space are presented without further comment. Plates XIII and XIV, "Relation of Time of Year to Need of Reservoir Space," are constructed in an identical way to Plates IV and V, "Relation of Time of Year to Flood Occurrence (pp. 30 and 32). Likewise Plates XV, XVI and XVII, "Relation of Progressive Rainfall Index to Need of Reservoir Space," are constructed in a way identically parallel to Plates VII, VIII and IX, "Relation of Progressive Rainfall Index to Flood Occurrence" (pp. 44, 45 and 46).

The limiting dates for the need of reservoir space to control floods on the four illustrative streams are found to vary not more than 33 days from the corresponding dates of flood occurrence (pp. 34 and 35) while the culminating dates are not more than 11 days apart. Likewise the limiting values of progressive rainfall index with which reservoir space is needed to control floods do not differ more than 16 points from the corresponding values with which floods occur and the greatest difference in the most favorable values of the index is 21 points. A complete tabulation of these dates and values of progressive rainfall index follow. These tables are parallel in every respect to those relating to flood occurrence in Chapter III (pp. 34, 35, 36, 48, 49 and 50) except that "need of reservoir space to control floods" is substituted for "flood occurrence."

PLATE XIII.

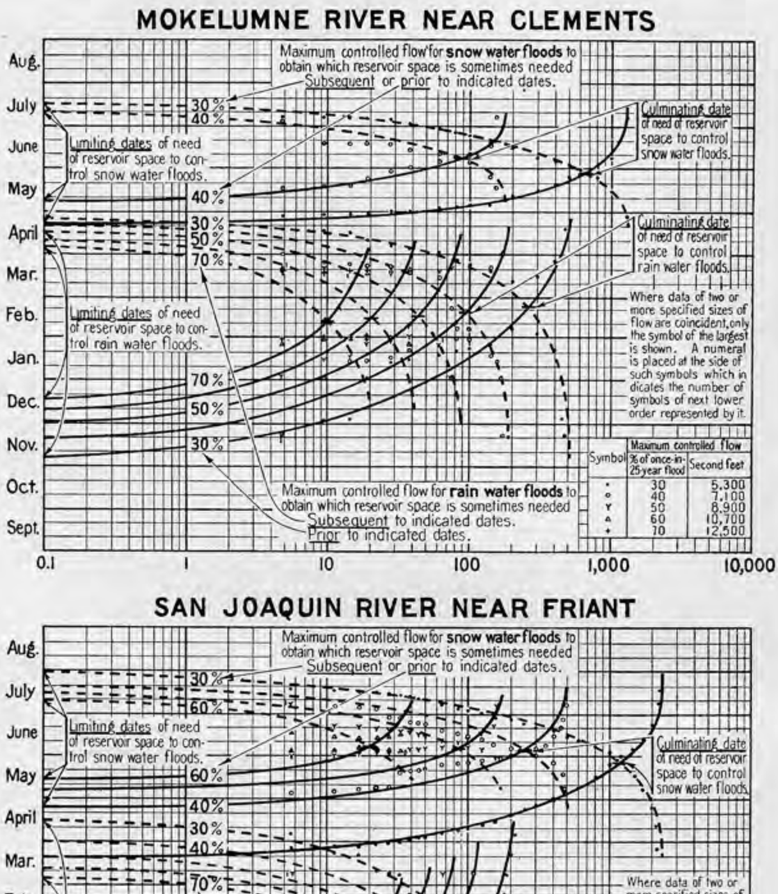


RELATION OF TIME OF YEAR TO NEED OF RESERVOIR SPACE

CURVES SHOW NUMBER OF DAYS IN 100 YEARS ON WHICH SOME RESERVOIR SPACE IS NEEDED PRIOR AND SUBSEQUENT TO INDICATED DATES TO CONTROL FLOODS TO SPECIFIED MAXIMUM FLOW

Maximum controlled flow expressed in per cent of greatest daily rate of flow of a once-in-25-year flood

PLATE XIV.

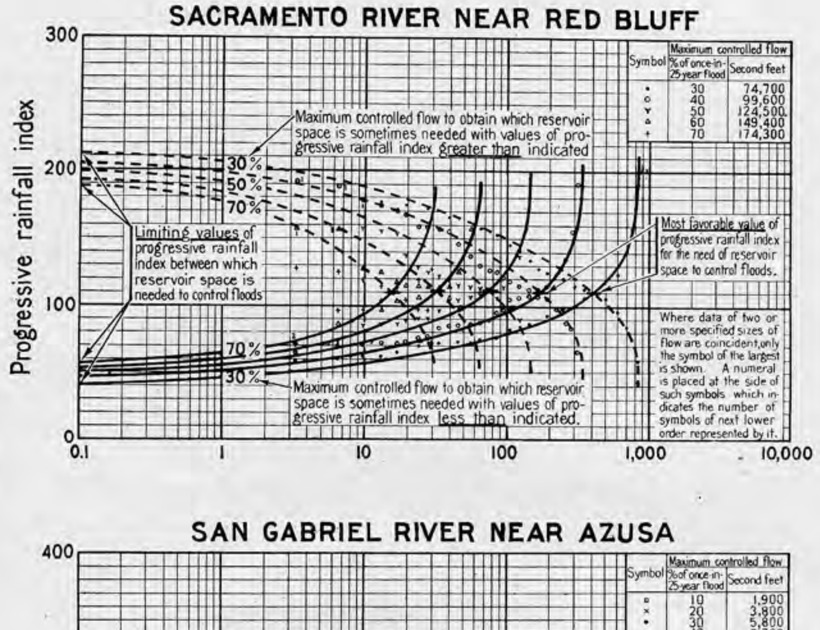


RELATION OF TIME OF YEAR TO NEED OF RESERVOIR SPACE

CURVES SHOW NUMBER OF DAYS IN 100 YEARS ON WHICH SOME RESERVOIR SPACE IS NEEDED PRIOR AND SUBSEQUENT TO INDICATED DATES TO CONTROL FLOODS TO SPECIFIED MAXIMUM FLOW

Maximum controlled flow expressed in per cent of greatest daily rate of flow of a once-in-25-year flood

PLATE XV.

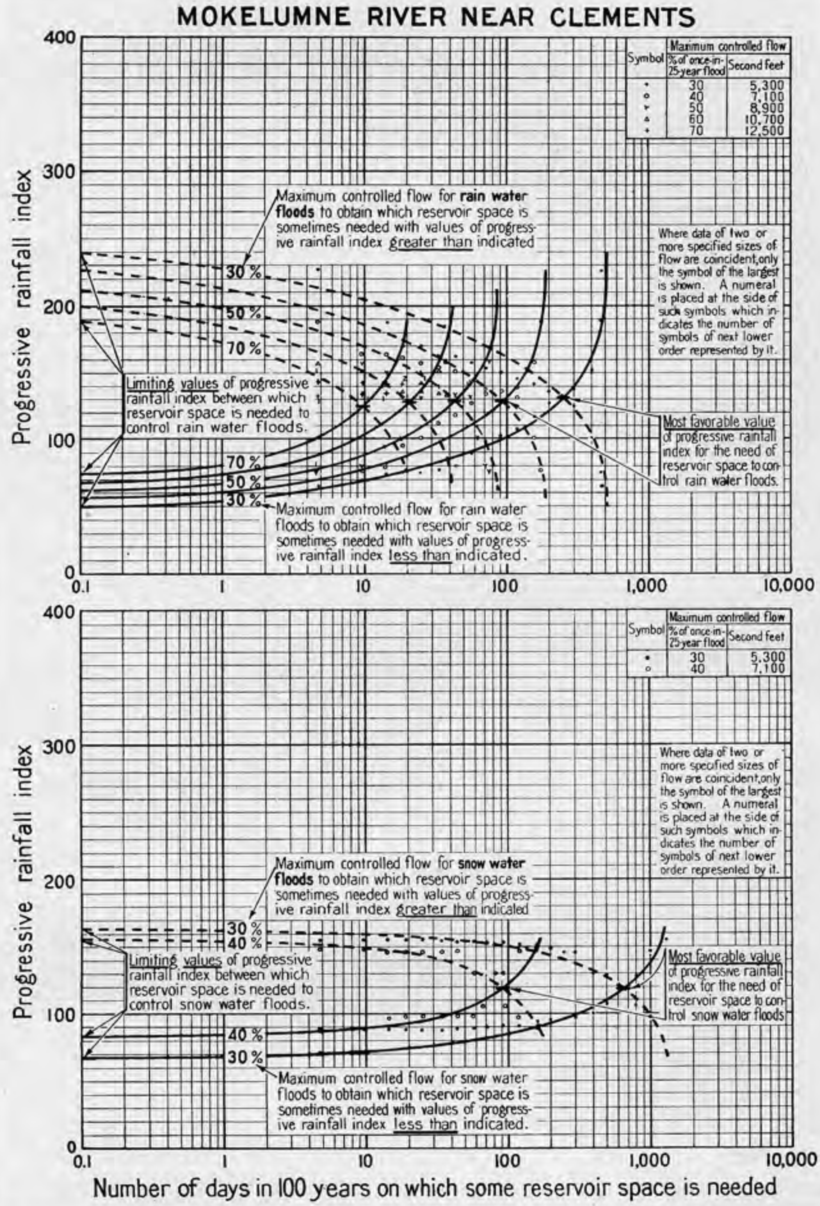


RELATION OF PROGRESSIVE RAINFALL INDEX TO NEED OF RESERVOIR SPACE

CURVES SHOW NUMBER OF DAYS IN 100 YEARS ON WHICH SOME RESERVOIR SPACE IS NEEDED TO CONTROL FLOODS TO SPECIFIED MAXIMUM FLOW WITH VALUES OF PROGRESSIVE RAINFALL INDEX GREATER AND LESS THAN INDICATED.

Maximum controlled flow expressed in per cent of greatest daily rate of flow of a once-in-25-year flood

PLATE XVI.



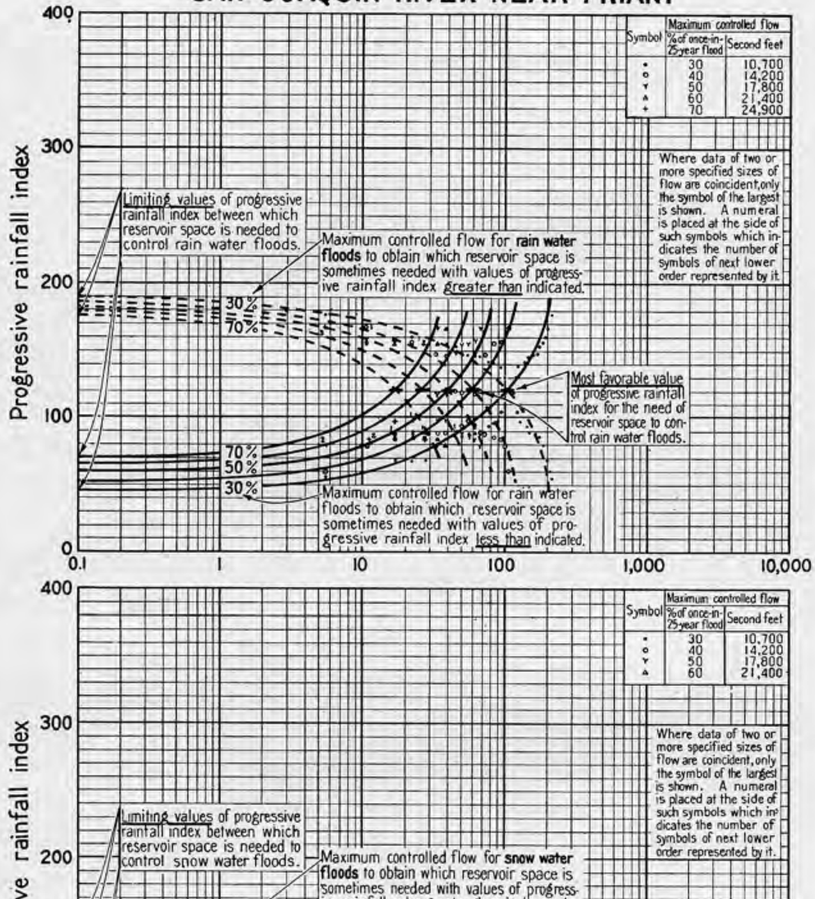
RELATION OF PROGRESSIVE RAINFALL INDEX TO NEED OF RESERVOIR SPACE

CURVES SHOW NUMBER OF DAYS IN 100 YEARS ON WHICH SOME RESERVOIR SPACE IS NEEDED TO CONTROL FLOODS TO SPECIFIED MAXIMUM FLOW WITH VALUES OF PROGRESSIVE RAINFALL INDEX GREATER AND LESS THAN INDICATED.

Maximum controlled flow expressed in per cent of greatest daily rate of flow of a once-in-25-year flood.

PLATE XVII.

SAN JOAQUIN RIVER NEAR FRIANT



RELATION OF PROGRESSIVE RAINFALL INDEX TO NEED OF RESERVOIR SPACE

CURVES SHOW NUMBER OF DAYS IN 100 YEARS ON WHICH SOME RESERVOIR SPACE IS NEEDED TO CONTROL FLOODS TO SPECIFIED MAXIMUM FLOW WITH VALUES OF PROGRESSIVE RAINFALL INDEX GREATER AND LESS THAN INDICATED.

Maximum controlled flow expressed in per cent of greatest daily rate of flow of a once-in-25-year flood

LIMITING DATES FOR NEED OF RESERVOIR SPACE TO CONTROL FLOODS ON SACRAMENTO RIVER.

Maximum controlled flow near Red Bluff		Opening dates					Closing dates				
		Frequency with which some reservoir space is needed **prior** to tabulated dates					Frequency with which some reservoir space is needed **subsequent** to tabulated dates				
In per cent of greatest daily rate of flow of once-in-25-year flood	In second-feet	One day in 1000 years	One day in 100 years	One day in 50 years	One day in 25 years	One day in 10 years	One day in 1000 years	One day in 100 years	One day in 50 years	One day in 25 years	One day in 10 years
30	74,700	Oct. 14	Oct. 21	Oct. 25	Nov. 1	Nov. 11	May 13	May 7	May 3	Apr. 28	Apr. 19
40	99,600	Oct. 26	Nov. 3	Nov. 8	Nov. 15	Nov. 27	May 1	Apr. 23	Apr. 19	Apr. 14	Apr. 4
50	124,500	Nov. 6	Nov. 15	Nov. 21	Nov. 29	Dec. 14	Apr. 22	Apr. 13	Apr. 8	Apr. 2	Mar. 21
60	149,400	Nov. 15	Nov. 26	Dec. 3	Dec. 13	Dec. 31	Apr. 14	Apr. 5	Mar. 31	Mar. 23	Mar. 8
70	174,300	Nov. 23	Dec. 6	Dec. 15	Dec. 27	Jan. 20	Apr. 8	Mar. 30	Mar. 24	Mar. 14	Feb. 20

LIMITING DATES FOR NEED OF RESERVOIR SPACE TO CONTROL FLOODS ON MOKELUMNE RIVER.

Maximum controlled flow near Clements		Opening dates					Closing dates				
		Frequency with which some reservoir space is needed **prior** to tabulated dates					Frequency with which some reservoir space is needed **subsequent** to tabulated dates				
In per cent of greatest daily rate of flow of once-in-25-year flood	In second-feet	One day in 1000 years	One day in 100 years	One day in 50 years	One day in 25 years	One day in 10 years	One day in 1000 years	One day in 100 years	One day in 50 years	One day in 25 years	One day in 10 years
						Rain-Water Floods.					
30	5,300	Nov. 6	Nov. 13	Nov. 17	Nov. 23	Dec. 3	Apr. 25	Apr. 22	Apr. 21	Apr. 19	Apr. 15
40	7,100	Nov. 19	Nov. 26	Dec. 1	Dec. 8	Dec. 20	Apr. 20	Apr. 17	Apr. 16	Apr. 13	Apr. 6
50	8,900	Nov. 30	Dec. 8	Dec. 14	Dec. 21	Jan. 4	Apr. 15	Apr. 12	Apr. 10	Apr. 6	Mar. 26
60	10,700	Dec. 9	Dec. 18	Dec. 25	Jan. 3	Jan. 21	Apr. 10	Apr. 5	Apr. 2	Mar. 27	Mar. 10
70	12,500	Dec. 17	Dec. 28	Jan. 5	Jan. 16	....	Apr. 5	Mar. 29	Mar. 24	Mar. 13	....
						Snow-Water Floods.					
30	5,300	Apr. 21	Apr. 22	Apr. 23	Apr. 24	Apr. 25	July 16	July 14	July 12	July 11	July 8
40	7,100	May 7	May 9	May 11	May 13	May 18	July 10	July 7	July 5	July 2	June 28

LIMITING DATES FOR NEED OF RESERVOIR SPACE TO CONTROL FLOODS ON SAN JOAQUIN RIVER.

Maximum controlled flow near Friant		Opening dates					Closing dates				
		Frequency with which some reservoir space is needed **prior** to tabulated dates					Frequency with which some reservoir space is needed **subsequent** to tabulated dates				
In per cent of greatest daily rate of flow of once-in-25-year flood	In second-feet	One day in 1000 years	One day in 100 years	One day in 50 years	One day in 25 years	One day in 10 years	One day in 1000 years	One day in 100 years	One day in 50 years	One day in 25 years	One day in 10 years
						Rain-Water Floods.					
30	10,700	Sept. 30	Oct. 16	Oct. 22	Oct. 31	Nov. 15	Apr. 15	Apr. 10	Apr. 7	Apr. 3	Mar. 25
40	14,200	Oct. 17	Oct. 31	Nov. 8	Nov. 17	Dec. 1	Mar. 31	Mar. 26	Mar. 23	Mar. 18	Mar. 9
50	17,800	Nov. 2	Nov. 15	Nov. 21	Nov. 30	Dec. 14	Mar. 20	Mar. 15	Mar. 12	Mar. 7	Feb. 24
60	21,400	Nov. 16	Nov. 28	Dec. 4	Dec. 12	Dec. 27	Mar. 12	Mar. 7	Mar. 4	Feb. 27	Feb. 15
70	24,900	Nov. 29	Dec. 10	Dec. 16	Dec. 24	Jan. 8	Mar. 5	Feb. 28	Feb. 24	Feb. 19	Feb. 5
						Snow-Water Floods.					
30	10,700	Mar. 19	Mar. 20	Mar. 22	Mar. 23	Mar. 26	July 30	July 26	July 25	July 22	July 19
40	14,200	Apr. 24	Apr. 25	Apr. 27	Apr. 28	May 1	July 21	July 17	July 16	July 13	July 10
50	17,800	May 7	May 8	May 9	May 11	May 15	July 14	July 10	July 9	July 6	July 2
60	21,400	May 14	May 16	May 17	May 20	May 26	July 9	July 5	July 3	June 29	June 19

LIMITING DATES FOR NEED OF RESERVOIR SPACE TO CONTROL FLOODS ON SAN GABRIEL RIVER.

Maximum controlled flow near Azusa		Opening dates					Closing dates				
		Frequency with which some reservoir space is needed **prior** to tabulated dates					Frequency with which some reservoir space is needed **subsequent** to tabulated dates				
In per cent of greatest daily rate of flow of once-in-25-year flood	In second-feet	One day in 1000 years	One day in 100 years	One day in 50 years	One day in 25 years	One day in 10 years	One day in 1000 years	One day in 100 years	One day in 50 years	One day in 25 years	One day in 10 years
10	1,900	Oct. 27	Nov. 3	Nov. 6	Nov. 11	Nov. 19	Apr. 19	Apr. 17	Apr. 14	Apr. 12	Apr. 7
20	3,800	Nov. 7	Nov. 15	Nov. 19	Nov. 25	Dec. 5	Apr. 13	Apr. 9	Apr. 7	Apr. 3	Mar. 27
30	5,800	Nov. 16	Nov. 25	Dec. 1	Dec. 7	Dec. 20	Apr. 8	Apr. 3	Apr. 1	Mar. 27	Mar. 19
40	7,700	Nov. 24	Dec. 4	Dec. 11	Dec. 19	Jan. 4	Apr. 2	Mar. 29	Mar. 26	Mar. 20	Mar. 9
50	9,600	Nov. 30	Dec. 12	Dec. 19	Dec. 29	Jan. 18	Mar. 30	Mar. 24	Mar. 20	Mar. 13	Feb. 24
60	11,500	Dec. 5	Dec. 18	Dec. 27	Jan. 8	Feb. 1	Mar. 24	Mar. 18	Mar. 13	Mar. 5	Feb. 7
70	13,400	Dec. 9	Dec. 25	Jan. 4	Jan. 17	....	Mar. 20	Mar. 13	Mar. 6	Feb. 23	....

CULMINATING DATE FOR NEED OF RESERVOIR SPACE TO CONTROL FLOODS.

Maximum controlled flow	Date					
In per cent of greatest daily rate of flow of once-in-25-year flood	Sacramento River near Red Bluff	Mokelumne River near Clements		San Joaquin River near Friant		San Gabriel River near Azusa
		Rain-water floods	Snow-water floods	Rain-water floods	Snow-water floods	
10	....	....	....	....	....	Feb. 7
20	....	....	....	....	....	Feb. 7
30	Feb. 4	Feb. 22	May 28	Jan. 18	May 26	Feb. 7
40	Feb. 4	Feb. 18	June 7	Jan. 19	June 4	Feb. 7
50	Feb. 4	Feb. 15	....	Jan. 20	June 5	Feb. 4
60	Feb. 4	Feb. 14	....	Jan. 21	June 6	Feb. 4
70	Feb. 4	Feb. 12	....	Jan. 22	....	Feb. 4

SACRAMENTO RIVER.

LIMITING VALUES OF PROGRESSIVE RAINFALL INDEX* BETWEEN WHICH RESERVOIR SPACE IS NEEDED TO CONTROL FLOODS.

Maximum controlled flow near Red Bluff		Minimum index values					Maximum index values				
		Frequency with which some reservoir space is needed, with progressive rainfall index **less** than values tabulated					Frequency with which some reservoir space is needed, with progressive rainfall index **greater** than values tabulated				
In per cent of greatest daily rate of flow of once-in-25-year flood	In second-feet	One day in 1000 years	One day in 100 years	One day in 50 years	One day in 25 years	One day in 10 years	One day in 1000 years	One day in 100 years	One day in 50 years	One day in 25 years	One day in 10 years
30	74,700	42	47	49	52	58	212	206	202	197	188
40	99,600	46	51	54	58	65	205	199	194	188	178
50	124,500	50	56	59	64	72	199	191	186	179	164
60	149,400	54	60	64	70	81	193	183	177	167	148
70	174,300	57	64	68	76	95	188	176	168	155	127

*At Red Bluff rainfall station.

MOKELUMNE RIVER.

LIMITING VALUES OF PROGRESSIVE RAINFALL INDEX* BETWEEN WHICH RESERVOIR SPACE IS NEEDED TO CONTROL FLOODS.

Maximum controlled flow near Clements		Minimum index values					Maximum index values				
		Frequency with which some reservoir space is needed, with progressive rainfall index **less** than values tabulated					Frequency with which some reservoir space is needed, with progressive rainfall index **greater** than values tabulated				
In per cent of greatest daily rate of flow of once-in-25-year flood	In second-feet	One day in 1000 years	One day in 100 years	One day in 50 years	One day in 25 years	One day in 10 years	One day in 1000 years	One day in 100 years	One day in 50 years	One day in 25 years	One day in 10 years
						Rain-Water Floods.					
30	5,300	50	55	58	62	70	240	228	222	215	204
40	7,100	56	61	64	69	78	226	213	207	199	186
50	8,900	62	67	71	77	88	212	198	191	183	169
60	10,700	68	74	78	86	103	200	185	177	168	150
70	12,500	74	81	86	97	....	188	172	163	151	....
						Snow-Water Floods.					
30	5,300	67	68	69	70	72	164	163	162	161	159
40	7,100	83	84	85	86	89	156	154	153	151	149

*At Electra rainfall station.

SAN JOAQUIN RIVER.

LIMITING VALUES OF PROGRESSIVE RAINFALL INDEX* BETWEEN WHICH RESERVOIR SPACE IS NEEDED TO CONTROL FLOODS.

Maximum controlled flow near Friant		Minimum index values					Maximum index values				
		Frequency with which some reservoir space is needed, with progressive rainfall index less than values tabulated					Frequency with which some reservoir space is needed, with progressive rainfall index greater than values tabulated				
In per cent of greatest daily rate of flow of once-in-25-year flood	In second-feet	One day in 1000 years	One day in 100 years	One day in 50 years	One day in 25 years	One day in 10 years	One day in 1000 years	One day in 100 years	One day in 50 years	One day in 25 years	One day in 10 years
						Rain-Water Floods.					
30	10,700	45	47	49	52	59	190	185	183	179	173
40	14,200	53	55	57	60	70	186	181	179	175	167
50	17,800	60	62	65	68	79	182	177	174	170	160
60	21,400	66	69	71	76	89	179	173	170	164	151
70	24,900	71	74	77	83	101	176	169	164	157	140
						Snow-Water Floods.					
30	10,700	60	62	64	65	68	150	148	147	146	144
40	14,200	69	71	73	74	77	143	140	139	137	135
50	17,800	77	80	82	84	88	138	134	133	131	128
60	21,400	84	88	91	94	101	134	129	127	125	119

*At Fresno rainfall station.

SAN GABRIEL RIVER.

LIMITING VALUES OF PROGRESSIVE RAINFALL INDEX* BETWEEN WHICH RESERVOIR SPACE IS NEEDED TO CONTROL FLOODS.

Maximum controlled flow near Azusa		Minimum index values					Maximum index values				
		Frequency with which some reservoir space is needed, with progressive rainfall index **less** than values tabulated					Frequency with which some reservoir space is needed, with progressive rainfall index **greater** than values tabulated				
In per cent of greatest daily rate of flow of once-in-25-year flood	In second-feet	One day in 1000 years	One day in 100 years	One day in 50 years	One day in 25 years	One day in 10 years	One day in 1000 years	One day in 100 years	One day in 50 years	One day in 25 years	One day in 10 years
10	1,900	27	30	32	35	40	294	282	277	270	257
20	3,800	35	39	41	45	51	279	264	256	245	226
30	5,800	42	47	49	53	61	265	248	238	226	203
40	7,700	48	54	57	63	78	252	233	222	207	181
50	9,600	54	59	66	77	102	241	219	206	189	158
60	11,500	58	66	76	90	127	230	205	191	173	133
70	13,400	63	73	86	106	....	220	193	178	156	....

*At Claremont rainfall station.

MOST FAVORABLE VALUES OF PROGRESSIVE RAINFALL INDEX FOR NEED OF RESERVOIR SPACE TO CONTROL FLOODS.

Maximum controlled flow	Sacramento River near Red Bluff	Mokelumne River near Clements		San Joaquin River near Friant		San Gabriel River near Azusa
In per cent of greatest daily rate of flow of once-in-25-year flood		Rain-water floods	Snow-water floods	Rain-water floods	Snow-water floods	
10	....	....	....	....	....	122
20	....	....	....	....	....	117
30	110	130	120	122	110	121
40	110	129	120	122	110	125
50	110	128	....	122	110	128
60	111	128	....	122	110	130
70	110	125	....	122	....	131

CHAPTER V.

THE RESERVOIR OPERATING DIAGRAM FOR CONTROLLING FLOODS.

Principles of operating reservoirs for controlling floods.

The use of reservoirs for flood control in California, being of comparatively recent date, has not been standardized by the engineering profession. The practice varies. In general, reservoirs now in use for flood control have allotted either the entire or a specific part of their capacity for this purpose alone. The usual method of operation is to hold this entire space empty at all times except as it may be temporarily filled while detaining excessive flood flows and the water that accumulates while thus controlling floods is released as soon as the streams subside in order that this space may be empty for the control of the run-off of subsequent storms. Any water that is retained in storage is held upon the prediction of the reservoir operators that the space occupied by it will not be needed again that season for controlling floods.

The prediction that floods will not occur again in any season involves an estimate of future weather conditions, the most uncertain of all events. When water is stored in flood control reservoirs on such an estimate, an error results in failure in control of subsequent floods because the reservoir space needed to detain excessive rates of flow would already be filled with water held from the first storm. Failure in the control of floods means the loss of property and sometimes of human life. Were this danger not real, flood control reservoirs would not be built. For matters of such importance, it would seem unsafe to rely upon the judgment of operators in the most uncertain of predictions, especially since the decisions of gravest moment must be made during the stress of large floods. The risk of an error in judgment under these circumstances is too great for attaining surety in protection. For this reason the use of flood control reservoirs for conservation purposes generally has not been looked upon with favor.

For a like reason, many engineers propose the exclusion of manually operated gates on the outlets of flood control reservoirs. Contention is made that the risk is great in relying upon human activity of any kind during critical periods; rather, they would have the reservoir discharge its water and empty automatically through ports in the dams with fixed openings. This view, however, would seem to be somewhat extreme, for it is now common practice to place manually operated gates in the spillways of reservoirs. These are closed toward the end of the run-off season in order to utilize the top layers of the reservoir for storing water. They are opened again after the summer's draft has lowered the reservoir level, but before the next season's rains. Should the attendants fail to open these gates, the capacity of the spillway would be destroyed and a fair-sized flood would overtop the dam. In spite of this danger, reliance is placed on the manual operation of these gates to clear the spillway prior to the occurrence of a flood.

The manual operation of control mechanism is customary in many other lines of endeavor where the safety of life and property is involved, especially in our transportation system. Custom relies upon hand-controlled signals, valves and steering apparatus for the safety of life and property in all modes of transportation. Dispatchers, tower men, engineers of railroads, auto-bus drivers, and captains of ocean-going vessels, in the faithful and exact performance of their duty, hold within their hands the safety of millions of passengers and vast wealth. These men are required to operate apparatus under guiding rules. Judgment, other than that necessary for applying the guiding rules, is not needed. Because of the many successful years of the operation of our transportation systems on both land and water, it would seem that the manual operation of apparatus under guiding rules is quite safe. By analogy, therefore, it would not seem necessary for safety to exclude the use of manually operated gates on the outlets of flood control reservoirs, provided that guiding rules, definite and enforcible, be laid down for their opening and closing.

Without gates controlled by hand on the outlets of flood control reservoirs, a coordinated use of their space for both flood control and conservation is impossible. Gates that may be closed when desired are necessary in order that flood control reservoirs may store water for any length of time. Therefore, the safe use of the same reservoir space for both flood control and conservation is contingent upon working out definite guiding rules for opening and closing the outlet gates that do not employ judgment in their execution and that can be enforced.

Rules for opening and closing reservoir outlet gates that will control floods with certainty may be worked out easily enough if no attempt is made to avoid interference with the conservation values of the reservoirs. To produce rules, however, that will hold sufficient reservoir space empty during the flood season to assure the successful control of floods while at the same time releasing this space as the season progresses so that it may fill with water before the end of the run-off season, is a complex undertaking. It has been the purpose of these investigations to develop the principles upon which such rules might be scientifically constructed and, by way of illustration, to construct several rules, test their accuracy and determine their effect on conservation. These principles have been developed in the foregoing chapters. The construction of the rules, the test of their accuracy and the determination of their effect on conservation occupy this and the concluding chapters.

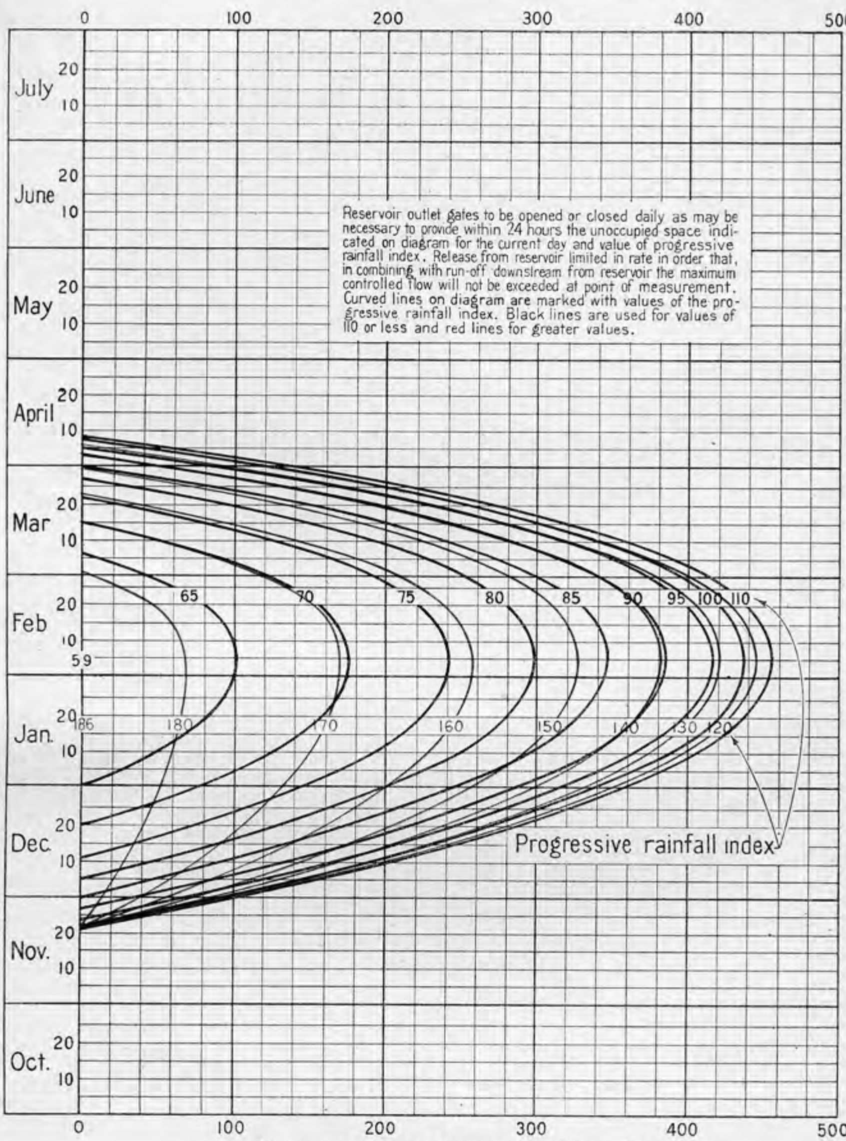
The reservoir operating diagram.

It has been pointed out in the preceding chapters, that the same amount of reservoir space is not needed for controlling floods at all times during a season nor in all seasons. The amount of space needed under the many circumstances of time of year and type of season is determined by the analysis of the need of reservoir space for controlling floods described in the previous pages. In general, the amount of space needed for detaining excessive flood flows so that only limited amounts pass the reservoir increases from zero in the early fall to a maximum in midwinter and then, as the season progresses, decreases to zero in the forepart of summer. It also fluctuates with the normalcy of the season's precipitation. In general, summarizing the deductions of the first four chapters, when the seasonal precipitation to date is less than half or more than double normal, large floods do not occur. Under these conditions, reservoir space is not needed for flood control regardless of the time of year. It is needed in the largest volume when the precipitation to date is between normal and 50 per cent above. The largest floods occur under these circumstances and the maximum reservoir space is then required for controlling floods. Space in amounts intermediate between zero and the maximum is necessary when the seasonal precipitation to date is between 50 and 100 or between 150 and 200 per cent normal. The exact value of these requirements varies with each stream and the degree of control desired.

The amount of reservoir space required under the many variant circumstances of time of year, type of season, and degree of desired control may be specifically derived through analyses similar to the ones in the preceding chapters. Having determined these amounts, rules may be laid down that will release the space required for flood control as soon as its need for that purpose has passed. This space may then fill for conservation. The dependability of such rules for controlling floods rests upon the selection of adequate amounts of space to be held empty during the flood season. Their value to conservation rests upon the immediate release of this space for filling as soon as its need for flood control has passed. Thus, the determination of the amount of space that should be held empty during the flood season and of the time that all or part of it may be released safely for filling is the foundation for formulating rules for the combined use of the same reservoir space for both flood control and conservation.

The rules, as devised by this investigation, are expressed in the form of graphic diagrams which show the amount of reservoir space that, for the circumstance existing on any current day, should be empty in order to assure the degree of flood control desired. The reservoir outlet gates would be opened or closed daily as may be necessary to provide within 24 hours the required empty space indicated on the diagram. The gates would be opened when this space is less than indicated and the discharge through the outlets is less than the desired maximum controlled flow. The gates would be closed whenever the empty space in the reservoir is greater than indicated on the diagram. All inflow to the reservoir would then enter storage except as water may be withdrawn for some useful purpose.

These graphic rules are called "Reservoir Operating Diagrams for Controlling Floods." Each diagram applies to a particular stream and to a particular degree of control. The degree of control is expressed by the maximum controlled flow desired at some point of measurement and the probability that this will not be exceeded. This probability is measured in the analyses herein described by the number of days in an average hundred years on which greater flows may occur. The greater the assurance of perfect control, the larger is the amount of reservoir space required and the longer is the period during which it should be held empty. Practical values in accord with the danger to life and property must be selected for design purposes in each instance. For sparsely settled rural lands, it is thought that adequate protection would be had if the desired maximum controlled flow were exceeded on



RESERVOIR OPERATING DIAGRAM FOR CONTROLLING FLOODS ON SACRAMENTO RIVER

MAXIMUM CONTROLLED FLOW NEAR RED BLUFF-125,000 SEC. FT.

CURVES SHOW SPACE NEEDED AT VARYING TIMES OF YEAR AND VALUES OF PROGRESSIVE RAINFALL INDEX TO ABSORB EXCESSIVE FLOOD FLOWS.

an average not oftener than one day in 25 years, while for very thickly populated territory, it probably should not be exceeded oftener than one day in a thousand years or more.

After selecting the degree of control desired, a reservoir operating diagram for controlling floods may be constructed for any stream from the analyses of its flow measurements. This diagram would apply only to reservoirs having drainage areas between them and the point of measurement that do not produce floods greater than the selected maximum controlled flow. In releasing water from reservoirs located upstream from the point of measurement, the amount would be governed by the flow at the point of measurement. The release from the reservoir would be limited to an amount that, combined with the natural run-off from the drainage area downstream, would not exceed the desired controlled flow at the point of measurement.

The analyses of stream flow data required for the construction of a reservoir operating diagram are identical to those described in Chapter IV. The analyses there described of the stream flow data on the Sacramento, Mokelumne, San Joaquin and San Gabriel rivers furnish information for the construction of reservoir operating diagrams for any desired degree of flood control on these four streams. The construction, from this information, of a diagram for one selected degree of control on each of the four streams is described in the following pages of this chapter.

For convenience in working with these diagrams, the use of the name "progressive rainfall index" that represents the normalcy of seasonal precipitation in the analyses of Chapters III and IV has been continued. It is the ratio of the precipitation from July 1st up to any current day in a season to the normal precipitation for the same period. Its value changes daily as the season progresses.

In using the diagrams, it is necessary to maintain a rain gage in order to obtain the current value of the progressive rainfall index. This gage should be read and the value of the progressive rainfall index computed on each day. The diagram should be entered with this value and the amount of space read-off that should be empty at the end of the current day. The outlet gates should then be regulated to obtain this empty space so far as may be done without causing a flow at the point of measurement greater than the desired maximum. If the reservoir outlet gates were so regulated daily, by reason of the method of constructing the diagram, the reservoir would not be expected to fill to overflowing except at the average intervals contemplated in the selection of the degree of probable control. At these average intervals, the reservoir would be expected to overflow while the maximum controlled flow is passing the point of measurement. Thus, the maximum controlled flow below the reservoir may be exceeded by the amount of this overflow at the average intervals selected in the construction of the diagram. The amount of the overflow might be anything larger than zero with the greatest likelihood of its being among the smaller values.

Reservoir operating diagram for controlling floods on Sacramento River.

Plate XVIII, "Reservoir Operating Diagram for Controlling Floods on Sacramento River," presents in graphic form the rule for operating a reservoir on the main Sacramento River in order to limit the flow in the channel near Red Bluff to 125,000 second-feet. It indicates the space in the reservoir that should be empty in order to detain run-off in excess of this desired regulated flow for all conditions of previous rainfall on every day of the season. The amount of space that should be empty changes with the time of year and the normalcy of the season's precipitation as shown by the value of the progressive rainfall index. A maximum of 454,000 acre-feet is required to be empty in the fore part of February if the precipitation up to that time is 10 per cent above normal. On preceding and subsequent days the space required becomes less until prior to November 21st and subsequent to April 8th, no space is needed at all. The required space also becomes less for seasonal precipitation to date either larger or smaller than 10 per cent above normal and reaches zero for precipitation greater than 186 per cent or less than 59 per cent normal.

Had there been a reservoir in existence and operated in accord with this diagram through the thirty years of stream flow record on the Sacramento River, the flow at Red Bluff would not have exceeded 125,000 second-feet at any time. Even the greatest flood of record on February 3, 1909, which reached a crest discharge of 278,000 second-feet, would have been limited to a flow of 125,000 second feet, 153,000 second-feet less than the actual occurrence. Although controlling floods to this discharge, the diagram holds space in the reservoir empty no longer than necessary. Thus, the rule of reservoir operation laid down by this diagram interferes as little as possible with the use of the reservoir for conservation.

The diagram applies to any reservoir of more than 454,000* acre-feet capacity that might be constructed on the main Sacramento River between the Red Bluff gaging station and the Kennett reservoir site near the confluence with the Pit River. It does not apply to reservoirs further upstream than Kennett because it is estimated that a flood as large as 125,000 second-feet may originate on the drainage area downstream from Kennett but tributary to the Red Bluff gaging station.

The values of the progressive rainfall index used in the construction of the diagram were computed from the rainfall records of the United States Weather Bureau at Red Bluff.† These values are marked on the curved lines of the diagram. Black lines are used for values of 110 or less and red lines for greater values. The intersections of the curved lines with the horizontal date lines indicate on the lower scale the amount of empty space needed at any time. The diagram assumes that the reservoir outlet gates will be opened or closed daily as may be necessary to provide as nearly as possible within 24 hours without causing the desired regulated flow to be exceeded, the empty space indicated on the diagram for the current day and value of progressive rainfall index. If the reservoir were located upstream from Red Bluff, the release through the outlet gates would be limited to amounts that would not exceed 125,000 second-feet after combining with the run-off from the drainage area between the reservoir and Red Bluff.

* The reservoir space needed for flood control in addition to 454,000 acre-feet is that which would furnish the minimum operating head on the reservoir outlets to discharge 125,000 second-feet.

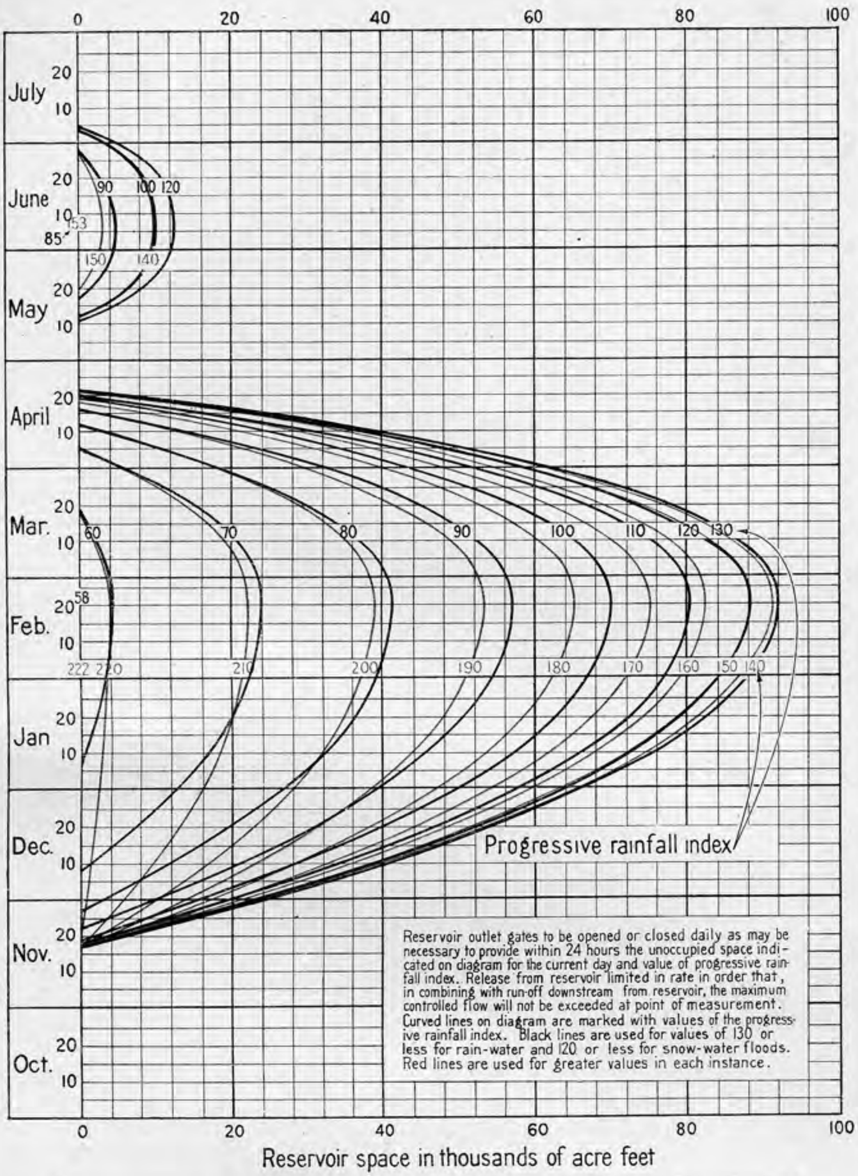
† Red Bluff is one of the principal stations in precipitation division B of which most of the flood producing area of the Sacramento Drainage Basin is part. See Chap. II, Bul. 5, "Flow in California Streams," issued by the Division of Engineering and Irrigation, State Department of Public Works.

The degree of control selected for construction of the Sacramento River diagram contemplates that the desired regulated flow may be exceeded on an average of one day in fifty years. This was used in taking values off the charts of Chapter IV for constructing the diagram. The maximum reservoir space required under the most severe circumstances is taken from Plate X, p. 55. In the upper figure on this plate, reading the 50 per cent curve (124,500 second-feet), it is found that reservoir space in the amount of 92 per cent of the greatest daily run-off of a once-in-25-year flood (454,000 acre-feet) is sufficient, on the average, to control floods to 125,000 second-feet maximum flow at Red Bluff on all but one day in fifty years. The time at which this maximum space is required is taken from the upper figure of Plate XIII, p. 63. The intersection of the full and dotted-line curves labeled 50 per cent (124,500 second-feet) determines that the culminating date of need of reservoir space to control floods is February 4th. This date and the maximum reservoir space needed locate on the diagram the apex of the outside curve, the one of largest values of reservoir space.

The two arms of the outside curve are fixed in position by their intersections with the vertical line on the left representing zero reservoir space. Their intersections with this vertical read on the time scale are at the days before and after which reservoir space is not needed to control floods. These dates are determined on the upper figure of Plate XIII, p. 63, by the intersection of the 50 per cent curves (124,500 second-feet) with the vertical representing two days in 100 years on which some reservoir space is required to control floods. The full-line curve intersects at November 21st, the date before which reservoir space is not needed. The dotted-line curve intersects at April 8th, the day after which reservoir space is not needed. These two dates, plotted on the operating diagram on the line of zero reservoir space, fix the position of the arms of the outside curve. With the apex and the position of the two arms fixed, the shape of the curve was estimated from a study of the data on twenty major streams in California and by the trial construction of diagrams. The shape given is the one that seems to fit the data best.

This curve, outermost of all others on the diagram, expresses the largest values of reservoir space that are required at any time. The amount of space indicated by it should be held empty when the conditions of previous rainfall are most favorable for the need of reservoir space to control floods. The value of the progressive rainfall index most favorable for the need of reservoir space is taken from the upper figure of Plate XV, p. 65. Here the dotted and full-line curves representing control to 50 per cent of a once-in-25-year flood (124,500 second-feet) intersect at a value of 110 read on the scale of progressive rainfall index. This is the most favorable value for need of reservoir space to control floods and hence is the value of the progressive rainfall index that applies to the outside curve of the operating diagram.

The interior curves that indicate the empty space required with values of the progressive rainfall index either greater or less than the one calling for the largest amount of empty reservoir space are drawn of a shape similar to the outside curve. There is one black curve for each increment of five in the values of the progressive rainfall index less than 110, and one red curve for each increment of ten in



Reservoir Operating Diagram for Controlling Floods on Mokelumne River

MAXIMUM CONTROLLED FLOW NEAR CLEMENTS
FOR
RAIN WATER FLOODS — 5,300 SEC. FT.
SNOW WATER FLOODS — 7,100 SEC. FT.

CURVES SHOW SPACE NEEDED AT VARYING TIMES OF YEAR AND VALUES OF PROGRESSIVE RAINFALL INDEX TO ABSORB EXCESSIVE FLOOD FLOWS.

the values of the progressive rainfall index greater than 110. The curve of smallest index value is 65 and largest 180. Both are close to the zero ordinate of reservoir space on the diagram. The index values coinciding with the zero ordinate of reservoir space are 59 and 186. These are the limiting values between which reservoir space is required to control floods. No space is needed when the index is either smaller or larger, respectively. These values are derived from Plate XV, p. 65. In the upper figure on this plate, the two 50 per cent curves (124,500 second-feet) intersect the vertical representing two days in 100 years that values will be exceeded, at 59 and 186 on the vertical scale of progressive rainfall index. The intersection of the full-line curve shows that, for values of the progressive rainfall index less than 59, reservoir space is not required oftener than two days in 100 years. Similarly, the intersection of the dotted-line curve shows that reservoir space is not required to control floods except for two days in 100 years when the progressive rainfall index exceeds 186.

The positions of the apices of the several interior curves on the diagram are interpolated between the outside curve of maximum reservoir space and zero on the reservoir space scale along the line representing February 4th, the culminating date for need of reservoir space in controlling floods. They are not arranged with uniform intervals between them, but rather take positions having increasingly smaller intervals as the maximum reservoir space is approached. The arms of the interior curves are drawn of the same general shape as the outside curve and are interpolated in position with increasingly smaller intervals between them toward the latter part of the flood season. While normally the arms toward the fore part of the flood season would take similar positions, since at this time of the year the index values fluctuate rapidly and are not well established, they are all passed through November 21st on the zero reservoir space line, the opening date of the flood season. This manner of fixing the positions of the apices and arms of the interior curves was found to fit the data best after construction of many trial and supplementary diagrams on this and other streams and for other degrees of flood control.

Reservoir operating diagram for controlling floods on Mokelumne River.

The rule for operating a reservoir to control floods on the Mokelumne River is expressed on Plate XIX, "Reservoir Operating Diagram for Controlling Floods on Mokelumne River." As on the one for the Sacramento River, the Mokelumne River diagram indicates the space in a reservoir that should be empty on each day of the season for all conditions of previous precipitation in order to detain discharges in excess of a certain desired controlled flow. The Mokelumne River diagram would limit the flow near Clements, the point of measurement on the Mokelumne River, to a maximum of 5300 second-feet for rain-water floods and 7100 second-feet for snow-water floods. The diagram applies to any reservoir within a distance of about 30 miles upstream from Clements. The reservoir would need to have a capacity greater than 92,000* acre-feet, the maximum space required. The Mokelumne diagram, like that for the Sacramento, assumes that the reservoir outlet

* The reservoir space needed for flood control in addition to 92,000 acre-feet is that which would furnish the minimum operating head on the reservoir outlets to discharge 5300 second-feet.

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gates will be opened or closed daily as may be necessary to provide as nearly as possible within 24 hours without causing a flow at Clements greater than desired, the empty space indicated on the diagram for the current day and value of progressive rainfall index.

The chief distinction between this diagram and the one for the Sacramento River is that it provides for controlling snow-water floods in the early summer. These do not occur on the Sacramento but are a part of the normal regime of the Mokelumne River. The Mokelumne diagram provides for limiting their maximum rate of discharge to 7100 second-feet, 1800 second-feet more than the maximum controlled flow for rain-water floods. It is estimated that these two controlled flows would be about equivalent one to the other in the lower channel of the river because the snow-water flow will be reduced by summer diversions for irrigation while the natural run-off downstream from the point of measurement will contribute some to the regulated rain-water floods.

The greatest rain-water flood contained in the twenty-one years of stream-flow record at Clements occurred on January 30, 1911. The crest discharge was 20,600* second-feet, 15,300 second-feet larger than the controlled flow to which rain-water floods would be limited by reservoir operation in accordance with the diagram. The mean daily flow on January 30, 1911, was 16,700 second-feet. The largest snow-water flood appears in the record on June 12, 1906, with a discharge of 8740 second-feet. This is only 1640 second-feet larger than the controlled snow-water flow that would result from use of the diagram. Since snow-water floods do not attain as great a rate of flow as those from rain water, large reductions are not necessary in order to confine them to a channel of reasonable size. For this reason the reservoir space required for the control of snow-water floods on the Mokelumne River is much less than for the control of rain-water floods. The greatest space required in order to limit snow-water floods to 7100 second-feet is 13,000 acre-feet. A maximum of 92,000 acre-feet is required to limit rain-water floods to 5300 second-feet.

On the Mokelumne diagram during the period of rain-water floods, the greatest space is held empty when the progressive rainfall index has a value of 130 and during the period of snow-water floods, when it has a value of 120. The curves in black indicate the space to be held empty for index values less than 130 and 120, respectively, while the curves in red indicate the space to be held empty for greater index values. The extreme values between which any reservoir space is needed at all are 58 and 222 for rain-water floods and 85 and 153 for snow-water floods. These differ somewhat from the corresponding values on the Sacramento River diagram. Similarly, the limiting dates of the flood season are slightly different. Unlike the Sacramento diagram, however, that for the Mokelumne holds a small amount of space

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* Water Supply Paper No. 551 of the United States Geological Survey, recently published, places the maximum discharge of the Mokelumne River at Clements at 25,500 second-feet. This is obtained by applying the rating curve of the 1911 flood to the gage heights of 1907. The crest discharge of the 1907 flood has been published as 17,000 second-feet in former publications including Water Supply Paper No. 299 in which are printed the daily discharges of the 1907 flood. The figures contained in Water Supply Paper No. 299 have been used in preparing this volume. Should the daily discharges of the 1907 flood be revised by application of the 1907 gage heights to the 1911 rating curve, the increase in their values would be so substantial as to require a complete revision of the analyses of floods on the Mokelumne River contained in this volume in order to make them harmonize.

empty between May 11th and July 5th for the control of snow-water floods that do not occur on the Sacramento River.

The diagram for controlling floods on the Mokelumne River is constructed in a way identical to that previously described for the one on the Sacramento River; the same probability of average exceptional behavior of one day in 50 years was selected, and the values are taken in exactly the same way from the analyses of Chapter IV which were carried out in parallel for the four illustrative streams. The values of the progressive rainfall index used in the Mokelumne River analyses were computed from the records of the United States Weather Bureau station at Electra.* This is the station at which the rainfall index should be determined in applying the diagram.

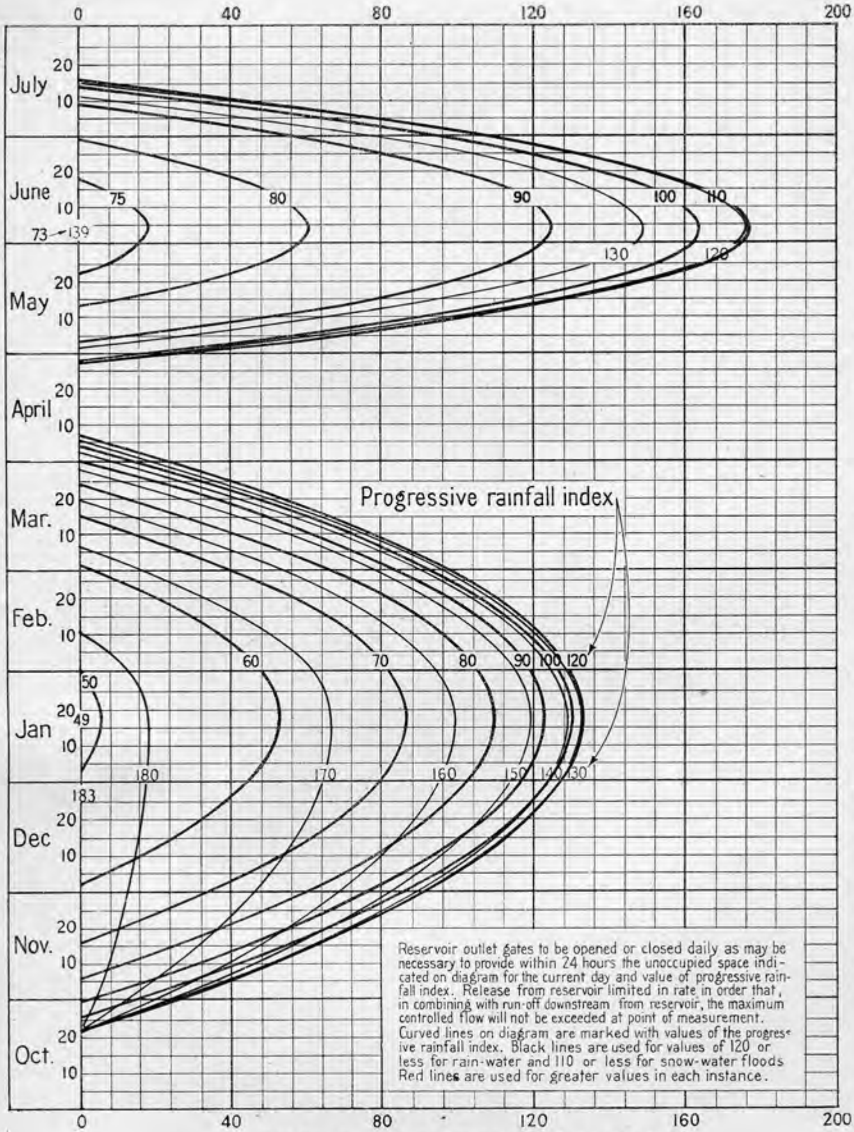
The maximum reservoir space required on the Mokelumne diagram under the most severe circumstances is taken from Plate XI, p. 56. Reading the 30 per cent (5300 second-feet) curve for rain-water floods and the 40 per cent (7100 second-feet) curve for snow-water floods, the reservoir space required for flood control except probably on an average of two days in 100 years is 260 per cent of the greatest daily run-off of a once-in-25-year flood (92,000 acre-feet) for the control of rain-water floods and 36 per cent (13,000 acre-feet) for the control of snow-water floods.

The culminating date of the two flood seasons, at which time the maximum empty space is needed, is determined from the upper figure of Plate XIV, p. 64. Here, on the part pertaining to rain-water floods, the intersection of the dotted and full-line curves labeled 30 per cent (5300 second-feet) shows the culminating date of the season to be February 22d; on the part pertaining to snow-water floods, the intersection of the dotted and full-line curves labeled 40 per cent (7100 second-feet) shows the culminating date of the snow-water flood season to be June 7th. These two dates on which maximum empty space is needed fix the position on the time scale of the apices of the two sets of curves of the reservoir operating diagram.

The positions of the arms of the outside curves are fixed by the limiting dates of the flood season. These dates are taken from the upper figure of Plate XIV, p. 64. On the part of this figure pertaining to rain-water floods, the intersections of the two 30 per cent (5300 second-feet) curves with the vertical representing two days in 100 years on which some reservoir space is needed to control floods, give November 17th and April 21st as the limiting dates of the flood season. Similarly, on the part pertaining to snow-water floods, the two 40 per cent (7100 second-feet) curves intersecting on the same vertical indicate the limiting dates for this season to be May 11th and July 5th. The arms of the outside curves on the reservoir operating diagram pass through these dates on the line of zero reservoir space. The shape of the curves was determined by the preparation of supplementary and trial diagrams in the same way as for the Sacramento River diagram.

The value of progressive rainfall index with which this maximum reservoir space is needed is taken from Plate XVI, p. 66. Here the intersections of the full and dotted-line curves labeled 30 per cent

* Electra is a cooperative station of the United States Weather Bureau and one of the principal stations in precipitation division K of which the Mokelumne drainage basin is part. See Chapter II, Bul. 5, "Flow in California Streams," issued by the Division of Engineering and Irrigation, State Department of Public Works.



RESERVOIR OPERATING DIAGRAM
FOR CONTROLLING FLOODS ON SAN JOAQUIN RIVER

MAXIMUM CONTROLLED FLOW NEAR FRIANT
FOR
RAIN WATER FLOODS – 10,700 SEC. FT.
SNOW WATER FLOODS – 14,200 SEC. FT.

CURVES SHOW SPACE NEEDED AT VARYING TIMES OF YEAR AND VALUES OF PROGRESSIVE RAINFALL INDEX TO ABSORB EXCESSIVE FLOOD FLOWS

(5300 second-feet) for rain-water floods and 40 per cent (7100 second-feet) for snow-water floods indicate values of 130 and 120, respectively. These are the index values of the outside curves on the operating diagram whose apices indicate respectively on the reservoir space scale the maximum empty space of 92,000 acre-feet for rain-water floods and 13,000 acre-feet for snow-water floods.

The interior curves are drafted in comparison with the exterior curves after interpolating the positions of their apices between that of the outside curve and the line of zero reservoir space and the positions of the arms of the curves between the limiting and central dates of the flood season as in the preparation of the Sacramento River diagram. There is one black curve for each increment of 10 in the progressive rainfall index values less than that most favorable for the need of reservoir space to control floods and one red curve for each similar increment greater than the most favorable value. The values of the progressive rainfall index that apply to the curves of smallest and largest values which are coincident with the line of zero reservoir space on the operating diagram, and above and below which reservoir space is not needed to control floods, are obtained from Plate XVI, p. 66. On the part pertaining to rain-water floods, the intersections of the dotted and full-line curves labeled 30 per cent (5300 second-feet) with the vertical representing two days in 100 years on which values will be exceeded, yield limiting values of the progressive rainfall index of 58 and 222; while on the part pertaining to snow-water floods, the intersections of the dotted and full-line curves labeled 40 per cent (7100 second-feet) yield limiting values of 85 and 153.

Reservoir operating diagram for controlling floods on San Joaquin River.

The rule for operating a reservoir on the San Joaquin River for flood control is delineated on Plate XX, "Reservoir Operating Diagram for Controlling Floods on San Joaquin River." This diagram is quite the same as the one for the Mokelumne River except that snow-water floods become relatively more important and require more reservoir space for their control than rain-water floods. The maximum space required to control rain-water floods is 133,000 acre-feet while 177,000 acre-feet are required for the control of snow-water floods. This maximum space for rain-water floods is needed on January 18th and for snow-water floods on June 4th when the values of the progressive rainfall index are 122 and 110, respectively. The space required on these and other dates when the index values are less than 122 for rain-water and 110 for snow-water floods, is indicated by the several black curves labeled with smaller index values. The red curves indicate the space required when the index values exceed 122 and 110, respectively.

The diagram applies to any reservoir within a distance of about 30 miles upstream from Friant, the point of measurement on the San Joaquin River. With a capacity greater than 177,000* acre-feet the application of the rule would result in limiting rain-water floods to a maximum flow of 10,700 second-feet and snow-water floods to a maximum flow of 14,200 second-feet at the point of measurement. It is estimated, because of diversions for irrigation from the snow-water

* The reservoir space needed for flood control in addition to 177,000 acre-feet is that which would furnish the minimum operating head on the reservoir outlets to discharge 14,200 second-feet.

flows and accretions to the rain-water run-off downstream from the point of measurement, that these two regulations will produce approximately an equivalent effect in the lower channel of the river.

With the exception of a small fall flood occurring on October 2, 1918, with a mean daily discharge of 10,900 second-feet, the diagram will control all floods shown in the eighteen years of continuous record by the United States Geological Survey. The flood of January 31, 1911, with a mean daily flow of 38,800 second-feet was the largest during this period. It was 28,100 second-feet greater than the maximum controlled rain-water flow that would be obtained by application of the diagram. The largest snow-water flood during the period occurred on June 13, 1911, when the mean daily flow was 23,100 second-feet. This is 8900 second-feet larger than the maximum controlled snow-water flow that would be obtained by application of the diagram.

The San Joaquin River diagram was constructed from data taken from the analytical graphs of Chapter IV in a way identical to that for the construction of the diagrams for the Sacramento and Mokelumne rivers. The same probability that the desired maximum controlled flow may be exceeded on an average of one day in 50 years was used. The values of the progressive rainfall index for the San Joaquin River were computed from the records of the United States Weather Bureau at Fresno.* This station should be used for determining the index values in applying the diagram.

The positions of the apices of the outside curves along the scale of reservoir space are taken from Plate XII, p. 57. Reading the 30 per cent curve (10,700 second-feet) for rain-water floods and the 40 per cent curve (14,200 second-feet) for snow-water floods, it is seen that, for full control except probably on an average of two days in 100 years, the maximum space required is 188 per cent of the greatest daily run-off of a once-in-25-year flood (133,000 acre-feet) for the control of rain-water floods, and 250 per cent (177,000 acre-feet) for the control of snow-water floods.

The dates on which this maximum space is required, the culminating dates of the two flood seasons, are taken from the lower figure of Plate XIV, p. 64. On the part of the figure pertaining to rain-water floods, the intersection of the dotted and full-line curves labeled 30 per cent (10,700 second-feet) shows this to be January 18th. On the part pertaining to snow-water floods, the intersection of the dotted and full-line curves labeled 40 per cent (14,200 second-feet) shows this date to be June 4th.

The arms of the outside curves of the diagram have their positions defined by the limiting dates of the flood season taken from the lower figure on Plate XIV, p. 64. Here, on the part pertaining to rain-water floods, the intersections of the two 30 per cent (10,700 second-feet) curves, one dotted and one full-line, with the vertical representing two days in 100 years on which some reservoir space is needed to control floods, give October 22d and April 7th. Similarly, on the part of the figure pertaining to snow-water floods, the two 40 per cent curves (14,200 second-feet) intersect the same vertical at April 27th and July 16th. These are the limiting dates of the two flood seasons before

* Fresno is one of the principal stations in precipitation division Q of which the San Joaquin drainage basin is part. See Chap. II, Bul. 5, "Flow in California Streams," issued by the Division of Engineering and Irrigation, State Department of Public Works.

and after which reservoir space is not needed to control floods. The positions of the arms of the interior curves and their shapes were determined as for the Sacramento and Mokelumne river diagrams.

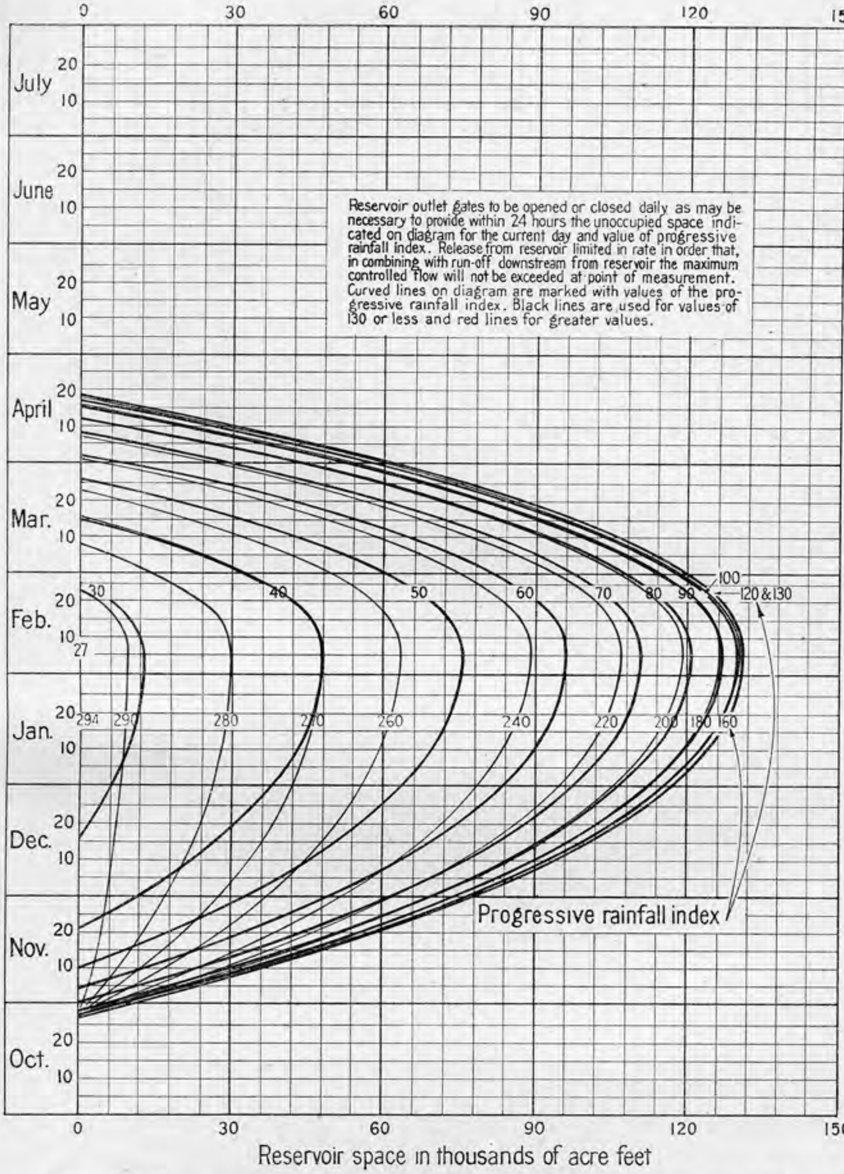
The index values with which the maximum reservoir space is needed were obtained from Plate XVII, p. 67. Here the intersections of the full and dotted-line curves labeled 30 per cent (10,700 second-feet) for rain-water floods and 40 per cent (14,200 second-feet) for snow-water floods indicate values between 110 and 122 as being most favorable for the need of reservoir space to control both rain and snow-water floods. These are the index values of the outside curves of the diagram. The index values for the extreme inside curves are taken from the same plate. On the part pertaining to rain-water floods, the intersections of the two 30 per cent (10,700 second-feet) curves, one dotted and one full-line, with the vertical representing two days in 100 years on which values will be exceeded, indicate limiting values of the index of 49 and 183. Reservoir space is not needed to control floods with either smaller or larger values than these. On the part of the figure pertaining to snow-water floods, the corresponding limiting values are found to be 73 and 139. The index values for the several interior curves on the operating diagram are interpolated between these and the values for the outside curve the same way as for the diagrams of the Sacramento and Mokelumne rivers.

Reservoir operating diagram for controlling floods on San Gabriel River.

Plate XXI, "Reservoir Operating Diagram for Controlling Floods on San Gabriel River," delineates the rule for operating a reservoir on this stream in order to control floods with least interference in its conservation use. Like the diagrams for the Sacramento, Mokelumne and San Joaquin rivers, that for the San Gabriel indicates the space that should be empty on each day of the flood season for the amount of seasonal precipitation to date, in order that excess flood waters may be detained. The curves in black indicate the space that should be empty when the value of the progressive rainfall index is less than 120 and the red curves the space when the value is greater than 130. The diagram assumes that the reservoir outlet gates will be opened and closed as may be necessary to provide within 24 hours as nearly as possible, without causing the desired regulated flow to be exceeded, the empty space indicated on the diagram for the current day and value of progressive rainfall index.

The San Gabriel River diagram is like that for the Sacramento River in that it does not provide for the control of snow-water floods. The snow on the San Gabriel drainage area that lasts until early summer is too small in quantity to do more than help sustain the summer flow of the stream when it melts.

The diagram applies to any reservoir whose dam is within a distance of about 5 miles upstream from the Azusa gaging station, the point of measurement. A capacity of 131,000 acre-feet available for flood control purposes would be required. The application of the rule to the operation of a reservoir of this or greater capacity would result in limiting flood flows to 1900 second-feet at Azusa gaging station. A much larger flow than this will pass safely down the channel of the San Gabriel River to the ocean but it could not all be conserved. It is



RESERVOIR OPERATING DIAGRAM FOR CONTROLLING FLOODS ON SAN GABRIEL RIVER

MAXIMUM CONTROLLED FLOW NEAR AZUSA - 1,900 SEC. FT.

CURVES SHOW SPACE NEEDED AT VARYING TIMES OF YEAR AND VALUES OF PROGRESSIVE RAINFALL INDEX TO ABSORB EXCESSIVE FLOOD FLOWS.

believed that flows up to 1900 second-feet may be conserved conveniently by sinking them into the large underground basin of the San Gabriel Valley. This makes it desirable to reduce the San Gabriel River floods to a much smaller flow than on the other illustrative streams.

The largest flood in the thirty years of stream flow record at Azusa occurred on January 18, 1916, with a crest flow of 40,000 second-feet. This is 38,100 second-feet greater than the controlled flow that would result from the application of the diagram. The greatest mean daily flow of the 1916 flood was 22,300 second-feet.

The diagram for the San Gabriel River was constructed from the analytical graphs of Chapter IV in a manner similar to that employed in the construction of diagrams for the other three illustrative streams. Instead, however, of using the probability that the desired maximum controlled flow may be exceeded on an average of one day in 50 years in taking information from the charts as in the preparation of the other diagrams, a frequency of one day in a thousand years was selected because of the greater property values and population concentrating below the San Gabriel dam. The records of the United States Weather Bureau rainfall station at Claremont* were used in computing values of the progressive rainfall index for the San Gabriel River. This is the station that should be used in the application of the diagram.

The apex of the outside curve on the San Gabriel diagram has its position determined on the reservoir space scale from the largest empty space that is required under the most severe circumstances as shown on the lower figure of Plate X, p. 55. The intersection of the 10 per cent curve (1900 second-feet) with the vertical representing full control except on an average of 0.1 day in 100 years (one day in 1000 years) shows that the maximum reservoir space required is 344 per cent of the greatest daily run-off of a once-in-25-year flood (131,000 acre-feet). Its position on the time scale is fixed by the date most favorable for the need of reservoir space for the control of floods. This is taken from the lower cut on Plate XIII, p. 63. The intersection of the dotted and full-line curves labeled 10 per cent (1900 second-feet) indicates February 7th as the most favorable date.

The positions of the arms of the outside curve of the diagram are also determined from Plate XIII, p. 63. Here the dotted and full-line curves labeled 10 per cent (1900 second-feet) intersect the vertical of 0.1 day exceptional behavior in 100 years (one day in 1000 years) on October 27th and April 19th, respectively. These are the limiting dates of the flood season before and after which reservoir space is not needed for the control of floods to the degree selected.

The value of the progressive rainfall index with which the greatest reservoir space is needed is taken from the lower figure of Plate XV, p. 65. The intersection of the full and dotted-line curves labeled 10 per cent (1900 second-feet) marks the index value 122 as being most favorable for the need of reservoir space. The outside curve that indicates the need of most space is given a value of from 120 to 130.

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* Claremont is a cooperative station of the United States Weather Bureau and one of the principal stations in precipitation division W of which the San Gabriel drainage basin is part. See Chap. II, Bul. No. 5, "Flow in California Streams," issued by Division of Engineering and Irrigation, State Department of Public Works.

The index value for the extreme inside curve is taken from the same plate. The intersections of the two curves, one dotted and one full-line, labeled 10 per cent (1900 second-feet) with the vertical on the extreme left representing an exceptional behavior of 0.1 day in 100 years (one day in 1000 years), give limiting values for the index of 27 and 294. Reservoir space is not needed for controlling floods when the index is either smaller or larger than these values. Therefore, 27 and 294 are the index values of the black and red curves respectively that are coincident with the line of zero reservoir space. The other interior curves are interpolated in position between these and the outside curve as in the construction of the diagrams for the other three illustrative streams.

Performance of the four illustrative reservoir operating diagrams in controlling floods, not coordinated with conservation.

The performance in controlling floods of the four reservoir operating diagrams just described has been tested by applying them respectively to the records of daily flow on each of the four illustrative streams. It was assumed that a reservoir of required capacity existed at the point of measurement on each stream, that it was full at the beginning of each flood season, that it was held as nearly full as the diagram would permit during the succeeding flood season, and that water was released from storage only as required to gain the empty space indicated on the diagram. The following tables show for all* the largest floods of record, both rain and snow-water, the dates on which the reservoirs would have been nearest full and the amount of space still empty on those days.

It may be noted that all floods of record on the four illustrative streams would have been controlled without the reservoirs overflowing except a small fall flood on the San Joaquin, occurring on October 2, 1918, with a discharge of only 200 second-feet in excess of the maximum controlled flow. On the Sacramento River even the historic floods of March 20, 1907, and February 3, 1909, would have been controlled with 53,500 and 188,800 acre-feet of space to spare respectively at the times the reservoir was nearest full. The average space to spare at the times nearest full while controlling all floods on the Sacramento River during the entire thirty years of record would have been equal to half the space required under the most severe circumstances.

* All floods exceeding the desired maximum regulated flow are listed when their number is less than twenty, otherwise the twenty largest are tabulated.

SACRAMENTO RIVER

UNUSED RESERVOIR SPACE

WHILE CONTROLLING ALL FLOODS OF RECORD BY RESERVOIR OPERATING DIAGRAM 1895-1926

Not Coordinated with Conservation

Maximum flood flow—uncontrolled		Flow controlled to 125,000 second-feet maximum near Red Bluff		
			Reservoir space not used in controlling flood	
Date	Mean daily flow in second-feet near Red Bluff	Date reservoir nearest full	In acre-feet	In per cent of maximum space required for flood control (454,000 acre-feet)
Feb. 3, 1909	254,000	Feb. 4, 1909	188,800	42
Feb. 2, 1915	249,000	Feb. 2, 1915	200,900	44
Mar. 20, 1907	196,000	Mar. 21, 1907	53,500	12
Jan. 16, 1909	188,000	Jan. 18, 1909	191,400	42
Feb. 16, 1904	188,000	Feb. 16, 1904	357,700	79
Jan. 21, 1909	177,000	Jan. 21, 1909	150,700	33
Feb. 25, 1917	176,000	Feb. 25, 1917	109,300	24
Feb. 21, 1914	160,000	Feb. 21, 1914	119,600	26
Jan. 1, 1914	151,000	Jan. 2, 1914	129,900	29
Feb. 24, 1902	151,000	Feb. 26, 1902	289,100	64
Mar. 8, 1904	147,000	Mar. 8, 1904	332,400	73
Feb. 10, 1902	140,000	Feb. 12, 1902	327,600	72
Mar. 31, 1906	137,000	Mar. 31, 1906	105,500	23
Jan. 19, 1906	136,000	Jan. 19, 1906	143,600	32
Feb. 4, 1907	134,000	Feb. 4, 1907	433,500	95
Jan. 25, 1903	131,000	Jan. 25, 1903	431,700	95
Mar. 7, 1911	130,000	Mar. 7, 1911	368,400	81
Jan. 27, 1896	128,000	Jan. 27, 1896	341,500	75
Average			237,500	52

MOKELUMNE RIVER

UNUSED RESERVOIR SPACE

WHILE CONTROLLING TWENTY LARGEST RAIN WATER FLOODS OF RECORD BY RESERVOIR OPERATING DIAGRAM 1904-1926

Not Coordinated with Conservation

Maximum flood flow—uncontrolled		Flow controlled to 5300 second-feet maximum near Clements		
Date	Mean daily flow in second-feet near Clements	Date reservoir nearest full	Reservoir space not used in controlling flood: In acre-feet	Reservoir space not used in controlling flood: In per cent of maximum space required for flood control (92,000 acre-feet)
Jan. 30, 1911	16,700	Feb. 1, 1911	35,200	38
Mar. 19, 1907	15,310	Mar. 27, 1907	7,100	8
Jan. 26, 1914	11,100	Jan. 27, 1914	68,900	75
Jan. 14, 1909	10,400	Jan. 17, 1909	5,200	6
Feb. 21, 1914	9,850	Feb. 21, 1914	82,700	90
Feb. 6, 1925	9,700	Feb. 6, 1925	27,800	30
Jan. 1, 1914	9,250	Jan. 1, 1914	36,100	39
Jan. 21, 1909	8,400	Jan. 22, 1909	8,500	9
Mar. 20, 1916	8,040	Mar. 21, 1916	64,400	70
Feb. 2, 1907	7,860	Feb. 4, 1907	79,300	86
Mar. 31, 1906	7,750	April 1, 1906	49,600	54
Mar. 23, 1907	7,610	Mar. 27, 1907	7,100	8
Jan. 22, 1914	7,470	Jan. 22, 1914	78,600	85
Jan. 18, 1921	7,350	Jan. 18, 1921	75,700	82
Mar. 7, 1911	7,210	Mar. 11, 1911	70,900	77
Nov. 21, 1909	7,200	Nov. 21 1909	0	0
Feb. 11, 1919	7,060	Feb. 11, 1919	29,000	32
Jan. 19, 1906	6,960	Jan. 19, 1906	24,400	27
Mar. 12, 1918	6,940	Mar. 12, 1918	9,400	10
April 16, 1925	6,910	April 17, 1925	6,600	7
Average			38,300	42

MOKELUMNE RIVER

UNUSED RESERVOIR SPACE

WHILE CONTROLLING ALL SNOW WATER FLOODS OF RECORD BY RESERVOIR OPERATING DIAGRAM 1904-1926

Not Coordinated with Conservation

Maximum flood flow—uncontrolled		Flow controlled to 7100 second-feet maximum near Clements		
Date	Mean daily flow in second-feet near Clements	Date reservoir nearest full	Reservoir space not used in controlling flood: In acre-feet	Reservoir space not used in controlling flood: In per cent of maximum space required for flood control (13,000 acre-feet)
June 12, 1906	8,740	June 13, 1906	1,900	15
June 18, 1911	8,030	June 18, 1911	3,300	25
June 3, 1922	7,970	June 5, 1922	2,600	20
June 12, 1911	7,960	June 12, 1911	3,100	24
June 6, 1911	7,880	June 6, 1911	4,000	31
May 31, 1922	7,770	June 1, 1922	6,700	52
June 1, 1915	7,750	June 1, 1915	10,000	77
May 18, 1922	7,670	May 19, 1922	1,800	14
June 16, 1906	7,600	June 17, 1906	4,500	35
June 10, 1917	7,550	June 10, 1917	2,900	22
May 24, 1911	7,500	May 24, 1911	800	6
July 4, 1906	7,480	July 4, 1906	1,100	8
Average			3,600	28

SAN JOAQUIN RIVER

UNUSED RESERVOIR SPACE

WHILE CONTROLLING ALL RAIN WATER FLOODS OF RECORD BY RESERVOIR OPERATING DIAGRAM 1907-1926

Not Coordinated with Conservation

Maximum flood flow—uncontrolled		Flow controlled to 10700 second-feet maximum near Friant		
Date	Mean daily flow in second-feet near Friant	Date reservoir nearest full	Reservoir space not used in controlling flood: In acre-feet	Reservoir space not used in controlling flood: In per cent of maximum space required for flood control (133,000 acre-feet)
Jan. 31, 1911	38,800	Feb. 1, 1911	14,200	11
Dec. 31, 1909	27,900	Jan. 1, 1910	43,600	33
Jan. 14, 1909	26,800	Jan. 15, 1909	16,400	12
Dec. 10, 1909	26,800	Dec. 10, 1909	28,200	21
Jan. 26, 1914	24,700	Jan. 30, 1914	13,800	10
Jan. 21, 1909	18,900	Jan. 22, 1909	62,700	47
Mar. 8, 1911	18,800	Mar. 8, 1911	67,400	51
Mar. 10, 1911	13,600	Mar. 12, 1911	55,900	42
Feb. 12, 1909	12,500	Feb. 14, 1909	104,100	78
Feb. 21, 1917	11,700	Feb. 21, 1917	100,700	76
April 6, 1911	11,600	April 6, 1911	0	0
Jan. 18, 1916	11,000	Jan. 20, 1916	113,100	85
Mar. 21, 1916	11,000	Mar. 21, 1916	15,100	11
Oct. 2, 1918	10,900	Oct. 2, 1918	0	0
Jan. 25, 1911	10,700	Jan. 25, 1911	79,300	60
Average			47,600	36

SAN JOAQUIN RIVER

UNUSED RESERVOIR SPACE

WHILE CONTROLLING ALL SNOW WATER FLOODS OF RECORD BY RESERVOIR OPERATING DIAGRAM 1907-1926

Not Coordinated with Conservation

Maximum flood flow—uncontrolled		Flow controlled to 14200 second-feet maximum near Friant		
			Reservoir space not used in controlling flood	
Date	Mean daily flow in second-feet near Friant	Date reservoir nearest full	In acre-feet	In per cent of maximum space required for flood control (177,000 acre-feet)
June 13, 1911	23,100	June 23, 1911	21,100	12
June 4, 1909	22,800	June 8, 1909	89,100	50
June 16, 1911	21,500	June 23, 1911	21,100	12
July 7, 1911	19,500	July 7, 1911	57,600	33
June 5, 1922	16,700	June 8, 1922	149,700	85
May 22, 1911	16,200	May 23, 1911	134,600	76
June 6, 1911	16,200	June 8, 1911	165,500	94
May 8, 1909	16,200	May 8, 1909	39,300	22
June 2, 1914	15,700	June 2, 1914	167,500	95
June 5, 1912	15,300	June 5, 1912	33,000	19
June 15, 1909	14,900	June 15, 1909	95,000	54
June 27, 1911	14,700	June 28, 1911	38,200	22
May 31, 1922	14,700	June 1, 1922	171,200	97
June 24, 1909	14,600	June 24, 1909	129,300	73
Average			93,700	53

SAN GABRIEL RIVER

UNUSED RESERVOIR SPACE

WHILE CONTROLLING TWENTY LARGEST FLOODS OF RECORD BY RESERVOIR OPERATING DIAGRAM 1895-1926

Not Coordinated with Conservation

Maximum flood flow—uncontrolled		Flow controlled to 1900 second-feet maximum near Azusa		
			Reservoir space not used in controlling flood	
Date	Mean daily flow in second-feet near Azusa	Date reservoir nearest full	In acre-feet	In per cent of maximum space required for flood control (131,000 acre-feet)
Jan. 18, 1916	22,300	Jan. 20, 1916	45,300	35
Dec. 19, 1921	16,000	Dec. 25, 1921	25,000	19
Jan. 1, 1910	12,500	Jan. 3, 1910	82,100	63
Feb. 20, 1914	11,800	Mar. 1, 1914	64,500	49
Mar. 12, 1905	11,130	Mar. 14, 1905	87,100	66
Mar. 26, 1906	9,430	Mar. 29, 1906	29,100	22
Mar. 10, 1911	9,160	Mar. 14, 1911	71,400	54
Jan. 26, 1914	9,150	Jan. 27, 1914	99,200	76
Feb. 9, 1922	8,200	Feb. 13, 1922	68,900	53
Mar. 12, 1906	8,020	Mar. 13, 1906	88,900	68
Jan. 27, 1916	7,940	Jan. 30, 1916	37,100	28
Feb. 7, 1909	7,100	Feb. 8, 1909	118,100	90
Mar. 5, 1907	6,810	Mar. 11, 1907	89,900	69
April 1, 1903	5,920	April 2, 1903	95,400	73
Dec. 27, 1921	5,900	Dec. 29, 1921	12,700	10
Jan. 29, 1911	5,260	Jan. 29, 1911	80,400	61
Jan. 18, 1914	5,110	Jan. 18, 1914	103,000	79
Mar. 11, 1918	5,030	Mar. 14, 1918	21,500	16
Jan. 10, 1907	4,670	Jan. 11, 1907	108,600	83
Jan. 31, 1911	4,220	Jan. 31, 1911	76,200	58
Average			70,200	54

On the Mokelumne River, the large flood of January 30, 1911, would have been reduced from 20,600 second-feet to 5300 second-feet with 35,200 acre-feet of empty space in the reservoir to spare at the time the reservoir was nearest full. The average spare space at the times nearest full while controlling the twenty largest rain-water floods on the Mokelumne River would have been 42 per cent of the maximum required by the diagram. One small flood in the fall of 1909 would have just filled the reservoir but there would have been more space than needed while controlling all other floods.

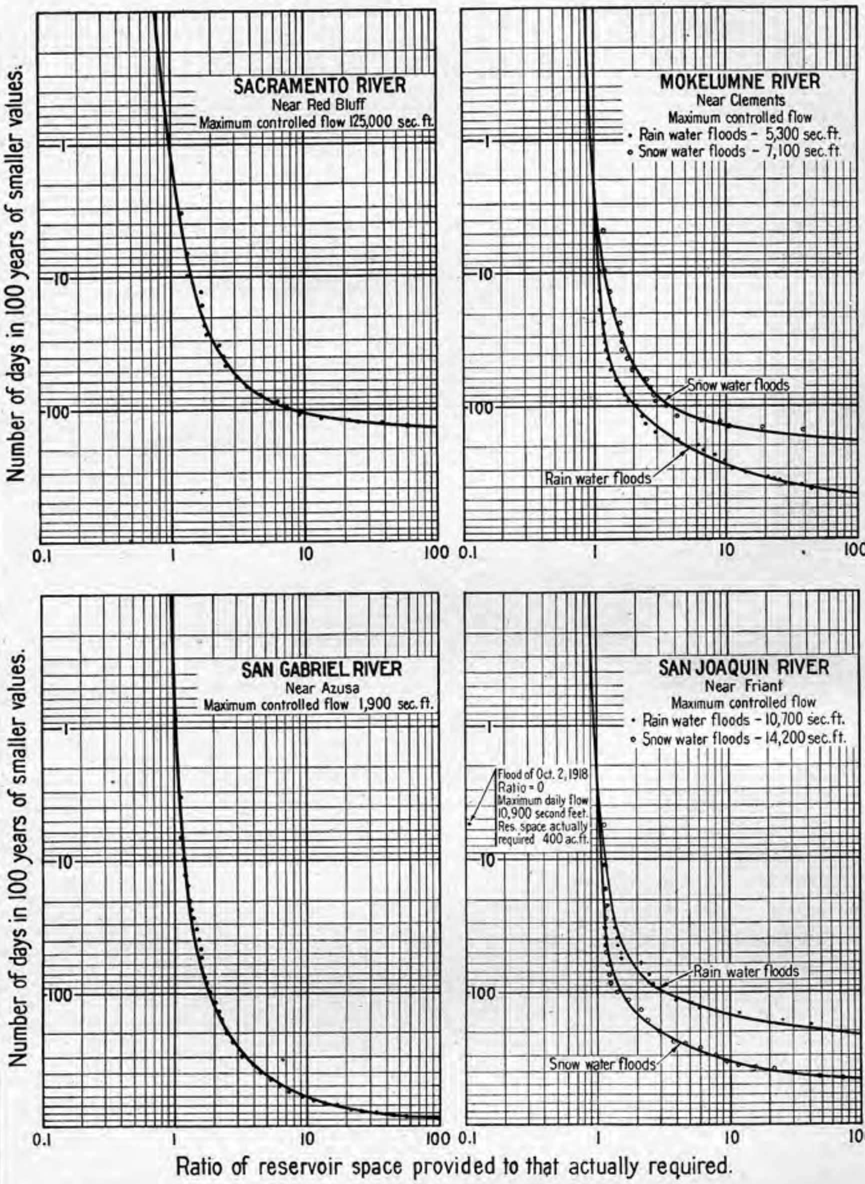
On the San Joaquin River, the largest flood during the eighteen years of record (January 31, 1911) would have been reduced from a mean daily flow of 38,800 second-feet to 10,700 second-feet without the use of the top 14,200 acre-feet in the reservoir. The average unused space at the times the reservoir was nearest full while controlling all rain-water floods would have been 36 per cent of the maximum space required by the diagram. There would have been space to spare while controlling all floods during the eighteen years of record except for two small floods barely larger than the controlled flow. One of these occurred before the opening date of the flood season, on October 2, 1918, and the other on April 6, 1911, the closing date of the flood season. All the snow-water floods of record on the San Joaquin River would have been controlled without the reservoir filling to within 21,100 acre-feet of the top. The average space to spare at the times nearest full while controlling snow-water floods would have been 53 per cent of the maximum required by the diagram.

On the San Gabriel River, the large flood of January 18, 1916, would have been controlled without the use of the top 45,300 acre-feet of reservoir space. The nearest the reservoir would have filled while controlling all floods during the 30 years of record would have been to 12,700 acre-feet of a full reservoir. The average unused space at the times nearest full during the twenty largest floods of record would have been 54 per cent of the maximum required by the diagram.

The full test of the four reservoir operating diagrams is expressed graphically on Plate XXII, "Performance of Reservoir Operating Diagrams in Controlling Floods of Record." The ratio of the empty reservoir space provided by application of the diagrams to that actually necessary to control the remainder of the flood was computed for every day of stream-flow record on each of the four illustrative streams. The ratios on each stream were arranged in order of increasing magnitude and the number smaller than each successive size counted. These counts were increased by proportion to the number had the stream-flow records been 100 years in length. Assuming that the trend of these figures expresses the average relations of the future, these counts were plotted on Plate XXII to show the probable frequency with which the empty space provided by application of the diagrams will approach the exact amount needed to secure the desired control.

Plate XXII indicates that the Sacramento River diagram would probably provide, on the average, more than twice the empty reservoir space actually required on all days except 30 in each 100-year period, more than half again as much as needed on all days except 12 in each 100-year period and that its reservoir would probably fill to overflowing about one day in each 80 years. For the Mokelumne River dia

PLATE XXII.



PERFORMANCE OF RESERVOIR OPERATING DIAGRAMS IN CONTROLLING FLOODS OF RECORD

CURVES SHOW NUMBER OF DAYS IN 100 YEARS ON WHICH RATIO OF RESERVOIR SPACE PROVIDED BY APPLICATION OF DIAGRAM TO THAT ACTUALLY REQUIRED FOR CONTROLLING FLOODS OF RECORD IS SMALLER THAN INDICATED.

gram, the indications are that probably more than twice the empty space actually needed would be provided on the average on all days except 100 in 100 years for rain-water floods and 50 in 100 years for snow-water floods; at least fifty per cent more than actually needed on all days except 60 in 100 years for rain-water floods and 24 in 100 years for snow-water floods; and that the reservoir would fill to overflowing on two to three days in 100 years for both rain and snow-water floods. The indications for the San Joaquin River diagram are that, on the average, probably more than twice the empty space actually needed would be provided on all days except 70 in 100 years for rain-water floods and 150 in 100 years for snow-water floods; at least half again as much as needed on all days except 43 in 100 years for rain-water floods and 100 in 100 years for snow-water floods; and that the reservoir would probably fill to overflowing on three days in 100 years for both rain and snow-water floods. For the San Gabriel River, the indications are that probably more than twice the empty space needed would be provided on all days except 120 in each 100-year period at least 50 per cent more than actually needed on all days except 50 in each 100 years, and that the reservoir would probably fill to overflowing on about one day in each 500 years.

These tests agree fairly closely with the probability of exceptional behavior selected for construction of the diagrams. On the Sacramento, Mokelumne and San Joaquin rivers, by construction, the controlled flow for both rain and snow-water floods would be expected to be exceeded on an average of one day in 50 years. By test against the period of record the desired controlled flow of the Sacramento River diagram would probably be exceeded on an average of one day in 80 years and the Mokelumne and San Joaquin river diagrams on an average of one day in 30 to 40 years for both rain and snow-water floods. The desired controlled flow of the San Gabriel River diagram by construction would be expected to be exceeded on an average of one day in 1000 years. By test against the period of record the probable exceptional behavior of this diagram is one day in 500 years.

CHAPTER VI.

EFFECT ON CONSERVATION OF CONTROLLING FLOODS BY RESERVOIR OPERATING DIAGRAM.

Effect determined by direct test.

Four reservoir operating diagrams are described in chapter V, one for controlling floods on each of the four streams previously used to illustrate the characteristics of flood occurrence. These diagrams indicate the reservoir space for all conditions of prior rainfall, that should be empty on each day of the flood season in order to detain flow that may occur in excess of a specified maximum rate. Subsequent to the central date of the flood season, less empty space is required as the season progresses toward its close. The diagrams are constructed to release this reserved space as quickly as possible without sacrifice in the effectiveness of flood control. Therefore, until some analysis is developed that fits the characteristics of flood occurrence closer than the one herein described, it may be said that reservoir operation in accord with these diagrams secures the control of floods with a minimum interference with the use of the same space for conservation.

To what extent, if any, the reservation of the varying amounts of space indicated on the diagrams may interfere with its use for conservation is not apparent. The amount of the reservations relative to the volume of subsequent run-off determines this in each instance. Therefore, it is evident that the degree of flood control desired and the regimen of the stream are important factors in determining the extent of interference, if any. Other factors are the size of the reservoir and the manner of its operation. If the total capacity of the reservoir were several times the largest reserve required for flood control, there would be many days on which the empty space due to normal operation for conservation would exceed that required for flood control. At such times there could be no interference with conservation by reason of the use of the same space for flood control. Therefore, the larger the total capacity of the reservoir in proportion to the maximum flood control reserve, the less is the opportunity for interference. Likewise the opportunity of interference is less, the greater the seasonal draw-down in the reservoir or the smaller the spring draft subsequent to the central date of the flood season during normal operation for conservation. Because of the complication of these relations, the determination of the effect on conservation of controlling floods by the reservoir operating diagrams must be made through the analysis of each specific proposal. The interference or approach toward interference might well be different for each stream, each degree of flood control, and each size of reservoir and manner of operating it for conserving water.

The succeeding pages of this chapter are devoted to the presentation of analyses of the effect on the water and power yield of combining flood control with several modes of operating four specific reservoirs, one on each of the illustrative streams. In these studies each reservoir is assumed to have been in existence at the beginning of continuous measurement of flow on its stream and to have been operated for conservation in a specific manner through the entire period of stream flow record both with and without flood control. The effect on conservation in these instances of the use of the same space for both flood control and conservation is determined by a comparison of the yield of water and power in the two parallel sets of computations. In these computations the inflow, evaporation and drafts from the reservoirs are balanced daily and the new reservoir levels tabulated both with and without the reservation of space for flood control in accord with the operating diagrams. In doing this the daily values of the progressive rainfall indices are computed from rainfall records and the flood control feature applied just as though the reservoirs had been operated through these years according to the rules laid down by the reservoir operating diagrams. All conditions are held the same in the two parallel sets of computations except for the inclusion of the flood control feature in one set.

Tables are included herein summarizing these computations and comparing the yields of water and power month by month and year by year through the entire period of run-off record. Graphical comparisons are also included of the reservoir levels with and without flood control and of the stream flow below the dam, controlled, as well as that unimpaired by reservoir construction.

Kennett Reservoir on Sacramento River.

The "Coordinated Plan" * for development of the State's waters presented to the 1927 session of the State Legislature proposes, among others, that a reservoir be constructed on the main Sacramento River with its dam near Kennett, about five miles below the confluence with the Pit River. The plan proposes that the dam be constructed to an initial height of 420 feet. This would impound 2,940,000 acre-feet of water. A power plant of 400,000 k. v. a. capacity would be constructed near the base of the dam.

The "Coordinated Plan" is distinguished from other plans in that its reservoirs would be operated coordinately for several different purposes in a way to subserve the best interests of the State. The Kennett reservoir would be operated coordinately for the benefit of irrigation and domestic supply, navigation, salinity control, generation of power and the control of floods. During the first period of years while the demand for water is growing to meet its large yield, the Kennett reservoir would be operated to secure the most valuable power output while at the same time limiting floods to half the largest on record. In so doing, for a number of years to come, there would be adequate water in the discharge from the power plant for the needs of irrigation, domestic supply, navigation and for salt water control in all except extremely dry years. Later, the increased demand for water will require that the operation of the reservoir be changed over to yield the greatest volume of water equalized in accord with the irrigation demand while at the same time meeting the other needs. The generation of power would become incidental to the yield of water. So

* See Bul. No. 12, "Summary Report on the Water Resources of California and a Coordinated Plan for their Development," Division of Engineering and Irrigation, State Department of Public Works.

operated, the initial height of dam would equalize for irrigation use three-fifths of the mean annual run-off of the stream and produce on an average 159,400* kilowatts of electric energy.

The yield of the Kennett reservoir in water and power for several heights of dam together with a full description of its uses is contained in Bulletin No. 15, "The Coordinated Plan of Water Development in the Sacramento Valley." The results of computations for several heights of dam are there tabulated. No special entries are included for navigation water nor for water for salinity control since their needs would be more or less coincident with the irrigation demand. They are regarded as part of this demand for estimating purposes. Likewise, no special entries are made for domestic water supply because its volume would be relatively small. The effect of the inclusion of the flood control feature of the "Coordinated Plan" upon the yield of a reservoir with a 420-foot dam, the initial height proposed, is analyzed in the following pages.

Plate XXIII, "Effect of Controlling Sacramento River Floods upon Stage of Kennett Reservoir," compares the reservoir stage day by day had it been in existence in the year 1895 and been operated continuously to January, 1926, as proposed in the "Coordinated Plan," with the stage had the flood control feature been omitted. This period of comparison is the extent of continuous records of stream flow on the Sacramento River. The comparison is delineated by lines extending across the plate in four rows. Each line represents a separate mode of operation. These lines fluctuate up and down and indicate by their vertical position the acre-feet of water in storage in the reservoir on each day of the thirty-year period under the several different modes of operation. The top guide line of each row represents a full reservoir and the bottom line an empty reservoir. The space between each pair of guide lines represents 200,000 acre-feet of capacity.

The heavy black line extending across each row indicates the reservoir stage had the most valuable power output been generated as proposed in the first or temporary mode of operation under the "Coordinated Plan." A dash and dot black line indicates the stage had the greatest yield of irrigation water been obtained with electric power as an incidental product as proposed in the second or permanent mode of operation under the "Coordinated Plan." These lines approximate operation as proposed by the "Coordinated Plan" except that the flood control feature is omitted.

The reservoir stage resulting from the introduction of the flood control feature is delineated by red lines. The light red line indicates the stage had the reservoir been operated for flood control alone in accordance with the rule developed in the fore part of this volume and expressed on Plate XVIII, "Reservoir Operating Diagram for Controlling Floods on Sacramento River," p. 76.

The heavy full red line indicates the departures in reservoir stage by reason of the inclusion of the flood control feature in the first or temporary mode of operation under the "Coordinated Plan." The light dash and dot red line indicates similarly the departures by reason of the inclusion of the flood control feature in the second or permanent mode of operation under the "Coordinated Plan." Where the light

* Average for the 54-year period, 1871–1925.

PLATE XXIII.

Effect of Controlling Sacramento River Floods
UPON
STAGE OF KENNETT RESERVOIR
IF OPERATED PRIMARILY FOR EITHER IRRIGATION OR POWER DRAFT

MAXIMUM CONTROLLED FLOW AT RED BLUFF 125,000 SEC. FT.
MAXIMUM FLOOD OF RECORD 278,000 SEC. FT.
RESERVOIR CAPACITY 2,940,000 AC. FT.
HEIGHT OF DAM 420 FT.

dash and dot red line coincides with the heavy full red line, both are represented by a heavy dash and dot red line.

Below the reservoir stage lines in each row are drafted to a special scale superimposed on the reservoir stage scale, a light black line showing the fluctuations of the stream flow unimpaired by reservoir storage and a light red line showing the stream flow as controlled by the second or permanent mode of operation under the "Coordinated Plan." Similarly, a black dotted line delineates the values of the progressive rainfall index that were used with the reservoir operating diagram (Plate XVIII) in computing the stage of the reservoir with the flood control feature included.

The greatest empty depth required for flood control during each season is noted on the graph in feet below full reservoir level. The largest is seen to be 21 of the 415 feet depth behind the dam when the reservoir is full. This was required during 13 of the 30 seasons. In 7 of the seasons there was no special lowering of the reservoir level for flood control since the empty space by reason of conservation operations was larger than required for flood control. The average amount of depression was about 11 feet, or 2.6 per cent, of the depth of a full reservoir at the dam. Of the entire elapsed time during the 30 seasons, the reservoir level would have had to be depressed especially for flood control only one-sixth of the time while operating primarily for power generation and one-eighth of the time while operating primarily for irrigation.

The effect of including the flood control feature of the "Coordinated Plan" upon the reservoir stage resulting from conservation operations is seen to be small, yet very substantial reduction in flood volume is obtained. The largest flood of record occurred in February, 1909. It reached a crest discharge of 278,000 second-feet. The flood control feature of the "Coordinated Plan" would have limited this flood to a discharge of 125,000 second-feet. Likewise the floods of ten other seasons of record that exceeded 125,000 second-feet would have been limited to this rate of discharge.

The effect upon the water and power yield of the Kennett reservoir in securing this limitation to flood flows is disclosed by comparison of parallel sets of computations, one with and the other without the flood control feature of the "Coordinated Plan." These computations of yield were carried out as described in Bulletin No. 15, "The Coordinated Plan of Water Development in the Sacramento Valley," except that they were made on a daily instead of a monthly basis. The set of computations with the flood control feature included had to be made on a daily basis because the reservoir operating diagrams require a daily adjustment of reservoir stage during the flood season. Therefore, in order to make the two sets of computations exactly comparable, both were carried through the entire 30 years on a daily basis. The assumptions employed are listed on page 216 herein.

The water yield (without deduction for prior rights downstream from the dam and with deficiencies in supply on an average of one year in ten) computed on a daily basis is identical with that of Bulletin No. 15 computed on a monthly basis except that the deficiencies in per cent of a full supply are increased from 0.1 to 0.3 per cent in three out of the five deficient seasons. The power yield, however, is about

3 per cent less when computed day by day rather than by monthly averages. It was 2.3 per cent less when operating primarily for power generation and 3.7 per cent less when power generation is incidental to irrigation use. This results from the assumption in the monthly computations that flow is available for power generation as an average monthly quantity instead of with the large daily fluctuations that sometimes occur. At times when the reservoir is full, some of this water included in the monthly averages actually would have passed over the spillway instead of through the turbines. Therefore, the computations on a monthly basis show somewhat more water running through the power turbines than actually could have passed through them.

The stream flow data employed in these computations are the estimated mean monthly discharges at the Kennett dam site with the entire flow of the Pit River above Bieber deducted but without deduction for prior rights downstream from the dam. These are published in Bulletin No. 15, "The Coordinated Plan of Water Development in the Sacramento Valley." For the purposes of computing the yield of the reservoir on a daily basis, these estimated monthly means were divided into daily discharges bearing the same relation to the corresponding daily flows measured at the Red Bluff gaging station as the estimated mean monthly flows at the Kennett dam site bear to the corresponding mean monthly flows measured at Red Bluff.

Summaries are prepared of these computations comparing the water and power yield of the Kennett reservoir in the "Coordinated Plan," with and without the flood control feature. Those by years follow herewith but those by months, because of their size, have been assembled in the last chapter of this volume.

It may be observed upon reviewing these tables that the inclusion of the flood control feature of the "Coordinated Plan" has practically no effect upon the yield of the Kennett reservoir either in water or power. The water yield equalized for irrigation use, both with and without flood control, is identical either in the temporary or permanent mode of operating the reservoir. The power yield is 0.9 per cent less under the temporary and 0.2 per cent greater under the permanent mode of operation, all in the secondary output. These differences are very small and are discernible only because of the minute comparisons made to detect them. They are much smaller than the error contained in the usual computations of power output that are based on monthly averages of stream flow.

The slightly less power output under the temporary mode of operation when flood control is included, results from the extra water that may be run through the turbines while the reservoir level is depressed for flood control, being insufficient at times to compensate for the slight reduction in power head. The table shows that this occurs at times during 16 of the 30 years. In 7 of the years the extra water available while the reservoir level is depressed for flood control is sufficient to develop a greater power output with flood control than without. In the remaining 7 years the reservoir stage is not affected by the inclusion of the flood control feature since the empty space, by reason of conservation operations, is at all times greater than needed for flood control. Under such circumstances the power yield with and without flood control is identical. The greatest difference in power yield with and without flood control in any year of the 30 analyzed is 6.7 per cent. This occurred in 1900. The average reduction in power head by the inclusion of flood control is 2.0 feet.

Under the permanent mode of operating the reservoir the power yield is greater with flood control than without because the extra volume of water that may be run through the turbines by reason of the inclusion of the flood control feature is more than sufficient to compensate for the small depression in head. The average reduction in power head that results from the depression of the reservoir level at times for flood control is 0.5 feet.

An alternate rule for controlling floods by reservoirs.

The rules for controlling floods by reservoirs described herein, grade with scientific nicety the flood control reserve in accord with the probable need for empty space to detain excess flood water. They were so constructed in order that the program of flood control evolved by the analysis would interfere as little as possible with conservation. It appears that, under some circumstances, this nicety of gradation in the amount of flood control reserve might be neglected without particular detriment to the reservoir yields. By holding the maximum empty space ever required, in reserve throughout each flood season until its close instead of varying it during the season with the changing value of the progressive rainfall index, results could be obtained at the Kennett reservoir not greatly different from those secured by the application of the reservoir operating diagram.

It is evident that such a rule would interfere with conservation very seriously under some circumstances, especially with a small reservoir. On the other hand, it is surprising how well it fits occurrences on the Sacramento River from 1895 to 1926 when applied to the size reservoir proposed at Kennett. The total reservoir capacity proposed at Kennett equals almost half the mean seasonal run-off and is about six times the maximum flood control reserve. In seasons of short run-off when it would seem that the nicety of gradation in the flood control reserve obtained by the operating diagram should be particularly valuable, it is found generally that conservation draft holds the reservoir below the level of the maximum flood control reserve. At such times flood control by either rule does not depress the reservoir level. Hypothetical seasons might be constructed in which this would not be so, however, the record of stream flow shows that none have occurred within the last thirty years. Should they occur, control by the reservoir operating diagram would interfere less with conservation than by the alternate rule.

The water and power yield of the Kennett reservoir holding the maximum flood control reserve (454,000 acre-feet) empty throughout the season (until April 8th) was computed in parallel to that without flood control and to that with control by the reservoir operating diagram. The yearly and monthly summaries of these computations are included with the others in the adjoining tables. The reduction in yield from that without flood control is small. In the temporary mode of operation under the "Coordinated Plan," the irrigation yield is identical but the primary power output is reduced 3.5 per cent. The secondary output, however, is increased 5.6 per cent so that the net reduction in total power is 1.0 per cent. Under the permanent mode of operation, the average irrigation yield is reduced 0.3 per cent because of the larger deficiencies in seasons of short supply. In 1923 the deficiency is increased by 210,000 acre-feet, 5.0 per cent of the average seasonal yield. The incidental power* under the permanent mode of operation is reduced between 1 and 2 per cent.*

* A full set of computations of the incidental power yield while operating primarily for irrigation was not completed. However, it is estimated the average power head would be reduced about 7.0 feet and 20,000 to 40,000 acre-feet more water would pass through the turbines.

KENNETT RESERVOIR ON SACRAMENTO RIVER.

Table of Yearly Summaries of Water and Power Yield Computed on a Daily Basis.

Showing the effect of inclusion of the flood control feature of the "Coordinated Plan." (See Chapter VIII for corresponding monthly summaries.)

TABLE 1—Operating primarily for power generation with incidental irrigation. With and without flood control by reservoir operating diagram.

TABLE 2—Operating primarily for irrigation with incidental power generation. With and without flood control by reservoir operating diagram.

TABLE 3—Operating primarily for irrigation. Comparison for two methods of flood control.

TABLE 4—Operating primarily for power generation with incidental irrigation. Comparison for two methods of flood control.

TABLE 5—Summary of power yield. With and without flood control by either of two methods.

TABLE 1. KENNETT RESER

WATER AND POWER YIELD, OPERATING PRIMARILY BOTH

WITH AND WITHOUT FLOOD CONTROL

Yearly Summary of Computations

(For corresponding monthly sum

Height of dam 420 feet. Capacity of reservoir 2,940,000 acre-feet.

Year	Estimated run-off at dam site in acre-feet	Without flood control								
		Stage of reservoir at beginning of year in acre-feet	Power draft through turbines in acre-feet		Evaporation in acre-feet	Waste over spillway in acre-feet	Average power head in feet	Average power yield in kilowatts (Load factor=0.75)		
			Primary	Secondary				*Primary	Secondary	Total
1896	8,306,000	2,256,000	3,205,000	1,968,000	78,000	2,491,000	400	113,000	69,500	182,500
1897	6,052,000	2,820,000	3,204,000	1 662,000	78,000	1,671,000	401	113,400	59,100	172,500
1898	3,308,000	2,257,000	3,248,000	21,000	75,000	0	392	113,400	700	114,100
1899	5,050,000	2,221,000	3,206,000	990,000	78,000	299,000	400	113,400	34,900	148,300
1900	5,720,000	2,698,000	3,193,000	1,537,000	78,000	1,081,000	402	113,400	54,200	167,600
1901	5,724,000	2,529,000	3,196,000	1,312,000	78,000	1,289,000	401	113,400	46,300	159,700
1902	8,685,000	2,378,000	3,201,000	1,659,000	78,000	3,185,000	400	113,400	58,900	172,300
1903	6,848,000	2,940,000	3,182,000	1,632,000	78,000	1,990,000	404	113,400	58,200	171,600
1904	10,378,000	2,906,000	3,204,000	2,437,000	78,000	5,144,000	400	113,000	85,600	198,600
1905	6,823,000	2,421,000	3,204,000	1,429,000	78,000	2,276,000	400	113,400	51,000	164,400
1906	7,981,000	2,257,000	3,212,000	1,807,000	78,000	2,673,000	399	113,400	63,900	177,300
1907	8,877,000	2,468,000	3,208,000	1,822,000	78,000	3,891,000	399	113,400	64,500	177,900
1908	5,355.000	2,346,000	3,202,000	1,390,000	78,000	774,000	400	113,000	49,500	162,500
1909	10,871,000	2,257,000	3,203,000	2,116,000	78,000	5,053,000	400	113,400	74,800	188,200
1910	5,801,000	2,678,000	3,201,000	1,478,000	78,000	1.465,000	401	113,400	52,300	165,700
1911	6,383,000	2,257,000	3,212,000	1,446,000	78,000	1,655,000	398	113,400	51,500	164,900
1912	4,935,000	2,249,000	3,211,000	1,333,000	78,000	305,000	398	113,000	46,900	159,900
1913	5,017,000	2,257,000	3,201,000	1,189,000	78,000	253,000	400	113,400	42,100	155,500
1914	9,085,000	2,553,000	3,211,000	1,921,000	78,000	4,171,000	399	113,400	68,000	181,400
1915	9.454,000	2,257,000	3,214,000	1,853,000	78,000	4,094,000	398	113,400	65,500	178,900
1916	7,127,000	2,472,000	3,208,000	1,588,000	78,000	2,468,000	400	113,000	56,300	169,300
1917	4,705,000	2,257.000	3,215.000	897,000	78,000	515,000	397	113,400	32,000	145,400
1918	3,862,000	2.257,000	3,222,000	462,000	78,000	100,000	396	113,400	16,300	129,700
1919	5,306,000	2,257,000	3,211,000	905,000	78,000	1,185,000	399	113,400	32,400	145,800
1920	4,455,000	2,184,000	3,373,000	269,000	66,000	0	376	113,000	9,400	122,400
1921	6,255,000	2,931,000	3,199,000	1,447,000	78,000	2,139,000	400	113,400	51,600	165,000
1922	4,504.000	2,323,000	3,212,000	913,000	78,000	296,000	398	113,400	32,300	145,700
1923	3,294,000	2,328,000	3,223,000	133,000	78,000	0	398	113,400	4,600	118,000
1924	2,431,000	2,188,000	3,759,000	0	53,000	0	339	113,000	0	113,000
1925	5,420,000	807,000	3,361,000	337,000	78,000	211,000	381	113,400	12,100	125.500
Total	188.012,000		97.101,000	37,953,000	2,300,000	50,674,000				
Average	6,267,000		3,236,000	1,265,000	77,000	1,689,000	395.8	113,400	44,800	158,200

*Total primary power production in February of leap years taken the same as in other years.

VOIR ON SACRAMENTO RIVER.

FOR POWER GENERATION WITH INCIDENTAL IRRIGATION

BY RESERVOIR OPERATING DIAGRAM.

Carried out on a Daily Basis.

mary, see Table 1a, page 218.)

Installed capacity of power plant 400,000 k.v.a. P.F. = 0.80.

Coordinated with flood control by reservoir operating diagram
Maximum controlled flow at Red Bluff 125,000 sec.-ft. Maximum reservoir space required 454,000 ac.-ft.

Stage of reservoir at beginning of year in acre-feet	Power draft through turbines in acre-feet		Evaporation in acre-feet	Release through flood control outlets in acre-feet	Waste over spillway in acre-feet	Average power head in feet	Average power yield in kilowatts (Load factor=0.75)			Year
	Primary	Secondary					*Primary	Secondary	Total	
2,256,000	3,225,000	1,701,000	78,000	1,640,000	1,323,000	398	113,000	59,700	172,700	1896
2,595,000	3,227,000	1,552,000	78,000	1,175,000	358,000	396	113,400	54,300	167,700	1897
2,257,000	3,248,000	21,000	75,000	0	0	392	113,400	700	114,100	1898
2,221,000	3,209,000	994,000	78,000	388,000	14,000	399	113,400	35,000	148,400	1899
2,588,000	3,214,000	1,238,000	78,000	1,228,000	21,000	398	113,400	42,900	156,300	1900
2,529,000	3,221,000	1.174,000	78,000	1,402,000	0	397	113,400	40,400	153,800	1901
2,378,000	3,214,000	1,569,000	78,000	2,936,000	614,000	398	113,400	55,300	168,700	1902
2,652,000	3,210,000	1,647,000	78.000	1,834,000	130,000	399	113 400	57,800	171,200	1903
2,601,000	3,238,000	2,449,000	78,000	3,592,000	1,201,000	395	113,000	85,100	198,100	1904
2,421,000	3,217,000	1,504,000	78,000	1,903,000	285,000	397	113,400	53,100	166,500	1905
2,257,000	3,224,000	1,849,000	78,000	1,780,000	839,000	397	113,400	65,100	178,500	1906
2,468,000	3,230,000	2,042,000	78 000	3,044,000	605,000	395	113,400	71,400	184,800	1907
2,346,000	3,226,000	1,146,000	78,000	930,000	64,000	398	113,000	40,200	153,200	1908
2,257,000	3,217,000	2,099,000	78,000	4,785,000	312,000	397	113,400	73,600	187,000	1909
2,637,000	3,210,000	1,443,000	78,000	1,036,000	414,000	399	113,400	50,800	164,200	1910
2,257,000	3,228,000	1,443,000	78,000	1,217,000	425,000	396	113,400	50,800	164,200	1911
2,249,000	3,211,000	1,333,000	78,000	0	305,000	398	113,000	46,900	159,900	1912
2,257,000	3,216,000	1,093,000	78,000	137,000	197,000	398	113,400	38,500	151,900	1913
2,553,000	3,221,000	1,914,000	78,000	3,358,000	810,000	397	113,400	67,400	180,800	1914
2,257,000	3,224,000	1,964,000	78,000	2,509,000	1,464,000	396	113,400	69,000	182,400	1915
2,472,000	3,236,000	1,704,000	78,000	2,149,000	175,000	396	113,000	59,500	172,500	1916
2,257,000	3,220,000	770,000	78,000	178,000	459,000	397	113,400	27,400	140,800	1917
2,257,000	3,222,000	462,000	78,000	0	100,000	396	113,400	16,300	129,700	1918
2,257,000	3,223,000	1,020,000	78,000	919,000	139,000	396	113,400	36,000	149,400	1919
2,184,000	3,374,000	270,000	66,000	202,000	0	375	113,000	9,400	122,400	1920
2,727,000	3,218,000	1,391,000	78,000	1,936,000	36,000	397	113,400	48,900	162,300	1921
2,323,000	3,215,000	832,000	78,000	136,000	238,000	398	113,400	29,400	142,800	1922
2,328,000	3.223,000	133,000	78,000	0	0	398	113,400	4,600	118,000	1923
2,188,000	3,759,000	0	53,000	0	0	339	113,000	0	113.000	1924
807,000	3,361,000	337,000	78,000	0	211,000	381	113,400	12,100	125,500	1925
	97,481,000	37,094,000	2,300,000	40,414,000	10,739,000					Total
	3,249,000	1,236,000	77,000	1,347,000	358,000	393.8	113,400	43,400	156,800	Average

TABLE 2. KENNETT RESER

WATER AND POWER YIELD, OPERATING PRIMARILY

BOTH

WITH AND WITHOUT FLOOD CONTROL

Yearly Summary of Computations

(For corresponding monthly sum

Height of dam 420 feet.

Capacity of reservoir 2,940,000 acre-feet.

Year	Estimated run-off at dam site in acre-feet	Without flood control							
		Stage of reservoir at beginning of year in acre-feet	Irrigation draft in acre-feet (no deduction for down-stream prior rights)	Evaporation in acre-feet	Power draft through turbines in acre-feet	Waste over spillway in acre-feet	Deficiency in irrigation supply in acre-feet	Average power head through period of operation in feet	Average power yield in kilowatts (Load factor=1.00)
1896	8,306,000	1,860,000	4,276,000	65,000	5,286,000	1,678,000	0	375	178,400
1897	6,052,000	2,586,000	4,276,000	59,000	5,531,000	1,172,000	0	359	180,800
1898	3,308,000	1,408,000	4,189,000	43,000	3,149,000	0	87,000	342	91,200
1899	5,050,000	484,000	4,123,000	39,000	3,130,000	0	153,000	329	88,700
1900	5,720,000	1,372,000	4,276,000	55,000	4,723,000	327,000	0	337	145,500
1901	5,724,000	1,534,000	4,276,000	54,000	4,721,000	759,000	0	336	144,900
1902	8,685,000	1,268,000	4,276,000	61,000	5,051,000	1,919,000	0	361	166,300
1903	6,848,000	2,432,000	4,276,000	54,000	5,545,000	1,350,000	0	347	176,700
1904	10,378,000	1,872,000	4,276,000	65,000	5,055,000	4,108,000	0	372	170,200
1905	6,823,000	2,462,000	4,276,000	59,000	5,727,000	1,822,000	0	361	188,300
1906	7,981,000	1,206,000	4,276,000	69,000	4,713,000	1,491,000	0	378	161,500
1907	8,877,000	2,309,000	4,276,000	65,000	5,552,000	3,257,000	0	369	186,200
1908	5,355,000	1,795,000	4,276,000	58,000	5,170,000	302,000	0	353	166,000
1909	10,871,000	1,155,000	4,276,000	59,000	5,723,000	3,543,000	0	362	190,400
1910	5,801,000	2,216,000	4,276,000	55,000	5,383,000	911,000	0	347	171,100
1911	6,383,000	1,215,000	4,276,000	63,000	4,709,000	868,000	0	362	155,500
1912	4,935,000	1,447,000	4,276,000	61,000	4,032,000	83,000	0	360	130,200
1913	5,017,000	1,709,000	4,276,000	58,000	4,537,000	58,000	0	348	143,800
1914	9,085,000	1,611,000	4,276,000	65,000	5,729,000	2,744,000	0	370	192,800
1915	9,454,000	1,631,000	4,276,000	66,000	5,341,000	2,972,000	0	374	181,100
1916	7,127,000	2,138,000	4,276,000	59,000	5,627,000	1,798,000	0	358	183,300
1917	4,705,000	1,321,000	4,276,000	59,000	4,124,000	236,000	0	348	129,700
1918	3,862,000	1,132,000	4,276,000	50,000	3,158,000	0	0	354	96,400
1919	5,306,000	668,000	4,276,000	54,000	4,533,000	215,000	0	334	138,500
1920	4,455,000	719,000	3,121,000	24,000	1,979,000	0	1,155,000	315	53,400
1921	6,255,000	2,029,000	4,276,000	56,000	5,514,000	1,186,000	0	350	176,800
1922	4,504,000	1,059,000	4,276,000	56,000	3,801,000	0	0	342	116,700
1923	3,294,000	1,226,000	4,101,000	43,000	3,134,000	0	175,000	341	91,100
1924	2,431,000	376,000	2,136,000	13,000	1,072,000	0	2,140,000	283	25,600
1925	5,420,000	658,000	4,276,000	54,000	4,353,000	297,000	0	352	135,500
Total	188,012,000		124,570.000	1,641,000	136,102,000	33,096,000	3,710,000		
Average	6,267,000	....	4,152,000	55,000	4,537,000	1,103,000	124,000	353.4	145,300

VOIR ON SACRAMENTO RIVER.

FOR IRRIGATION WITH INCIDENTAL POWER GENERATION

BY RESERVOIR OPERATING DIAGRAM.

Carried out on a Daily Basis.

mary, see Table 2a, page 234.)

Seasonal irrigation yield (deficiency in supply one year in ten, no deduction for downstream prior rights) 4,276,000 acre-feet.

Installed capacity of power plant 400,000 k.v.a. P.F. = 0.80.

Coordinated with flood control by reservoir operating diagram. Maximum controlled flow at Red Bluff 125,000 sec.-ft. Maximum reservoir space required 454,000 ac.-ft.									
Stage of reservoir at beginning of year in acre-feet	Irrigation draft in acre-feet (no deduction for down-stream prior rights)	Evapora-tion in acre-feet	Power draft through turbines in acre-feet	Release through flood control outlets in acre-feet	Waste over spillway in acre-feet	Deficiency in irrigation supply in acre-feet	Average power head through period of operation in feet	Average power yield in kilowatts (Load factor= 1.00)	Year
1,860,000	4,276,000	65,000	4,901,000	1,148,000	915,000	0	373	164,000	1896
2,586,000	4,276,000	59,000	5,616,000	916,000	171,000	0	358	181,900	1897
1,408,000	4,189,000	43,000	3,149,000	0	0	87,000	342	91,200	1898
484,000	4,123,000	39,000	3,130,000	0	0	153,000	329	88,700	1899
1,372,000	4,276,000	55,000	4,745,000	305,000	0	0	342	145,300	1900
1,534,000	4,276,000	54,000	4,670,000	810,000	0	0	337	142,000	1901
1,268,000	4,276,000	61,000	4,949,000	1,682,000	339,000	0	359	161,600	1902
2,432,000	4,276,000	54,000	5,722,000	1,149,000	24,000	0	345	181,000	1903
1,872,000	4,276,000	65,000	5,152,000	3,170,000	841,000	0	370	172,600	1904
2,462,000	4,276,000	59,000	5,908,000	1,550,000	91,000	0	359	193,300	1905
1,206,000	4,276,000	69,000	4,798,000	1,100,000	306,000	0	377	163,700	1906
2,309,000	4,276,000	65,000	5,989,000	2,468,000	352,000	0	366	199,700	1907
1,795,000	4,276,000	58,000	4,919,000	553,000	0	0	352	155,900	1908
1,155,000	4,276,000	59,000	5,648,000	3,524,000	94,000	0	363	186,400	1909
2,216,000	4,276,000	55,000	5,369,000	708,000	217,000	0	347	170,100	1910
1,215,000	4,276,000	63,000	4,952,000	481,000	144,000	0	363	163,400	1911
1,447,000	4,276,000	61,000	4,032,000	0	83,000	0	360	130,200	1912
1,709,000	4,276,000	58,000	4,533,000	10,000	52,000	0	352	143,600	1913
1,611,000	4,276,000	65,000	5,761,000	2,214,000	498,000	0	369	192,900	1914
1,631,000	4,276,000	66,000	5,390,000	1,896,000	1,027,000	0	372	181,900	1915
2,138,000	4,276,000	59,000	5,790,000	1,598,000	37,000	0	355	187,200	1916
1,321,000	4,276,000	59,000	4,124,000	0	236,000	0	348	129,700	1917
1,132,000	4,276,000	50,000	3,158,000	0	0	0	354	96,400	1918
668,000	4,276,000	54,000	4,665,000	48,000	35,000	0	332	142,900	1919
719,000	3,121,000	24,000	1,979,000	0	0	1,155,000	315	53,400	1920
2,029,000	4,276,000	56,000	5,608,000	1,092,000	0	0	348	178,700	1921
1,059,000	4,276,000	56,000	3,801,000	0	0	0	342	116,700	1922
1,226,000	4,101,000	43,000	3,134,000	0	0	175,000	341	91,100	1923
376,000	2,136,000	13,000	1,072,000	0	0	2,140,000	283	25,600	1924
658,000	4,276,000	54,000	4,318,000	152,000	180,000	0	352	133,900	1925
	124,570,000	1,641,000	136,982,000	26,574,000	5,642,000	3,710,000			Total
	4,152,000	55,000	4,566,000	886,000	188,000	124,000	352.9	145,600	Average

TABLE 3. KENNETT RESER

COMPARISON OF WATER YIELD

FOR

TWO METHODS OF

Yearly Summary of Computations

(For corresponding monthly sum

Height of dam 420 feet. Capacity of reservoir 2,940,000 acre-feet.

Year	Estimated run-off at dam site in acre-feet	Flood control by reservoir operating diagram Maximum controlled flow at Red Bluff 125,000 sec.-ft. Maximum reservoir space required 454,000 ac.-ft.					
		Stage of reservoir at beginning of year in acre-feet	Irrigation draft in acre-feet (no deduction for downstrean prior rights)	Evaporation in acre-feet	Release through flood control outlets in acre-feet	Waste over spillway in acre-feet	Deficiency in irrigation supply in acre-feet
1896	8,306,000	1,860,000	4,276,000	65,000	1,767,000	1,472,000	0
1897	6,052,000	2,586,000	4,276,000	59,000	2,413,000	482,000	0
1898	3,308,000	1,408,000	4,189,000	43,000	0	0	87,000
1899	5,050,000	484,000	4,123,000	39,000	0	0	153,000
1900	5,720,000	1,372,000	4,276,000	55,000	1,053,000	174,000	0
1901	5,724,000	1,534,000	4,276,000	54,000	1,635,000	25,000	0
1902	8,685,000	1,268,000	4,276,000	61,000	2,507,000	677,000	0
1903	6,848,000	2,432,000	4,276,000	54,000	2,773,000	305,000	0
1904	10,378,000	1,872,000	4,276,000	65,000	4,264,000	1,183,000	0
1905	6,823,000	2,462,000	4,276,000	59,000	3,278,000	466,000	0
1906	7,981,000	1,206,000	4,276,000	69,000	1,887,000	646,000	0
1907	8,877,000	2,309,000	4,276,000	65,000	4,385,000	665,000	0
1908	5,355,000	1,795,000	4,276,000	58,000	1,401,000	260.000	0
1909	10,871,000	1,155,000	4,276,000	59,000	5,001,000	474,000	0
1910	5,801,000	2,216,000	4,276,000	55,000	1,586,000	885,000	0
1911	6,383,000	1,215,000	4,276,000	63,000	1,357,000	455,000	0
1912	4,935,000	1,447,000	4,276,000	61,000	0	336,000	0
1913	5,017,000	1,709,000	4,276,000	58,000	172,000	609,000	0
1914	9,085,000	1,611,000	4,276,000	65,000	3,843,000	881,000	0
1915	9,454,000	1,631,000	4,276,000	66,000	3,165,000	1,440,000	0
1916	7,127,000	2,138,000	4,276,000	59,000	3,223,000	386,000	0
1917	4,705 000	1,321,000	4,276,000	59,000	0	559,000	0
1918	3,862,000	1,132,000	4,276,000	50,000	0	0	0
1919	5,306,000	668,000	4,276,000	54,000	591,000	334,000	0
1920	4,455,000	719,000	3,121,000	24,000	0	0	1,155,000
1921	6,255.000	2,029,000	4,276,000	56,000	2,682,000	211,000	0
1922	4,504,000	1,059,000	4,276,000	56,000	0	5,000	0
1923	3,294,000	1,226,000	4,101,000	43,000	0	0	175,000
1924	2.431,000	376,000	2,136,000	13,000	0	0	2,140,000
1925	5,420,000	658,000	4,276,000	54,000	526,000	487,000	0
Total	188,012,000		124,570,000	1,641,000	49,509,000	13,417,000	3,710,000
Average	6,267,000		4,152,000	55,000	1,650,000	447,000	124,000

VOIR ON SACRAMENTO RIVER.

OPERATING PRIMARILY FOR IRRIGATION

FLOOD CONTROL.

Carried out on a Daily Basis.

mary, see Table 3a, page 250.)

Seasonal irrigation yield (deficiency in supply one year in ten, no deduction for downstream prior rights) 4,276,000 acre-feet.

Flood control, holding maximum reservoir space required (454,000 ac.-ft.) in reserve throughout flood season. Maximum controlled flow at Red Bluff-125,000 sec.-ft.						
Stage of reservoir at beginning of year in acre-feet	Irrigation draft in acre-feet (no deduction for downstream prior rights)	Evaporation in acre-feet	Release through flood control outlets in acre-feet	Waste over spillway in acre-feet	Deficiency in irrigation supply in acre-feet	Year
1,860,000	4,276,000	65,000	2,760,000	579,000	0	1896
2,486,000	4,276,000	59,000	2,747,000	48,000	0	1897
1,408,000	4,184,000	43,000	5,000	0	92,000	1898
484,000	4,123,000	39,000	0	0	153,000	1899
1,372,000	4,276,000	47,000	1,506,000	0	0	1900
1,263,000	4,268,000	44,000	1,727,000	0	8,000	1901
948,000	4,276,000	61,000	2,705,000	159,000	0	1902
2,432,000	4,276,000	53,000	3,206,000	0	0	1903
1,745,000	4,276,000	65,000	4,634,000	686,000	0	1904
2,462,000	4,276,000	57,000	3,862,000	0	0	1905
1,090,000	4,276,000	69,000	2,253,000	164,000	0	1906
2,309,000	4,276,000	65,000	4,792,000	258,000	0	1907
1,795,000	4,276,000	54,000	1,867,000	0	0	1908
953,000	4,276,000	59,000	5,331,000	0	0	1909
2,158,000	4,276,000	53,000	2,556,000	0	0	1910
1,074,000	4,276,000	63,000	1,634,000	37,000	0	1911
1,447,000	4,276,000	59,000	511,000	0	0	1912
1,536,000	4,276,000	55,000	734,000	0	0	1913
1,488,000	4,276,000	65,000	4,337,000	264,000	0	1914
1,631,000	4,276,000	66,000	3,894,000	711,000	0	1915
2,138,000	4,276,000	55,000	3,735,000	0	0	1916
1,199,000	4,276,000	59,000	323,000	114,000	0	1917
1,132,000	4,248,000	45,000	110,000	0	28,000	1918
591,000	4,276,000	51,000	948,000	0	0	1919
622,000	3,026,000	22,000	0	0	1,250,000	1920
2,029,000	4,276,000	51,000	3,119,000	0	0	1921
838,000	4,276,000	53,000	2,000	0	0	1922
1,011,000	3,891,000	38,000	0	0	385,000	1923
376,000	2,136,000	13,000	0	0	2,140,000	1924
658,000	4,276,000	54,000	959,000	54,000	0	1925
	124,224,000	1,582,000	60,257,000	3,074,000	4,056,000	Total
	4,141,000	53,000	2,009,000	102,000	135,000	Average

TABLE 4. KENNETT RESER

COMPARISON OF WATER AND POWER YIELD, OPERATING PRIMARILY

TWO METHODS OF

Yearly Summary of Computations

(For corresponding monthly sum

Height of dam 420 feet. Capacity of reservoir 2,940,000 acre-feet.

Year	Estimated run-off at dam site in acre-feet	Flood control by reservoir operating diagram Maximum controlled flow at Red Bluff 125,000 sec.-ft. Maximum reserve space required 454,000 ac.-ft.									
		Stage of reservoir at beginning of year in acre-feet	Power draft through turbines in acre-feet		Evaporation in acre-feet	Release through flood control outlets in acre-feet	Waste over spillway in acre-feet	Average power head in feet	Average power yield in kilowatts (Load factor=0.75)		
			Primary	Secondary					*Primary	Secondary	Total
1896	8,306,000	2,256,000	3,225,000	1,701,000	78,000	1,640,000	1,323,000	398	113,000	59,700	172,700
1897	6,052,000	2,595,000	3,227,000	1,552,000	78,000	1,175,000	358,000	396	113,400	54,300	167,700
1898	3,308,000	2,257,000	3,248,000	21,000	75,000	0	0	392	113,400	700	114,100
1899	5,050,000	2,221,000	3,209,000	994,000	78,000	388,000	14,000	399	113,400	35,000	148,400
1900	5,720,000	2,588,000	3,214,000	1,238,000	78,000	1,228,000	21,000	398	113,400	42,900	156,300
1901	5,724,000	2,529,000	3,221,000	1,174,000	78,000	1,402,000	0	397	113,400	40,400	153,800
1902	8,685,000	2,378,000	3,214,000	1,569,000	78,000	2,936,000	614,000	398	113,400	55,300	168,700
1903	6,848,000	2,652,000	3,210,000	1,647,000	78,000	1,834,000	130,000	399	113,400	57,800	171,200
1904	10,378,000	2,601,000	3,238,000	2,449,000	78,000	3,592,000	1,201,000	395	113,000	85,100	198,100
1905	6,823,000	2,421,000	3,217,000	1,504,000	78,000	1,903,000	285,000	397	113,400	53,100	166,500
1906	7,981,000	2,257,000	3,224,000	1,849,000	78,000	1,780,000	839,000	397	113,400	65,100	178,500
1907	8,877,000	2,468,000	3,230,000	2,042,000	78,000	3,044,000	605,000	395	113,400	71,400	184,800
1908	5,355,000	2,346,000	3,226,000	1,146,000	78,000	930,000	64,000	398	113,000	40,200	153,200
1909	10,871,000	2,257,000	3,217,000	2,099,000	78,000	4,785,000	312,000	397	113,400	73,600	187,000
1910	5,801,000	2,637,000	3,210,000	1,443,000	78,000	1,036,000	414,000	399	113,400	50,800	164,200
1911	6,383,000	2,257,000	3,228,000	1,443,000	78,000	1,217,000	425,000	396	113,400	50,800	164,200
1912	4,935,000	2,249,000	3,211,000	1,333,000	78,000	0	305,000	398	113,000	46,900	159,900
1913	5,017,000	2,257,000	3,216,000	1,093,000	78,000	137,000	197,000	398	113,400	38,500	151,900
1914	9,085,000	2,553,000	3,221,000	1,914,000	78,000	3,358,000	810,000	397	113,400	67,400	180,800
1915	9,454,000	2,257,000	3,224,000	1,964,000	78,000	2,509,000	1,464,000	396	113,400	69,000	182,400
1916	7,127,000	2,472,000	3,236,000	1,704,000	78,000	2,149,900	175,000	396	113,000	59,500	172,500
1917	4,705,000	2,257,000	3,220,000	770,000	78,000	178,000	459,000	397	113,400	27,400	140,800
1918	3,862,000	2,257,000	3,222,000	462,000	78,000	0	100,000	396	113,400	16,300	129,700
1919	5,306,000	2,257,000	3,223,000	1,020,000	78,000	919,000	139,000	396	113,400	36,000	149,400
1920	4,455,000	2,184,000	3,374,000	270,000	66,000	202,000	0	375	113,000	9,400	122,400
1921	6,255,000	2,727,000	3,218,000	1,391,000	78,000	1,936,000	36,000	397	113,400	48,900	162,300
1922	4,504,000	2,323,000	3,215,000	832,000	78,000	136,000	238,000	398	113,400	29,400	142,800
1923	3,294,000	2,328,000	3,223,000	133,000	78,000	0	0	398	113,400	4,600	118,000
1924	2,431,000	2,188,000	3,759,000	0	53,000	0	0	339	115,000	0	113,000
1925	5,420,000	807,000	3,361,000	337,000	78,000	0	211,000	381	113,400	12,100	125,500
Total	188,012,000		97,481,000	37,094,000	2,300,000	40.414,000	10,739,000				
Average	6,267,000		3,249,000	1,236,000	77,000	1,347,000	358,000	393.8	113,400	43,400	156,800

*Total primary power production in February of leap years taken the same as in other years.

VOIR ON SACRAMENTO RIVER.

FOR POWER GENERATION WITH INCIDENTAL IRRIGATION FOR FLOOD CONTROL.

Carried out on a Daily Basis.

mary, see Table 4a, page 266.)

Installed capacity of power plant 400,000 k.v.a. P.F. = 0.80.

Flood control, holding maximum reservoir space required (454,000 ac.-ft.) in reserve throughout flood season
Maximum controlled flow at Red Bluff 125,000 sec.-ft.

Stage of reservoir at beginning of year in acre-feet	Power draft through turbines in acre-feet		Evaporation in acre-feet	Release through flood control outlets in acre-feet	Waste over spillway in acre-feet	Average power head in feet	Average power yield in kilowatts (Load factor=0.75)			Year
	Primary	Secondary					*Primary	Secondary	Total	
2,075,000	3,149,000	2,102,000	76,000	1,800,000	768,000	392	109,100	73,000	182,100	1896
2,486,000	3,149,000	1,933,000	75,000	1,306,000	0	391	109,400	67,100	176,500	1897
2,075,000	3,190,000	46,000	72,000	0	0	384	109,400	1,500	110,900	1898
2,075,000	3,149,000	887,000	73,000	541,000	0	390	109,400	30,400	139,800	1899
2,475,000	3,146,000	1,373,000	74,000	1,222,000	0	391	109,400	47,100	156,500	1900
2,380,000	3,154,000	1,270,000	73,000	1,356,000	0	389	109,400	43,400	152,800	1901
2,251,000	3,143,000	1,853,000	75,000	3,194,000	185,000	391	109,400	64,500	173,900	1902
2,486,000	3,140,000	1,567,000	74,000	2,089,000	0	392	109,400	54,100	163,500	1903
2,464,000	3,155,000	2,679,000	77,000	3,930,000	764,000	391	109,100	92,300	201,400	1904
2,237,000	3,157,000	1,525,000	74,000	2,229,000	0	390	109,400	52,800	162,200	1905
2,075,000	3,144,000	2,131,000	77,000	1,914,000	465,000	391	109,400	74,100	183,500	1906
2,325,000	3,147,000	2,264,000	76,000	3,307,000	233,000	391	109,400	78,500	187,900	1907
2,175,000	3,164,000	1,339,000	74,000	878,000	0	390	109,100	46,200	155,300	1908
2,075,000	3,153,000	2,202,000	75,000	5,055,000	0	390	109,400	76,100	185,500	1909
2,461,000	3,151,000	1,575,000	74,000	1,387,000	0	390	109,400	54,100	163,500	1910
2,075,000	3,157,000	1,699,000	75,000	1,378,000	74,000	390	109,400	59,300	168,700	1911
2,075,000	3,161,000	1,577,000	75,000	120,000	0	390	109,100	54,500	163,600	1912
2,077,000	3,152,000	1,388,000	74,000	91,000	0	390	109,400	48,000	157,400	1913
2,389,000	3,147,000	2,209,000	76,000	3,695,000	272,000	390	109,400	76,500	185,900	1914
2,075,000	3,147,000	2,087,000	76,000	3,042,000	834,000	391	109,400	72,400	181,800	1915
2,343,000	3,164,000	1,695,000	74,000	2,462,000	0	389	109,100	58,300	167,400	1916
2,075,000	3,158,000	1,188,000	75,000	227,000	57,000	389	109,400	41,700	151,100	1917
2,075,000	3,168,000	409,000	74,900	211,000	0	387	109,400	14,000	123,400	1918
2,075,000	3,156,000	835,000	74,000	1,245,000	0	389	109,400	29,000	138,400	1919
2,071,000	3,290,000	192,000	66,000	492,000	0	371	109,100	6,500	115,600	1920
2,486,000	3,154,000	1,309,000	74,000	2,043,000	0	390	109,400	45,100	154,500	1921
2,161,000	3,159,000	981,000	74,000	296,000	0	389	109,400	33,900	143,300	1922
2,155,000	3,152,000	71,000	74,000	77,000	0	390	109,400	2,500	111,900	1923
2,075,000	3,692,000	0	53,000	0	0	334	109,100	0	109,100	1924
761,000	3,290,000	594,000	75,000	147,000	0	375	109,400	20,900	130,300	1925
	95,438,000	40,980,000	2,208,000	45,734,000	3,652,000					Total
	3,181,000	1,366,000	74,000	1,524,000	122,000	386.9	109,400	47,300	156,700	Average

TABLE 5. KENNETT RESER

SUMMARY OF POWER

BOTH

WITH AND WITHOUT

Summary of Tables

(For corresponding monthly sum

Height of dam 420 feet. Capacity of reservoir 2,940,000 acre-feet.

Year	**Operating primarily for power generation with incidental irrigation** Average power yield in kilowatts (Load factor=0.75)								
	Without flood control			Coordinated with flood control by reservoir operating diagram Maximum controlled flow at Red Bluff 125,000 sec.-ft. Maximum reservoir space required 454,000 acre-feet			With flood control, holding maximum reservoir space required (454,000 ac.-ft.) in reserve throughout flood season Maximum controlled flow at Red Bluff 125,000 sec.-ft		
	*Primary	Secondary	Total	*Primary	Secondary	Total	*Primary	Secondary	Total
1896	113.000	69,500	182,500	113,000	59,700	172,700	109,100	73,000	182,100
1897	113,400	59,100	172,500	113,400	54,300	167.700	109,400	67,100	176,500
1898	113,400	700	114,100	113,400	700	114,100	109,400	1,500	110,900
1899	113,400	34,900	148,300	113,400	35,000	148,400	109,400	30,400	139,800
1900	113,400	54,200	167,600	113,400	42,900	156,300	109,400	47 100	156 500
1901	113,400	46,300	159,700	113,400	40,400	153,800	109,400	43,400	152,800
1902	113,400	58,900	172,300	113,400	55,300	168,700	109,400	64,500	173,900
1903	113,400	58,200	171,600	113,400	57,800	171,200	109,400	54,100	163,500
1904	113,000	85,600	198,600	113,000	85,100	198,100	109,100	92,300	201,400
1905	113,400	51,000	164,400	113,400	53,100	166,500	109,400	52,800	162,200
1906	113,400	63,900	177,300	113,400	65,100	178 500	109,400	74,100	183 500
1907	113,400	64,500	177,900	113,400	71.400	184,800	109,400	78,500	187,900
1908	113,000	49,500	162,500	113,000	40,200	153,200	109,100	46,200	155,300
1909	113,400	74,800	188,200	113,400	73,600	187,000	109,400	76,100	185,500
1910	113,400	52,300	165,700	113,400	50,800	164,200	109,400	54,100	163,500
1911	113,400	51,500	164,900	113,400	50,800	164,200	109,400	59,300	168,700
1912	113,000	46,900	159,900	113,000	46,900	159,900	109,100	54,500	163,600
1913	113,400	42,100	155,500	113,400	38,500	151,900	109,400	48,000	157,400
1914	113,400	68,000	181,400	113,400	67,400	180,800	109,400	76.500	185,900
1915	113,400	65,500	178,900	113,400	69,000	182,400	109,400	72,400	181,800
1916	113,000	56,300	169,300	113,000	59,500	172,500	109,100	58,300	167,400
1917	113,400	32,000	145,400	113,400	27,400	140,800	109,400	41,700	151,100
1918	113,400	16,300	129,700	113,400	16,300	129,700	109,400	14,000	123,400
1919	113,400	32,400	145,800	113,400	36,000	149,400	109,400	29,000	138,400
1920	113,000	9,400	122,400	113,000	9,400	122,400	109,100	6,500	115,600
1921	113,400	51,600	165,000	113,400	48,900	162,300	109,400	45,100	154,500
1922	113,400	32,300	145,700	113,400	29,400	142,800	109,400	33,900	143,300
1923	113,400	4,600	118,000	113,400	4,600	118,000	109,400	2,500	111,900
1924	113,000	0	113,000	113,000	0	113,000	109,100	0	109,100
1925	113,400	12,100	125,500	113,400	12,100	125,500	109,400	20,900	130,300
Average	113,400	44,800	158,200	113,400	43,400	156,800	109,400	47,300	156,700

*Total primary power production of leap years taken the same as in other years.

VOIR ON SACRAMENTO RIVER.

YIELD BY YEARS

FLOOD CONTROL.

1, 2, and 4.

mary, see Table 5a, page 282.)

Installed capacity of power plant 400,000 k.v.a. P.F. = 0.80.

Operating primarily for irrigation with incidental power generation Seasonal irrigation yield 4,276,000 ac.-ft. (Deficiency in supply one year in ten. No deduction for downstream prior rights) Average power yield in kilowatts (Load factor=1.00)						Year
Without flood control			Coordinated with flood control by reservoir operating diagram Maximum controlled flow at Red Bluff 125,000 sec.-ft. Maximum reservoir space required 454,000 acre-feet			
Primary	Secondary	Total	Primary	Secondary	Total	
0	178,400	178,400	0	164,000	164,000	1896
0	180,800	180,800	0	181,900	181,900	1897
0	91,200	91,200	0	91,200	91,200	1898
0	88,700	88,700	0	88,700	88,700	1899
0	145,500	145,500	0	145,300	145,300	1900
0	144,900	144,900	0	142,000	142,000	1901
0	166,300	166,300	0	161,600	161,600	1902
0	176,700	176,700	0	181,000	181,000	1903
0	170,200	170,200	0	172,600	172,600	1904
0	188,300	188,300	0	193,300	193,300	1905
0	161,500	161,500	0	163,700	163,700	1906
0	186,200	186,200	0	199,700	199,700	1907
0	166,000	166,000	0	155,900	155,900	1908
0	190,400	190,400	0	186,400	186,400	1909
0	171,100	171,100	0	170,100	170,100	1910
0	155,500	155,500	0	163,400	163,400	1911
0	130,200	130,200	0	130,200	130,200	1912
0	143,800	143,800	0	143,600	143,600	1913
0	192,800	192,800	0	192,900	192,900	1914
0	181,100	181,100	0	181,900	181,900	1915
0	183,300	183,300	0	187,200	187,200	1916
0	129,700	129,700	0	129,700	129,700	1917
0	96,400	96,400	0	96,400	96,400	1918
0	138,500	138,500	0	142,900	142,900	1919
0	53,400	53,400	0	53,400	53,400	1920
0	176,800	176,800	0	178,700	178,700	1921
0	116,700	116,700	0	116,700	116,700	1922
0	91,100	91,100	0	91,100	91,100	1923
0	25,600	25,600	0	25,600	25,600	1924
0	135,500	135,500	0	133,900	133,900	1925
0	145,300	145,300	0	145,600	145,600	Average

Pardee Reservoir on Mokelumne River.

The East Bay Municipal Utility District proposes to construct the Pardee reservoir of 222,000 acre-feet capacity at the site on the Mokelumne River known by many as the Lancha Plana. It is estimated that this reservoir will yield 200 million gallons per day equalized for municipal supply. The dam would be 345 feet high. A power plant of 15,000 k.w. capacity at its base would generate electricity with the water passing by the dam. The effect of including in the plans of the East Bay Municipal Utility District a flood control feature similar to that devised for the reservoirs of the "Coordinated Plan" was investigated by the Division of Engineering and Irrigation under agreement with the district of date February 5, 1926.

The size of floods to be controlled on the Mokelumne River is indicated by the largest ones in the stream flow records. The largest rain-water flood in the twenty-one years of measured flow occurred on January 30, 1911, with a crest discharge of 20,600* second-feet. The largest snow-water flood occurred on June 12, 1906, with a discharge of 8740 second-feet. The crest discharge of these floods could be limited by the Pardee reservoir through the use of a diagram like that on Plate XIX, "Reservoir Operating Diagram for Controlling Floods on Mokelumne River" (p. 80), to 5300 second-feet for rain-water floods and to 7100 second-feet for snow-water floods. This reduction in flood flows could be obtained by the use at times of a maximum reserve for flood control of 92,000 acre-feet, about two-fifths the total capacity of the reservoir.

The effect of including this flood control feature upon reservoir stage and the yield of water and power from the Pardee reservoir is derived from a comparison of two sets of computations of the yield, one with and the other without flood control. As in studying the effect of the inclusion of a flood control feature upon the yield of the Kennett reservoir, both sets of computations were carried through the entire period of measured flow on a daily basis instead of on the usual monthly basis in order to make the set without flood control exactly comparable to the one with flood control included. The latter had to be carried through on a daily basis to accommodate the requirements of the reservoir operating diagram which requires a daily adjustment of reservoir level during the flood season. The stream flow data used are those published in the Water Supply Papers of the United States Geological Survey for the Clements gaging station together with those in preparation for publication. No deduction was made for the 59 square miles of drainage area between Clements and the dam. The assumptions employed in these computations are listed on page 298.

The effect of including this flood control feature upon the reservoir stage is delineated upon Plate XXIV, "Effect of Controlling Mokel-

* Water Supply Paper No. 551 of the United States Geological Survey, recently published, places the maximum discharge of the Mokelumne River at Clements at 25,500 second-feet. This is obtained by applying the rating curve of the 1911 flood to the gage heights of 1907. The crest discharge of the 1907 flood has been published as 17,000 second-feet in former publications including Water Supply Paper No. 299 in which are printed the daily discharges of the 1907 flood. The figures contained in Water Supply Paper No. 299 have been used in preparing this volume. Should the daily discharges of the 1907 flood be revised by application of the 1907 gage heights to the 1911 rating curve, the increase in their values would be so substantial as to require a complete revision of the analyses of floods on the Mokelumne River contained in this volume in order to make the analyses harmonize with the increased discharge values.

Effect of Controlling Mokelumne River Floods upon Stage of Pardee Reservoir if Operated Primarily for Municipal Supply

MAXIMUM CONTROLLED FLOW AT CLEMENTS
RAIN WATER FLOODS 5,300 SEC. FT.
SNOW WATER FLOODS 7,100 SEC. FT.

MAXIMUM FLOOD OF RECORD 20,600 SEC. FT.
RESERVOIR CAPACITY 222,000 AC. FT.
HEIGHT OF DAM 345 FT.

umne River Floods upon Stage of Pardee Reservoir." It is assumed in preparing this plate that the Pardee reservoir was constructed some time prior to 1904, the opening year of continuous stream flow measurements on the Mokelumne River, and operated both with and without flood control through the succeeding years for a municipal supply of 200 million gallons per day together with incidental power development as proposed by the East Bay Municipal Utility District. The reservoir stage for every day of the 21 years from 1905 to 1926 is indicated by lines extending across the plate in several rows. Their vertical position, read on the reservoir stage scale, shows the number of acre-feet of water in storage at all times. On this scale, the space between parallel guide lines represents 20,000 acre-feet of reservoir capacity. The top guide line of each row represents a full reservoir and the bottom one an empty reservoir.

The heavy black line extending across each row indicates the stage were 200 million gallons per day drawn from the reservoir and 140,000 acre-feet per year passed by the dam for prior rights. The heavy red line indicates the departures from this stage by reason of the introduction of the flood control feature. The light red line indicates the stage were the reservoir operated for flood control alone in accordance with the diagram. Red figures translate into feet of depth the greatest draw down from a full reservoir required by flood control during each season. A light black line in each row below the reservoir stage lines indicates on a special scale superimposed on the reservoir stage scale, the undisturbed daily flow in the Mokelumne River at Clements. The light red line close at hand shows the flow below the dam as controlled by the coordinate operation of the reservoir for flood control and conservation. A black dotted line shows throughout the flood season the daily value of the progressive rainfall index used in entering the reservoir operating diagram to obtain the flood control reserve on each day.

In 8 out of the 21 seasons displayed on the plate, flood control requires a maximum depth of empty space from 50 to 52.5 feet below the full reservoir level. In the other 13 seasons, the maximum depths required range from 0 to 50 feet. In one-third of the seasons, the water level due to conservation operations is lower than required for flood control. The average actual depression of water level due to flood control is 10 feet, 3.4 per cent of the average depth of water in the reservoir at the dam. The reservoir level is depressed for flood control more than one foot, about one-quarter of the entire elapsed time of the analysis.

The water yield of the reservoir is practically* the same both with and without the inclusion of the flood control feature. A continuous draft of 200 million gallons per day can be sustained through the entire 21 years either with or without flood control except in the fall of 1924 when there is a shortage of 19.9 billion gallons with and 19.1 billion gallons without flood control, a difference* of 1.1 per cent of the annual supply.

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* It appears probable that the yield of water and power both with and without flood control would be the same were indices of snow-on-the-ground used instead of rainfall indices in constructing and applying that part of the reservoir operating diagram pertaining to snow-water floods (see page 213).

The average incidental power generated is 6640 kilowatts without flood control and 6510 kilowatts with flood control, a difference of 2 per cent. In both instances the entire amount is secondary power.

If flood control were attained by holding the maximum reserve empty throughout the flood season the inclusion of flood control would affect the yield of water and power a little more than if attained by use of the reservoir operating diagram. In the computations for this comparison, 92,000 acre-feet of capacity are held empty each year until April 21st, the close of the rain-water flood season. The reserve is then reduced to 13,000 acre-feet. This is held empty from May 11th to July 5th, the season of snow-water floods. Under this plan of operation, flood control increases the shortage in water yield in 1924, the only year of deficient supply, from 19.1 to 24.6 billion gallons, an increase of 2.8 per cent of the annual supply. A full supply is obtained in all of the other 20 years analyzed. The average power output is reduced 2.9 per cent.

The following tables present yearly summaries of all the computations of yield of the reservoir. Tables of monthly summaries, because of their volume, are placed in a separate chapter.

PARDEE RESERVOIR ON MOKELUMNE RIVER

Table of Yearly Summaries of Water and Power Yield Computed on a Daily Basis

Showing the effect of inclusion of the flood control feature.

(See Chapter VIII for corresponding monthly summaries.)

TABLE 6—With and without flood control by reservoir operating diagram.

TABLE 7—Yield compared for two methods of flood control.

TABLE 8—Summary of Tables 6 and 7.

TABLE 6. PARDEE RESERVOIR
WATER AND
BOTH
WITH AND WITHOUT FLOOD CONTROL

Yearly Summary of Computations

For corresponding monthly sum

Height of dam 345 feet.

Capacity of reservoir 222,000 acre-feet.

Year	Run-off at Clements in acre-feet	Without flood control							
		Stage of reservoir at beginning of year in acre-feet	Municipal draft in acre-feet	Power draft through turbines including water passed for prior rights in acre-feet	Evaporation in acre-feet	Waste over spillway in acre-feet	Deficiency in municipal supply in acre-feet	Average power head through period of operation in feet	Average power yield in kilowatts (Load factor=1.00)
1905	578,060	145,860	224,040	241,480	5,860	135,880	0	303	6,320
1906	1,415,400	116,660	224,040	325,760	6,400	794,280	0	307	8,650
1907	1,642,700	181,580	224,040	398,680	6,150	1,046,510	0	313	10,820
1908	455,340	148,900	224,650	236,970	5,820	10,770	0	299	6,020
1909	1,278,230	126,030	224,040	346,350	6,160	618,790	0	315	9,480
1910	788,060	208,920	224,040	279,830	5,740	355,440	0	314	7,670
1911	1,515,830	131,930	224,040	315,670	6,210	970,250	0	311	8,630
1912	410,540	131,590	224,650	169,020	5,340	10,360	0	279	3,870
1913	405,950	132,760	224,040	183,270	5,820	3,280	0	286	4,370
1914	1,075,890	122,300	224,040	302,610	6,240	541,320	0	314	8,280
1915	829 400	123,980	224,040	248,280	6,210	336,460	0	303	6,580
1916	1,049,320	138,390	224,650	303,750	6,210	508,860	0	308	8,240
1917	828,860	144,240	224,040	275,060	6,260	352,930	0	302	7,190
1918	546,170	114,810	224,040	179,270	6,220	116,680	0	293	4,680
1919	573,130	134,770	224,040	196,310	5,720	171,570	0	294	4,970
1920	506,310	110,260	224,650	159,980	5,870	64,340	0	283	3,930
1921	823,280	161,730	224,040	282,720	5,890	345,540	0	313	7,660
1922	974,010	126,820	224,040	243,190	6,300	450,540	0	301	6,390
1923	648,880	176,760	224,040	313,070	5,860	152,490	0	300	7,930
1924	206,650	130,180	166,010	140,000	1,760	0	58,640	208	2,590
1925	802,990	29,060	224,040	190,680	6,610	277,080	0	288	5,100
Total	17,355,000		4,649,250	5,331,950	122,650	7,263,370	58,640		
Average	826,430		221,390	253,900	5,840	345,870	2,790	296	6,640

ON MOKELUMNE RIVER.

POWER YIELD

BY RESERVOIR OPERATING DIAGRAM.

Carried out on a Daily Basis.

mary see Table 6a, page 300.)

Yield in municipal supply 200 million gallons daily.

Installed capacity of power plant 15,000 k.w.

Coordinated with flood control by reservoir operating diagram

Maximum controlled flow at Clements—rain-water floods, 5,300 sec.-ft; snow-water floods, 7,100 sec.-ft.
Maximum reservoir space required—rain-water floods, 92,000 ac.-ft.; snow-water floods, 13,000 ac.-ft.

Stage of reservoir at beginning of year in acre-feet	Municipal draft in acre-feet	Power draft through turbines including water passed for prior rights in acre-feet	Evaporation in acre-feet	Release through flood control outlets in acre-feet	Waste over spillway in acre-feet	Deficiency in municipal supply in acre-feet	Average power head through period of operation in feet	Average power yield in kilowatts (Load factor=1.00)	Year
145,860	224,040	241,160	5,860	111,840	26,380	0	302	6,300	1905
114,640	224,040	330,460	6,400	571,150	232,320	0	305	8,680	1906
165,670	224,040	415,450	6,150	521,260	492,570	0	305	10,820	1907
148,900	224,650	236,970	5,820	0	10,770	0	299	6,020	1908
126,030	224,040	345,820	6,160	552,980	114,450	0	304	9,010	1909
160,810	224,040	269,630	5,740	224,410	103,660	0	298	6,900	1910
121,390	224,040	339,400	6,210	730,430	205,550	0	302	8,850	1911
131,590	224,650	169,020	5,340	0	10,360	0	279	3,870	1912
132,760	224,040	183,270	5,820	0	3,280	0	286	4,370	1913
122,300	224,040	328,090	6,240	449,110	66,730	0	302	8,450	1914
123,980	224,040	230,140	6,210	333,570	21,030	0	302	6,080	1915
138,390	224,650	339,580	6,210	346,920	126,110	0	298	8,690	1916
144,240	224,040	259,550	6,260	263,350	105,090	0	302	6,790	1917
114,810	224,040	179,270	6,220	0	116,680	0	293	4,680	1918
134,770	224,040	196,310	5,720	0	171,570	0	294	4,970	1919
110,260	224,650	159,980	5,870	0	64,340	0	283	3,930	1920
161,730	224,040	280,900	5,890	293,730	55,850	0	302	7,170	1921
124,600	224,040	235,780	6,300	394,730	61,000	0	300	6,220	1922
176,760	224,040	288,000	5,860	169,370	10,520	0	297	7,250	1923
127,850	163,680	140,000	1,760	0	0	60,970	206	2,570	1924
29,060	224,040	189,850	6,610	182,850	99,770	0	286	5,040	1925
	4,646,920	5,358,630	122,650	5,145,700	2,098,030	60,970			Total
	221,280	255,170	5,840	245,030	99,910	2,900	292	6,510	Average

TABLE 7. PARDEE RESER
COMPARISON OF WATER
FOR
TWO METHODS OF

Yearly Summary of Computations
(For corresponding monthly sum

Height of dam 345 feet.

Capacity of reservoir 222,000 acre-feet.

Year	Run-off at Clements in acre-feet	Flood control by reservoir operating diagram. Maximum controlled flow at Clements—rain-water floods, 5,300 sec.-ft.; snow-water floods, 7,100 sec.-ft. Maximum reservoir space required—rain-water floods, 92,000 ac.-ft.; snow-water floods, 13,000 ac.-ft.								
		Stage of reservoir at beginning of year in acre-feet	Municipal draft in acre-feet	Power draft through turbines including water passed for prior rights in acre-feet	Evaporation in acre-feet	Release through flood control outlets in acre-feet	Waste over spillway in acre-feet	Deficiency in municipal supply in acre-feet	Average power head through period of operation in feet	Average power yield in kilowatts (Load factor=1.00)
1905	578,060	145,860	224,040	241,160	5,860	111,840	26,380	0	302	6,300
1906	1,415,400	114,640	224,040	330,460	6,400	571,150	232,320	0	305	8,680
1907	1,642,700	165,670	224,040	415,450	6,150	521,260	492,570	0	305	10,820
1908	455,340	148,900	224,650	236,970	5,820	0	10,770	0	299	6,020
1909	1,278,230	126,030	224,040	345,820	6,160	552,980	114,450	0	304	9.010
1910	788,060	160,810	224,040	269,630	5,740	224,410	103,660	0	298	6,900
1911	1,515,830	121,390	224,040	339,400	6,210	730,430	205,550	0	302	8,850
1912	410,540	131,590	224,650	169,020	5,340	0	10,360	0	279	3,870
1913	405,950	132,760	224,040	183,270	5,820	0	3,280	0	286	4,370
1914	1,075,890	122,300	224,040	328,090	6,240	449,110	66,730	0	302	8,450
1915	829,400	123,980	224,040	230,140	6,210	333,570	21,030	0	302	6,080
1916	1,049,320	138,390	224,650	339,580	6,210	346,920	126,110	0	298	8,690
1917	828,860	144,240	224 040	259,550	6,260	263,350	105,090	0	302	6,790
1918	546,170	114,810	224,040	179,270	6,220	0	116,680	0	293	4,680
1919	573,130	134,770	224,040	196,310	5,720	0	171,570	0	294	4,970
1920	506,310	110,260	224,650	159,980	5,870	0	64,340	0	283	3,930
1921	823,280	161,730	224,040	280,900	5,890	293,730	55,850	0	302	7,170
1922	974,010	124,600	224,040	235,780	6,300	394,730	61,000	0	300	6,220
1923	648,880	176,760	224,040	288,000	5,860	169,370	10,520	0	297	7,250
1924	206,650	127,850	163,680	140,000	1,760	0	0	60,970	206	2,570
1925	802,990	29,060	224,040	189.850	6,610	182,850	99,770	0	286	5,040
Total	17,355,000		4,646,920	5,358,630	122,650	5,145,700	2,098,030	60,970		
Average	826,430		221,280	255,170	5,840	245,030	99,910	2,900	292	6,510

VOIR ON MOKELUMNE RIVER.

AND POWER YIELD

FLOOD CONTROL.

Carried out on a Daily Basis.
mary, see Table 7a, page 312.)

Yield in municipal supply 200 million gallons daily.

Installed capacity of power plant 15,000 k.w.

Flood control, holding maximum reservoir space required (rain-water floods, 92,000 ac.-ft. snow-water floods, 13,000 ac.-ft.) in reserve throughout flood season
Maximum controlled flow at Clements—rain-water floods, 5,300 sec.-ft.; snow-water floods, 7,100 sec.-ft.

Stage of reservoir at beginning of year in acre-feet	Municipal draft in acre-feet	Power draft through turbines including water passed for prior rights in acre-feet	Evaporation in acre-feet	Release through flood control outlets in acre-feet	Waste over spillway in acre-feet	Deficiency in municipal supply in acre-feet	Average power head through period of operation in feet	Average power yield in kilowatts (Load factor=1.00)	Year
101,560	224,040	234,520	5,860	111,540	0	0	285	5,700	1905
103,660	224,040	352,970	6,400	657,380	148,270	0	295	8,850	1906
130,000	224,040	412,760	6,150	864,760	141,480	0	298	10,560	1907
123,510	224,650	217,880	5,820	17,460	0	0	285	5,220	1908
113,040	224,040	386,170	6,160	617,970	32,030	0	292	9,490	1909
124,900	224,040	290,070	5,740	255,830	18,370	0	290	7,090	1910
118,910	224,040	347,480	6,210	877,030	64,780	0	295	8,750	1911
115,200	224,650	169,220	5,340	17,480	0	0	267	3,700	1912
109,050	224,040	175,860	5,820	0	0	0	273	3,950	1913
109,280	224,040	331,090	6,240	504,940	0	0	294	8,200	1914
118,860	224,040	253,800	6,210	336,770	0	0	293	6,340	1915
127,440	224,650	340,750	6,210	434,230	41,730	0	292	8,450	1916
129,190	224,040	262,890	6,260	350,310	6,030	0	293	6,580	1917
108,520	224,040	189,640	6,220	113,300	0	0	284	4,730	1918
121,490	224,040	193,870	5,720	134,780	38,960	0	286	4,760	1919
97,250	224,650	177,420	5,870	65,620	0	0	274	4,230	1920
130,000	224,040	301,710	5,890	307,810	0	0	292	7,440	1921
113,830	224,040	256,700	6,300	444,980	25,820	0	291	6,420	1922
130,000	224,040	299,750	5,860	136,040	0	0	282	7,010	1923
113,190	149,020	140,000	1,760	0	0	75,630	198	2,450	1924
29,060	224,040	214,330	6,610	248,080	18,280	0	279	5,420	1925
	4,632,260	5,548,880	122,650	6,496,310	535,750	75,630			Total
	220,580	264,230	5,840	309,350	25,510	3,600	283	6,450	Average

TABLE 8. PARDEE RESERVOIR ON MOKELUMNE RIVER.

SUMMARY OF WATER AND POWER YIELD BY YEARS BOTH WITH AND WITHOUT FLOOD CONTROL.

Summary of Tables 6 and 7.

(For corresponding monthly summary, see Table 8a, page 324.)

Height of dam 345 feet. Yield in municipal supply 200 million gallons daily.

Capacity of reservoir 222,000 ac.-ft. Installed capacity of power plant 15,000 k.w.

Year	Without flood contro			Coordinated with flood control by reservoir operating diagram Maximum controlled flow at Clements—rain-water floods, 5,300 sec.-ft.; snow-water floods, 7,100 sec.-ft. Maximum reservoir space required—rain-water floods 92,000 ac.-ft.; snow-water floods, 13,000 ac.-ft.			Flood control, holding maximum reservoir space required (rain-water floods, 92,000 ac.-ft.; snow-water floods, 13,000 ac.-ft.) in reserve throughout flood season Maximum controlled flow at Clements—rain-water floods, 5,300 sec.-ft.; snow-water floods, 7,100 sec.-ft.		
	Municipal draft in acre-feet	Deficiency in municipal supply in acre-feet	Average power yield in kilowatts (Load factor=1.00)	Municipal draft in acre-feet	Deficiency in municipal supply in acre-feet	Average power yield in kilowatts (Load factor=1.00)	Municipal draft in acre-feet	Deficiency in municipal supply in acre-feet	Average power yield in kilowatts (Load factor=1.00)
1905	224,040	0	6,320	224,040	0	6,300	224,040	0	5,700
1906	224,040	0	8,650	224,040	0	8,680	224,040	0	8,850
1907	224,040	0	10,820	224,040	0	10,820	224,040	0	10,560
1908	224,650	0	6,020	224,650	0	6,020	224,650	0	5,220
1909	224,040	0	9,480	224,040	0	9,010	224,040	0	9,490
1910	224,040	0	7,670	224,040	0	6,900	224,040	0	7,090
1911	224,040	0	8,630	224,040	0	8,850	224,040	0	8,750
1912	224,650	0	3,870	224,650	0	3,870	224,650	0	3,700
1913	224,040	0	4,370	224,040	0	4,370	224,040	0	3,950
1914	224,040	0	8,280	224,040	0	8,450	224,040	0	8,200
1915	224,040	0	6,580	224,040	0	6,080	224,040	0	6,340
1916	224,650	0	8,240	224,650	0	8,690	224,650	0	8,450
1917	224,040	0	7,190	224,040	0	6,790	224,040	0	6,580
1918	224,040	0	4,680	224,040	0	4,680	224,040	0	4,730
1919	224,040	0	4,970	224,040	0	4,970	224,040	0	4,760
1920	224,650	0	3,930	224,650	0	3,930	224,650	0	4,230
1921	224,040	0	7,660	224,040	0	7,170	224,040	0	7,440
1922	224,040	0	6,390	224,040	0	6,220	244,040	0	6,420
1923	224,040	0	7,930	224,040	0	7,250	224,040	0	7,010
1924	166,010	58,640	2,590	163,680	60,970	2,570	149,020	75,630	2,450
1925	224,040	0	5,100	224,040	0	5,040	224,040	0	5,420
Total	4,649,250	58,640		4,646,920	60,970		4,632,260	75,630	
Average	221,390	2,790	6,640	221,280	2,900	6,510	220,580	3,600	6,450

Temperance Flat Reservoir on San Joaquin River.

Among the reservoirs of the "Coordinated Plan,"* for developing the State's waters is one on the San Joaquin River, six miles upstream from Friant. It is proposed that a dam 595 feet high be constructed at this point. This would create a reservoir of 1,071,000 acre-feet capacity, sufficiently large to equalize seven-eighths of the mean annual run-off of the San Joaquin River for irrigation use and generate on an average 62,000 kilowatts of incidental power at a plant erected near the base of the dam. The installed capacity of the plant would be 220,000 k.v.a. Also, large floods would be controlled to about one-

* See Bul. No. 12, "Summary Report on the Water Resources of California and a Coordinated Plan for their Development," Division of Engineering and Irrigation, State Department of Public Works.

quarter of their natural size. A full description of this unit of the "Coordinated Plan," together with estimates of the water and power yield without flood control is contained in Bulletin No. 16, "The Coordinated Plan of Water Development in the San Joaquin Valley." The effect of including the flood control feature of the plan is described in the following pages.

The rule for operating the Temperance Flat Reservoir for flood control has been developed in the previous chapters of this volume. It is expressed on Plate XX, "Reservoir Operating Diagram for Controlling Floods on the San Joaquin River" (p. 84). It would limit rain-water floods, including the maximum of record, to 10,700 second-feet and snow-water floods to 14,200 second-feet. The maximum rain-water flood of record had a mean daily flow of 38,800 second-feet. It occurred on Jan. 31, 1911. The maximum snow-water flood discharged 23,100 second-feet and occurred on June 13, 1911. The reduction in flood flows obtained through the use of this reservoir operating diagram requires a reservation at times of a maximum space of 177,000 acre-feet, one-sixth of the total capacity of the reservoir.

The effect of including this flood control feature upon the reservoir stage and upon the yield of water and power is derived from a comparison of the yield computed both with and without flood control. In order that this might be an exact comparison, both sets of computations are carried out on a daily basis to conform to the requirements of the reservoir operating diagram which calls for daily adjustment of reservoir level during the flood season. The parallel sets of computations are made in exactly the same way except for the exclusion of the flood control feature in one set. They are carried out similarly to the computations of yield described in Bulletin No. 16, except that they are made on a daily instead of the usual monthly basis, include only the 18 years of continuous stream flow record and make no deduction for the 108 square miles of drainage area between the Friant gaging station and the dam site.* The stream flow data used are those published in the Water Supply Papers of the United States Geological Survey for the Friant gaging station together with those in preparation for publication. The assumptions of the computations are listed on page 331.

The effect of inclusion of the flood control feature upon reservoir stage is delineated on Plate XXV, "Effect of Controlling San Joaquin River Floods upon Stage of Temperance Flat Reservoir." Here the reservoir stage is shown day by day from 1908 to 1926, the period of continuous measurement of flow in the San Joaquin River. It is assumed for constructing this plate that the reservoir was in existence in 1907 and operated through the succeeding years as proposed in the "Coordinated Plan," first excluding and then including the flood control feature. The volume of water in storage throughout the 18-year period is shown on each day by the vertical position on the reservoir stage scale of lines extending across the plate in several rows. To the scale of the plate, each space between horizontal guide lines equals 100,000 acre-feet. The top guide line of each row represents a full reservoir and the bottom line an empty reservoir.

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* The water and power yield published in Bul. No. 16 is an estimate made on a monthly basis covering the 54-year period 1871–1925. It makes a deduction of 1.5 per cent from the measured flow at Friant for the area between the gaging station and the dam site. For this reason the estimates in Bul. No. 16 are not exactly comparable with the ones contained in this volume.

The reservoir stage operating with the flood control feature excluded is indicated by the heavy black line extending across each row. The departure from this stage caused by the inclusion of the flood control feature is shown by a heavy red line. A light red line indicates the reservoir stage were it operated for flood control alone in accord with the diagram. Red figures translate into feet depth from full reservoir level, the greatest draw down required by flood control in each season. Below the reservoir stage lines in each row is shown in a light black line to a special scale superimposed on the reservoir stage scale, the uncontrolled flow of the river at Friant and in a light red line the controlled flow downstream from the dam when the "Coordinated Plan" with its flood control feature is in operation. A line of black dots shows the daily values of the progressive rainfall index used in entering the reservoir operating diagram to obtain the necessary flood control reserve.

It is observed in reviewing Plate XXV that in 12 of the 18 seasons analyzed, the reservoir stage resulting from operation for conservation is less than that required for flood control. In these seasons the inclusion of the flood control feature does not affect the reservoir stage at all. In the other six seasons at times, the drawdown from a full reservoir level reaches a maximum of 35 feet, 6 per cent of the depth of a full reservoir at the dam. The average actual depression of the water level due to flood control is 17 feet, 3.5 per cent of the average depth of water in the reservoir at the dam. The reservoir level is depressed by reason of the inclusion of the flood control feature, one-quarter of the entire elapsed time of the analyses.

The effect of the inclusion of the flood control feature in the "Coordinated Plan" upon the water and power yield of the Temperance Flat reservoir is shown by the accompanying summary tabulations of the computations of yield with and without flood control carried out on a daily basis in order to accommodate the requirements of the reservoir operating diagram. Monthly and yearly summaries are prepared of these computations. The yearly summaries follow herewith but the monthly summaries, because of their volume, are placed in a separate chapter.

These data show that the inclusion of the flood control feature has no effect at all upon the water yield of the reservoir and very little effect* upon the power generated. With flood control the average power output is 61,400 kilowatts and without flood control 62,000 kilowatts, a difference of 1.0 per cent. All is secondary power in both instances.

If flood control were attained by holding the maximum reserve empty throughout the flood season instead of by use of the reservoir operating diagram, the inclusion of flood control would have a small effect on the water as well as on the power yield. In the computations for this comparison, 133,000 acre-feet of capacity are held empty each year until April 7th, the close of the rain-water flood season. The reserve is then increased to 177,000 acre-feet which is held empty from April 27th to July 16th, the season of snow-water floods. For these conditions, the average yield of irrigation water is reduced 1.0 per cent, the reductions occurring in the seasons of short supply, and the average power output is reduced 6.0 per cent.

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* It appears probable that the power yield would be almost identical both with and without flood control were indices of snow-on-the-ground used instead of rainfall indices in constructing and applying that part of the reservoir operating diagram pertaining to snow-water floods (see p. 213).

EFFECT OF CONTROLLING SAN JOAQUIN RIVER FLOODS
UPON
STAGE OF TEMPERANCE FLAT RESERVOIR
IF OPERATED PRIMARILY FOR IRRIGATION

MAXIMUM CONTROLLED FLOW AT FRIANT
RAIN WATER FLOODS 10,700 SEC. FT.
SNOW WATER FLOODS 14,200 SEC. FT.

MAXIMUM FLOOD OF RECORD 38,800 SEC. FT.
RESERVOIR CAPACITY 1,071,000 AC. FT.
HEIGHT OF DAM 595 FT.

TEMPERANCE FLAT RESERVOIR ON SAN JOAQUIN RIVER.

Table of Yearly Summaries of Water and Power Yield Computed on a Daily Basis.

Showing the effect of inclusion of the flood control feature of the "Coordinated Plan." (See Chapter VIII for corresponding monthly summaries.)

TABLE 9—With and without flood control by reservoir operating diagram.

TABLE 10—Yield compared for two methods of flood control.

TABLE 11—Summary of Tables 9 and 10.

TABLE 9. TEMPERANCE FLAT RESER
WATER AND
BOTH
WITH AND WITHOUT FLOOD CONTROL

Yearly Summary of Computations

(For corresponding monthly sum

Height of dam 595 feet.

Capacity of reservoir 1,071,000 acre-feet.

Year	Run-off at Friant in acre-feet	Without flood control							
		Stage of reservoir at beginning of year in acre-feet	Irrigation draft in acre-feet (no deduction for down-stream prior rights)	Evaporation in acre-feet	Power draft through turbines in acre-feet	Waste over spillway in acre-feet	Deficiency in irrigation supply in acre-feet	Average power head through period of operation in feet	Average power yield in kilowatts (Load factor=1.00)
1908	1,115,000	797,100	1,800,000	13,700	1,699,100	0	0	488	73,800
1909	3,136,700	98,400	1,800,000	18,400	1,811,400	568,600	0	510	85,800
1910	1,825,500	836,700	1,800,000	18,500	1,876,600	347,300	0	538	91,100
1911	3,562,200	419,800	1,800,000	20,100	1,831,700	1,416,500	0	556	91,900
1912	1,023,700	713,700	1,686,900	10,200	1,510,300	0	113,100	454	60,900
1913	874,100	40,300	863,300	100	0	0	936,700	0	0
1914	2,905,300	51,000	1,800,000	18,900	1,811,600	361,100	0	514	86,600
1915	1,954,600	764,700	1,800,000	19,200	1,808,300	250,400	0	540	88,700
1916	2,827,000	641,400	1,800,000	20,200	1,868,800	849,600	0	557	93,500
1917	1,860,100	729,800	1,800,000	18,900	1,804,700	176,900	0	537	88,100
1918	1,596,500	589,400	1,800,000	14,600	1,800,000	0	0	466	77,700
1919	1,191,400	371,300	1,505,700	8,300	1,302,600	0	294,300	416	49,200
1920	1,362,000	48,700	1,320,700	2,400	420,900	0	479,300	329	12,300
1921	1,580,300	87,600	1,576,000	5,600	1,361,500	0	224,000	344	42,700
1922	2,376,800	86,300	1,800,000	15,000	1,652,700	0	0	443	69,300
1923	1,604,900	648,100	1,800,000	16,400	1,800,000	0	0	500	82,900
1924	466,100	436,600	844,300	1,900	536,400	0	955,700	394	17,800
1925	1,413,400	56,500	1,387,600	2,600	111,400	0	412,400	298	2,900
Total	32,675,600		28,984,500	225,000	25,008,000	3,970,400	3,415,500		
Average	1,815,300		1,610,300	12,500	1,389,300	220,600	189,700	490	62,000

VOIR ON SAN JOAQUIN RIVER

POWER YIELD

BY RESERVOIR OPERATING DIAGRAM.

Carried out on a Daily Basis.

mary, see Table 9a, page 332.)

Seasonal irrigation yield 1,800,000 acre-feet. (Supplemented by ground water supply in years of deficiency. No deduction for downstream prior rights).

Installed capacity of power plant 220,000 k.v.a. P.F.0.80.

Coordinated with flood control by reservoir operating diagram. Maximum controlled flow at Friant—rain-water floods, 10,700 sec.-ft; snow-water floods, 14,200 sec.-ft. Maximum space required for flood control—rain-water floods, 133,000 ac.-ft; snow-water floods, 177,000 ac-ft.									
Stage of reservoir at beginning of year in acre-feet	Irrigation draft in acre-feet (no deduction for down-stream prior rights)	Evaporation in acre-feet	Power draft through turbines in acre-feet	Release through flood control outlets in acre-feet	Waste over spillway in acre-feet	Deficiency in irrigation supply in acre-feet	Average power head through period of operation in feet	Average power yield in kilowatts (Load factor= 1.00)	Year
797,100	1,800,000	13,700	1,699,100	0	0	0	488	73,800	1908
98,400	1,800 000	17,800	1,820,300	605,900	0	0	503	85,100	1909
791,100	1,800,000	16,500	1,868,200	401,300	66,500	0	506	86,200	1910
264,100	1,800,000	19,500	1,842,400	1,176,100	74,600	0	542	91,000	1911
713,700	1,686,900	10,200	1,510,300	0	0	113,100	454	60,900	1912
40,300	863,300	100	0	0	0	936,700	0	0	1913
51,000	1,800,000	18,600	1,821,400	357,900	0	0	510	86,400	1914
758,400	1,800,000	18,600	1,819,600	287,700	0	0	530	87,800	1915
587,100	1,800,000	19,400	1,838,500	644,200	232,200	0	544	90,300	1916
679,800	1,800,000	18,600	1,805,100	57,600	69,200	0	532	87,500	1917
589,400	1,800,000	14,600	1,800,000	0	0	0	466	77,700	1918
371,300	1,505,700	8,300	1,302,600	0	0	294,300	416	49,200	1919
48,700	1,320,700	2,400	420,900	0	0	479,300	329	12,300	1920
87,600	1,576,000	5,600	1,361,500	0	0	224,000	344	42,700	1921
86,300	1,800,000	15,000	1,652,700	0	0	0	443	69,300	1922
648,100	1,800,000	16,400	1,800,000	0	0	0	500	82,900	1923
436,600	844,300	1,900	536,400	0	0	955,700	394	17,800	1924
56,500	1,387,600	2,600	111,400	0	0	412,400	298	2,900	1925
	28,984,500	219,800	25,010,400	3,530,700	442,500	3,415,500			Total
	1,610,300	12,200	1,389,500	196,100	24,600	189,700	484	61,400	Average

TABLE 10. TEMPERANCE FLAT RESER
COMPARISON OF WATER
FOR
TWO METHODS OF

Yearly Summary of Computations
(For corresponding monthly sum

Height of dam 595 feet.

Capacity of reservoir 1,071,000 acre-feet.

Year	Run-off at Friant in acre-feet	Flood control by reservoir operating diagram Maximum controlled flow at Friant—rain-water floods, 10,700 sec.-ft.; snow-water floods, 14,200 sec.-ft. Maximum reservoir space required—rain-water floods, 133,000 ac.-ft.; snow-water floods, 177,000 ac.-ft.								
		Stage of reservoir at beginning of year in acre-feet	Irrigation draft in acre-feet (no deduction for down-stream prior rights)	Evaporation in acre-feet	Power draft through turbines in acre-feet	Release through flood control outlets in acre-feet	Waste over spillway in acre-feet	Deficiency in irrigation supply in acre-feet	Average power head through period of operation in feet	Average power yield in kilowatts (Load factor=1.00)
1908	1,115,000	797,100	1,800,000	13,700	1,699,100	0	0	0	488	73,800
1909	3,136,700	98,400	1,800,000	17,800	1,820,300	605,900	0	0	503	85,100
1910	1,825,500	791,100	1,800,000	16,500	1,868,200	401,300	66,500	0	506	86,200
1911	3,562,200	264,100	1,800,000	19,500	1,842,400	1,176,100	74,600	0	542	91,000
1912	1,023,700	713,700	1,686,900	10,200	1,510,300	0	0	113,100	454	60,900
1913	874,100	40,300	863,300	100	0	0	0	936,700	0	0
1914	2,905,300	51,000	1,800,000	18,600	1,821,400	357,900	0	0	510	86,400
1915	1,954,600	758,400	1,800,000	18,600	1,819,600	287,700	0	0	530	87,800
1916	2,827,000	587,100	1,800,000	19,400	1,838,500	644,200	232,200	0	544	90,300
1917	1,860,100	679,800	1,800,000	18,600	1,805,100	57,600	69,200	0	532	87,500
1918	1,596,500	589,400	1,800,000	14,600	1,800,000	0	0	0	466	77,700
1919	1,191,400	371,300	1,505,700	8,300	1,302,600	0	0	294,300	416	49,200
1920	1,362,000	48,700	1,320,700	2,400	420,900	0	0	479,300	329	12,300
1921	1,580,300	87,600	1,576,000	5,600	1,361,500	0	0	224,000	344	42,700
1922	2,376,800	86,300	1,800,000	15,000	1,652,700	0	0	0	443	69,300
1923	1,604,900	648,100	1,800,000	16,400	1,800,000	0	0	0	500	82,900
1924	466,100	436,600	844,300	1,900	536,400	0	0	955,700	394	17,800
1925	1,413,400	56,500	1,387,600	2,600	111,400	0	0	412,400	298	2,900
Total	32,675,600		28,984,500	219,800	25,010,400	3,530,700	442,500	3,415,500		
Average	1,815,300		1,610,300	12,200	1,389,500	196,100	24,600	189,700	484	61,400

VOIR ON SAN JOAQUIN RIVER.
AND POWER YIELD

FLOOD CONTROL

Carried out on a Daily Basis.
mary, see Table 10a, page 342.)

Seasonal irrigation yield 1,800,000 acre-feet. (Supplemented by ground water supply in years of deficiency. No deduction for downstream prior rights).

Installed capacity of power plant 220,000 k.v.a. P.F. = 0.80.

Flood control, holding maximum reservoir space required (rain-water floods 133,000 ac.-ft., snow-water floods 177,000 ac.-ft.) in reserve throughout flood season
Maximum controlled flow at Friant—rain-water floods, 10,700 sec.-ft; snow-water floods, 14,200 sec.-ft.

Stage of reservoir at beginning of year in acre-feet	Irrigation draft in acre-feet (no deduction for down-stream prior rights)	Evaporation in acre-feet	Power draft through turbines in acre-feet	Release through flood control outlets in acre-feet	Waste over spillway in acre-feet	Deficiency in irrigation supply in acre-feet	Average power head through period of operation in feet	Average power yield in kilowatts (Load factor= 1.00)	Year
797,100	1,800,000	13,700	1,699,100	0	0	0	488	73,800	1908
98,400	1,800,000	16,500	1,833,000	724,500	0	0	488	83,700	1909
661,100	1,800,000	16,000	1,848,200	377,500	0	0	496	83,900	1910
244,900	1,800,000	19,300	1,847,100	1,237,600	0	0	536	90,600	1911
703,100	1,676,500	10,000	1,494,600	0	0	123,500	454	59,900	1912
40,300	863,300	100	0	0	0	936,700	0	0	1913
51,000	1,800,000	17,500	1,832,100	497,400	0	0	495	85,000	1914
609,300	1,800,000	16,700	1,823,000	258,400	0	0	503	84,600	1915
465.800	1,800,000	18,000	1,862,900	852,100	4,200	0	522	89,000	1916
555,600	1,800,000	16,500	1,815,900	169,500	0	0	498	83,700	1917
413,800	1,800,000	11,300	1,662,100	0	0	0	423	64,600	1918
199,000	1,336,800	4,900	1,100,500	0	0	463,200	357	35,500	1919
48,700	1,320,700	2,400	420,900	0	0	479,300	329	12,300	1920
87.600	1,576,000	5,600	1,361,500	0	0	224,000	344	42,700	1921
86,300	1,800,000	13,800	1,664,900	91,400	0	0	431	68,200	1922
545,700	1,800,000	14,900	1,800,000	0	0	0	473	79,000	1923
335,700	744,200	1,100	313,900	0	0	1,055,800	378	10,100	1924
56,500	1,387,600	2,600	111,400	0	0	412,400	298	2,900	1925
	28,705,100	200,900	24,491,100	4,208,400	4,200	3,694,900			Total
	1,594,700	11,200	1.360,600	233,800	200	205,300	467	58,300	Average

TABLE 11. TEMPERANCE FLAT RESERVOIR ON SAN JOAQUIN RIVER.

SUMMARY OF WATER AND POWER YIELD BY YEARS BOTH WITH AND WITHOUT FLOOD CONTROL.

Summary of Tables 9 and 10.

(For corresponding monthly summary, see Table 11a, page 352.)

Height of dam 595 feet. Capacity of reservoir 1,071,000 acre-feet.

Seasonal irrigation yield, 1,800,000 acre-feet. (Supplemented by ground water supply in years of deficiency. No deduction for downstream prior rights).

Installed capacity of power plant 220,000 k.v.a. P.F. = 0.80.

Year	Without flood contro			Coordinated with flood control by reservoir operating diagram Maximum controlled flow at Friant—rain-water floods, 10,700 sec.-ft.; snow-water floods, 14,200 sec.-ft. Maximum reservoir space required—rain-water floods, 133,000 ac.-ft.; snow-water floods, 177,000 ac.-ft.			Flood control, holding maximum reservoir space required (rain-water floods, 133,000 ac.-ft.; snow-water floods, 177,000 ac.-ft.) in reserve throughout flood season Maximum controlled flow at Friant—rain-water floods, 10,700 sec.-ft.; snow-water floods, 14,200 sec.-ft.		
	Irrigation draft in acre-feet (no deduction for down-stream prior rights)	Deficiency in irrigation supply in acre-feet	Average power yield in kilowatts (Load factor= 1.00)	Irrigation draft in acre-feet (no deduction for down-stream prior rights)	Deficiency in irrigation supply in acre-feet	Average power yield in kilowatts (Load factor= 1.00)	Irrigation draft in acre-feet (no deduction for down-stream prior rights)	Deficiency in irrigation supply in acre-feet	Average power yield in kilowatts (Load factor= 1.00)
1908	1,800,000	0	73,800	1,800,000	0	73,800	1,800,000	0	73,800
1909	1,800,000	0	85,800	1,800,000	0	85,100	1,800,000	0	83,700
1910	1,800,000	0	91,100	1,800,000	0	86,200	1,800,000	0	83,900
1911	1,800,000	0	91,900	1,800,000	0	91,000	1,800,000	0	90,600
1912	1,686,900	113,100	60,900	1,686,900	113,100	60,900	1,676,500	123,500	59,900
1913	863,300	936,700	0	863,300	936,700	0	863,300	936,700	0
1914	1,800,000	0	86,600	1,800,000	0	86,400	1,800,000	0	85,000
1915	1,800,000	0	88,700	1,800,000	0	87,800	1,800,000	0	84,600
1916	1,800,000	0	93,500	1,800,000	0	90,300	1,800,000	0	89,000
1917	1,800,000	0	88,100	1,300,000	0	87,500	1,800,000	0	83,700
1918	1,800,000	0	77,700	1,800,000	0	77,700	1,800,000	0	64,600
1919	1,505,700	294,300	49,200	1,505,700	294,300	49,200	1,336,800	463.200	35,500
1920	1,320,700	479,300	12,300	1,320,700	479,300	12,300	1,320,700	479,300	12,300
1921	1,576,000	224,000	42,700	1,576,000	224,000	42,700	1,576,000	224,000	42,700
1922	1,800,000	0	69,300	1,800,000	0	69,300	1,800,000	0	68,200
1923	1,800,000	0	82,900	1,800,000	0	82,900	1,800,000	0	79,000
1924	844,300	955,700	17,800	844,300	955,700	17,800	744,200	1,055,800	10,100
1925	1,387,600	412,400	2,900	1,387,600	412,400	2,900	1,387,600	412,400	2,900
Total	28,984,500	3,415,500		28,984,500	3,415,500		28,705,100	3,694.900	
Average	1,610,300	189,700	62,000	1,610,300	189,700	61,400	1,594,700	205,300	58,300

San Gabriel Reservoir on the San Gabriel River.

The "Coordinated Plan" * in southern California contemplates the construction of reservoirs on all streams of suitable terrain for joint operation in controlling floods and conserving water now unused. It provides on each stream, to the extent desirable and to the extent that physical conditions permit, for the coordination of flood control with irrigation and municipal supply through both surface and underground storage. It proposes, wherever possible, that flood control be coordi-

* See Bul. No. 12, "Summary Report on the Water Resources of California and a Coordinated Plan for their Development," Division of Engineering and Irrigation, State Department of Public Works.

nated with the charging of the underground basins, from which such a large part of local supplies are obtained, with practically the entire unused seasonal run-off. The irregularly occurring flood waters would be reduced by surface reservoirs to flows of a workable size for introducing into the subterranean basins but the principal storage of water for equalizing the intermittent run-off would be in the large natural underground basins on the lower reaches of the streams wherever they are available. In their natural state, flood waters rush down the channels in volumes too large for complete absorption by the underground basins even with extensive spreading works. By reducing these flood flows through reservoir control, practically their entire volume may be introduced into the underground basins either through absorption by the natural stream channels or by artificially prepared spreading works. This water may then be pumped from wells penetrating the subterranean basins at such times and for such purposes as necessity demands. It is available for useful purposes in the same way that most of the local supplies in southern California are now obtained. In some instances, it may be a matter of economy to take part of the additional water made available through the construction of surface storage, directly from the reservoir without incurring the expense of sinking it underground and pumping it out again. Reservoir operation under the "Coordinated Plan," therefore involves all or in part, the control of floods, the temporary storage of flood water to be released later at a convenient time and rate for sinking underground, and the equalization of some of the run-off between seasons for an independent surface supply. A description of this plan for southern California is contained in Bulletin No. 17, "The Coordinated Plan of Water Development in Southern California."

The method devised by the "Coordinated Plan" for operating surface reservoirs in southern California in order to secure the greatest use of their capacity for both flood control and conservation is illustrated in the following pages. The San Gabriel River is employed for this purpose through the exemplary use of the San Gabriel reservoir. This river, in having the longest record * of daily flow, is found to be the most favorable of large southern California streams for an analysis of the characteristics of flood flow and is so used in the previous chapters. The San Gabriel reservoir extends up the east and west branches of the San Gabriel River from its dam site which is immediately below the forks and eight miles up the canyon from the edge of the valley floor. The reservoir is proposed for construction by the Los Angeles County Flood Control District. Since, at the time of preparing this text, the desirable capacity for this reservoir is still under discussion, two capacities are employed in the illustrations, one 180,000 and the other 240,000 acre-feet. These correspond to dam heights of 383 and 425 feet, respectively.

Capacity as large as these is not necessary for flood protection alone. The removal of the flood menace requires only that flow be limited to an amount that will pass down the river channel without endangering life or inflicting serious property damage. Flows exceeding 10,000

* The Santa Ana has a record almost as long as the San Gabriel River, but part for the 1916 flood is missing. This makes it less suitable for the purpose at hand than the San Gabriel River since 1916 is the largest flood year of the period of measurement.

second-feet * have passed to the ocean without serious difficulty within the last several years. Exclusive of space that should be provided for the accumulation of silt and debris, the limitation of floods to 10,000 second-feet requires only 75,000 acre-feet of reservoir capacity. Similarly, 52,000 acre-feet is sufficient to limit flood flows to 15,000 second-feet (see p. 61). Capacity in excess of these amounts, employed for limiting floods to more convenient sizes, is essentially useful in conserving water that would otherwise waste into the ocean. It makes possible the sinking of greater portions of the total run-off into the underground basins than could be done with flows as large as 10,000 or 15,000 second-feet. The illustrations herein, limit flows to 1900 second-feet, an amount that, it is believed, can be sunk conveniently into the large subterranean basin underlying the San Gabriel Valley.

A rule for operating a reservoir on the San Gabriel River that will limit floods to 1900 second-feet, is developed in the previous chapters of this volume. It is expressed on Plate XXI, "Reservoir Operating Diagram for Controlling Floods on the San Gabriel River," p. 88. It would limit floods at Azusa, including the maximum of record, to 1900 second-feet. The maximum flood of record on the San Gabriel River occurred on January 18, 1916, and discharged 40,000 second-feet. To limit this and even larger floods to 1900 second-feet, requires the reservation at times of a maximum space for flood control of 131,000 acre-feet.

The use of the operating diagram on Plate XXI for controlling floods by a reservoir as far upstream as the San Gabriel, slightly exceeds the technical limits of its application. If the technical limitations were strictly adhered to, not more than half the 16 square miles of drainage area below the San Gabriel reservoir but tributary to the Azusa gaging station, should remain uncontrolled since this area may produce floods at long intervals about double the desired regulated flow of 1900 second-feet. However, the only consequence of applying the diagram to the San Gabriel reservoir is that the desired maximum flow of 1900 second-feet at Azusa will be exceeded at average intervals of several decades by the uncontrolled run-off originating downstream from the dam. The probable limit in the rate of flow at Azusa would be about double the desired quantity, but several centuries may elapse between flows approaching such magnitude. At times of excess flow at Azusa the gates at the dam would be closed if operated in accord with the reservoir operating diagram. The excess flow would all originate downstream from the reservoir.

In using the reservoir operating diagram of Plate XXI for limiting the maximum flow to 1900 second-feet, only 131,000 acre-feet of the total capacity of the San Gabriel reservoir need be employed for this purpose. A diagram could be constructed that would employ a greater capacity and regulate the flow to less than 1900 second-feet, however, if applied to the San Gabriel reservoir, the desired regulated flow, if made much less than 1900 second-feet, would be exceeded rather frequently by the run-off from the drainage area downstream from the dam. If the maximum flood control reserve were increased, say to 160,000 acre-feet, the flow might be limited to 1000 second-feet at Azusa except at the times the drainage area between the dam site and

* The crest discharge at Azusa was 8,680 second-feet on March 7, 1918, 22,300 second-feet on December 19, 1921, and 11,600 second-feet on February 9, 1922.

Azusa produces a greater amount. This might occur every few years but the accumulated duration of flows in excess of 1000 second-feet would be reduced and less effort would be required in sinking the water into the underground basin. However, since it is believed that flows approximating 1900 second-feet may be made to percolate into the underground basin at a cost small in comparison with that of 29,000 acre-feet of additional reservoir capacity, 1900 second-feet was selected as a suitable regulated flow for illustrating the principles of coordinating flood control and conservation in the same reservoir.

The reservoir operating diagram, in addition to securing the control of floods through the reservation of adequate space at all times for temporarily detaining excess flow that might occur under the circumstances then existing, accomplishes the storage of water in amounts varying with the season. Through holding in reserve only the space required for the control of floods that may occur under existing circumstances and releasing this reserve immediately as the possibility of its need for flood control has passed, run-off may be stored in the part of the maximum flood control reserve not required at that time for flood control. In this way during many seasons, considerable volumes of stored water are accumulated without the use of reservoir space other than that included in the maximum flood control reserve, and this is done without jeopardizing the certainty of the control effected. The water so stored may be drawn from the reservoir at whatever rate and time desired during the season of its detention. Should it be held into the next flood season, it is subject to release as flood control water if the space occupied by it is needed in the flood control reserve.

Where the reservoir capacity exceeds the maximum flood control reserve required by the diagram, as in the illustrations herewith, the excess capacity may be employed either for the seasonal or over-year storage of water. If employed for seasonal storage, its yield will be of the same character as the water stored seasonally in the unused part of the maximum flood control reserve and will augment the quantity of stored water available in irregular amounts from season to season. If employed for over-year storage, its yield may be drawn from the reservoir in uniform amounts through all seasons and so constitute an independent surface supply that does not require auxiliary sources during seasons of deficient run-off. Thus the yield of reservoirs under the "Coordinated Plan" may be divided into three parts, namely, the variable flow of limited size that occurs during the winter and spring months as a result of the flood control operations, the seasonally stored water that may be drawn from the reservoir at any desired rate and time during the summer and fall of the year of its detention, and the flow equalized between seasons that may be drawn off at a uniform rate year in and year out. The yield of the first class, in passing down the channel in flows of limited size but at the time of natural run-off, is controlled in volume of flow only, while that of the second and third class, in being stored water, is controlled both in time and volume. The yield of all three classes is useful. The first, arriving in the winter and spring in flows of limited size, may be sunk underground as it occurs. The second, in being stored water, may be drawn from the reservoir as convenient either for sinking underground or for supplementing surface supplies. It being of irregular amount from season to season and in some seasons there being none at all, the yield of the second class can not become an independent source of supply without further equalization in an underground basin. The yield of the third class, in being equalized between seasons, may constitute an independent surface supply.

These three classes into which the yield may be divided, together with the water passed for prior rights and evaporated from the reservoir surface, include the entire surface run-off of the stream. Reservoir capacity just equal to the required maximum flood control reserve will convert the entire mean seasonal run-off into yield of the first two classes. Capacity in addition to this either changes part of the yield of the first class to yield of the second class or from the first two classes to the third, according as the space in excess of the maximum flood control reserve is employed for seasonal or over-year storage. On streams having a large subterranean basin on their lower courses, the total useful yield of a reservoir can not be increased by enlarging the capacity to an amount exceeding the maximum flood control reserve required to control flows to a size that may be completely sunk into the underground basin. The function of additional reservoir capacity is limited to making the water available more conveniently either in smaller flows or at special times of the year.

Analyses were made of the 30 years of stream flow record on the San Gabriel River to determine the yield of the San Gabriel reservoir under several modes of operation. In these tests it is assumed that the reservoir was in existence at the beginning of the period and was operated through the succeeding 30 years as described in the several instances. The destruction of reservoir capacity by the accumulation of silt and debris is neglected and the first 152 second-feet of natural flow are passed for prior rights. The water passed for prior rights in all modes of reservoir operation and for all reservoir capacities constitutes 40.5 per cent of the total surface run-off of the period of analysis.

The application of the reservoir operating diagram herein described to the daily flows throughout the 30-year period of record, results in the average yield on the part of the maximum flood control reserve which is the first 131,000 acre-feet of capacity, of 37,100 acre-feet per season during the winter and spring months in flows controlled to less than 1900 second-feet and of 36,700 acre-feet per season in seasonally stored water that may be drawn from the reservoir as desired within the year of its detention. These yields are 29.6 and 29.2 per cent respectively of the average run-off for the period. Some water is stored in 27 of the 30 seasons analyzed but in no season is the entire 131,000 acre-feet filled. The nearest to filling is in 1907 when 110,300 acre-feet are held in storage. This reservoired water, in being stored with facilities required to secure the desired limit to flood flows of 1900 second-feet, is held without extra expense. Together with the winter and spring controlled flows resulting from flood regulation, it constitutes the entire run-off from the San Gabriel watershed tributary to Azusa, with the exception of the water passed for prior rights and evaporated from the reservoir surface.

With a capacity of 180,000 acre-feet, the space in excess of the maximum flood control reserve (131,000 acre-feet), if employed for seasonal storage in conjunction with flood control, would convert 17,400 acre-feet of the average winter and spring yield in controlled flows of the maximum flood control reserve, into 17,100 acre-feet of seasonally stored water. On an average about 300 acre-feet per season would be lost by evaporation in doing this. Similarly, with a capacity of 240,000 acre-feet, the space in excess of the maximum flood control reserve (131,000 acre-feet) would convert 28,800 acre-feet of the average winter and spring yield in controlled flows of the maximum flood control reserve, into 28,400 acre-feet of seasonally stored water. About 400 acre-feet per season would be lost by evaporation on the average in doing this. These yields are 13.6 and 22.6 per cent respectively of the average run-off of the 30-year period. Thus, in a capacity of 180,000 acre-feet, the 49,000 acre-feet additional to the maximum flood control reserve would convert on an average 17,100 acre-feet of yield controlled only in volume, to yield controlled both in time and volume or one acre-foot for each 2.9 acre-feet of storage capacity. In a capacity of 240,000 acre-feet, the 60,000 acre-feet additional to 180,000 acre-feet, would similarly convert on an average 11,300 acre-feet per season from flow controlled only in volume to flow controlled both in time and volume, or one acre-foot for each 5.3 acre-feet of storage capacity.

If the capacity in excess of the maximum flood control reserve of 131,000 acre-feet were employed for over-year instead of seasonal storage in conjunction with flood control, a uniformly continuous supply of 22 second-feet or 15,900 acre-feet per season could be drawn from a capacity of 180,000 acre-feet. Similarly, a uniformly continuous supply of 32* second-feet or 23,300 acre feet per season could be drawn from a capacity of 240,000 acre-feet. These yields are 12.7 and 18.6 per cent, respectively, of the average run-off of the 30-year period. In both instances this water would be derived from the winter and spring controlled flows and the seasonally stored water of the maximum flood control reserve. Thus, in a capacity of 180,000 acre-feet, the 49,000 acre-feet additional to the maximum flood control reserve would convert 3300 acre-feet per season controlled only in volume together with 14,000 acre-feet controlled both in time and volume but not equalized between seasons, into 15,900 acre-feet per season controlled both in time and volume and equalized between the years, or one acre-foot per season brought under complete control for each 3.1 acre-feet of additional capacity. On an average about 1400 acre-feet per season would be lost by evaporation in doing this. In a capacity of 240,000 acre-feet, the 60,000 acre-feet additional to the 180,000 acre-feet would similarly convert 11,600 acre-feet per season controlled only in volume into 10,600 acre-feet per season controlled in both time and volume, of which 7400 acre-feet per season would be equalized between seasons, or one acre-foot per season brought under control as to time for each 5.7 acre-feet of additional storage capacity.

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* In the analyses of reservoir yield for the period of measured run-off, Tables 13 and 13*a*, a yield of 41 second-feet continuous flow is obtained from Jan. 1, 1897, to Oct. 1, 1926, with a draft of 61,300 acre-feet on water stored in the reservoir prior to the beginning of the period. At the time of making the computations, it was thought that the rainfall of the seasons just prior to Jan. 1, 1897, would yield this extra water so that 41 second-feet would be the long time average yield; however, subsequent detail study of rainfall records indicates that it is improbable that so large an amount of extra water would have accumulated during the seasons just prior to 1897, but, sufficient would probably have accumulated to increase the yield considerably over that for the exact period of analyses. The exact yield in continuous flow for the period Jan. 1, 1897, to Oct. 1, 1926, is 32 second-feet or 23,300 acre-feet per season.

On an average about 1000 acre-feet per season would be lost by evaporation in doing this.

The three following tables summarize the yield of 180,000 and 240,000 acre-feet of capacity operated in accordance with the "Coordinated Plan" and compare it with the yield of the maximum flood control reserve if not employed in conjunction with additional capacity. The first two tabulate the average run-off divided between the yield in prior rights water, controlled flows resulting from flood regulation, seasonally stored water, continuous uniform flow equalized between seasons by over-year storage, and evaporation loss from the reservoir surface. The first table assumes that the space in addition to the maximum flood control reserve is employed for seasonal storage in conjunction with the flood control operations and the second table for over-year storage. The third table further segregates the yields of the first two tables according to the size of total flows passing Azusa. Still further detail is printed in the tables of yearly summaries at the end of this section and in the tables of monthly summaries in Chapter VIII. The actual computations were carried out on a daily basis to meet the requirements of the reservoir operating diagram which calls for a daily adjustment of reservoir level during the flood season. The daily computations are too voluminous to place in print.

It may be observed on reviewing the three following tables that the maximum flood control reserve, without additional capacity, controls all floods and renders the entire run-off of the stream, except for 0.7 per cent loss by evaporation, available for sinking underground. It yields 29.2 per cent of the average run-off in seasonally stored water but does not create an independent surface supply. The two larger capacities employed for flood control and seasonal storage, control all floods and render the entire run-off, except for slightly larger evaporation losses, available for sinking underground. However, a larger fraction of the average run-off is made available as seasonally stored water. The two larger capacities convert 42.9 and 51.9 per cent, respectively, of the average run-off into seasonally stored water instead of 29.2 per cent, the yield of the maximum flood control reserve without additional capacity. In so doing the two larger capacities do not conserve more water but rather make larger portions of the average run-off more conveniently available. When employed for over-year storage in conjunction with flood control, the two larger capacities still control all floods and render the entire run-off of the stream available for sinking underground if desired, but 12.7 and 18.6 per cent, respectively, of the average run-off is in a uniformly continuous yield suitable for direct diversion from the reservoir for municipal purposes. The losses by evaporation from the reservoir surface are 1.8 and 2.6 per cent, respectively, in doing this. In all instances 40.5 per cent of the average run-off passes the dam to satisfy downstream prior surface rights.

In size of total flow passing Azusa, the maximum flood control reserve yields 66.4 per cent of the average run-off in flows of less than 500 second-feet and 73.5 per cent in flows less than 1000 second-feet. The two larger capacities of 180,000 and 240,000 acre-feet, employed for flood control and seasonal storage, yield 85.7 and 93.5 per cent of their water, respectively, in flows less than 1000 second-feet. Employed for flood control in conjunction with over-year storage, 180,000 acre-feet of capacity would yield 74.3 per cent of the average run-off in flows of less than 1000 second-feet. Had a reservoir operating diagram been constructed to limit flows to 1000 second-feet instead of 1900, as in the foregoing illustrations, its maximum flood control reserve of 160,000 acre-feet would yield over 99 per cent of the average run-off in flows of size less than 1000 second-feet. For a total capacity of 180,000 acre feet, the division of the yield into controlled flows and seasonally stored water, however, would be different, the amount of the seasonally stored water being less.

AVERAGE WATER YIELD OF SAN GABRIEL RESERVOIR UNDER "COORDINATED PLAN."

FLOOD CONTROL AND SEASONAL STORAGE COORDINATED

January 1, 1897 to October 1, 1926

(For yearly values, see Table 12, page 158.)

Item	Maximum flood control reserve or first 131,000 acre-feet of capacity		180,000 acre-feet capacity		240,000 acre-feet capacity	
	Acre-feet per season	Per cent of average seasonal run-off	Acre-feet per season	Per cent of average seasonal run-off	Acre-feet per season	Per cent of average seasonal run-off
Passed by dam for prior rights (first 152 second-feet of natural flow)	50,900	40.5	50,900	40.5	50,900	40.5
Flood control water passing Azusa during flood season at rates less than 1,900 second-feet	37,100	29.6	19,700	15.7	8,300	6.6
Seasonally stored water	36,700	29.2	53,800	42.9	65,100	51.9
Evaporation from reservoir surface	800	0.7	1,100	0.9	1,200	1.0
Total	125,500	100.0	125,500	100.0	125,500	100.0

AVERAGE WATER YIELD OF SAN GABRIEL RESERVOIR UNDER "COORDINATED PLAN." FLOOD CONTROL, SEASONAL AND OVER-YEAR STORAGE COORDINATED

January 1, 1897 to October 1, 1926

(For yearly values, see Table 13, page 160.)

Item	Maximum flood control reserve or first 131,000 acre-feet of capacity		180,000 acre-feet capacity		240,000 acre-feet capacity	
	Acre-feet per season	Per cent of average seasonal run-off	Acre-feet per season	Per cent of average seasonal run-off	Acre-feet per season	Per cent of average seasonal run-off
Passed by dam for prior rights (first 152 second-feet of natural flow)	50,900	40.5	50,900	40.5	50,900	40.5
Flood control water passing Azusa during flood season at rates less than 1,900 second-feet	37,100	29.6	[a]33,800	26.9	[b]22,200	17.7
Seasonally stored water	36,700	29.2	22,700	18.1	[b]25,900	20.6
Yield in a uniformly continuous flow	0	0	15,900	12.7	[b]23,300	18.6
Evaporation from reservoir surface	800	0.7	2,200	1.8	3,200	2.6
Total	125,500	100.0	125,500	100.0	125,500	100.0

[a] The average yield in flood control water shown in Tables 13 and 13a from which this summary is compiled, is 34,000 acre-feet per season. In the computations for these tables, the period of analysis closed with 7,600 acre-feet less water in storage than at the beginning. This water, the equivalent of 200 acre-feet per season, entered storage prior to the beginning of the period and was released as flood control water during the first year. Therefore, it is deducted from the average yield in flood control water shown in Tables 13 and 13a to obtain the exact yield for the period of analysis.

[b] The average yield in flood control water, seasonally stored water and uniformly continuous flow shown in Tables 13 and 13a from which this summary is compiled, is 30,000, 13,800 and 29,700 acre-feet per season, respectively. In the computations for these tables the period of analysis closed with 61,300 acre-feet less water in storage than at the beginning. This water, the equivalent of 2,060 acre-feet per season, entered storage prior to the beginning of the period. To obtain the exact yield for the period, a supplementary analysis was made having the same amount of water in storage at the beginning and at the end of the period. This gave the smaller values for flood control water of 22,200 acre-feet per season and for uniformly continuous flow of 23,300 acre-feet per season, and the larger value for seasonally stored water of 25,900 acre-feet per season, entered herein.

AVERAGE SIZE OF FLOWS
OF
WATER YIELD OF SAN GABRIEL RESERVOIR UNDER "COORDINATED PLAN."

Jan. 1, 1897 to Oct. 1, 1926.

(For yearly values see Table 14, page 162.)

Maximum controlled flow at Azusa 1,900 second-feet. **Maximum flood control reserve 131,000 acre-feet.**

Reservoir emptied of seasonal storage each year.

Natural flow up to 152 second-feet passed for prior rights.

Size of total flow at Azusa in second-feet	**Flood control water passing Azusa** during flood season at rates less than 1,900 second-feet in acre-feet per season				**Seasonally stored water** in acre-feet per season				**Yield in uniformly continuous flow** equalized between seasons by over-year storage in acre-feet per season			
	Flood control and seasonal storage coordinated			Flood control, seasonal and over-year storage coordinated	Flood control and seasonal storage coordinated			Flood control, seasonal and over-year storage coordinated	Flood control and seasonal storage coordinated			Flood control, seasonal and over-year storage coordinated
	Maximum flood control reserve or first 131,000 acre-feet capacity[a]	180,000 acre-feet capacity	240,000 acre-feet capacity	180,000 acre-feet capacity[c e]	Maximum flood control reserve or first 131,000 acre-feet capacity[b]	180,000 acre-feet capacity	240,000 acre-feet capacity	180,000 acre-feet capacity[d]	Maximum flood control reserve or first 131,000 acre-feet capacity	180,000 acre-feet capacity	240,000 acre-feet capacity	180,000 acre-feet capacity

0- 250	230	90	30	190	14,640	11,720	11,350	6,060	0	0	0	13,540
250- 500	1,370	470	150	1,340	16,240	27,360	16,590	13,630	0	0	0	1,710
500- 750	1,540	1,120	580	1,380	5,800	14,700	29,830	2,980	0	0	0	240
750-1,000	1,500	1,260	680	1,250	0	0	7,300	0	0	0	0	40
1,000-1,250	1,150	890	330	1,550	70	0	0	0	0	0	0	40
1,250-1,500	1,470	730	670	650	0	0	0	0	0	0	0	10
1,500-1,900	29,170	15,170	5,890	27,090	590	0	0	580	0	0	0	350
Total	36,430	19,730	8,330	33,450	37,340	53,780	65,070	23,250	0	0	0	15,930
Aggregate of natural flow up to 152 second-feet passed for prior rights	24,250	24,250	24,250	24,250	26,620	26,620	26,620	26,620	...	...	...	...
Evaporation loss from reservoir surface	0	0	0	300	800	1,060	1,170	1,900	...	...	...	...
Grand total	[a] 60,680	43,980	32,580	[e] 58,000	[b] 64,760	81,460	92,860	[d] 51,770	...	...	...	15,930

[a] The aggregate of the entries in this column is smaller than the corresponding entries in the summary table, page 146, and Tables 12 and 12a, from which it is derived, by an average of about 700 acre-feet per season. This water was released in controlling floods during April, 1906, total amount 19,600 acre-feet, but was included in seasonally stored water in preparing this table.

[b] The aggregate of the entries in this column is larger than the corresponding entries in the summary table, page 146, and Tables 13 and 13a, from which it is derived, by an average of about 700 acre-feet per season. This water was released in controlling floods during April, 1906, total amount 19,600 acre-feet, but was included in seasonally stored water in preparing this table.

[c] The aggregate of the entries in this column is smaller than the corresponding entries in Tables 13 and 13a, from which it is derived, by an average of about 500 acre-feet per season. This water, 15,400 acre-feet total, was released in controlling floods during April, 1906, but was included in seasonally stored water in preparing this table.

[d] The aggregate of the entries in this column is larger than the corresponding entries in Tables 13 and 13a, from which it is derived, by an average of about 500 acre-feet per season. This water, 15,400 acre-feet total, was released in controlling floods during April, 1906, but was included in the seasonally stored water in preparing this table.

[e] Entries in this column taken from Tables 13 and 13a. In the computations for these tables, the period closed with 7,600 acre-feet less water in storage than at the beginning. This water, the equivalent of about 200 acre-feet per season, entered storage prior to the beginning of the period and was released as flood control water during the first flood season. It should, therefore, be deducted from the average yield in flood control water to obtain the exact yield for the period. This was not done in preparing this table.

AVERAGE SIZE OF FLOWS

OF

WATER YIELD OF SAN GABRIEL RESERVOIR UNDER "COORDINATED PLAN"—Concluded.

Jan. 1, 1897 to Oct. 1, 1926.

(For yearly values see Table 14, page 162.)

Maximum controlled flow at Azusa 1,900 second-feet. Maximum flood control reserve 131,000 acre-feet.

Reservoir emptied of seasonal storage each year.

Natural flow up to 152 second-feet passed for prior rights.

Size of total flow at Azusa in second-feet	Total yield							
	In acre-feet per season				In per cent of average seasonal run-off			
	Flood control and seasonal storage coordinated			Flood control, seasonal and over-year storage coordinated	Flood control and seasonal storage coordinated			Flood control, seasonal and over-year storage coordinated
	Maximum flood control reserve or first 131,000 acre-feet capacity	180,000 acre-feet capacity	240,000 acre-feet capacity	180,000 acre-feet capacity[a]	Maximum flood control reserve or first 131,000 acre-feet capacity	180,000 acre-feet capacity	240,000 acre-feet capacity	180,000 acre-feet capacity[a]
0– 250	14,870	11,810	11,380	19,790	11.9	9.4	9.1	15.8
250– 500	17,610	27,830	16,740	16,680	14.0	22.2	13.3	13.3
500– 750	7,340	15,820	30,410	4,600	5.9	12.6	24.2	3.7
750–1,000	1,500	1,260	7,980	1,290	1.2	1.0	6.4	1.0
1,000–1,250	1,220	890	330	1,590	1.0	0.7	0.3	1.3
1,250–1,500	1,470	730	670	660	1.2	0.6	0.5	0.5
1,500–1,900	29,760	15,170	5,890	28,020	23.7	12.1	4.7	22.3
Total	73,770	73,510	73,400	72,630	58.9	58.6	58.5	57.9
Aggregate of natural flow up to 152 second-feet passed for prior rights	50,870	50,870	50,870	50,870	40.5	40.5	40.5	40.5
Evaporation loss from reservoir surface	800	1,060	1,170	2,200	0.6	0.9	1.0	1.8
Grand total	125,440	125,440	125,440	[a]125,700	100.0	100.0	100.0	[a]100.2

[a] Entries in this column taken from Tables 13 and 13a. In the computations for these tables, the period closed with 7,600 acre-feet less water in storage than at the beginning. This water, the equivalent of about 200 acre-feet per season, entered storage prior to the beginning of the period and was released as flood control water during the first flood season. It should, therefore, be deducted from the average yield in flood control water to obtain the exact yield for the period. This was not done in preparing this table.

PLATE XXVI.

EFFECT OF CONTROLLING SAN GABRIEL RIVER FLOODS UPON STAGE OF SAN GABRIEL RESERVOIR

FLOOD CONTROL AND CONSERVATION COORDINATED

MAXIMUM CONTROLLED FLOW AT AZUSA 1,900 SEC. FT.
MAXIMUM FLOOD OF RECORD 40,000 SEC. FT.
RESERVOIR CAPACITY 180,000 AC. FT.
HEIGHT OF DAM 383 FT.

Monthly and yearly summaries of the computations from which the foregoing tables were prepared have been assembled, together with summaries of other comparisons made in studying various modes of reservoir operation. The yearly summaries follow herewith but the monthly summaries, because of their bulk, are placed in a separate chapter. Included in these is the test of 180,000 acre-feet reservoir capacity operating as proposed in the "Coordinated Plan" except that, instead of employing the reservoir operating diagram to grade the flood control reserve in accord with current necessities, the maximum amount of 131,000 acre-feet was held empty until April 19th, the close of the flood season. With over-year storage, this change reduced the average yield in seasonal stored water from 22,700 to 3000 acre-feet per season, a reduction of 87 per cent. It also reduced the yield in uniformly continuous flow from 15,900 to 13,000 acre-feet per season. Floods would have been limited to 1900 second-feet just the same.

In addition to the water yield, these computations furnish information upon the reservoir stage under the several conditions of operation. Plate XXVI, "Effect of Controlling San Gabriel River Floods upon the Stage of the San Gabriel Reservoir," delineates the reservoir stage day by day from 1896 to 1927 for three conditions of operation representing three steps in coordinating the several uses of 180,000 acre-feet of reservoir space; first, operating for flood control alone by the reservoir operating diagram, second, operating for flood control in combination with a constant draft from over-year storage, and third, completely coordinating the usefulness of the reservoir space by operating for flood control, a constant draft from over-year storage and a variable summer draft from seasonally stored water.

Plate XXVI assumes that a reservoir of 180,000 acre-feet capacity was in existence in 1896 and operated through subsequent years in accord successively with each of the three conditions of operation above mentioned. The volume of water in storage expressed in acre-feet is shown on every day of the 30-year period by the vertical position on the reservoir space scale, of lines extending across the plate in several rows. The top guide line of each row represents a full reservoir and the bottom line an empty reservoir. The space between each pair of horizontal guide lines represents 20,000 acre-feet.

The light red line delineates the reservoir stage were it operated for flood control alone by releasing water only as required by the reservoir operating diagram. The heavy black line delineates the reservoir stage were it operated for flood control and a constant draft of 22 second-feet from over-year storage. The heavy red line delineates the reservoir stage were it operated coordinately for flood control, a constant draft of 22 second-feet from over-year storage and a variable summer draft from the seasonally stored water. Below the reservoir stage lines in each row is shown in a light black line to a special scale superimposed upon the reservoir stage scale, the unimpaired flow of the river at Azusa and in a light red line, the flow as controlled by the coordination of flood control, seasonal and over-year storage. A line of black dots shows the daily value of the progressive rainfall index used in entering the reservoir operating diagram to determine the necessary flood control reserve.

The following table shows the average size of the total flow passing Azusa for the three steps in coordinating the use of reservoir space described above.

AVERAGE SIZE OF FLOWS OF WATER YIELD FROM SAN GABRIEL RESERVOIR FOR THREE STEPS IN COORDINATING THE USE OF RESERVOIR SPACE.

Jan. 1, 1897 to Oct. 1, 1926.

(For yearly values, see Table 18, page 186.)

Height of dam 383 feet. **Maximum controlled flow at Azusa 1,900 second-feet.**

Capacity of reservoir 180,000 acre-feet. **Maximum flood control reserve 131,000 acre-feet.**

Natural flow up to 152 second-feet passed for prior rights.

Size of total flow at Azusa in second-feet	**Flood control alone** Water drawn from reservoir only as required by reservoir operating diagram			**Flood control partially coordinated with conservation** Constant draft of 22 second-feet maintained, other drafts only as required by reservoir operating diagram				**Flood control completely coordinated with conservation** Reservoir emptied each summer to a level that would maintain constant draft through critical period, constant draft of 22 second-feet maintained, other drafts only as required by reservoir operating diagram **"Coordinated Plan"**			
	Flood control water and waste over spillway passing Azusa at rates less than 1,900 second-feet in acre-feet per season[a f]	Seasonally stored water released as a variable summer flow in acre-feet per season	Total in acre-feet per season[a]	Flood control water and waste over spillway passing Azusa at rates less than 1,900 second-feet in acre-feet per season[b g]	Seasonally stored water released as a variable summer flow in acre-feet per season	Constant flow from over-year storage in acre-feet per season	Total in acre-feet per season[b]	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet per season[c d]	Seasonally stored water released as a variable summer flow in acre-feet per season[e]	Constant flow from over-year storage in acre-feet per season	Total in acre-feet per season[b c]
0– 250	740	0	740	300	0	14,860	15,160	190	6,060	13,540	19,790
250– 500	2,870	0	2,870	2,160	0	190	2,350	1,340	13,630	1,710	16,680
500– 750	3,820	0	3,820	3,100	0	140	3,240	1,380	2,980	240	4,600
750–1,000	4,200	0	4,200	3,300	0	100	3,400	1,250	0	40	1,290
1,000–1,250	4,000	0	4,000	3,430	0	80	3,510	1,550	0	40	1,590
1,250–1,500	2,750	0	2,750	2,290	0	40	2,330	650	0	10	660
1,500–1,900	51,660	0	51,660	41,740	0	520	42,260	27,090	580	350	28,020
Total	70,040	0	70,040	56,320	0	15,930	72,250	33,450	23,250	15,930	72,630

Aggregate of natural flow up to 152 second-feet passed for prior rights....	24,250	26,620	50,870	24,250	26,620	....	50,870	24,250	26,620	....	50,870
Evaporation loss from reservoir surface..	460	2,480	2,940	390	2,190	....	2,580	300	1,900	....	2,200
Grand total........................	[a] 94,750	29,100	[a] 123,850	[b] 80,960	28,810	15,930	[b] 125,700	[cd] 58,000	[e] 51,770	15,930	[c] 125,700

[a] Entries in this column taken from Tables 16 and 16a. In the computations for these tables, the period closed with 47,700 acre-feet more water in storage than at the beginning, the equivalent of about 1,600 acre-feet per season. It should be added to the average yield in flood control water to obtain the exact yield of the period. This was not done in preparing this table.

[b] Entries in this column taken from Tables 16 and 16a. In the computations for these tables, the period closed with 7,600 acre-feet less water in storage than at the beginning. This water, the equivalent of about 200 acre-feet per season, entered storage prior to the beginning of the period and was released as flood control water during the first flood season. It should, therefore, be deducted from average yield in flood control water to obtain the exact yield of the period. This was not done in preparing this table.

[c] Entries in this column taken from Tables 16 and 16a. In the computations for these tables, the period closed with 7,600 acre-feet less water in storage than at the beginning. This water, the equivalent of about 200 acre-feet per season, entered storage prior to the beginning of the period and was released as flood control water during the first flood season. It should, therefore, be deducted from the average yield in flood control water to obtain the exact yield for the period. This was not done in preparing this table.

[d] The aggregate of the entries in this column is smaller than the corresponding entries in Tables 16 and 16a, from which it is derived, by an average of about 500 acre-feet per season This water, 15,400 acre-feet total, was released in controlling floods during April, 1906, but was included in the seasonally stored water in preparing this table.

[e] The aggregate of the entries in this column is larger than the corresponding entries in Tables 16 and 16a, from which it is derived, by an average of about 500 acre-feet per season. This water, 15,400 acre-feet total, was released in controlling floods during April, 1906, but was included in the seasonally stored water in preparing this table.

[f] Waste over spillway is included in these entries for year 1907, as follows: May, flow 0–250 second feet, 172 acre-feet; 250–500 second feet, 1728 acre-feet; June, flow 0–250 second feet, 2494 acre-feet; 250–500 second feet, 2844 acre-feet; July, flow 0–250 second feet, 188 acre-feet.

[g] Waste over spillway is included in these entries for year 1907, as follows: June, flow 0–250 second feet, 1244 acre-feet; 250–500 second feet, 2107 acre-feet.

SAN GABRIEL RESERVOIR ON SAN GABRIEL RIVER.

Tables of Yearly Summaries of Water Yield Computed on a Daily Basis.

Showing the effect of coordinating flood control and conservation. (See Chapter VIII for corresponding monthly summaries.*)

*Monthly summaries not prepared for Tables 14 and 18.

TABLE 12. SAN GABRIEL RESERVOIR ON SAN GABRIEL RIVER.

WATER YIELD UNDER "COORDINATED PLAN"
FLOOD CONTROL AND SEASONAL STORAGE COORDINATED

Yearly Summary of Computations Carried out on a Daily Basis.

(For corresponding monthly summary, see Table 12a, page 360.)

Maximum controlled flow at Azusa 1,900 second-feet. **Maximum flood control reserve 131,000 acre-feet.**

Natural flow up to 152 second-feet passed for prior rights.

Reservoir emptied of seasonal storage each year.

Year	Maximum flood control reserve or first 131,000 acre-feet of capacity					180,000 acre-feet capacity					240,000 acre-feet capacity				
	Passed by dam for prior rights (first 152 second-feet of natural flow) in acre-feet	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Seasonally stored water in acre-feet	Evaporation from reservoir surface in acre-feet	Total in acre-feet	Passed by dam for prior rights (first 152 second-feet of natural flow) in acre-feet	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Seasonally stored water in acre-feet	Evaporation from reservoir surface in acre-feet	Total in acre-feet	Passed by dam for prior rights (first 152 second-feet of natural flow) in acre-feet	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Seasonally stored water in acre-feet	Evaporation from reservoir surface in acre-feet	Total in acre-feet
1897	52,963	4,913	34,488	984	93,348	52,963	0	39,304	1,081	93,348	52,963	0	39,304	1,081	93,348
1898	15,687	0	2,732	190	18,609	15,687	0	2,732	190	18,609	15,687	0	2,732	190	18,609
1899	10,463	0	0	0	10,463	10,463	0	0	0	10,463	10,463	0	0	0	10,463
1900	11,976	0	0	0	11,976	11,976	0	0	0	11,976	11,976	0	0	0	11,976
1901	50,570	32,694	15,717	589	99,570	50,570	0	47,822	1,178	99,570	50,570	0	47,822	1,178	99,570
1902	21,816	0	437	61	22,314	21,816	0	437	61	22,314	21,816	0	437	61	22,314
1903	50,037	6,045	49,747	1,156	106,985	50,037	0	55,685	1,263	106,985	50,037	0	55,685	1,263	106,985
1904	24,180	0	2,482	174	26,836	24,180	0	2,482	174	26,836	24,180	0	2,482	174	26,836
1905	62,587	29,996	70,682	1,450	164,715	62,587	0	100,310	1,818	164,715	62,587	0	100,310	1,818	164,715
1906	67,456	43,937	120,438	2,029	233,860	67,456	2,864	161,113	2,427	233,860	67,456	0	163,981	2,423	233,860
1907	82,808	129,172	138,732	2,178	352,890	82,808	80,172	187,233	2,677	352,890	82,808	20,172	246,672	3,238	352,890

1908	56,444	9,758	6,461	287	72,950	56,444	0	15,887	619	72,950	56,444	0	15,887	619	72,950
1909	72,101	62,243	49,468	1,174	184,986	72,101	13,243	97,859	1,783	184,986	72,101	0	110,956	1,929	184,986
1910	54,518	76,272	2,117	97	133,004	54,518	27,272	50,000	1,214	133,004	54,518	0	76,937	1,549	133,004
1911	70,413	118,339	85,892	1,636	276,280	70,413	69,339	134,347	2,181	276,280	70,413	10,977	192,140	2,750	276,280
1912	47,362	0	25,435	823	73,620	47,362	0	25,435	823	73,620	47,362	0	25,435	823	73,620
1913	40,386	0	9,481	456	50,323	40,386	0	9,481	456	50,323	40,386	0	9,481	456	50,323
1914	72,456	154,577	71,219	1,458	299,710	72,456	105,577	119,650	2,027	299,710	72,456	48,271	176,383	2,600	299,710
1915	73,157	15,828	41,744	1,071	131,800	73,157	0	57,350	1,293	131,800	73,157	0	57,350	1,293	131,800
1916	77,852	152,147	54,093	1,251	285,343	77,852	103,704	101,945	1,842	285,343	77,852	43,704	161,330	2,457	285,343
1917	60,160	9,467	11,487	473	81,587	60,160	0	20,698	729	81,587	60,160	0	20,698	729	81,587
1918	58,741	11,341	65,660	1,398	137,140	58,741	0	76,848	1,551	137,140	58,741	0	76,848	1,551	137,140
1919	37,874	0	0	0	37,874	37,874	0	0	0	37,874	37,874	0	0	0	37,874
1920	60,683	0	51,949	1,229	113,861	60,683	0	51,949	1,229	113,861	60,683	0	51,949	1,229	113,861
1921	54,013	38,907	18,143	649	111,712	54,013	6,295	18,143	649	79,100	54,013	0	18,143	649	72,805
1922	87,587	194,681	93,935	1,700	377,903	87,587	178,450	142,243	2,235	410,515	87,587	124,588	201,811	2,824	416,810
1923	51,298	13,042	1,199	46	65,585	51,298	0	13,714	573	65,585	51,298	0	13,714	573	65,585
1924	25,517	0	360	56	25,933	25,517	0	360	56	25,933	25,517	0	360	56	25,933
1925	21,878	0	1,411	111	23,400	21,878	0	1,411	111	23,400	21,878	0	1,411	111	23,400
*1926	40,320	0	65,743	1,337	107,400	40,320	0	65,743	1,337	107,400	40,320	0	65,743	1,337	107,400
Total	1,513,303	1,103,359	1,091,252	24,063	3,731,977	1,513,303	586,916	1,600,181	31,577	3,731,977	1,513,303	247,712	1,936,001	34,961	3,731,977
Average	50,867	37,088	36,681	809	125,445	50,867	19 729	53,788	1 061	125,445	50,867	8,327	65,076	1,175	125,445

*Partial year, January 1 to October 1.

TABLE 13. SAN GABRIEL RESERVOIR ON SAN GABRIEL RIVER.

WATER YIELD UNDER "COORDINATED PLAN"
FLOOD CONTROL, SEASONAL AND OVER-YEAR STORAGE COORDINATED.

Yearly Summary of Computations Carried out on a Daily Basis.

(For corresponding monthly summary, see Table 13a, page 382.)

Maximum controlled flow at Azusa 1,900 second-feet. **Maximum flood control reserve 131,000 acre-feet.**

Natural flow up to 152 second-feet passed for prior rights.

Reservoir emptied of seasonal storage each year.

Year	Maximum flood control reserve or first 131,000 acre-feet of capacity						180,000 acre-feet total capacity						240,000 acre-feet total capacity					
	Passed by dam for prior rights (first 152 second-feet of natural flow) in acre-feet	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Seasonally stored water in acre-feet	Yield in a uniformly continuous supply from over-year storage in acre-feet	Evaporation from reservoir surface in acre-feet	Total in acre-feet	Passed by dam for prior rights (first 152 second-feet of natural flow) in acre-feet	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Seasonally stored water in acre-feet	Yield in a uniformly continuous supply from over-year storage in acre-feet	Evaporation from reservoir surface in acre-feet	Total in acre-feet	Passed by dam for prior rights (first 152 second-feet of natural flow) in acre-feet	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Seasonally stored water in acre-feet	Yield in a uniformly continuous supply from over-year storage in acre-feet	Evaporation from reservoir surface in acre-feet	Total in acre-feet
1897	52,963	4,913	34,488	0	984	93,348	52,963	16,407	16,901	15,922	2,466	104,659	52,963	15,089	0	29,672	3,802	101,526
1898	15,687	0	2,732	0	190	18,609	15,687	0	0	15,922	1,926	33,535	15,687	0	0	29,672	3,170	48,529
1899	10,463	0	0	0	0	10,463	10,463	0	0	15,922	1,448	27,833	10,463	0	0	29,672	2,461	42,596
1900	11,976	0	0	0	0	11,976	11,976	0	0	15,922	796	28,694	11,976	0	0	29,672	1,677	43,325
1901	50,570	32,694	15,717	0	589	99,570	50,570	0	0	15,922	1,846	68,338	50,570	0	0	29,672	2,116	82,358
1902	21,816	0	437	0	61	22,314	21,816	0	0	15,922	1,374	39,112	21,816	0	0	29,672	1,269	52,757
1903	50,037	6,045	49,747	0	1,156	106,985	50,037	0	4,235	15,922	2,293	72,487	50,037	0	0	29,672	1,959	81,668
1904	24,180	0	2,482	0	174	26,836	24,180	0	0	15,965	1,922	42,067	24,180	0	0	29,754	1,168	55,102
1905	62,587	29,996	70,682	0	1,450	164,715	62,587	13,658	54,528	15,922	2,781	149,476	62,587	0	0	29,672	2,931	95,190

1906	67,456	43,937	120,438	0	2,029	233,860	67,456	39,397	107,768	15,922	3,189	233,732	67,456	9,428	82,724	29,672	4,536	193,816
1907	82,808	129,172	138,732	0	2,178	352,890	82,808	127 639	123,335	15,922	3,301	353,005	82,808	127,605	108,051	29,672	4,755	352,891
1908	56,444	9,758	6,461	0	287	72,950	56,444	10,159	0	15,965	2,012	84,580	56,444	11,779	0	29,754	3,216	101,193
1909	72,101	62,243	49,468	0	1,174	184,986	72,101	52,260	32,119	15,922	2.593	174,995	72,101	38,721	15,706	29,672	3,968	160,168
1910	54,518	76,272	2,117	0	97	133,004	54,518	75,162	0	15,922	1,892	147,494	54,518	75,055	0	29,672	3,114	162,359
1911	70,413	118,339	85,892	0	1,636	276,280	70,413	100,816	70,041	15,922	2,916	260,108	70,413	84,954	54,152	29,672	4,309	243,500
1912	47,362	0	25,435	0	823	73,620	47,362	0	7,761	15,965	2,356	73,444	47,362	0	0	29,754	3,658	80,774
1913	40,386	0	9,481	0	456	50,323	40,386	0	0	15,922	2,099	58,407	40,386	0	0	29,672	3,209	73,267
1914	72,456	154,577	71,219	0	1,458	299,710	72,456	145,722	54,901	15,922	2,785	291,786	72,456	123,839	39,467	29,672	4,178	269,612
1915	73,157	15,828	41,744	0	1,071	131,800	73,157	15,984	24,232	15,922	2,514	131,809	73,157	17,290	7,812	29,672	3,869	131,800
1916	77,852	152,147	54,093	0	1,251	285,343	77,852	152,317	36,625	15,965	2,625	285,384	77,852	153,289	20,566	29,754	4,016	285,477
1917	60,160	9,467	11,487	0	473	81,587	60,160	10,464	0	15,922	2,122	88,668	60,160	12,270	0	29,672	3,308	105,410
1918	58,741	11,341	65,660	0	1,398	137,140	58,741	3,595	49,016	15,922	2,741	130,015	58,741	0	20,748	29,672	4,022	113,183
1919	37,874	0	0	0	0	37,874	37,874	0	0	15,922	1,848	55,644	37,874	0	0	29,672	3,150	70,696
1920	60,683	0	51,949	0	1,229	113,861	60,683	0	16,978	15,965	2,454	96,080	60,683	0	0	29,754	3,527	93,964
1921	54,013	38,907	18,143	0	649	111,712	54,013	39,506	606	15,922	2,269	112,316	54,013	20,952	0	29,672	3,225	107,862
1922	87,587	194,681	93,935	0	1,700	377,903	87,587	195,520	77,276	15,922	2,970	379,275	87,587	190,726	61,586	29,672	4,349	373,920
1923	51,298	13,042	1,199	0	46	65,585	51,298	12,056	0	15,922	1,858	81,134	51,298	10,928	0	29,672	3,084	94,982
1924	25,517	0	360	0	56	25,933	25,517	0	0	15,965	1,380	42,862	25,517	0	0	29,754	2,376	57,647
1925	21,878	0	1,411	0	111	23,400	21,878	0	0	15,922	744	38,544	21,878	0	0	29,672	1,601	53,151
[a]1926	40,320	0	65,743	0	1,337	107,400	40,320	0	0	11,909	1,866	54,095	40,320	0	0	22,193	2,054	64,567
Total	1,513,303	1,103,359	1,091,252	0	24,063	3,731,977	1,513,303	1,010,662	676,322	473,905	65,386	3,739,578	1,513,303	891,925	410,812	883,173	94,077	3,793,290
Average	50,867	37,088	36,681	0	809	125,445	50,867	[b]33,972	22,734	15,930	2,198	[b]125,701	50,867	[c]29,981	[c]13,809	[c]29,686	3,162	[c]127,505

[a] Partial year, January 1 to October 1.

[b] These figures contain 7601 acre-feet total or an average of 256 acre-feet per season of water contributed from outside the exact period of analysis. In the computations from which this table is prepared, the water in storage on October 1, 1926, the end of the period is less by this amount than on January 1, 1897, the beginning of the period. Since in the computations, this water was released as flood control water during the first flood season of the period, the exact yield of flood control water for the period is less than here shown by this amount.

[c] These figures contain 61,313 acre-feet total or an average of 2060 acre-feet per season of water contributed from outside the exact period of analysis. In the computations from which this table is prepared, the water in storage on October 1, 1926, the end of the period is less by this amount than on January 1, 1897, the beginning of the period. A supplementary analysis, having the same amount of water in storage at the beginning and at the end of the period, was made to obtzin the exact yield for the period. This gave 22,200, 25,900 and 23,300 acre-feet per season, respectively, for the flood control water, seasonally stored water, and uniformly continuous flow instead of 29,981, 13,809 and 29,686 acre-feet, respectively, that are shown herein.

TABLE 14. SAN GABRIEL RESERVOIR ON SAN GABRIEL RIVER.

AVERAGE SIZE OF FLOWS OF WATER YIELD UNDER "COORDINATED PLAN"

Yearly Summary of Computations Carried out on a Daily Basis.

Maximum controlled flow at Azusa 1,900 second-feet. Maximum flood control reserve 131,000 acre-feet.

Natural flow up to 152 second-feet passed for prior rights.

Reservoir emptied of seasonal storage each year.

Year	Size of total flow at Azusa in second-feet												
	0-250												
	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet				Seasonally stored water in acre-feet				Aggregate of natural flow up to 152 second-feet passed for prior rights in acre-feet				Yield in a uniformly continuous flow equalized between seasons by over-year storage in acre-feet
	Flood control and seasonal storage coordinated			**Flood control, seasonal and over-year storage coordinated**	**Flood control and seasonal storage coordinated**			**Flood control, seasonal and over-year storage coordinated**	**Flood control and seasonal storage coordinated**			**Flood control, seasonal and over-year storage coordinated**	**Flood control, seasonal and over-year storage coordinated**
	Maximum flood control reserve or first 131,000 acre-feet of capacity	180,000 acre-feet capacity	240,000 acre-feet capacity	180,000 acre-feet capacity	Maximum flood control reserve or first 131,000 acre-feet of capacity	180,000 acre-feet capacity	240,000 acre-feet capacity	180,000 acre-feet capacity	Maximum flood control reserve or first 131,000 acre-feet of capacity	180,000 acre-feet capacity	240,000 acre-feet capacity	180,000 acre-feet capacity	180,000 acre-feet capacity

1897	334	0	0	1,966	34,488	36,002	39,304	16,901	51,458	48.473	52,963	50,358	15,049
1898	0	0	0	0	2,732	2,732	2,732	0	15,687	15,687	15,687	15,687	15,922
1899	0	0	0	0	0	0	0	0	10,463	10,463	10,463	10,463	15,922
1900	0	0	0	0	0	0	0	0	11,976	11,976	11,976	11,976	15,922
1901	491	0	0	0	15,717	43,170	47,822	0	41,389	45,763	50,570	50,570	15,922
1902	0	0	0	0	437	437	437	0	21,816	21,816	21,816	21,816	15,922
1903	319	0	0	0	33,345	36,819	36,823	4,235	35,014	35,899	35,899	50,037	15,922
1904	0	0	0	0	2,482	2,482	2,482	0	24,180	24,180	24,180	24,180	15,965
1905	312	0	0	0	15,912	0	0	20,865	26,053	26,638	26,638	29,862	10,469
1906	0	0	0	0	0	0	0	0	21,922	23,733	24,034	21,924	7,635
1907	813	984	320	1,103	0	0	0	0	19,494	25,222	34,569	20,105	5,280
1908	521	0	0	148	6,461	15,887	15,887	0	53,735	56,444	56,444	53,130	15,484
1909	16	16	0	0	29,885	0	0	21,613	43,763	32,207	34,916	46,321	12,127
1910	443	570	0	310	2,117	42,369	32,809	0	43,970	39,889	36,569	43,969	14,397
1911	0	0	36	79	85,892	0	0	0	59,261	23,992	30,924	22,485	6,413
1912	0	0	0	0	25,435	25,435	25,435	7,761	47,362	47.362	47,362	47,362	15,965
1913	0	0	0	0	9.481	9,481	9,481	0	40,386	40,386	40,386	40,386	15,922
1914	262	570	81	156	0	0	0	15,509	17,576	21,496	29,033	22,308	7,676
1915	403	0	0	199	27,352	18,246	18,979	19,211	54,447	37,123	37,384	59,693	13,960
1916	18	79	79	134	32,598	0	0	29,799	42,928	31,848	36,068	54,632	12,564
1917	823	0	0	558	11,487	20.698	20,698	0	55,310	60.160	60,160	54,615	15,006
1918	0	0	0	0	28,115	0	0	26,724	31,208	25,556	25,556	34,747	12,040
1919	0	0	0	0	0	0	0	0	37,874	37,874	37,874	37,874	15,922
1920	0	0	0	0	33,268	27.878	33,580	16,978	43,615	34,573	43,802	60,683	15,965
1921	342	0	0	16	18,143	18,143	18,143	606	50,697	53,411	54,013	50,396	15,398
1922	412	601	412	298	0	16,660	0	0	24,225	26,778	28,141	23,680	5,104
1923	1,219	0	0	610	1,199	13,714	13,714	0	47,709	51.298	51,298	47,445	15,224
1924	0	0	0	0	360	360	360	0	25,517	25,517	25,517	25,517	15,965
1925	0	0	0	0	1,411	1,411	1,411	0	21,878	21,878	21,878	21,878	15,922
[a]1926	0	0	0	0	17,286	16,852	17,722	0	20,986	20,924	21,049	40,320	11,909
Total	6,728	2,820	928	5,577	435,603	348,776	337,819	180,202	1,041,899	978,566	1,027,169	1,094,419	402,893
Average	226	95	31	188	14,642	11,724	11,355	6,057	35,021	32,893	34,526	36,788	13,543

[a] Partial year, January 1 to October 1.

TABLE 14 (Continued). SAN GABRIEL RESERVOIR ON SAN GABRIEL RIVER.

AVERAGE SIZE OF FLOWS OF WATER YIELD UNDER "COORDINATED PLAN"

Yearly Summary of Computations Carried out on a Daily Basis.

Maximum controlled flow at Azusa 1,900 second-feet. Maximum flood control reserve 131,000 acre-feet.

Natural flow up to 152 second-feet passed for prior rights.

Reservoir emptied of seasonal storage each year.

Year	Size of total flow at Azusa in second-feet												
	250-500												
	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet				Seasonally stored water in acre-feet				Aggregate of natural flow up to 152 second-feet passed for prior rights in acre-feet				Yield in a uniformly continuous flow equalized between seasons by over-year storage in acre-feet
	Flood control and seasonal storage coordinated			Flood control, seasonal and over-year storage coordinated	Flood control and seasonal storage coordinated			Flood control, seasonal and over-year storage coordinated	Flood control and seasonal storage coordinated			Flood control, seasonal and over-year storage coordinated	Flood control, seasonal and over-year storage coordinated
	Maximum flood control reserve or first 131,000 acre-feet of capacity	180,000 acre-feet capacity	240,000 acre-feet capacity	180,000 acre-feet capacity	Maximum flood control reserve or first 131,000 acre-feet of capacity	180,000 acre-feet capacity	240,000 acre-feet capacity	180,000 acre-feet capacity	Maximum flood control reserve or first 131,000 acre-feet of capacity	180,000 acre-feet capacity	240,000 acre-feet capacity	180,000 acre-feet capacity	180,000 acre-feet capacity

1897	771	0	0	10,201	0	3,302	0	0	903	4,490	0	2,003	785
1898	0	0	0	0	0	0	0	0	0	0	0	0	0
1899	0	0	0	0	0	0	0	0	0	0	0	0	0
1900	0	0	0	0	0	0	0	0	0	0	0	0	0
1901	8,201	0	0	0	0	4,652	0	0	4,252	4,807	0	0	0
1902	0	0	0	0	0	0	0	0	0	0	0	0	0
1903	989	0	0	0	16,402	18,866	18,862	0	14,421	14,138	14,138	0	0
1904	0	0	0	0	0	0	0	0	0	0	0	0	0
1905	0	0	0	0	54,770	100,310	100,310	33,664	33,520	35,949	35,949	31,219	5,235
1906	0	0	0	0	103,666	19,209	19,674	91,153	34,757	9,042	9,042	35,314	6,804
1907	3,411	3,411	1,142	2,696	20,515	19,650	0	49,281	12,451	11,450	905	23,442	4,100
1908	1,308	0	0	1,286	0	0	0	0	1,505	0	0	1,809	262
1909	4,489	1,246	0	4,553	19,583	97,859	110,956	10,506	22,612	38,088	37,185	20,355	3,011
1910	3,861	3,861	0	3,468	0	7,631	44,128	0	2,709	10,407	17,949	2,712	393
1911	1,152	1,596	373	634	0	94,422	0	70,041	903	23,290	301	37,981	8,070
1912	0	0	0	0	0	0	0	0	0	0	0	0	0
1913	0	0	0	0	0	0	0	0	0	0	0	0	0
1914	1,541	1,539	293	1,994	71,219	119,650	0	39,392	40,108	40,106	302	35,980	6,195
1915	2,390	0	0	2,170	14,392	39,104	38,371	5,021	15,997	36,034	35,773	10,759	1,570
1916	0	1,262	200	468	21,495	101,945	17,933	6,825	21,662	36,055	2,122	9,958	1,484
1917	7,851	0	0	7,658	0	0	0	0	4,628	0	0	4,863	785
1918	0	0	0	0	0	76,848	76,848	22,293	0	33,185	33,185	23,391	3,795
1919	0	0	0	0	0	0	0	0	0	0	0	0	0
1920	0	0	0	0	18,681	24,071	18,369	0	17,068	26,110	16,881	0	0
1921	0	0	0	0	0	0	0	0	0	0	0	0	0
1922	1,029	1,071	2,338	955	93,935	37,518	0	77,275	44,976	18,990	1,810	44,977	8,071
1923	3,638	0	0	3,871	0	0	0	0	1,609	0	0	1,874	349
1924	0	0	0	0	0	0	0	0	0	0	0	0	0
1925	0	0	0	0	0	0	0	0	0	0	0	0	0
[a]1926	0	0	0	0	48,457	48,891	48,021	0	19,334	19,396	19,271	0	0
Total	40,631	13,986	4,346	39,954	483,115	813,928	493,472	405,451	293,415	361,537	224,813	286,637	50,909
Average	1,366	470	146	1,343	16,239	27,359	16,588	13,629	9,863	12,153	7,557	9,635	1,711

[a] Partial year, January 1 to October 1.

TABLE 14 (Continued). SAN GABRIEL RESERVOIR ON SAN GABRIEL RIVER.

AVERAGE SIZE OF FLOWS OF WATER YIELD UNDER "COORDINATED PLAN"

Yearly Summary of Computations Carried out on a Daily Basis.

Maximum controlled flow at Azusa 1,900 second-feet. Maximum flood control reserve 131,000 acre-feet.

Natural flow up to 152 second-feet passed for prior rights.

Reservoir emptied of seasonal storage each year.

Year	Size of total flow at Azusa in second-feet												
	500-750												
	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet				Seasonally stored water in acre-feet				Aggregate of natural flow up to 152 second-feet passed for prior rights in acre-feet				Yield in a uniformly continuous flow equalized between seasons by over-year storage in acre-feet
	Flood control and seasonal storage coordinated			Flood control, seasonal and over-year storage coordinated	Flood control and seasonal storage coordinated			Flood control, seasonal and over-year storage coordinated	Flood control and seasonal storage coordinated			Flood control, seasonal and over-year storage coordinated	Flood control, seasonal and over-year storage coordinated
	Maximum flood control reserve or first 131,000 acre-feet of capacity	180,000 acre-feet capacity	240,000 acre-feet capacity	180,000 acre-feet capacity	Maximum flood control reserve or first 131,000 acre-feet of capacity	180,000 acre-feet capacity	240,000 acre feet capacity	180,000 acre-feet capacity	Maximum flood control reserve or first 131,000 acre-feet of capacity	180,000 acre-feet capacity	240,000 acre-feet capacity	180,000 acre-feet capacity	180,000 acre-feet capacity

1897	1,033	0	0	990	0	0	0	0	301	0	0	301	44
1898	0	0	0	0	0	0	0	0	0	0	0	0	0
1899	0	0	0	0	0	0	0	0	0	0	0	0	0
1900	0	0	0	0	0	0	0	0	0	0	0	0	0
1901	10,044	0	0	0	0	0	0	0	2,986	0	0	0	0
1902	0	0	0	0	0	0	0	0	0	0	0	0	0
1903	0	0	0	0	0	0	0	0	0	0	0	0	0
1904	0	0	0	0	0	0	0	0	0	0	0	0	0
1905	968	0	0	0	0	0	0	0	302	0	0	0	0
1906	0	0	0	0	16,772	141,904	144,307	14,756	6,859	34,380	34,380	6,601	960
1907	9,390	9,390	3,856	8,960	118,217	167,583	29,388	74,054	37,287	38,288	10,247	25,999	4,624
1908	0	0	0	1,064	0	0	0	0	0	0	0	301	44
1909	2,358	1,556	0	2,988	0	0	0	0	903	602	0	1,206	175
1910	2,832	2,835	0	2,705	0	0	0	0	903	903	0	904	131
1911	945	5,479	1,146	4,161	0	39,925	192,140	0	301	17,098	37,680	1,507	218
1912	0	0	0	0	0	0	0	0	0	0	0	0	0
1913	0	0	0	0	0	0	0	0	0	0	0	0	0
1914	3,828	4,071	0	3,673	0	0	176,383	0	1,207	1,204	38,901	1,206	174
1915	1,754	0	0	1,682	0	0	0	0	602	0	0	601	87
1916	0	3,788	6,006	0	0	0	143,397	0	0	1,208	35,442	0	0
1917	793	0	0	2,248	0	0	0	0	222	0	0	682	131
1918	978	0	0	0	37,545	0	0	0	26,630	0	0	0	0
1919	0	0	0	0	0	0	0	0	0	0	0	0	0
1920	0	0	0	0	0	0	0	0	0	0	0	0	0
1921	0	0	0	1,107	0	0	0	0	0	0	0	301	44
1922	4,619	6,080	6,141	5,696	0	88,065	201,811	0	1,508	25,841	46,181	1,749	262
1923	6,240	0	0	5,683	0	0	0	0	1,730	0	0	1,729	305
1924	0	0	0	0	0	0	0	0	0	0	0	0	0
1925	0	0	0	0	0	0	0	0	0	0	0	0	0
[a]1926	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	45,782	33,199	17,149	40,957	172,534	437,477	887,426	88,810	81,741	119,524	202,831	43,087	7,199
Average	1,539	1,116	577	1,377	5,800	14,705	29,829	2,985	2,748	4,017	6,817	1,448	242

[a] Partial year, January 1 to October 1.

TABLE 14 (Continued). SAN GABRIEL RESERVOIR ON SAN GABRIEL RIVER.

AVERAGE SIZE OF FLOWS
OF WATER YIELD UNDER "COORDINATED PLAN"

Yearly Summary of Computations Carried out on a Daily Basis.

Maximum controlled flow at Azusa 1,900 second-feet. Maximum flood control reserve 131,000 acre-feet.

Natural flow up to 152 second-feet passed for prior rights.

Reservoir emptied of seasonal storage each year.

Year	Size of total flow at Azusa in second-feet												
	750-1,000												
	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre feet				Seasonally stored water in acre-feet				Aggregate of natural flow up to 152 second-feet passed for prior rights in acre-feet				Yield in a uniformly continuous flow equalized between seasons by over-year storage in acre-feet
	Flood control and seasonal storage coordinated			**Flood control, seasonal and over-year storage coordinated**	**Flood control and seasonal storage coordinated**			**Flood control, seasonal and over-year storage coordinated**	**Flood control and seasonal storage coordinated**			**Flood control, seasonal and over-year storage coordinated**	**Flood control, seasonal and over-year storage coordinated**
	Maximum flood control reserve or first 131,000 acre-feet of capacity	180,000 acre-feet capacity	240,000 acre-feet capacity	180,000 acre-feet capacity	Maximum flood control reserve or first 131,000 acre-feet of capacity	180,000 acre-feet capacity	240,000 acre-feet capacity	180,000 acre-feet capacity	Maximum flood control reserve or first 131,000 acre-feet of capacity	180,000 acre-feet capacity	240,000 acre-feet capacity	180,000 acre-feet capacity	180,000 acre-feet capacity

1897	0	0	0	0	0	0	0	0	0	0	0	0	0
1898	0	0	0	0	0	0	0	0	0	0	0	0	0
1899	0	0	0	0	0	0	0	0	0	0	0	0	0
1900	0	0	0	0	0	0	0	0	0	0	0	0	0
1901	6,946	0	0	0	0	0	0	0	1,339	0	0	0	0
1902	0	0	0	0	0	0	0	0	0	0	0	0	0
1903	1,241	0	0	0	0	0	0	0	301	0	0	0	0
1904	0	0	0	0	0	0	0	0	0	0	0	0	0
1905	1,573	0	0	1,520	0	0	0	0	301	0	0	301	44
1906	0	0	0	0	0	0	0	0	0	0	0	0	0
1907	11,494	8.693	1,257	13,220	0	0	217,284	0	2,410	1,808	35,578	2,713	393
1908	2,907	0	0	2,800	0	0	0	0	602	0	0	602	87
1909	0	1,438	0	1,427	0	0	0	0	0	301	0	301	44
1910	5,564	8,347	0	5,393	0	0	0	0	1,207	1,812	0	1,206	174
1911	0	3,834	4,825	0	0	0	0	0	0	903	904	0	0
1912	0	0	0	0	0	0	0	0	0	0	0	0	0
1913	0	0	0	0	0	0	0	0	0	0	0	0	0
1914	4,068	7,138	0	3,740	0	0	0	0	906	1,505	0	904	131
1915	5,437	0	0	5,204	0	0	0	0	1,207	0	0	1,206	174
1916	1,249	1,235	4,142	0	0	0	0	0	301	302	903	0	0
1917	0	0	0	0	0	0	0	0	0	0	0	0	0
1918	0	0	0	0	0	0	0	0	0	0	0	0	0
1919	0	0	0	0	0	0	0	0	0	0	0	0	0
1920	0	0	0	0	0	0	0	0	0	0	0	0	0
1921	0	0	0	0	0	0	0	0	0	0	0	0	0
1922	4,067	6,882	9,875	3,919	0	0	0	0	903	1,510	2,112	904	131
1923	0	0	0	0	0	0	0	0	0	0	0	0	0
1924	0	0	0	0	0	0	0	0	0	0	0	0	0
1925	0	0	0	0	0	0	0	0	0	0	0	0	0
[a]1926	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	44,546	37,567	20,099	37,223	0	0	217,284	0	9,477	8,141	39,497	8,137	1,178
Average	1,497	1,263	676	1,251	0	0	7,304	0	318	274	1,328	273	40

[a] Partial year, January 1 to October 1.

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TABLE 14 (Continued). SAN GABRIEL RESERVOIR ON SAN GABRIEL RIVER.

AVERAGE SIZE OF FLOWS
OF WATER YIELD UNDER "COORDINATED PLAN"

Yearly Summary of Computations Carried out on a Daily Basis.

Maximum controlled flow at Azusa 1,900 second-feet. Maximum flood control reserve 131,000 acre-feet.

Natural flow up to 152 second-feet passed for prior rights.

Reservoir emptied of seasonal storage each year.

Year	Size of total flow at Azusa in second-feet										
	1,000-1,250										
	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet				Seasonally stored water in acre-feet				Aggregate of natural flow up to 152 second-feet passed for prior rights in acre-feet				Yield in a uniformly continuous flow equalized between seasons by over-year storage in acre-feet
	Flood control and seasonal storage coordinated			**Flood control, seasonal and over-year storage coordinated**	**Flood control and seasonal storage coordinated**			**Flood control, seasonal and over-year storage coordinated**	**Flood control and seasonal storage coordinated**			**Flood control, seasonal and over-year storage coordinated**	**Flood control, seasonal and over-year storage coordinated**
	Maximum flood control reserve or first 131,000 acre-feet of capacity	180,000 acre-feet capacity	240,000 acre-feet capacity	180,000 acre-feet capacity	Maximum flood control reserve or first 131,000 acre-feet of capacity	180,000 acre-feet capacity	240,000 acre-feet capacity	180,000 acre-feet capacity	Maximum flood control reserve or first 131,000 acre-feet of capacity	180,000 acre-feet capacity	240,000 acre-feet capacity	180,000 acre-feet capacity	180,000 acre-feet capacity

1897	0	0	0	0	0	0	0	0	0	0	0	0	0
1898	0	0	0	0	0	0	0	0	0	0	0	0	0
1899	0	0	0	0	0	0	0	0	0	0	0	0	0
1900	0	0	0	0	0	0	0	0	0	0	0	0	0
1901	0	0	0	0	0	0	0	0	0	0	0	0	0
1902	0	0	0	0	0	0	0	0	0	0	0	0	0
1903	0	0	0	0	0	0	0	0	0	0	0	0	0
1904	0	0	0	0	0	0	0	0	0	0	0	0	0
1905	0	0	0	1,850	0	0	0	0	0	0	0	301	44
1906	0	0	0	0	2,139	0	0	0	301	0	0	0	0
1907	18,039	12,375	1,963	25,319	0	0	0	0	2,715	1,812	302	3,616	523
1908	0	0	0	2,136	0	0	0	0	0	0	0	301	44
1909	0	2,116	0	1,679	0	0	0	0	0	301	0	301	44
1910	3,937	5,845	0	1,741	0	0	0	0	604	903	0	301	44
1911	0	1,870	2,118	2,013	0	0	0	0	0	301	302	301	44
1912	0	0	0	0	0	0	0	0	0	0	0	0	0
1913	0	0	0	0	0	0	0	0	0	0	0	0	0
1914	1,947	2,140	1,833	1,909	0	0	0	0	302	302	302	301	44
1915	5,844	0	0	3,959	0	0	0	0	904	0	0	601	87
1916	0	0	2,148	0	0	0	0	0	0	0	301	0	0
1917	0	0	0	0	0	0	0	0	0	0	0	0	0
1918	0	0	0	3,594	0	0	0	0	0	0	0	603	87
1919	0	0	0	0	0	0	0	0	0	0	0	0	0
1920	0	0	0	0	0	0	0	0	0	0	0	0	0
1921	0	0	0	0	0	0	0	0	0	0	0	0	0
1922	2,614	2,065	1,828	0	0	0	0	0	301	301	301	0	0
1923	1,945	0	0	1,892	0	0	0	0	250	0	0	250	44
1924	0	0	0	0	0	0	0	0	0	0	0	0	0
1925	0	0	0	0	0	0	0	0	0	0	0	0	0
[a]1926	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	34,326	26,411	9,890	46,092	2,139	0	0	0	5,377	3,920	1,508	6,876	1,005
Average	1,154	888	333	1,549	72	0	0	0	181	132	51	231	34

[a] Partial year, January 1 to October 1.

TABLE 14 (Continued). SAN GABRIEL RESERVOIR ON SAN GABRIEL RIVER.

AVERAGE SIZE OF FLOWS
OF WATER YIELD UNDER "COORDINATED PLAN"

Yearly Summary of Computations Carried out on a Daily Basis.

Maximum controlled flow at Azusa 1,900 second-feet. Maximum flood control reserve 131,000 acre-feet.

Natural flow up to 152 second-feet passed for prior rights.

Reservoir emptied of seasonal storage each year.

Year	Size of total flow at Azusa in second-feet												
	1,250-1,500												
	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet				Seasonally stored water in acre-feet				Aggregate of natural flow up to 152 second-feet passed for prior rights in acre-feet				Yield in a uniformly continuous flow equalized between seasons by over-year storage in acre-feet
	Flood control and seasonal storage coordinated			**Flood control, seasonal and over-year storage coordinated**	**Flood control and seasonal storage coordinated**			**Flood control, seasonal and over-year storage coordinated**	**Flood control and seasonal storage coordinated**			**Flood control, seasonal and over-year storage coordinated**	**Flood control, seasonal and over-year storage coordinated**
	Maximum flood control reserve or first 131,000 acre-feet of capacity	180,000 acre-feet capacity	240,000 acre-feet capacity	180,000 acre-feet capacity	Maximum flood control reserve or first 131,000 acre-feet of capacity	180,000 acre-feet capacity	240,000 acre-feet capacity	180,000 acre-feet capacity	Maximum flood control reserve or first 131,000 acre-feet of capacity	180,000 acre-feet capacity	240,000 acre-feet capacity	180,000 acre-feet capacity	180,000 acre-feet capacity

1897	0	0	0	0	0	0	0	0	0	0	0	0	0
1898	0	0	0	0	0	0	0	0	0	0	0	0	0
1899	0	0	0	0	0	0	0	0	0	0	0	0	0
1900	0	0	0	0	0	0	0	0	0	0	0	0	0
1901	0	0	0	0	0	0	0	0	0	0	0	0	0
1902	0	0	0	0	0	0	0	0	0	0	0	0	0
1903	0	0	0	0	0	0	0	0	0	0	0	0	0
1904	0	0	0	0	0	0	0	0	0	0	0	0	0
1905	0	0	0	0	0	0	0	0	0	0	0	0	0
1906	0	0	0	0	0	0	0	0	0	0	0	0	0
1907	26,259	6,621	4,622	12,354	0	0	0	0	3,321	906	603	1,507	218
1908	2,235	0	0	0	0	0	0	0	301	0	0	0	0
1909	2,656	0	0	0	0	0	0	0	301	0	0	0	0
1910	0	2,516	0	0	0	0	0	0	0	302	0	0	0
1911	0	0	2,479	0	0	0	0	0	0	0	302	0	0
1912	0	0	0	0	0	0	0	0	0	0	0	0	0
1913	0	0	0	0	0	0	0	0	0	0	0	0	0
1914	2,286	2,280	0	2,157	0	0	0	0	302	302	0	301	44
1915	0	0	0	0	0	0	0	0	0	0	0	0	0
1916	0	2,556	10,346	0	0	0	0	0	0	301	1,208	0	0
1917	0	0	0	0	0	0	0	0	0	0	0	0	0
1918	10,363	0	0	0	0	0	0	0	903	0	0	0	0
1919	0	0	0	0	0	0	0	0	0	0	0	0	0
1920	0	0	0	0	0	0	0	0	0	0	0	0	0
1921	0	2,588	0	0	0	0	0	0	0	301	0	0	0
1922	0	5,069	2,614	4,861	0	0	0	0	0	602	301	603	87
1923	0	0	0	0	0	0	0	0	0	0	0	0	0
1924	0	0	0	0	0	0	0	0	0	0	0	0	0
1925	0	0	0	0	0	0	0	0	0	0	0	0	0
[a]1926	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	43,799	21,630	20,061	19,372	0	0	0	0	5,128	2,714	2,414	2,411	349
Average	1,472	727	674	651	0	0	0	0	172	91	81	81	12

[a] Partial year, January 1 to October 1.

TABLE 14 (Continued). SAN GABRIEL RESERVOIR ON SAN GABRIEL RIVER.

AVERAGE SIZE OF FLOWS
OF WATER YIELD UNDER "COORDINATED PLAN"

Yearly Summary of Computations Carried out on a Daily Basis.

Maximum controlled flow at Azusa 1,900 second-feet. Maximum flood control reserve 131,000 acre-feet.

Natural flow up to 152 second-feet passed for prior rights.

Reservoir emptied of seasonal storage each year.

Year	Size of total flow at Azusa in second-feet												
	1,500-1,900												
	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet				Seasonally stored water in acre-feet				Aggregate of natural flow up to 152 second-feet passed for prior rights in acre-feet				Yield in a uniformly continuous flow equalized between seasons by over-year storage in acre-feet
	Flood control and seasonal storage coordinated			Flood control, seasonal and over-year storage coordinated	Flood control and seasonal storage coordinated			Flood control, seasonal and over-year storage coordinated	Flood control and seasonal storage coordinated			Flood control, seasonal and over-year storage coordinated	Flood control, seasonal and over-year storage coordinated
	Maximum flood control reserve or first 131,000 acre-feet of capacity	180,000 acre-feet capacity	240,000 acre-feet capacity	180,000 acre-feet capacity	Maximum flood control reserve or first 131,000 acre-feet of capacity	180,000 acre-feet capacity	240,000 acre-feet capacity	180,000 acre-feet capacity	Maximum flood control reserve or first 131,000 acre-feet of capacity	180,000 acre-feet capacity	240,000 acre-feet capacity	180,000 acre-feet capacity	180,000 acre-feet capacity

1897	2,775	0	0	3,250	0	0	0	0	301	0	0	301	44
1898	0	0	0	0	0	0	0	0	0	0	0	0	0
1899	0	0	0	0	0	0	0	0	0	0	0	0	0
1900	0	0	0	0	0	0	0	0	0	0	0	0	0
1901	7,012	0	0	0	0	0	0	0	604	0	0	0	0
1902	0	0	0	0	0	0	0	0	0	0	0	0	0
1903	3,496	0	0	0	0	0	0	0	301	0	0	0	0
1904	0	0	0	0	0	0	0	0	0	0	0	0	0
1905	27,143	0	0	10,287	0	0	0	0	2,411	0	0	904	130
1906	24303	2,864	0	23,964	17,495	0	0	17,292	3,617	301	0	3,617	523
1907	59,766	38,698	7,012	63,987	0	0	0	0	5,130	3,322	604	5,426	784
1908	2,787	0	0	2,725	0	0	0	0	301	0	0	301	44
1909	52,724	6,871	0	41,613	0	0	0	0	4,522	602	0	3,617	521
1910	59,635	3,298	0	61,545	0	0	0	0	5,125	302	0	5,426	783
1911	116,242	56,560	0	93,929	0	0	0	0	9,948	4,829	0	8,139	1,177
1912	0	0	0	0	0	0	0	0	0	0	0	0	0
1913	0	0	0	0	0	0	0	0	0	0	0	0	0
1914	140,645	87,839	46,064	132,093	0	0	0	0	12,055	7,541	3,918	11,456	1,658
1915	0	0	0	2,770	0	0	0	0	0	0	0	297	44
1916	150,880	94,784	20,783	151,716	0	0	0	0	12,961	8,138	1,808	13,262	1,917
1917	0	0	0	0	0	0	0	0	0	0	0	0	0
1918	0	0	0	0	0	0	0	0	0	0	0	0	0
1919	0	0	0	0	0	0	0	0	0	0	0	0	0
1920	0	0	0	0	0	0	0	0	0	0	0	0	0
1921	38,565	3,707	0	38,383	0	0	0	0	3,316	301	0	3,316	480
1922	181,940	156,682	101,380	179,792	0	0	0	0	15,674	13,565	8,741	15,674	2,267
1923	0	0	0	0	0	0	0	0	0	0	0	0	0
1924	0	0	0	0	0	0	0	0	0	0	0	0	0
1925	0	0	0	0	0	0	0	0	0	0	0	0	0
[a]1926	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	867,913	451,303	175,239	806,054	17,495	0	0	17,292	76,266	38,901	15,071	71,736	10,372
Average	29,174	15,170	5,890	27,095	588	0	0	581	2,564	1,307	507	2,411	348

[a] Partial year, January 1 to October 1.

TABLE 14 (Continued). SAN GABRIEL RESERVOIR ON SAN GABRIEL RIVER.

AVERAGE SIZE OF FLOWS
OF WATER YIELD UNDER "COORDINATED PLAN"

Yearly Summary of Computations Carried out on a Daily Basis.

Maximum controlled flow at Azusa 1,900 second-feet. Maximum flood control reserve 131,000 acre-feet.

Natural flow up to 152 second-feet passed for prior rights.

Reservoir emptied of seasonal storage each year.

Year	Size of total flow at Azusa in second-feet												
	Total												
	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet				Seasonally stored water in acre-feet				Aggregate of natural flow up to 152 second-feet passed for prior rights in acre-feet				Yield in a uniformly continuous flow equalized between seasons by over-year storage in acre-feet
	Flood control and seasonal storage coordinated			**Flood control, seasonal and over-year storage coordinated**	**Flood control and seasonal storage coordinated**			**Flood control, seasonal and over-year storage coordinated**	**Flood control and seasonal storage coordinated**			**Flood control, seasonal and over-year storage coordinated**	**Flood control, seasonal and over-year storage coordinated**
	[b]Maximum flood control reserve or first 131,000 acre-feet of capacity	180,000 acre-feet capacity	240,000 acre-feet capacity	[d] [f]180,000 acre-feet capacity	[c]Maximum flood control reserve or first 131,000 acre-feet of capacity	180,000 acre-feet capacity	240,000 acre-feet capacity	[e]180,000 acre-feet capacity	Maximum flood control reserve or first 131,000 acre-feet of capacity	180,000 acre-feet capacity	240,000 acre-feet capacity	180,000 acre-feet capacity	180,000 acre-feet capacity

1897	4,913	0	0	16,407	34,488	39,304	39,304	16,901	52,963	52,963	52,963	52,963	15,922
1898	0	0	0	0	2,732	2,732	2,732	0	15,687	15,687	15,687	15,687	15,922
1899	0	0	0	0	0	0	0	0	10,463	10,463	10,463	10,463	15,922
1900	0	0	0	0	0	0	0	0	11,976	11,976	11,976	11,976	15,922
1901	32,694	0	0	0	15,717	47,822	47,822	0	50,570	50,570	50,570	50,570	15,922
1902	0	0	0	0	437	437	437	0	21,816	21,816	21,816	21,816	15,922
1903	6,045	0	0	0	49,747	55,685	55,685	4,235	50,037	50,037	50,037	50,037	15,922
1904	0	0	0	0	2,482	2,482	2,482	0	24,180	24,180	24,180	24,180	15,965
1905	29,996	0	0	13,657	70,682	100,310	100,310	54,529	62,587	62,587	62,587	62,587	15,922
1906	24,303	2,864	0	23,964	140,072	161,113	163,981	123,201	67,456	67,456	67,456	67,456	15,922
1907	129,172	80,172	20,172	127,639	138,732	187,233	246,672	123,335	82,808	82,808	82,808	82,808	15,922
1908	9,758	0	0	10,159	6,461	15,887	15,887	0	56,444	56,444	56,444	56,444	15,965
1909	62,243	13,243	0	52,260	49,468	97,859	110,956	32,119	72,101	72,101	72,101	72,101	15,922
1910	76,272	27,272	0	75,162	2,117	50,000	76,937	0	54,518	54,518	54,518	54,518	15,922
1911	118,339	69,339	10,977	100,816	85,892	134,347	192,140	70,041	70,413	70,413	70,413	70,413	15,922
1912	0	0	0	0	25,435	25,435	25,435	7,761	47,362	47,362	47,362	47,362	15,965
1913	0	0	0	0	9,481	9,481	9,481	0	40,386	40,386	40,386	40,386	15,922
1914	154,577	105,577	48,271	145,722	71,219	119,650	176,383	54,901	72,456	72,456	72,456	72,456	15,922
1915	15,828	0	0	15,984	41,744	57,350	57,350	24,232	73,157	73,157	73,157	73,157	15,922
1916	152,147	103,704	43,704	152,318	54,093	101,945	161,330	36,624	77,852	77,852	77,852	77,852	15,965
1917	9,467	0	0	10,464	11,487	20,698	20,698	0	60,160	60,160	60,160	60,160	15,922
1918	11,341	0	0	3,594	65,660	76,848	76,848	49,017	58,741	58,741	58,741	58,741	15,922
1919	0	0	0	0	0	0	0	0	37,874	37,874	37,874	37,874	15,922
1920	0	0	0	0	51,949	51,949	51,949	16,978	60,683	60,683	60,683	60,683	15,965
1921	38,907	6,295	0	39,506	18,143	18,143	18,143	606	54,013	54,013	54,013	54,013	15,922
1922	194,681	178,450	124,588	195,521	93,935	142,243	201,811	77,275	87,587	87,587	87,587	87,587	15,922
1923	13,042	0	0	12,056	1,199	13,714	13,714	0	51,298	51,298	51,298	51,298	15,922
1924	0	0	0	0	360	360	360	0	25,517	25,517	25,517	25,517	15,965
1925	0	0	0	0	1,411	1,411	1,411	0	21,878	21,878	21,878	21,878	15,922
[a]1926	0	0	0	0	65,743	65,743	65,743	0	40,320	40,320	40,320	40,320	11,909
Total	1,083,725	586,916	247,712	995,229	1,110,886	1,600,181	1,936,001	691,755	1,513,303	1,513,303	1,513,303	1,513,303	473,905
Average	36,428	19,729	8,327	33,454	37,341	53,788	65,076	23,252	50,867	50,867	50,867	50,867	15,930

[a] Partial year, January 1 to October 1.

[b] The aggregate of the entries in this column is smaller than the corresponding entries in the summary table page 146, and Tables 12 and 12a, from which it is derived, by an average of about 700 acre-feet per season. This water was released in controlling floods during April, 1906, total amount 19,600 acre-feet, but was included in seasonally stored water in preparing this table.

[c] The aggregate of the entries in this column is larger than the corresponding entries in the summary table page 146 and Tables 12 and 12a, from which it is derived, by an average of about 700 acre-feet per season. This water was released in controlling floods during April, 1906, total amount 19,600 acre-feet, but was included in seasonally stored water in preparing this table.

[d] The aggregate of the entries in this column is smaller than the corresponding entries in Tables 13 and 13a, from which it is derived, by an average of about 500 acre-feet per season. This water, 15,400 acre-feet total, was released in controlling floods during April, 1906, but was included in seasonally stored water in preparing this table.

[e] The aggregate of the entries in this column is larger than the corresponding entries in Tables 13 and 13a, from which it is derived, by an average of about 500 acre-feet per season. This water, 15,400 acre-feet total, was released in controlling floods during April, 1906, but was included in the seasonally stored water in preparing this table.

[f] Entries in this column taken from Tables 13 and 13a. In the computations for these tables, the period closed with 7601 acre-feet less water in storage than at the beginning. This water, the equivalent of 256 acre-feet per season, entered storage prior to the beginning of the period and was released as flood control water during the first flood season. It should, therefore, be deducted from the average yield in flood control water to obtain the exact yield for the period. This was not done in preparing this table.

TABLE 14 (Concluded). SAN GABRIEL RESERVOIR ON SAN GABRIEL RIVER.

AVERAGE SIZE OF FLOWS OF WATER YIELD UNDER "COORDINATED PLAN"

Yearly Summary of Computations Carried out on a Daily Basis.

Maximum controlled flow at Azusa 1,900 second-feet. **Maximum flood control reserve 131,000 acre-feet.**

Natural flow up to 152 second-feet passed for prior rights.

Reservoir emptied of seasonal storage each year.

Year	Grand total in acre-feet			
	Flood control and seasonal storage coordinated			Flood control, seasonal and over-year storage coordinated
	Maximum flood control reserve or first 131,000 acre-feet of capacity	180,000 acre-feet capacity	240,000 acre-feet capacity	180,000 acre-feet capacity
1897	92,364	92,267	92,267	102,193
1898	18,419	18,419	18,419	31,609
1899	10,463	10,463	10,463	26,385
1900	11,976	11,976	11,976	27,898
1901	98,981	98,392	98,392	66,492
1902	22,253	22,253	22,253	37,738
1903	105,829	105,722	105,722	70,194
1904	26,662	26,662	26,662	40,145
1905	163,265	162,897	162,897	146,695
1906	231,831	231,433	231,437	230,543
1907	350,712	350,213	349,652	349,704
1908	72,663	72,331	72,331	82,568
1909	183,812	183,203	183,057	172,402
1910	132,907	131,790	131,455	145,602
1911	274,644	274,099	273,530	257,192
1912	72,797	72,797	72,797	71,088
1913	49,867	49,867	49,867	56,308

Year	Grand total in acre-feet			
	Flood control and seasonal storage coordinated			Flood control, seasonal and over-year storage coordinated
	Maximum flood control reserve or first 131,000 acre-feet of capacity	180,000 acre-feet capacity	240,000 acre-feet capacity	[b]180,000 acre-feet capacity
1914	298,252	297,683	297,110	289,001
1915	130,729	130,507	130,507	129,295
1916	284,092	283,501	282,886	282,759
1917	81,114	80,858	80,858	86,546
1918	135,742	135,589	135,589	127,274
1919	37,874	37,874	37,874	53,796
1920	112,632	112,632	112,632	93,626
1921	111,063	78,451	72,156	110,047
1922	376,203	408,280	413,986	376,305
1923	65,539	65,012	65,012	79,276
1924	25,877	25,877	25,877	41,482
1925	23,289	23,289	23,289	37,800
[a]1926	106,063	106,063	106,063	52,229
Total	3,707,914	3,700,400	3,697,016	3,674,192
Average	124,636	124,384	124,270	123,503
Average evaporation	809	1,061	1,175	2,198
Average total flow	125,445	125,445	125,445	125,701

[a] Partial year, January 1 to October 1.

[b] Entries in this column taken from Tables 13 and 13a. In the computations for these tables, the period closed with 7601 acre-feet less water in storage than at the beginning. This water, the equivalent of 256 acre-feet per season, entered storage prior to the beginning of the period and was released as flood control water during the first flood season. It should, therefore, be deducted from the average yield in flood control water to obtain the exact yield for the period. This was not done in preparing this table.

TABLE 15. SAN GABRIEL RESER
COMPARISON OF WATER YIELD FOR
COORDINATED WITH SEASONAL

Yearly Summary of Computations

(For corresponding monthly sum

Height of dam 383 feet.
Capacity of reservoir 180,000 acre-feet.
Natural flow up to 152 second-feet passed for prior rights.

Year	Run-off at Azusa in acre-feet	**Flood control by reservoir operating diagram** Reservoir emptied each summer to a level that would maintain constant draft through critical period; constant draft of 22 sec.-ft. maintained, other drafts only as required by reservoir operating diagram						
		Stage of reservoir at beginning of year in acre-feet	Passed by dam for prior rights in acre-feet	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Constant draft from over-year storage (22 second-feet) in acre-feet	Seasonally stored water in acre-feet	Evaporation from reservoir surface in acre-feet	Waste over spillway in acre-feet
1897	96,270	62,650	52,963	16,407	15,922	16,901	2,466	0
1898	15,687	54,261	15,687	0	15,922	0	1,926	0
1899	10,463	36,413	10,463	0	15,922	0	1,448	0
1900	21,986	19,043	11,976	0	15,922	0	796	0
1901	89,560	12,335	50,570	0	15,922	0	1,846	0
1902	22,314	33,557	21,816	0	15,922	0	1,374	0
1903	106,985	16,759	50,037	0	15,922	4,235	2,293	0
1904	26.836	51,257	24,180	0	15,965	0	1,922	0
1905	164,715	36,026	62,587	13,658	15,922	54,528	2,781	0
1906	241,430	51,265	67,456	39,397	15,922	107,768	3,189	0
1907	345,320	58,963	82,808	127,639	15,922	123,335	3,301	0
1908	72,950	51,278	56,444	10,159	15,965	0	2,012	0
1909	199,540	39,648	72,101	52,260	15,922	32,119	2,593	0
1910	118,450	64,193	54,518	75,162	15,922	0	1,892	0
1911	276,280	35,149	70,413	100,816	15,922	70,041	2,916	0
1912	73,620	51,321	47,362	0	15,965	7,761	2,356	0
1913	50,323	51,497	40,386	0	15,922	0	2,099	0
1914	299,710	43,413	72,456	145,722	15,922	54,901	2,785	0
1915	131,800	51,337	73,157	15,984	15,922	24,232	2,514	0
1916	294,220	51,328	77,852	152,317	15,965	36,625	2,625	0
1917	72,710	60,164	60,160	10,464	15,922	0	2,122	0
1918	137,140	44,206	58,741	3,595	15,922	49,016	2,741	0
1919	38,005	51,331	37,874	0	15,922	0	1,848	0
1920	113,730	33,692	60,683	0	15,965	16,978	2,454	0
1921	186,760	51,342	54,013	39,506	15,922	606	2,269	0
1922	316,690	125,786	87,587	195,520	15,922	77,276	2,970	0
1923	51,750	63,201	51,298	12,056	15,922	0	1,858	0
1924	25,933	33,817	25,517	0	15,965	0	1,380	0
1925	23,400	16,888	21,878	0	15,922	0	744	0
[a]1926	107,400	1,744	40,320	0	11,909	0	1,866	0
Total	3,731,977		1,513,303	[b]1,010,662	473,905	676,322	65,386	0
Average	125,445		50,867	[b]33,972	15,930	22,734	2,198	

[a] Partial year, January 1 to October 1.

[b] These figures contain 7601 acre-feet total or an average of 256 acre-feet per season of water contributed from outside the exact period of analysis. In the computations from which this table is prepared, the water in storage on October 1, 1926, the end of the period, is less by this amount than on January 1, 1897, the beginning of the period. Since in the computations this water was released as flood control water during the first flood season of the period, the exact yield of flood control water for the period is less than here shown by this amount.

VOIR ON SAN GABRIEL RIVER.
TWO METHODS OF FLOOD CONTROL
AND OVER-YEAR STORAGE.

Carried out on a Daily Basis.
mary, see Table 15a, page 404.)

Maximum controlled flow at Azusa 1900 second-feet.
Maximum flood control reserve 131,000 acre-feet.
Reservoir emptied of seasonal storage each year.

Flood control, holding maximum reservoir space required (131,000 ac.-ft.) in reserve throughout flood season. Reservoir emptied each summer to a level that would maintain constant draft through critical period; constant draft of 18 sec.-ft. maintained, other drafts only as required by reservoir operating diagram							
Stage of reservoir at beginning of year in acre-feet	Passed by dam for prior rights in acre-feet	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Constant draft from over-year storage (18 second-feet) in acre-feet	Seasonally stored water in acre-feet	Evaporation from reservoir surface in acre-feet	Waste over spillway in acre-feet	Year
49,122	52,963	33,933	13,032	0	2,006	0	1897
43,458	15,687	0	13,032	0	1,688	0	1898
28,738	10,463	0	13,032	0	1,263	0	1899
14,443	11,976	0	13,032	0	644	0	1900
10,777	50,570	0	13,032	0	1,854	0	1901
34,881	21,816	0	13,032	0	1,463	0	1902
20,884	50,037	11,429	13,032	4,588	2,186	0	1903
46,597	24,180	0	13,068	0	1,836	0	1904
34,349	62,587	73,010	13,032	1,734	2,140	0	1905
46,561	67,456	136,655	13,032	19,376	2,350	0	1906
49,122	82,808	228,430	13,032	21,229	2,352	0	1907
46,591	56,444	10,356	13,068	0	1,928	0	1908
37,745	72,101	91,415	13,032	2,644	2,165	0	1909
55,928	54,518	68,002	13,032	0	1,911	0	1910
36,915	70,413	176,382	13,032	4,617	2,194	0	1911
46,557	47,362	13,060	13,068	0	2,082	0	1912
44,605	40,386	2,687	13,032	0	1,909	0	1913
36,914	72,456	197,801	13,032	4,554	2,176	0	1914
46,605	73,157	35,855	13,032	7,618	2,201	0	1915
46,542	77,852	198,835	13,068	0	2,028	0	1916
48,979	60,160	8,027	13,032	0	1,946	0	1917
38,524	58,741	60,968	13,032	0	2,000	0	1918
40,923	37,874	0	13,032	0	1,623	0	1919
26,399	60,683	20,118	13,068	0	2,068	0	1920
44,192	54,013	46,345	13,032	352	2,108	0	1921
115,102	87,587	259,909	13,032	19,973	2,328	0	1922
48,963	51,298	0	13,032	0	1,850	0	1923
34,533	25,517	0	13,068	0	1,453	0	1924
20,428	21,878	0	13,032	0	1,010	0	1925
7,908	40,320	11,836	9,747	1,088	1,772	0	[a]1926
	1,513,303	1,685,053	387,891	[c]87,773	56,534	0	Total
	50,867	56,641	13,039	[c]2,950	1,900		Average

[c] In the computations for this table, the period of analysis closed with 1423 acre-feet more water in storage than at the beginning, the equivalent of 48 acre-feet per season. Since in the computations this water was stored in the last year of the period of analysis, the exact yield in seasonally stored water for the period is larger than here shown by this amount.

TABLE 16. SAN GABRIEL RESER

COMPARISON OF WATER YIELD FOR THE USE OF

Yearly Summary of Computations
(For corresponding monthly sum

Natural flow up to 152 second-

Height of dam 383 feet.

Capacity of reservoir 180,000 acre-feet.

Year	Run-off at Azusa in acre-feet	Flood control alone Water drawn from reservoir only as required by reservoir operating diagram					Flood control partially coordinated Constant draft of 22 sec.-ft. maintained, required by reservoir			
		Stage of reservoir at beginning of year in acre-feet	Passed by dam for prior rights in acre-feet	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Evaporation from reservoir surface in acre-feet	Waste over spillway in acre-feet	Stage of reservoir at beginning of year in acre-feet	Passed by dam for prior rights in acre-feet	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Constant draft from over-year storage (22 second-feet) in acre-feet
1897	96,270	62,650	52,963	30,209	2,830	0	62,650	52,963	16 407	15,922
1898	15,687	72,918	15,687	13,484	2,273	0	70,937	15,687	10,849	15,922
1899	10,463	57,161	10,463	0	2,219	0	42,090	10,463	0	15,922
1900	21,986	54,942	11,976	0	2,166	0	24,561	11,976	0	15,922
1901	89,560	62,786	50,570	36,470	2,405	0	17,571	50,570	0	15,922
1902	22,314	62,901	21,816	0	2,357	0	38,663	21,816	0	15,922
1903	106,985	61,042	50,037	18,087	3,100	0	21,716	50,037	0	15,922
1904	26,836	96,803	24,180	0	3,157	0	60,266	24,180	0	15,965
1905	164,715	96,302	62,587	99,337	3,569	0	44,803	62,587	32,989	15,922
1906	241,430	95,524	67,456	201,800	4,497	0	94,565	67,456	184,996	15,922
1907	345,320	63,201	82,808	212,060	4,663	7,426	63,201	82,808	201,165	15,922
1908	72,950	101,564	56,444	62,322	2,245	0	100,648	56,444	59,529	15,965
1909	199,540	53,503	72,101	104,979	3,124	0	39,648	72,101	75,341	15,922
1910	118,450	72,839	54,518	85,557	2,072	0	72,839	54,518	83,808	15,922
1911	276,280	49,142	70,413	153,559	3,871	0	35,149	70,413	124,229	15,922
1912	73,620	97,579	47,362	11,255	3,573	0	97,099	47,362	496	15,965
1913	50,323	109,009	40,386	47,834	2,546	0	103,463	40,386	39,563	15,922
1914	299,710	68,566	72,456	227,682	3,549	0	55,522	72,456	198,812	15,922
1915	131,800	64,589	73,157	31,417	2,967	0	64,589	73,157	29,236	15,922
1916	294,220	88,848	77,852	238,753	3,262	0	75,288	77,852	209,378	15,965
1917	72,710	63,201	60,160	14,791	2,302	0	63,201	60,160	13,501	15,922
1918	137,140	58,658	58,741	61,007	3,529	0	44,206	58,741	31,054	15,922
1919	38,005	72,521	37,874	7,081	2,568	0	72,261	37,874	0	15,922
1920	113,730	63,003	60,683	41,059	3,263	0	54,111	60,683	16,619	15,965
1921	186,760	71,728	54,013	62,355	2,484	0	71,466	54,013	60,199	15,922
1922	316,690	139,636	87,587	301,585	3,953	0	125,786	87,587	271,925	15,922
1923	51,750	63,201	51,298	13,408	2,048	0	63,201	51,298	12,056	15,922
1924	25,933	48,197	25,517	0	2,012	0	33,817	25,517	0	15,965
1925	23,400	46,601	21,878	0	1,984	0	16,888	21,878	0	15,922
[a]1926	107,400	46,139	40,320	0	2,842	0	1,744	40,320	0	11,909
Total	3,731,977		1,513,303	[b]2,076,091	87,430	7,426		1,513,303	[c]1,672,152	473,905
Average	125,445		50,867	[b]69,785	2,939	250		50,867	[c]56,207	15,930

[a] Partial year, January 1 to October 1.

[b] In the computations for this table, the period of analysis closed with 47,727 acre-feet more water in storage than at the beginning, the equivalent of 1604 acre-feet per season. Since in the computations this water was stored in the last year of the period of analysis, the exact yield of flood control water for the period is greater than here shown by this amount.

VOIR ON SAN GABRIEL RIVER.

THREE STEPS IN COORDINATING RESERVOIR SPACE.

Carried out on a Daily Basis.

mary, see Table 16a, page 426.)

feet passed for prior rights.

Maximum controlled flow at Azusa 1900 second-feet.

Maximum flood control reserve 131,000 acre-feet.

with conservation other drafts only as operating diagram		Flood control completely coordinated with conservation Reservoir emptied each summer to a level that would maintain constant draft through critical period; constant draft of 22 sec.-ft. maintained, other drafts only as required by reservoir operating diagram							
Evaporation from reservoir surface in acre-feet	Waste over spillway in acre-feet	Stage of reservoir at beginning of year in acre-feet	Passed by dam for prior rights in acre-feet	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Constant draft from over-year storage (22 second-feet) in acre-feet	Variable summer draft from seasonal storage in acre-feet	Evaporation from reservoir surface in acre-feet	Waste over spillway in acre-feet	Year
2,691	0	62,650	52,963	16,407	15,922	16.901	2,466	0	1897
2,076	0	54,261	15,687	0	15,922	0	1,926	0	1898
1,607	0	36,413	10,463	0	15,922	0	1,448	0	1899
1,078	0	19,043	11,976	0	15,922	0	796	0	1900
1,976	0	12,335	50,570	0	15,922	0	1,846	0	1901
1,523	0	33,557	21,816	0	15,922	0	1,374	0	1902
2,476	0	16,759	50,037	0	15,922	4,235	2,293	0	1903
2,154	0	51,257	24,180	0	15,965	0	1,922	0	1904
3,455	0	36,026	62,587	13,658	15,922	54,528	2,781	0	1905
4,420	0	51,265	67,456	39,397	15,922	107,768	3,189	0	1906
4,627	3,351	58,963	82,808	127,639	15,922	123,335	3,301	0	1907
2,012	0	51,278	56,444	10,159	15,965	0	2,012	0	1908
2,985	0	39,648	72,101	52,260	15,922	32,119	2,593	0	1909
1,892	0	64,193	54,518	75,162	15,922	0	1,892	0	1910
3,766	0	35,149	70,413	100,816	15,922	70,041	2,916	0	1911
3,433	0	51,321	47,362	0	15,965	7,761	2,356	0	1912
2,393	0	51,497	40,386	0	15,922	0	2,099	0	1913
3,453	0	43,413	72,456	145,722	15,922	54,901	2,785	0	1914
2,786	0	51,337	73,157	15,984	15,922	24,232	2,514	0	1915
3,112	0	51,328	77,852	152,317	15,965	36,625	2,625	0	1916
2,122	0	60,164	60,160	10,464	15,922	0	2,122	0	1917
3,368	0	44,206	58,741	3,595	15,922	49,016	2,741	0	1918
2,359	0	51,331	37,874	0	15,922	0	1,848	0	1919
3,108	0	33,692	60,683	0	15,965	16,978	2,454	0	1920
2,306	0	51,342	54,013	39,506	15,922	606	2,269	0	1921
3,841	0	125,786	87,587	195,520	15,922	77,276	2,970	0	1922
1,858	0	63,201	51,298	12,056	15,922	0	1,858	0	1923
1,380	0	33,817	25,517	0	15,965	0	1,380	0	1924
744	0	16,888	21,878	0	15,922	0	744	0	1925
1,866	0	1,744	40,320	0	11,909	0	1,866	0	[a]1926
76,867	3,351		1,513,303	[c]1,010,662	473,905	676,322	65,386	0	Total
2,584	113		50,867	[c]33,972	15,930	22,734	2,198	0	Average

[c] These figures contain 7601 acre-feet total or an average of 256 acre-feet per season of water contributed from outside the exact period of analysis. In the computations from which this table is prepared, the water in storage on October 1, 1926, the end of the period, is less by this amount than on January 1, 1897, the beginning of the period. Since in the computations this water was released as flood control water during the first flood season of the period, the exact yield of flood control water for the period is less than here shown by this amount.

TABLE 17. SAN GABRIEL RESER

COMPARISON OF WATER YIELD FOR OPERATING FOR FLOOD CONTROL

Yearly Summary of Computations
(For corresponding monthly sum

Natural flow up to 152 second-

Maximum controlled flow at Azusa 1900 second-feet.

Year	Run-off at Azusa in acre-feet	Height of dam 383 feet — Capacity of reservoir 180,000 ac.-ft. Constant draft of 22 sec.-ft. maintained, other drafts only as required by reservoir operating diagram					
		Stage of reservoir at beginning of year in acre-feet	Passed by dam for prior rights in acre-feet	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Constant draft from over-year storage (22 second-feet) in acre-feet	Evaporation from reservoir surface in acre-feet	Waste over spillway in acre-feet
1897	96,270	62,650	52,963	16,407	15,922	2,691	0
1898	15,687	70,937	15,687	10,849	15,922	2,076	0
1899	10,463	42,090	10,463	0	15,922	1,607	0
1900	21,986	24,561	11,976	0	15,922	1,078	0
1901	89,560	17,571	50,570	0	15,922	1,976	0
1902	22,314	38,663	21,816	0	15,922	1,523	0
1903	106,985	21,716	50,037	0	15,922	2,476	0
1904	26,836	60,266	24,180	0	15,965	2,154	0
1905	164,715	44,803	62,587	32,989	15,922	3,455	0
1906	241,430	94,565	67,456	184,996	15,922	4,420	0
1907	345,320	63,201	82,808	201,165	15,922	4,627	3,351
1908	72,950	100,648	56.444	59,529	15,965	2,012	0
1909	199,540	39,648	72,101	75,341	15,922	2,985	0
1910	118,450	72,839	54,518	83,808	15,922	1,892	0
1911	276,280	35,149	70,413	124,229	15,922	3,766	0
1912	73,620	97,099	47,362	496	15,965	3,433	0
1913	50,323	103,463	40,386	39,563	15,922	2,393	0
1914	299,710	55,522	72,456	198,812	15,922	3,453	0
1915	131,800	64,589	73,157	29,236	15,922	2,786	0
1916	294,220	75,288	77,852	209,378	15,965	3,112	0
1917	72,710	63,201	60,160	13,501	15,922	2,122	0
1918	137,140	44,206	58,741	31,054	15,922	3,368	0
1919	38,005	72,261	37,874	0	15,922	2,359	0
1920	113,730	54,111	60,683	16,619	15,965	3,108	0
1921	186,760	71,466	54,013	60,199	15,922	2,306	0
1922	316,690	125,786	87,587	271,925	15,922	3,841	0
1923	51,750	63,201	51,298	12,056	15,922	1,858	0
1924	25,933	33,817	25,517	0	15,965	1,380	0
1925	23,400	16,888	21,878	0	15,922	744	0
[a]1926	107,400	1,744	40,320	0	11,909	1,866	0
Total	3,731,977		1,513,303	[b]1,672,152	473,905	76.867	3,351
Average	125,445		50,867	[b]56,207	15,930	2,584	113

[a] Partial year, January 1 to October 1.

[b] These figures contain 7601 acre-feet total or an average of 256 acre-feet per season of water contributed from outside the exact period of analysis. In the computations from which this table is prepared, the water in storage on October 1, 1926, the end of the period, is less by this amount than on January 1, 1897, the beginning of the period. Since in the computations this water was released as flood control water during the first flood season of the period, the exact yield of flood control water for the period is less than here shown by this amount.

VOIR ON SAN GABRIEL RIVER.

TWO SIZES OF RESERVOIR AND CONSTANT DRAFT ONLY.

Carried out on a Daily Basis.
mary, see Table 17a, page 448.)

feet passed for prior rights.

Maximum flood control reserve 131,000 acre-feet.

Height of dam 425 feet — Constant draft of 41 sec.-ft. maintained, other drafts only as required by reservoir operating diagram — Capacity of reservoir 240,000 ac.-ft.						
Stage of reservoir at beginning of year in acre-feet	Passed by dam for prior rights in acre-feet	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Constant draft (41 second-feet) in acre-feet	Evaporation from reservoir surface in acre-feet	Waste over spillway in acre-feet	Year
122,650	52,963	15,089	29,672	3,802	0	1897
117,394	15,687	0	29,672	3,170	0	1898
84,552	10,463	0	29,672	2,461	0	1899
52,419	11,976	0	29,672	1,677	0	1900
31,080	50,570	0	29,672	2,116	0	1901
38,282	21,816	0	29,672	1,269	0	1902
7,839	50,037	0	29,672	1,959	0	1903
33,156	24,180	0	29,754	1,168	0	1904
4,890	62,587	0	29,672	2,931	0	1905
74,415	67,456	90,216	29,672	5,300	0	1906
123,201	82,808	190,451	29,672	5,733	0	1907
159,857	56,444	57,178	29,754	3,216	0	1908
86,215	72,101	47,055	29,672	4,088	0	1909
132,839	54,518	82,307	29,672	3,114	0	1910
81,678	70,413	96,025	29,672	4,819	0	1911
157,029	47,362	0	29,754	4,471	0	1912
149,062	40,386	24,723	29,672	3,529	0	1913
101,075	72,456	169,521	29,672	4,543	0	1914
124,593	73,157	27,425	29,672	3,903	0	1915
122,236	77,852	181,433	29,754	4,216	0	1916
123,201	60,160	12,270	29,672	3,308	0	1917
90,501	58,741	2,982	29,672	4,212	0	1918
132,034	37,874	0	29,672	3,481	0	1919
99,012	60,683	0	29,754	3,860	0	1920
118,445	54,013	35,443	29,672	3.457	0	1921
182,620	87,587	253,954	29,672	4,896	0	9122
123,201	51,298	10,928	29,672	3,084	0	1923
79,969	25,517	0	29,754	2,376	0	1924
48,255	21,878	0	29,672	1,601	0	1925
18,504	40.320	0	22,193	2,054	0	[a]1926
	1,513,303	1,297,000	[c]883,173	99,814	0	Total
	50,867	[c]43,597	[c]29,686	3,355	0	Average

[c] These figures contain 61,313 acre-feet total or an average of 2060 acre-feet per season of water contributed from outside the exact period of analysis. In the computations from which this table is prepared the water in storage on October 1, 1926, the end of the period, is less by this amount than on January 1, 1897, the beginning of the period. A supplementary analysis, having the same amount of water in storage at the beginning and at the end of the period, was made to obtain the exact yield for the period. This gave 47,900 and 23,300 acre-feet per season, respectively, for the flood control wate rand uniformly continuous flow instead of 43,597 and 29,686 acre-feet, respectively, that are shown herein.

TABLE 18. SAN GABRIEL RESERVOIR ON SAN GABRIEL RIVER.

AVERAGE SIZE OF FLOWS OF WATER YIELD FOR THREE STEPS IN COORDINATING THE USE OF RESERVOIR SPACE

Height of dam, 383 feet. Maximum controlled flow at Azusa, 1,900 second-feet.
Capacity of reservoir, 180,000 acre-feet. Maximum flood control reserve, 131,000 acre-feet.
Natural flow up to 152 second-feet passed for prior rights.

Year	Size of total flow at Azusa in second-feet								
	0-250								
	Flood control alone Water drawn from reservoir only as required by reservoir operating diagram			**Flood control partially coordinated with conservation** Constant draft of 22 second-feet maintained, other drafts only as required by reservoir operating diagram			**Flood control completely coordinated with conservation** Reservoir emptied each summer to a level that would maintain a constant draft of 22 second-feet through critical period; constant draft of 22 second-feet maintained, other drafts only as required by reservoir operating diagram		
	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Seasonally stored water released as a variable summer flow in acre-feet	Constant flow from over-year storage in acre-feet	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Seasonally stored water released as a variable summer flow in acre-feet	Constant flow from over-year storage in acre-feet	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Seasonally stored water released as a variable summer flow in acre-feet	Constant flow from over-year storage in acre-feet
1897	4,122	0	0	1,966	0	15,049	1,966	16,901	15,049
1898	191	0	0	107	0	15,747	0	0	15,922
1899	0	0	0	0	0	15,922	0	0	15,922
1900	0	0	0	0	0	15,922	0	0	15,922
1901	889	0	0	0	0	15,922	0	0	15,922
1902	0	0	0	0	0	15,922	0	0	15,922
1903	1,808	0	0	0	0	15,922	0	4,235	15,922
1904	0	0	0	0	0	15,965	0	0	15,965
1905	513	0	0	401	0	15,137	0	20,865	10,469
1906	591	0	0	688	0	13,391	0	0	7,635
1907	4,590	0	0	2,251	0	10,950	1,103	0	5,280
1908	62	0	0	23	0	15,179	148	0	15,484
1909	1,409	0	0	88	0	14,003	0	21,613	12,127
1910	445	0	0	310	0	14,307	310	0	14,397
1911	1,342	0	0	261	0	14,046	79	0	6,413
1912	161	0	0	143	0	15,921	0	7,761	15,965
1913	0	0	0	12	0	15,311	0	0	15,922
1914	477	0	0	151	0	12,694	156	15,509	7,676
1915	597	0	0	324	0	15,182	199	19,211	13,960
1916	14	0	0	0	0	12,563	134	29,799	12,564
1917	793	0	0	0	0	15,398	558	0	15,006
1918	209	0	0	78	0	14,831	0	26,724	12,040
1919	137	0	0	0	0	15,922	0	0	15,922
1920	2,341	0	0	1,375	0	15,485	0	16,978	15,965
1921	0	0	0	0	0	15,092	16	606	15,398
1922	307	0	0	225	0	11,342	228	0	5,104
1923	984	0	0	610	0	15,224	610	0	15,224
1924	0	0	0	0	0	15,965	0	0	15,965
1925	0	0	0	0	0	15,922	0	0	15,922
[a]1926	0	0	0	0	0	11,909	0	0	11,909
Total	21,982	0	0	9,013	0	442,145	5,577	180,202	402,893
Average	739	0	0	303	0	14,862	188	6,057	13,543

[a] Partial year, January 1 to October 1.

TABLE 18 (Continued). SAN GABRIEL RESERVOIR ON SAN GABRIEL RIVER.

AVERAGE SIZE OF FLOWS OF WATER YIELD FOR THREE STEPS IN COORDINATING THE USE OF RESERVOIR SPACE

Height of dam, 383 feet. Maximum controlled flow at Azusa, 1,900 second-feet.
Capacity of reservoir, 180,000 acre-feet. Maximum flood control reserve, 131,000 acre-feet.
Natural flow up to 152 second-feet passed for prior rights.

Year	Size of total flow at Azusa in second-feet								
	250-500								
	Flood control alone Water drawn from reservoir only as required by reservoir operating diagram			**Flood control partially coordinated with conservation** Constant draft of 22 second-feet maintained, other drafts only as required by reservoir operating diagram			**Flood control completely coordinated with conservation** Reservoir emptied each summer to a level that would maintain a constant draft of 22 second-feet through critical period; constant draft of 22 second-feet maintained, other drafts only as required by reservoir operating diagram		
	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Seasonally stored water released as a variable summer flow in acre-feet	Constant flow from over-year storage in acre-feet	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Seasonally stored water released as a variable summer flow in acre-feet	Constant flow from over-year storage in acre-feet	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Seasonally stored water released as a variable summer flow in acre-feet	Constant flow from over-year storage in acre-feet
1897	12,490	0	0	10,201	0	785	10,201	0	785
1898	0	0	0	0	0	0	0	0	0
1899	0	0	0	0	0	0	0	0	0
1900	0	0	0	0	0	0	0	0	0
1901	8,976	0	0	0	0	0	0	0	0
1902	0	0	0	0	0	0	0	0	0
1903	0	0	0	0	0	0	0	0	0
1904	0	0	0	0	0	0	0	0	0
1905	952	0	0	1,699	0	174	0	33,664	5,235
1906	2,815	0	0	2,679	0	174	0	91,153	6,804
1907	10,817	0	0	7,772	0	1,090	2,696	49,281	4,100
1908	0	0	0	566	0	44	1,286	0	262
1909	2,624	0	0	4,553	0	524	4,553	10,506	3,011
1910	3,861	0	0	3,468	0	393	3,468	0	393
1911	1,156	0	0	634	0	87	634	70,041	8,070
1912	0	0	0	353	0	44	0	0	0
1913	0	0	0	1,191	0	131	0	0	0
1914	4,524	0	0	5,633	0	480	1,994	39,392	6,195
1915	2,581	0	0	2,186	0	218	2,170	5,021	1,570
1916	3,074	0	0	2,304	0	174	468	6,825	1,484
1917	8,843	0	0	8,589	0	262	7,658	0	785
1918	2,197	0	0	2,149	0	175	0	22,293	3,795
1919	1,586	0	0	0	0	0	0	0	0
1920	11,700	0	0	3,424	0	218	0	0	0
1921	0	0	0	352	0	44	0	0	0
1922	2,899	0	0	2,714	0	218	955	77,275	8,071
1923	4,220	0	0	3,871	0	349	3,871	0	349
1924	0	0	0	0	0	0	0	0	0
1925	0	0	0	0	0	0	0	0	0
[a]1926	0	0	0	0	0	0	0	0	0
Total	85,315	0	0	64,338	0	5,584	39,954	405,451	50,909
Average	2,868	0	0	2,162	0	188	1,343	13,629	1,711

[a] Partial year, January 1 to October 1.

TABLE 18 (Continued). SAN GABRIEL RESERVOIR ON SAN GABRIEL RIVER.

AVERAGE SIZE OF FLOWS OF WATER YIELD FOR THREE STEPS IN COORDINATING THE USE OF RESERVOIR SPACE

Height of dam, 383 feet. Maximum controlled flow at Azusa, 1,900 second-feet.
Capacity of reservoir, 180,000 acre-feet. Maximum flood control reserve, 131,000 acre-feet.
Natural flow up to 152 second-feet passed for prior rights.

Year	Size of total flow at Azusa in second-feet								
	500-750								
	Flood control alone Water drawn from reservoir only as required by reservoir operating diagram			**Flood control partially coordinated with conservation** Constant draft of 22 second-feet maintained, other drafts only as required by reservoir operating diagram			**Flood control completely coordinated with conservation** Reservoir emptied each summer to a level that would maintain a constant draft of 22 second-feet through critical period; constant draft of 22 second-feet maintained, other drafts only as required by reservoir operating diagram		
	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Seasonally stored water released as a variable summer flow in acre-feet	Constant flow from over-year storage in acre-feet	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Seasonally stored water released as a variable summer flow in acre-feet	Constant flow from over-year storage in acre-feet	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Seasonally stored water released as a variable summer flow in acre-feet	Constant flow from over-year storage in acre-feet
1897	3,366	0	0	990	0	44	990	0	44
1898	0	0	0	1,316	0	44	0	0	0
1899	0	0	0	0	0	0	0	0	0
1900	0	0	0	0	0	0	0	0	0
1901	11,032	0	0	0	0	0	0	0	0
1902	0	0	0	0	0	0	0	0	0
1903	0	0	0	0	0	0	0	0	0
1904	0	0	0	0	0	0	0	0	0
1905	2,133	0	0	1,345	0	44	0	0	0
1906	3,195	0	0	3,177	0	131	0	14,756	960
1907	14,447	0	0	13,749	0	654	8,960	74,054	4,624
1908	0	0	0	0	0	0	1,064	0	44
1909	3,735	0	0	6,253	0	305	2,988	0	175
1910	2,833	0	0	2,705	0	131	2,705	0	131
1911	5,594	0	0	5,907	0	305	4,161	0	218
1912	0	0	0	0	0	0	0	0	0
1913	823	0	0	0	0	0	0	0	0
1914	4,869	0	0	5,780	0	262	3,673	0	174
1915	1,816	0	0	2,200	0	87	1,682	0	87
1916	15,131	0	0	14,527	0	611	0	0	0
1917	5,155	0	0	4,912	0	262	2,248	0	131
1918	13,094	0	0	11,619	0	480	0	0	0
1919	5,358	0	0	0	0	0	0	0	0
1920	8,181	0	0	3,402	0	131	0	0	0
1921	878	0	0	0	0	0	1,107	0	44
1922	5,753	0	0	8,547	0	392	5,696	0	262
1923	6,225	0	0	5,683	0	305	5,683	0	305
1924	0	0	0	0	0	0	0	0	0
1925	0	0	0	0	0	0	0	0	0
[a]1926	0	0	0	0	0	0	0	0	0
Total	113,618	0	0	92,112	0	4,188	40,957	88,810	7,199
Average	3,819	0	0	3,096	0	141	1,377	2,985	242

[a] Partial year, January 1 to October 1.

TABLE 18 (Continued). SAN GABRIEL RESERVOIR ON SAN GABRIEL RIVER.

AVERAGE SIZE OF FLOWS OF WATER YIELD FOR THREE STEPS IN COORDINATING THE USE OF RESERVOIR SPACE

Height of dam, 383 feet. Maximum controlled flow at Azusa, 1,900 second-feet.
Capacity of reservoir, 180,000 acre-feet. Maximum flood control reserve, 131,000 acre-feet.
Natural flow up to 152 second-feet passed for prior rights.

Year	Size of total flow at Azusa in second-feet								
	750-1,000								
	Flood control alone Water drawn from reservoir only as required by reservoir operating diagram			**Flood control partially coordinated with conservation** Constant draft of 22 second-feet maintained, other drafts only as required by reservoir operating diagram			**Flood control completely coordinated with conservation** Reservoir emptied each summer to a level that would maintain a constant draft of 22 second-feet through critical period; constant draft of 22 second-feet maintained, other drafts only as required by reservoir operating diagram		
	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Seasonally stored water released as a variable summer flow in acre-feet	Constant flow from over-year storage in acre-feet	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Seasonally stored water released as a variable summer flow in acre-feet	Constant flow from over-year storage in acre-feet	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Seasonally stored water released as a variable summer flow in acre-feet	Constant flow from over-year storage in acre-feet
1897	1,783	0	0	0	0	0	0	0	0
1898	0	0	0	0	0	0	0	0	0
1899	0	0	0	0	0	0	0	0	0
1900	0	0	0	0	0	0	0	0	0
1901	5,590	0	0	0	0	0	0	0	0
1902	0	0	0	0	0	0	0	0	0
1903	0	0	0	0	0	0	0	0	0
1904	0	0	0	0	0	0	0	0	0
1905	3,360	0	0	10,971	0	305	1,520	0	44
1906	3,183	0	0	4,145	0	131	0	0	0
1907	17,511	0	0	16,833	0	524	13,220	0	393
1908	0	0	0	0	0	0	2,800	0	87
1909	11,714	0	0	10,091	0	305	1,427	0	44
1910	4,034	0	0	3,903	0	131	5,393	0	174
1911	1,563	0	0	0	0	0	0	0	0
1912	0	0	0	0	0	0	0	0	0
1913	1,501	0	0	0	0	0	0	0	0
1914	0	0	0	2,504	0	87	3,740	0	131
1915	6,824	0	0	5,204	0	174	5,204	0	174
1916	16,279	0	0	9,467	0	305	0	0	0
1917	0	0	0	0	0	0	0	0	0
1918	16,235	0	0	7,715	0	218	0	0	0
1919	0	0	0	0	0	0	0	0	0
1920	9,715	0	0	1,546	0	44	0	0	0
1921	1,436	0	0	1,215	0	44	0	0	0
1922	24,377	0	0	24,627	0	742	3,919	0	131
1923	0	0	0	0	0	0	0	0	0
1924	0	0	0	0	0	0	0	0	0
1925	0	0	0	0	0	0	0	0	0
[a]1926	0	0	0	0	0	0	0	0	0
Total	125,105	0	0	98,221	0	3,010	37,223	0	1,178
Average	4,205	0	0	3,302	0	101	1,251	0	40

[a] Partial year, January 1 to October 1.

TABLE 18 (Continued). SAN GABRIEL RESERVOIR ON SAN GABRIEL RIVER.

AVERAGE SIZE OF FLOWS OF WATER YIELD FOR THREE STEPS IN COORDINATING THE USE OF RESERVOIR SPACE.

Height of dam, 383 feet. Maximum controlled flow at Azusa, 1,900 second-feet.
Capacity of reservoir, 180,000 acre-feet. Maximum flood control reserve, 131,000 acre-feet.
Natural flow up to 152 second-feet passed for prior rights.

Year	Size of total flow at Azusa in second-feet								
	1,000-1,250								
	Flood control alone Water drawn from reservoir only as required by reservoir operating diagram			**Flood control partially coordinated with conservation** Constant draft of 22 second-feet maintained, other drafts only as required by reservoir operating diagram			**Flood control completely coordinated with conservation** Reservoir emptied each summer to a level that would maintain a constant draft of 22 second-feet through critical period; constant draft of 22 second-feet maintained, other drafts only as required by reservoir operating diagram		
	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Seasonally stored water released as a variable summer flow in acre-feet	Constant flow from over-year storage in acre-feet	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Seasonally stored water released as a variable summer flow in acre-feet	Constant flow from over-year storage in acre-feet	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Seasonally stored water released as a variable summer flow in acre-feet	Constant flow from over-year storage in acre-feet
1897	2,181	0	0	0	0	0	0	0	0
1898	2,199	0	0	2,136	0	44	0	0	0
1899	0	0	0	0	0	0	0	0	0
1900	0	0	0	0	0	0	0	0	0
1901	0	0	0	0	0	0	0	0	0
1902	0	0	0	0	0	0	0	0	0
1903	0	0	0	0	0	0	0	0	0
1904	0	0	0	0	0	0	0	0	0
1905	8,014	0	0	1,923	0	44	1,850	0	44
1906	2,182	0	0	2,238	0	44	0	0	0
1907	42,477	0	0	41,522	0	916	25,319	0	523
1908	0	0	0	0	0	0	2,136	0	44
1909	9,501	0	0	9,302	0	218	1,679	0	44
1910	1,802	0	0	1,758	0	44	1,741	0	44
1911	6,102	0	0	2,013	0	44	2,013	0	44
1912	0	0	0	0	0	0	0	0	0
1913	0	0	0	0	0	0	0	0	0
1914	0	0	0	5,845	0	131	1,909	0	44
1915	2,059	0	0	2,014	0	43	3,959	0	87
1916	6,170	0	0	4,061	0	87	0	0	0
1917	0	0	0	0	0	0	0	0	0
1918	11,795	0	0	9,493	0	218	3,594	0	87
1919	0	0	0	0	0	0	0	0	0
1920	2,182	0	0	0	0	0	0	0	0
1921	0	0	0	0	0	0	0	0	0
1922	20,396	0	0	17,755	0	392	0	0	0
1923	1,979	0	0	1,892	0	44	1,892	0	44
1924	0	0	0	0	0	0	0	0	0
1925	0	0	0	0	0	0	0	0	0
[a]1926	0	0	0	0	0	0	0	0	0
Total	119,039	0	0	101,952	0	2,269	46,092	0	1,005
Average	4,001	0	0	3,427	0	76	1,549	0	34

[a] Partial year, January 1 to October 1.

TABLE 18 (Continued). SAN GABRIEL RESERVOIR ON SAN GABRIEL RIVER.

AVERAGE SIZE OF FLOWS OF WATER YIELD FOR THREE STEPS IN COORDINATING THE USE OF RESERVOIR SPACE.

Height of dam, 383 feet. Maximum controlled flow at Azusa, 1,900 second-feet.
Capacity of reservoir, 180,000 acre-feet. Maximum flood control reserve, 131,000 acre-feet.
Natural flow up to 152 second-feet passed for prior rights.

Year	Size of total flow at Azusa in second-feet								
	1,250-1,500								
	Flood control alone Water drawn from reservoir only as required by reservoir operating diagram			**Flood control partially coordinated with conservation** Constant draft of 22 second-feet maintained, other drafts only as required by reservoir operating diagram			**Flood control completely coordinated with conservation** Reservoir emptied each summer to a level that would maintain a constant draft of 22 second-feet through critical period; constant draft of 22 second-feet maintained, other drafts only as required by reservoir operating diagram		
	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Seasonally stored water released as a variable summer flow in acre-feet	Constant flow from over-year storage in acre-feet	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Seasonally stored water released as a variable summer flow in acre-feet	Constant flow from over-year storage in acre-feet	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Seasonally stored water released as a variable summer flow in acre-feet	Constant flow from over-year storage in acre-feet
1897	0	0	0	0	0	0	0	0	0
1898	0	0	0	0	0	0	0	0	0
1899	0	0	0	0	0	0	0	0	0
1900	0	0	0	0	0	0	0	0	0
1901	0	0	0	0	0	0	0	0	0
1902	0	0	0	0	0	0	0	0	0
1903	2,255	0	0	0	0	0	0	0	0
1904	0	0	0	0	0	0	0	0	0
1905	0	0	0	0	0	0	0	0	0
1906	0	0	0	2,957	0	44	0	0	0
1907	46,603	0	0	43,615	0	785	12,354	0	218
1908	2,576	0	0	0	0	0	0	0	0
1909	2,404	0	0	0	0	0	0	0	0
1910	2,435	0	0	2,391	0	44	0	0	0
1911	0	0	0	0	0	0	0	0	0
1912	0	0	0	0	0	0	0	0	0
1913	0	0	0	0	0	0	0	0	0
1914	2,284	0	0	4,890	0	87	2,157	0	44
1915	0	0	0	0	0	0	0	0	0
1916	8,806	0	0	2,334	0	44	0	0	0
1917	0	0	0	0	0	0	0	0	0
1918	0	0	0	0	0	0	0	0	0
1919	0	0	0	0	0	0	0	0	0
1920	0	0	0	0	0	0	0	0	0
1921	0	0	0	0	0	0	0	0	0
1922	14,287	0	0	11,906	0	218	4,861	0	87
1923	0	0	0	0	0	0	0	0	0
1924	0	0	0	0	0	0	0	0	0
1925	0	0	0	0	0	0	0	0	0
[a]1926	0	0	0	0	0	0	0	0	0
Total	81,650	0	0	68,093	0	1,222	19,372	0	349
Average	2,745	0	0	2,289	0	41	651	0	12

[a] Partial year, January 1 to October 1.

TABLE 18 (Continued). SAN GABRIEL RESERVOIR ON SAN GABRIEL RIVER.

AVERAGE SIZE OF FLOWS OF WATER YIELD FOR THREE STEPS IN COORDINATING THE USE OF RESERVOIR SPACE.

Height of dam, 383 feet. Maximum controlled flow at Azusa, 1,900 second-feet.
Capacity of reservoir, 180,000 acre-feet. Maximum flood control reserve, 131,000 acre-feet.

Natural flow up to 152 second-feet passed for prior rights.

Year	Size of total flow at Azusa in second-feet								
	1,500-1,900								
	Flood control alone Water drawn from reservoir only as required by reservoir operating diagram			**Flood control partially coordinated with conservation** Constant draft of 22 second-feet maintained, other drafts only as required by reservoir operating diagram			**Flood control completely coordinated with conservation** Reservoir emptied each summer to a level that would maintain a constant draft of 22 second-feet through critical period; constant draft of 22 second-feet maintained, other drafts only as required by reservoir operating diagram		
	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Seasonally stored water released as a variable summer flow in acre feet	Constant flow from over year storage in acre feet	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Seasonally stored water released as a variable summer flow in acre feet	Constant flow from over-year storage in acre-feet	Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Seasonally stored water released as a variable summer flow in acre feet	Constant flow from over year storage in acre-feet
1897	6,267	0	0	3,250	0	44	3,250	0	44
1898	11,094	0	0	7,290	0	87	0	0	0
1899	0	0	0	0	0	0	0	0	0
1900	0	0	0	0	0	0	0	0	0
1901	9,983	0	0	0	0	0	0	0	0
1902	0	0	0	0	0	0	0	0	0
1903	14,024	0	0	0	0	0	0	0	0
1904	0	0	0	0	0	0	0	0	0
1905	84,365	0	0	16,650	0	218	10,287	0	130
1906	189,834	0	0	169,112	0	2,007	23,964	17,292	523
1907	83,041	0	0	78,774	0	1,003	63,987	0	784
1908	59,684	0	0	58,940	0	742	2,725	0	44
1909	73,592	0	0	45,054	0	567	41,613	0	521
1910	70,147	0	0	69,273	0	872	61,545	0	783
1911	137,802	0	0	115,414	0	1,440	93,929	0	1,177
1912	11,094	0	0	0	0	0	0	0	0
1913	45,510	0	0	38,360	0	480	0	0	0
1914	215,528	0	0	174,009	0	2,181	132,093	0	1,658
1915	17,540	0	0	17,308	0	218	2,770	0	44
1916	189,279	0	0	176,685	0	2,181	151,716	0	1,917
1917	0	0	0	0	0	0	0	0	0
1918	17,477	0	0	0	0	0	0	0	0
1919	0	0	0	0	0	0	0	0	0
1920	6,940	0	0	6,872	0	87	0	0	0
1921	60,041	0	0	58,632	0	742	38,383	0	480
1922	233,566	0	0	206,151	0	2,618	179,792	0	2,267
1923	0	0	0	0	0	0	0	0	0
1924	0	0	0	0	0	0	0	0	0
1925	0	0	0	0	0	0	0	0	0
[a]1926	0	0	0	0	0	0	0	0	0
Total	1,536,808	0	0	1,241,774	0	15,487	806,054	17,292	10,372
Average	51,658	0	0	41,741	0	521	27,095	581	348

[a] Partial year, January 1 to October 1.

TABLE 18. (Continued). SAN GABRIEL RESERVOIR ON SAN GABRIEL RIVER.

AVERAGE SIZE OF FLOWS OF WATER
YIELD FOR THREE STEPS IN COORDINATING THE USE OF RESERVOIR SPACE.

Height of dam, 383 feet. Maximum controlled flow at Azusa, 1,900 second-feet.

Capacity of reservoir, 180,000 acre-feet. Maximum flood control reserve, 131,000 acre-feet.

Natural flow up to 152 second-feet passed for prior rights.

Year	Size of total flow at Azusa in second-feet											
	Total, 0–1900											
	Flood Control Alone Water drawn from reservoir only as required by reservoir operating diagram				**Flood control partially coordinated with conservation** Constant draft of 22 second-feet maintained, other drafts only as required by reservoir operating diagram				**Flood control completely coordinated with conservation** Reservoir emptied each summer to a level that would maintain a constant draft of 22 second-feet through critical period, constant draft of 22 second-feet maintained, other drafts only as required by reservoir operating diagram			
	[b]Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Seasonally stored water released as a variable summer flow in acre-feet	Aggregate of natural flow up to 152 second-feet passed for prior rights in acre-feet	Constant flow from over-year storage in acre-feet	[c]Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	Seasonally stored water released as a variable summer flow in acre-feet	Aggregate of natural flow up to 152 second-feet passed for prior rights in acre-feet	Constant flow from over-year storage in acre-feet	[d e]Flood control water passing Azusa during flood season at rates less than 1,900 second-feet in acre-feet	[f]Seasonally stored water released as a variable summer flow in acre-feet	Aggregate of natural flow up to 152 second-feet passed for prior rights in acre-feet	Constant flow from over-year storage in acre-feet
1897	30,209	0	52,963	0	16,407	0	52,963	15,922	16,407	16,901	52,963	15,922
1898	13,484	0	15,687	0	10,849	0	15,687	15,922	0	0	15,687	15,922
1899	0	0	10,463	0	0	0	10,463	15,922	0	0	10,463	15,922
1900	0	0	11,976	0	0	0	11,976	15,922	0	0	11,976	15,922

1901	36,470	0	50,570	0	0	0	50,570	15,922	0	0	50,570	15,922
1902	0	0	21,816	0	0	0	21,816	15,922	0	0	21,816	15,922
1903	18,087	0	50,037	0	0	0	50,037	15,922	0	4,235	50,037	15,922
1904	0	0	24,180	0	0	0	24,180	15,965	0	0	24,180	15,965
1905	99,337	0	62,587	0	32,989	0	62,587	15,922	13,657	54,529	62,587	15,922
1906	201,800	0	67,456	0	184,996	0	67,456	15,922	23,964	123,201	67,456	15,922
1907	219,486	0	82,808	0	204,516	0	82,808	15,922	127,639	123,335	82,808	15,922
1908	62,322	0	56,444	0	59,529	0	56,444	15,965	10,159	0	56,444	15,965
1909	104,979	0	72,101	0	75,341	0	72,101	15,922	52,260	32,119	72,101	15,922
1910	85,557	0	54,518	0	83,808	0	54,518	15,922	75,162	0	54,518	15,922
1911	153,559	0	70,413	0	124,229	0	70,413	15,922	100,816	70,041	70,413	15,922
1912	11,255	0	47,362	0	496	0	47,362	15,965	0	7,761	47,362	15,965
1913	47,834	0	40,386	0	39,563	0	40,386	15,922	0	0	40,386	15,922
1914	227,682	0	72,456	0	198,812	0	72,456	15,922	145,722	54,901	72,456	15,922
1915	31,417	0	73,157	0	29,236	0	73,157	15,922	15,984	24,232	73,157	15,922
1916	238,753	0	77,852	0	209,378	0	77,852	15,965	152,318	36,624	77,852	15,965
1917	14,791	0	60,160	0	13,501	0	60,160	15,922	10,464	0	60,160	15,922
1918	61,007	0	58,741	0	31,054	0	58,741	15,922	3,594	49,017	58,741	15,922
1919	7,081	0	37,874	0	0	0	37,874	15,922	0	0	37,874	15,922
1920	41,059	0	60,683	0	16,619	0	60,683	15,965	0	16,978	60,683	15,965
1921	62,355	0	54,013	0	60,199	0	54,013	15,922	39,506	606	54,013	15,922
1922	301,585	0	87,587	0	271,925	0	87,587	15,922	195,521	77,275	87,587	15,922
1923	13,408	0	51,298	0	12,056	0	51,298	15,922	12,056	0	51,298	15,922
1924	0	0	25,517	0	0	0	25,517	15,965	0	0	25,517	15,965
9125	0	0	21,878	0	0	0	21,878	15,922	0	0	21,878	15,922
[a]1926	0	0	40,320	0	0	0	40,320	11,909	0	0	40,320	11,909
Total	2,083,517	0	1,513,303	0	1,675,503	0	1,513,303	473,905	995,229	691,755	1,513,303	473,905
Average	[b]70,035	0	50,867	0	[c]56,320	0	50,867	15,930	[d e]33,454	[f]23,252	50,867	15,930

[a] Partial year, January 1 to October 1.

[b] Entries in this column taken from Tables 16 and 16a. In the computation for these tables, the period closed with 47,727 acre-feet more water in storage than at the beginning, the equivalent of 1,604 acre-feet per season. It should be added to the average yield in flood control water to obtain the exact yield of the period. This was not done in preparing this table.

[c] Entries in this column taken from Tables 16 and 16a. In the computations for these tables, the period closed with 7601 acre-feet less water in storage than at the beginning. This water, the equivalent of 256 acre-feet per season, entered storage prior to the beginning of the period and was released as flood control water during the first flood season. It should, therefore, be deducted from average yield in flood control water to obtain the exact yield of the period. This was not done in preparing this table.

[d] Entries in this column taken from Tables 13 and 13a. In the computations for these tables, the period closed with 7601 acre-feet less water in storage than at the beginning. This water, the equivalent of 256 acre-feet per season, entered storage prior to the beginning of the period and was released as flood control water during the first flood season. It should, therefore, be deducted from the average yield in flood control water to obtain the exact yield for the period. This was not done in preparing this table.

[e] The aggregate of the entries in this column is smaller than the corresponding entries in Tables 13 and 13a, from which it is derived, by an average of about 500 acre-feet per season. This water, 15,400 acre-feet total, was released in controlling floods during April, 1906, but was included in seasonally stored water in preparing this table.

[f] The aggregate of the entries in this column is larger than the corresponding entries in Tables 13 and 13a, from which it is derived, by an average of about 500 acre-feet per season. This water, 15,400 acre-feet total, was released in controlling floods during April, 1906, but was included in seasonally stored water in preparing this table.

TABLE 18. (Concluded). SAN GABRIEL RESERVOIR ON SAN GABRIEL RIVER.

AVERAGE SIZE OF FLOWS OF WATER YIELD FOR THREE STEPS IN COORDINATING THE USE OF RESERVOIR SPACE.

Height of dam, 383 feet. Maximum controlled flow at Azusa, 1,900 second-feet.

Capacity of reservoir, 180,000 acre-feet. Maximum flood control reserve, 131,000 acre-feet.

Natural flow up to 152 second-feet passed for prior rights.

Year	Size of total flow at Azusa in second-feet — Grand total, 0–1900 — **Flood control alone** [b]Water drawn from reservoir only as required by reservoir operating diagram, in acre-feet	Size of total flow at Azusa in second-feet — Grand total, 0–1900 — **Flood control partially coordinated with conservation** [c]Constant draft of 22 second-feet maintained, other drafts only as required by reservoir operating diagram, in acre-feet	Size of total flow at Azusa in second-feet — Grand total, 0–1900 — **Flood control completely coordinated with conservation** [d]Reservoir emptied each summer to a level that would maintain a constant draft of 22 second-feet through critical period, constant draft of 22 second-feet maintained, other drafts only as required by reservoir operating diagram, in acre-feet	Year	Size of total flow at Azusa in second-feet — Grand total, 0–1900 — **Flood control alone** [b]Water drawn from reservoir only as required by reservoir operating diagram, in acre-feet	Size of total flow at Azusa in second-feet — Grand total, 0–1900 — **Flood control partially coordinated with conservation** [c]Constant draft of 22 second-feet maintained, other drafts only as required by reservoir operating diagram, in acre-feet	Size of total flow at Azusa in second-feet — Grand total, 0–1900 — **Flood control completely coordinated with conservation** [d]Reservoir emptied each summer to a level that would maintain a constant draft of 22 second-feet through critical period, constant draft of 22 second-feet maintained, other drafts only as required by reservoir operating diagram, in acre-feet
1897	83,172	85,292	102,193	1914	300,138	287,190	289.001
1898	29,171	42,458	31,609	1915	104,574	118,315	129,295
1899	10,463	26,385	26,385	1916	316,605	303,195	282,759
1900	11,976	27,898	27,898	1917	74,951	89,583	86,546
1901	87,040	66,492	66,492	1918	119,748	105,717	127,274
1902	21,816	37,738	37,738	1919	44,955	53,796	53,796

1903	68,124	65,959	70,194	1920	101,742	93,267	93,626
1904	24,180	40,145	40,145	1921	116,368	130,134	110,047
1905	161,924	111,498	146,695	1922	389,172	375,434	376,305
1906	269,256	268,374	230,543	1923	64,706	79,276	79,276
1907	302,294	303,246	349,704	1924	25,517	41,482	41,482
1908	118,766	131,938	82,568	1925	21,878	37,800	37,800
1909	177,080	163,364	172,402	[a]1926	40,320	52,229	52,229
1910	140,075	154,248	145,602				
1911	223,972	210,564	257,192	Total	3,596,820	3,662,711	3,674,192
1912	58,617	63,823	71,088	Average	120,902	123,117	123,503
1913	88,220	95,871	56,308	Average evaporation	2,939	2,584	2,198
				Average total flow	123,841	125,701	125,701

[a] Partial year, January 1 to October 1.

[b] Entries in this column taken from Tables 16 and 16a. In the computations for these tables, the period closed with 47,727 acre-feet more water in storage than at the beginning, the equivalent of 1604 acre-feet per season. It should be added to the average yield in flood control water to obtain the exact yield of the period. This was not done in preparing this table.

[c] Entries in this column taken from Tables 16 and 16a. In the computations for these tables, the period closed with 7601 acre-feet less water in storage than at the beginning. This water, the equivalent of 256 acre-feet per season, entered storage prior to the beginning of the period and was released as flood control water during the first flood season. It should, therefore, be deducted from average yield in flood control water to obtain the exact yield of the period. This was not done in preparing this table.

[d] Entries in this column taken from Tables 13 and 13a. In the computations for these tables, the period closed with 7601 acre-feet less water in storage than at the beginning. This water, the equivalent of 256 acre-feet per season, entered storage prior to the beginning of the period and was released as flood control water during the first flood season. It should, therefore, be deducted from the average yield in flood control water to obtain the exact yield for the period. This was not done in preparing this table.

Performance of the four illustrative reservoir operating diagrams in controlling floods when coordinated with conservation.

The last section of Chapter V describes the performance of the four illustrative reservoir operating diagrams in controlling floods. Tests are tabulated of their application to the records of all important floods on their respective streams. It was shown that reservoir operation in accord with these diagrams would provide more space than needed to detain the excess water of all floods of record and that the average space to spare while controlling all the large floods of record would have been about half the maximum reserve. In these computations, it was assumed that no water was released from the reservoir except as required by the diagrams. It may be observed in reviewing Plates XXIII to XXVI, inclusive, on which is delineated the reservoir stage while so controlling floods, together with the stage while controlling floods coordinately with conservation as described in this chapter, that at times the reservoir is needlessly full of water when operating for flood control alone, but when flood control is coordinated with conservation, it may be observed that the draft for useful purposes lowers the reservoir level much of the time below that required for flood control only. At these times the space available for detaining flood water is increased over that resulting from the application of the diagram not coordinated with conservation. Although this extra empty space is variable in the time and amount of its occurrence, nevertheless, it is useful in detaining some flood water.

Tables of unused reservoir space in controlling the floods of record when flood control and conservation are coordinated as described in this chapter, are prepared in parallel to those of Chapter V which tabulates the unused space in controlling the same floods by the same reservoirs and by the same reservoir operating diagrams but independently of conservation. A comparison of these tables shows that coordination with conservation as herein described for the Kennett reservoir on the Sacramento River did not alter the minimum space to spare of 53,500 acre-feet on March 20, 1907, but did increase the average space to spare in controlling all the floods of record from 52 to 85 per cent of the maximum flood control reserve. Coordination with conservation in the Pardee reservoir on the Mokelumne River, as described herein, increased the minimum space to spare in controlling the rain-water floods from zero to 6600 acre-feet and the average from 42 to 68 per cent of the maximum flood control reserve. It had no effect, however, on the unused space in controlling snow-water floods. On the San Joaquin River, the coordination of flood control and conservation in the Temperance Flat reservoir, as described herein, increased the minimum unused space in controlling the rain-water floods from zero to 74,500 acre-feet and the average from 37 to 370 per cent of the maximum flood control reserve. It did not increase the minimum unused space in controlling the snow-water floods of record but did raise the average unused space from 53 to 111 per cent of the maximum space required. On the San Gabriel River, coordination of flood control with seasonal storage and a constant draft, as described herein, increased the minimum unused space from 12,700 to 32,600 acre-feet and the average unused space while regulating all the floods of record from 54 to 69 per cent of the maximum flood control reserve.

KENNETT RESERVOIR ON SACRAMENTO RIVER.
UNUSED SPACE WHILE CONTROLLING ALL FLOODS OF RECORD BY RESERVOIR OPERATING DIAGRAM, 1895-1926.

Reservoir Operated Coordinately for Irrigation with Incidental Power, and Flood Control.

Height of dam 420 feet. **Capacity of reservoir 2,940,000 acre-feet.**

Maximum flood flow—uncontrolled		Flow controlled to 125,000 second-feet maximum near Red Bluff		
			Reservoir space not used in controlling flood	
Date	Mean daily flow near Red Bluff in second-feet	Date reservoir nearest full	In acre-feet	In per cent of maximum space required for flood control (454,000 acre-feet)
Feb. 3, 1909	254,000	Feb. 4, 1909	188,800	42
Feb. 2, 1915	249,000	Feb. 2, 1915	200,900	44
Mar. 20, 1907	196,000	Mar. 21, 1907	53,500	12
Jan. 16, 1909	188,000	Jan. 18, 1909	191,400	42
Feb. 16, 1904	188,000	Feb. 16, 1904	357,700	79
Jan. 21, 1909	177,000	Jan. 21, 1909	150,700	33
Feb. 25, 1917	176,000	Feb. 25, 1917	761,400	168
Feb. 21, 1914	160,000	Feb. 21, 1914	119,600	26
Jan. 1, 1914	151,000	Jan. 2, 1914	926,300	204
Feb. 24, 1902	151,000	Feb. 26, 1902	289,100	64
Mar. 8, 1904	147,000	Mar. 8, 1904	332,400	73
Feb. 10, 1902	140,000	Feb. 12, 1902	528,400	116
Mar. 31, 1906	137,000	Mar. 31, 1906	105,500	23
Jan. 19, 1906	136,000	Jan. 19, 1906	1,158,800	255
Feb. 4, 1907	134,000	Feb. 4, 1907	433,500	95
Jan. 25, 1903	131,000	Jan. 25, 1903	431,700	95
Mar. 7, 1911	130,000	Mar. 7, 1911	368,400	81
Jan. 27, 1896	128,000	Jan. 27, 1896	341,500	75
Average........	....	....	385,500	85

PARDEE RESERVOIR ON MOKELUMNE RIVER.

UNUSED SPACE WHILE CONTROLLING TWENTY LARGEST RAIN WATER FLOODS OF RECORD BY RESERVOIR OPERATING DIAGRAM, 1904-1926.

Reservoir Operated Coordinately for Municipal Supply with Incidental Power, and Flood Control.

Height of dam 345 feet. Capacity of reservoir 222,000 acre-feet.

Maximum flood flow—uncontrolled		Flow controlled to 5,300 second-feet maximum near Clements		
			Reservoir space not used in controlling flood	
Date	Mean daily flow near Clements in second-feet	Date reservoir nearest full	In acre-feet	In per cent of maximum space required for flood control (92,000 acre-feet)
Jan. 30, 1911	16,700	Feb. 1, 1911	35,200	38
Mar. 19, 1907	15,310	Mar. 27, 1907	7,100	8
Jan. 26, 1914	11,100	Jan. 27, 1914	68,900	75
Jan. 14, 1909	10,400	Jan. 17, 1909	19,500	21
Feb. 21, 1914	9,850	Feb. 21, 1914	82,700	90
Feb. 6, 1925	9,700	Feb. 6, 1925	167,800	182
Jan. 1, 1914	9,250	Jan. 1, 1914	82,000	89
Jan. 21, 1909	8,400	Jan. 22, 1909	8,500	9
Mar. 20, 1916	8,040	Mar. 21, 1916	64,400	70
Feb. 2, 1907	7,860	Feb. 4, 1907	79,300	86
Mar. 31, 1906	7,750	April 1, 1906	49,600	54
Mar. 23, 1907	7,610	Mar. 27, 1907	7,100	8
Jan. 22, 1914	7,470	Jan. 22, 1914	78,600	85
Jan. 18, 1921	7,350	Jan. 18, 1921	75,700	82
Mar. 7, 1911	7,210	Mar. 11, 1911	70,900	77
Nov. 21, 1909	7,200	Nov. 21, 1909	68,300	74
Feb. 11, 1919	7,060	Feb. 11, 1919	90,400	98
Jan. 19, 1906	6,960	Jan. 19, 1906	76,400	83
Mar. 12, 1918	6,940	Mar. 12, 1918	109,600	119
April 16, 1925	6,910	April 17, 1925	6,600	7
Average			62,400	68

PARDEE RESERVOIR ON MOKELUMNE RIVER.
UNUSED SPACE WHILE CONTROLLING ALL SNOW WATER FLOODS OF RECORD BY RESERVOIR OPERATING DIAGRAM, 1904-1926.

Reservoir Operated Coordinately for Municipal Supply with Incidental Power, and Flood Control.

Height of dam 345 feet. Capacity of reservoir 222,000 acre-feet.

Maximum flood flow—uncontrolled		Flow controlled to 7,100 second-feet maximum near Clements		
			Reservoir space not used in controlling flood	
Date	Mean daily flow near Clements in second-feet	Date reservoir nearest full	In acre-feet	In per cent of maximum space required for flood control (13,000 acre-feet)
June 12, 1906	8,740	June 13, 1906	1,900	15
June 18, 1911	8,030	June 18, 1911	3,300	25
June 3, 1922	7,970	June 5, 1922	2,600	20
June 12, 1911	7,960	June 12, 1911	3,100	24
June 6, 1911	7,880	June 6, 1911	4,000	31
May 31, 1922	7,770	June 1, 1922	6,700	52
June 1, 1915	7,750	June 1, 1915	10,000	77
May 18, 1922	7,670	May 19, 1922	1,800	14
June 16, 1906	7,600	June 17, 1906	4,500	35
June 10, 1917	7,550	June 10, 1917	2,900	22
May 24, 1911	7,500	May 24, 1911	800	6
July 4, 1906	7,480	July 4, 1906	1,100	8
Average			3,600	28

13—52411

TEMPERANCE FLAT RESERVOIR ON SAN JOAQUIN RIVER.
UNUSED SPACE WHILE CONTROLLING ALL RAIN WATER FLOODS OF RECORD BY RESERVOIR OPERATING DIAGRAM, 1907-1926.

Reservoir Operated Coordinately for Irrigation with Incidental Power, and Flood Control.

Height of dam 595 feet. Capacity of reservoir 1,071,000 acre-feet.

Maximum flood flow—uncontrolled		Flow controlled to 10,700 second-feet maximum near Friant		
			Reservoir space not used in controlling flood	
Date	Mean daily flow near Friant in second-feet	Date reservoir nearest full	In acre-feet	In per cent of maximum space required for flood control (133,000 acre-feet)
Jan. 31, 1911	38,800	Feb. 1, 1911	538,000	405
Dec. 31, 1909	27,900	Jan. 1, 1910	260,300	196
Jan. 14, 1909	26,800	Jan. 15, 1909	853,400	642
Dec. 10, 1909	26,800	Dec. 10, 1909	418,100	314
Jan. 26, 1914	24,700	Jan. 26, 1914	811,700	610
Jan. 21, 1909	18,900	Jan. 22, 1909	751,400	565
Mar. 8, 1911	18,800	Mar. 8, 1911	344,700	259
Mar. 10, 1911	13,600	Mar. 10, 1911	310,200	233
Feb. 12, 1909	12,500	Feb. 12, 1909	631,800	475
Feb. 21, 1917	11,700	Feb. 21, 1917	321,700	242
April 6, 1911	11,600	April 6, 1911	141,900	107
Jan. 18, 1916	11,000	Jan. 18, 1916	414,500	312
Mar. 21, 1916	11,000	Mar. 21, 1916	74,500	56
Oct. 2, 1918	10,900	Oct. 2, 1918	775,000	583
Jan. 25, 1911	10,700	Jan. 25, 1911	735,900	553
Average			492,200	370

TEMPERANCE FLAT RESERVOIR ON SAN JOAQUIN RIVER. UNUSED SPACE WHILE CONTROLLING ALL SNOW WATER FLOODS OF RECORD BY RESERVOIR OPERATING DIAGRAM 1907-1926.

Reservoir Operated Coordinately for Irrigation with Incidental Power, and Flood Control.

Height of dam 595 feet. Capacity of reservoir 1,071,000 acre-feet.

Maximum flood flow—uncontrolled		Flow controlled to 14,200 second-feet maximum near Friant		
			Reservoir space not used in controlling flood	
Date	Mean daily flow near Friant in second-feet	Date reservoir nearest full	In acre-feet	In per cent of maximum space required for flood control (177,000 acre-feet)
June 13, 1911	23,100	June 23, 1911	21,100	12
June 4, 1909	22,800	June 8, 1909	89,100	50
June 16, 1911	21,500	June 23, 1911	21,100	12
July 7, 1911	19,500	July 7, 1911	57,600	33
June 5, 1922	16,700	June 8, 1922	417,100	236
May 22, 1911	16,200	May 23, 1911	134,600	76
June 6, 1911	16,200	June 8, 1911	165,500	94
May 8, 1909	16,200	May 8, 1909	308,800	174
June 2, 1914	15,700	June 2, 1914	167,500	95
June 5, 1912	15,300	June 5, 1912	526,400	297
June 15, 1909	14,900	June 15, 1909	95,000	54
June 27, 1911	14,700	June 28, 1911	38,200	22
May 31, 1922	14,700	June 1, 1922	575,000	325
June 24, 1909	14,600	June 24, 1909	129,300	73
Average			196,200	111

SAN GABRIEL RESERVOIR ON SAN GABRIEL RIVER.

UNUSED SPACE WHILE CONTROLLING TWENTY LARGEST FLOODS OF RECORD BY RESERVOIR OPERATING DIAGRAM, 1895-1926.

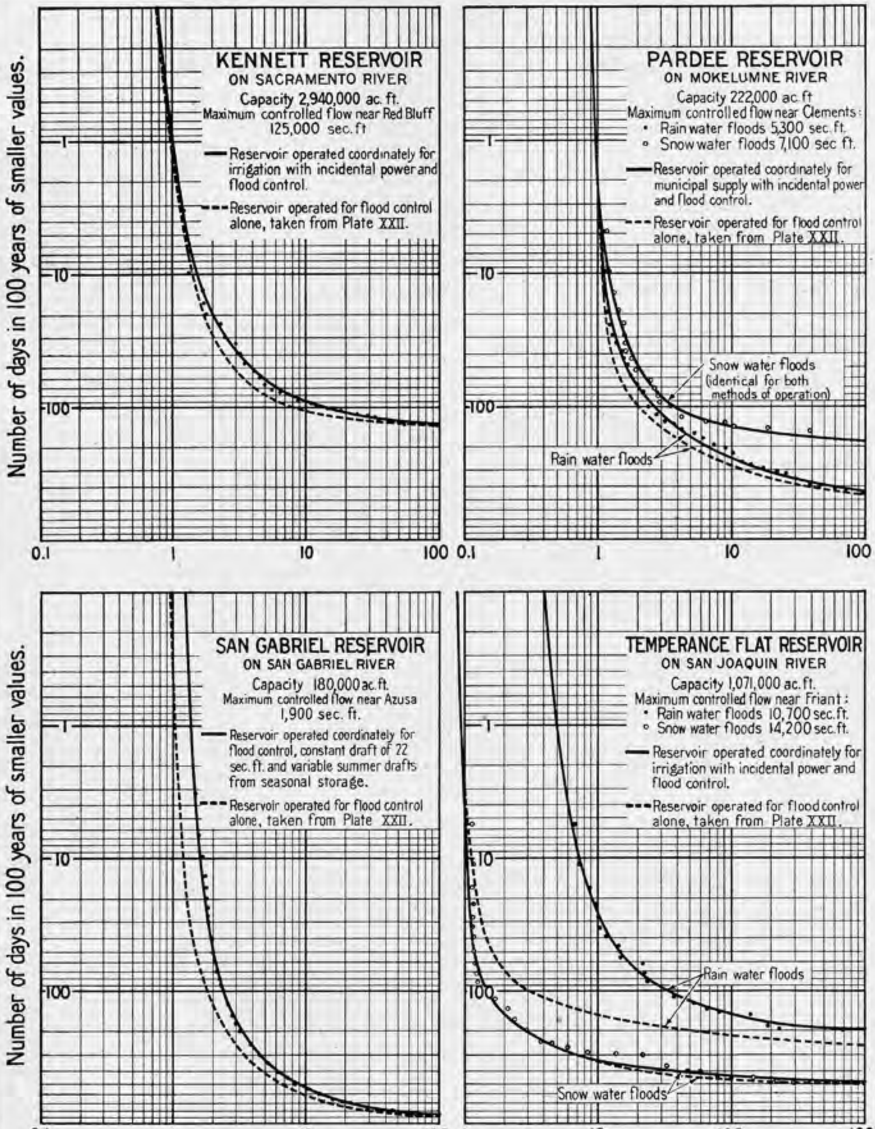
Reservoir Operated Coordinately for Flood Control, Seasonal and Over-year Storage.

Height of dam 383 feet. **Capacity of reservoir 180,000 acre-feet.**

Maximum flood flow—uncontrolled		Flow controlled to 1,900 second-feet maximum near Azusa		
			Reservoir space not used in controlling flood	
Date	Mean daily flow near Azusa in second-feet	Date reservoir nearest full	In acre-feet	In per cent of maximum space required for flood control (131,000 acre-feet)
Jan. 18, 1916	22,300	Jan. 20, 1916	50,800	39
Dec. 19, 1921	16,000	Dec. 25, 1921	71,800	55
Jan. 1, 1910	12,500	Jan. 3, 1910	89,000	68
Feb. 20, 1914	11,800	Mar. 1, 1914	64,500	49
Mar. 12, 1905	11,130	Mar. 14, 1905	94,000	72
Mar. 26, 1906	9,430	Mar. 29, 1906	32,600	25
Mar. 10, 1911	9,160	Mar. 14, 1911	71,400	54
Jan. 26, 1914	9,150	Jan. 27, 1914	111,600	85
Feb. 9, 1922	8,200	Feb. 13, 1922	104,300	80
Mar. 12, 1906	8,020	Mar. 13, 1906	103,400	79
Jan. 27, 1916	7,940	Jan. 30, 1916	42,600	33
Feb. 7, 1909	7,100	Feb. 8, 1909	118,100	90
Mar. 5, 1907	6,810	Mar. 11, 1907	89,900	69
April 1, 1903	5,920	April 2, 1903	137,700	105
Dec. 27, 1921	5,900	Dec. 29, 1921	53,700	41
Jan. 29, 1911	5,260	Jan. 29, 1911	126,600	97
Jan. 18, 1914	5,110	Jan. 18, 1914	125,600	96
Mar. 11, 1918	5,030	Mar. 14, 1918	91,600	70
Jan. 10, 1907	4,670	Jan. 11, 1907	110,900	85
Jan. 31, 1911	4,220	Jan. 31, 1911	122,400	93
Average			90,600	69

The full tests are expressed graphically on Plate XXVII, "Performance of Reservoir Operating Diagrams in Controlling Floods of Record Coordinately with Conservation." The ratio of the empty reservoir space while controlling floods coordinately with conservation as described herein, to that actually necessary for control of the remainder of the flood was computed for every day of stream flow record on each of the four illustrative streams. The ratios on each stream were arranged in order of increasing magnitude and the number smaller than each successive size counted. These counts were increased by proportion to the number had the stream flow records been 100 years in length, and plotted on Plate XXVII. Smooth curves were drawn which indicate the probable frequency with which the empty space on hand at any time will approach the exact amount that should be on hand to insure the desired flood regulation. Superimposed on these are dashed-line curves transposed from Plate XXII, p. 96. These indicate the corresponding relations in controlling floods when not coordinated with conservation.

Comparison is made in the following table of the probable number of days in 100 years on which empty space equal to or greater than the exact amount required for controlling floods would be provided in



PERFORMANCE OF RESERVOIR OPERATING DIAGRAMS IN CONTROLLING FLOODS OF RECORD COORDINATELY WITH CONSERVATION

CURVES SHOW NUMBER OF DAYS IN 100 YEARS ON WHICH RATIO OF RESERVOIR SPACE PROVIDED BY APPLICATION OF DIAGRAM TO THAT ACTUALLY REQUIRED FOR CONTROLLING FLOODS OF RECORD IS SMALLER THAN INDICATED.

the two instances. The probable frequency with which the desired controlled flow would be exceeded downstream from the Kennett reservoir on the Sacramento River, would be raised by coordination with conservation as described herein, from about one day in 80 to one day in 100 years; downstream from the Pardee reservoir from about one day in 40 to one day in 50 years for rain-water floods with no change for snow-water floods; downstream from the Temperance Flat reservoir from about one day in 30 to one day in more than 1000 years for rain-water floods, but with no change for snow-water floods; and below the San Gabriel reservoir the frequency with which the desired controlled flow may be exceeded would be increased from one day in 500 to one day in more than 1000 years.

PROBABLE FREQUENCY WITH WHICH LESS EMPTY SPACE THAN FROM ONE TO TWO TIMES THE EXACT AMOUNT REQUIRED TO CONTROL FLOODS WILL BE PROVIDED.

(Frequency in number of days in 100 years).

Reservoir as described herein	Flood control **coordinated** with conservation as described in Chapter VI			Flood control as described in Chapter V, **not coordinated** with conservation		
	Equal to that required	Half again that required	Twice that required	Equal to that required	Half again that required	Twice that required
Kennett	1	9	20	1.2	12	30
Pardee—						
Rain-water floods	2.0	40	70	2.5	60	100
Snow-water floods	2.5	24	50	2.5	24	50
Temperance Flat—						
Rain-water floods	Less than 0.1	Less than 0.1	Less than 0.1	3.2	43	70
Snow-water floods	3.2	100	150	3.2	100	150
San Gabriel	Less than 0.1	40	50	0.5	50	120

CHAPTER VII.

CONCLUSIONS.

Reliability of analyses.

The system of flood analysis herein described, illustrated, and tested is entirely empirical. Although it is in accord with theoretic considerations, nevertheless, it does not rest upon hypothesis but rather is deduced directly from the past behavior of floods as shown by the records of their measurement. But one assumption is employed, namely, that whatever relation that may exist between the time of year, the occasion and the size of flood occurrence, should be contained within existing stream-flow data. In order to discover this relation, the usual distinction between flood and normal flow is omitted. The relation between time of year, occasion and size of occurrence is sought for flows of all magnitudes contained in the measured record with the expectancy that this relation, when found, may be extended to disclose the circumstances under which flows of extraordinary size may occur, flows larger than are contained within the stream flow records or are evidenced by high water marks or dimensions of existing flood channels. In seeking this relation interest is not centered in average occurrences as in many engineering investigations, but rather in the limiting conditions of flood occurrence. The safety of lives and property require that works for flood protection be designed for exceptional rather than average conditions, otherwise, the flood menace would not be removed. Therefore, the analyses take the form of discussions of the frequency with which various size flows occur at different times of the year and with different amounts of seasonal precipitation up to the time of their occurrence.

The limiting conditions of flood occurrence about which knowledge is desired, are the circumstances under which the very infrequent floods occur. The limits in time of year and in the amount of previous rainfall with which extraordinary stream discharge occurs, are sought through the development of curves expressing the average frequency of past occurrences. It was found by trial that the data expressing the relation between size of flow and average frequency of its occurrence plot on fairly smooth curves of similar shape for all California streams on which continuous measurements have been made. While most of the data from which these curves are developed concern ordinary events, as they happen less frequently they approach the extraordinary. By the extension of these curves beyond the limits of the plotted data, the frequency may be anticipated of events so extraordinary that not even a single one is contained within the period of record. By this system of graphical analysis, estimate is made of what the records would disclose were they many times longer than they actually are.*

The inclusion in these analyses of all data on stream discharge without distinction between flood and normal flow multiplies many times the number of data available to guide the drafting of curves of relationship. In a record of stream flow, say thirty years long, there may be from three to six thousand entries of daily flow while the entries customarily regarded as floods may be limited to perhaps from fifteen to thirty. Thus, in the system of analyses herein employed, a large volume of data defines with considerable certainty that part of the curves of relationship pertaining to usual occurrences so that the trend of the curves is established as they approach the zones of infrequent occurrence into which they are extended.

Whether or not stream discharge follows sufficiently definite rules to warrant the close consideration herein given was seriously questioned at the time the work was started. For this reason, the first effort held to a comparatively simple scheme of analysis. Working with an appreciation that the subject is not one favorable for exactness, two efforts were made before the subject could be adequately gauged. While a casual review of the work as finally completed is not entirely convincing that the great volume of detail with which the subject has been pursued, is warranted, yet, to those who have taken part in the intricate comparisons, it became evident before proceeding very far, that much of the apparent scattering of plotted points on the diagrams is the result of the small amount of data on infrequent flows contained in the comparatively short period of stream flow record in California, rather than of inconsistencies in relationship. The relationship under study pertains only to the average frequency of occurrence without regard to the sequence of events, so that, in plotting the data, frequencies were assigned necessarily based upon the number of times events occurred within the period of measured record. The infrequent events that

* Inasmuch as this entire work is an analysis of the historical trend of flood occurrence, as disclosed by the period of measured stream flow record, it is of interest to discover if possible to what extent discordant events may be expected to occur. In reviewing this possibility among rainfall data that antedate stream flow records by some 30 or 40 years, it was observed that the seasons 1883–4 and 1889–90 in southern California were very unusual. Both had more than double normal precipitation while the largest season during the period of measured run-off had barely 50 per cent more than normal precipitation. Also the season 1883–4, as disclosed by the records at Los Angeles, was unusual in having a storm of 2.32 inches in two days during the fore part of April, while the season 1889–90 was extremely unusual in the volume of fall precipitation, it aggregating by January 1, 1890, 62 per cent in excess of the total for a normal season. A detail study of the daily precipitation of these two seasons shows that, had the reservoir operating diagram for the San Gabriel River been in use, there might have been technical failure in its operation by the reservoir filling and some water passing over the spillway to augment the controlled flow below the reservoir, however, no reason was found to suppose that this quantity would have been large enough to be serious. It is evident from studying the records that both of these seasons had unusual features that depart materially from the trend of the period of measured run-off so that some modification of the reservoir operating diagram for the San Gabriel River, as herein presented, would probably be required if it were desired that the operation of the diagram be technically perfect in these two seasons and run-off records were at hand to work with.

Run-off data collected on the four illustrative streams since the close of the analyses contained in this bulletin have also been reviewed for discordant events. It was found that all floods, including that of March 25–27, 1928, would have been controlled as anticipated. The flood of March 25–27, 1928, on the Mokelumne River, however, exceeded the once-in-50-year value which, by construction, the diagram is not expected to control. Therefore, the empty space provided by the diagram fails to control this flood under direct test. Nevertheless, with flood control and conservation coordinated as described herein, this flood would have been controlled to the specified maximum flow by reason of the additional empty space provided by the drawdown resulting from normal conservation draft.

occur but once or twice within the period of record, are thus accorded an average standing that may or may not be actually theirs. It is apparent that the occurrence of these infrequent events within the years during which stream flow measurements happened to be made, is much a matter of circumstance since there appears to be no orderly sequence in the size of stream flow. When longer records of stream flow become available, no doubt many of these events will be found to pertain to quite different average intervals than those herein assigned. With this viewpoint in mind, positions on the diagrams were found for the curves and parts of curves representing infrequent events that are logical in relation to the plotted data but that appear in places to be out of sympathy with some of them. Whether or not the interpretations are correct can not be foretold. Greater length of stream flow record alone can furnish the means of improving these interpretations of the data. In the meantime the results of the analyses should be employed with judgment.

The four reservoir operating diagrams, constructed as a conclusion of the analyses described herein, are tested against the entire period of stream-flow record on their respective streams at the close of Chapters V and VI and are found to be entirely adequate for controlling all floods of record. In fact, for the most part, more than half the space provided by the diagrams for detaining excess flood water is seldom used in these tests. Even the largest floods of record do not require the entire reserve to detain their volume of excessive flow. Although in engineering practice, test against the period of record is often deemed sufficient to determine the reliability of performance of proposed control works, nevertheless, it is thought that a particular advantage of the system of analysis herein described is that it affords the means of designing flood control works not only adequate for all occurrences of historical record but adequate, to the degree selected, for future expectancies as disclosed by the trend of the historical record. It is of interest to note, for instance, in connection with the reservoir operating diagram for controlling floods on the San Gabriel River when employed in the "Coordinated Plan," that only three-fifths of the 131,000 acre-feet of maximum flood control reserve is filled while controlling the largest flood of record to 1900 second-feet, and that only one-third of this maximum reserve is filled on an average in so controlling the twenty largest recorded floods. This reservoir operating diagram was designed to control floods larger than have occurred within the period of record. For this reason the floods of record do not fill the entire reserve. A safety factor either greater or less than indicated by the above figures could have been introduced in the diagram at the time of its construction if it were thought desirable.

In response to the question as to what would happen if several large floods should follow one another, the largest flood of record in each calendar month from December to April on the San Gabriel River was selected and they were assumed to follow one another, each occurring on its actual calendar date under the conditions of recorded precipitation but transposed to a hypothetical year. The transposition was made from one year to the other on the day before the first rapid increase in flow of the next flood. By test against this series of floods, the San Gabriel diagram was thus found to be adequate to control in succession the floods of December, 1921, January, 1916, February, 1914, March, 1905, and April, 1926.

It may be concluded, therefore, that the reliability of the system of analyses herein described is essentially dependent upon the extent to which the future will repeat the past. If it does and the years of stream flow record at hand disclose the past correctly, then the deductions of these analyses are reliable. If it does not, the deductions involve the same error that is contained in all other hydraulic estimates of common use. The foundation of all engineering rests upon the expectancy of a repetition of past events under like circumstances in the future. Many millions of dollars are spent annually and whole cities are erected upon this assumption. Without it practical engineering could not progress. The nineteen to thirty-one years of stream flow measurement upon which the illustrations of this volume are based, furnish a longer record than is available in many instances for hydraulic design. The lack of data often makes it necessary to base hydraulic design on rather brief stream flow records and sometimes none at all. Because these illustrations are based upon the longest records of stream flow in the state, it is believed that they have a stronger claim for accuracy than most work of the kind. Therefore, the analyses of this volume are presented as illustrative of principles relating to the control of floods by reservoirs adequately reliable in their essential features for practical application, if judgment is employed. Although the reservoir operating diagrams are presented as a culmination to these analyses, nevertheless, it is not intended that their features should be applied indiscriminately. They are presented as illustrations and their features should be adjusted to the necessities of each specific instance in order to secure good results.

Accuracy of analyses.

Essentially speaking, the accuracy of the analyses contained herein is dependent upon the correctness of the rainfall and stream gaging records employed. It is commonly known that the cost of gaging streams with exactness is prohibitive for general work. On the other hand, experience in California indicates that for the most part, the records of the United States Geological Survey that have been used exclusively in this work, are substantially correct. To seriously affect the analyses there would have to be an error in either the observations of rainfall or stream flow continuing through years of time, or in the records of the larger floods that cast the greater influence in the extension of the curves of the several diagrams. This volume is prepared with full acceptance of the stream gaging and rainfall records as published or in preparation for publication by the federal bureaus. It has been left to the judgment of whoever may utilize its contents, to introduce such safety factor in this respect as may be deemed desirable under the circumstances at the time of use. Attention has been placed on producing a work that would make this possible.

Effect of length of stream flow record upon the accuracy of deductions.

In reviewing the analyses described in this volume, it may seem rather bold to attempt to predict the vast future from the trend of occurrences during the past 15 to 30 years, yet, there appears to be no alternative, if such knowledge is desired, until sufficient time has elapsed from the beginning of systematic records for the accumulation of more data. Systematic measurements of California streams started in 1895, only thirty-two years ago. It was some time, however, before many streams were included in the program, so that there are now only a few that have been measured for more than twenty years. Fortunately, as closer settlement and larger property values urge greater accuracy in flood analysis than can be attained at present, the experience of additional years will be at hand for more perfect analyses than can be attained with present information. In the meantime, judgment must be employed in the application of the best analyses possible of available data.

In order to throw some light upon the extent to which the length of stream flow record affects the required reservoir space for controlling floods indicated by these analyses, Plate XXVIII, "Effect of Omission of the First Half of the Years of Record that Contains Five of the Largest Floods on Indicated Reservoir Space Required to Control Floods on Sacramento River near Red Bluff," has been prepared. It illustrates the variance in deductions that may be made from two records, one half the length of the other and containing only the lesser floods. The analysis shown in black is taken from Plate X of Chapter IV. It employs the entire thirty years of record on the Sacramento River. Superimposed in red is an analysis of the last fifteen years, similar in all respects to the first except that it employs only the half of the record subsequent to the historic flood years of 1907 and 1909.

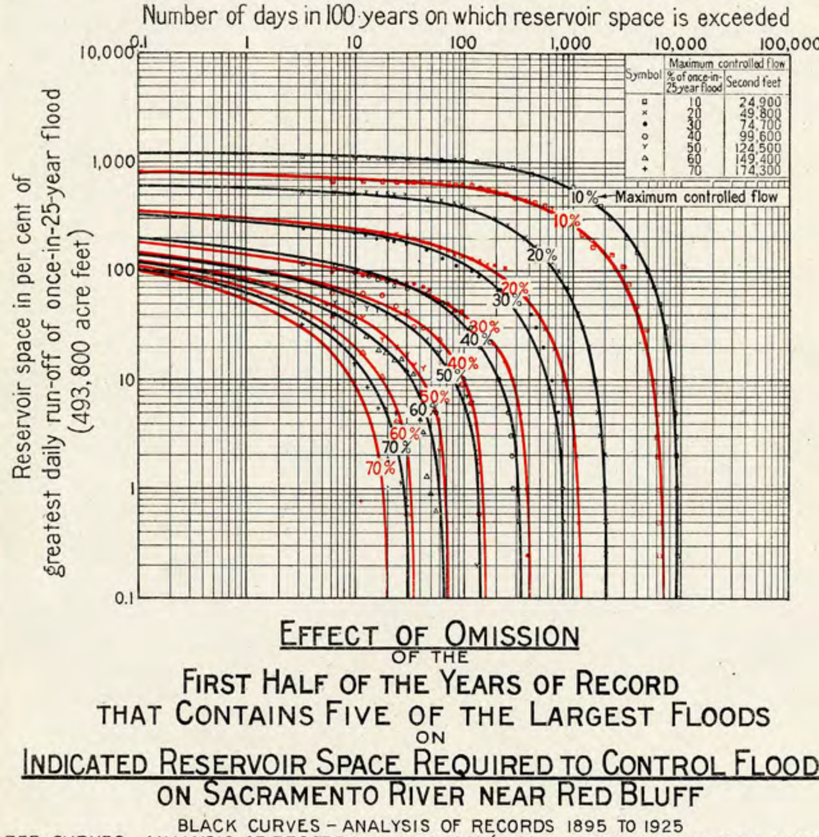
It may be observed, in the part of the plate relating to the data used in constructing Plate XVIII, "Reservoir Operating Diagram for Controlling Floods on the Sacramento River," that the difference in the maximum flood control reserve determined by these two analyses, is 15 per cent.

Geographical limitations of system of analysis.

Since the entire analysis herein presented is empirical and has been developed and tested entirely from data on California streams, it is not known to what extent it may be successfully applied in other localities. No doubt the definite limits to the flood season found in these analyses bear some relation to the sharp demarcation between the wet and dry seasons, one of the distinctive features of California climate. Since this distinct wet and dry season is the reason for conserving flood waters in California, it seems probable that the double use of the same reservoir space for both flood control and conservation would not be of such economic importance if climatic conditions were different. Therefore, it can not be said, without extended inquiry which has not been made, to what extent the system of analyses herein described applies to localities of less marked wet and dry seasons than California. The discussion herein presented is of California conditions.

Future possibilities of improving proposals for control of floods by reservoirs.

The proposals for controlling floods by reservoirs described herein all pertain to single reservoirs. At the time of preparing this work, a large program of reservoir construction is in its inception in California.



EFFECT OF OMISSION OF THE FIRST HALF OF THE YEARS OF RECORD THAT CONTAINS FIVE OF THE LARGEST FLOODS ON INDICATED RESERVOIR SPACE REQUIRED TO CONTROL FLOODS ON SACRAMENTO RIVER NEAR RED BLUFF

BLACK CURVES – ANALYSIS OF RECORDS 1895 TO 1925
RED CURVES – ANALYSIS OF RECORDS 1910 TO 1925 (FLOODS OF 1904, 1907 AND 1909 OMITTED)

CURVES SHOW NUMBER OF DAYS IN 100 YEARS ON WHICH RESERVOIR SPACE GREATER THAN INDICATED IS NEEDED TO CONTROL FLOODS TO SPECIFIED MAXIMUM FLOW.

Maximum controlled flow expressed in per cent of greatest daily rate of flow of a once-in-25-year flood

Since this program must necessarily be constructed progressively, the possibility of coordinating flood control by reservoirs and conservation is illustrated herein in its relation to the first installment of this large reservoir construction program. The examples worked out demonstrate that the first units of this large reservoir construction program may be used to control floods without interference with conservation values. However, as time goes on and more than one large reservoir is constructed on each stream, the flood control reserve may be divided among several reservoirs instead of being allocated entirely to one as in the illustrations herein. In doing this, either a greater degree of flood control may be effected by enlarging the total reserve or the possibility of interference with conservation may be made even more remote than in the proposals herein described and tested by dividing the reserve without enlargement among several reservoirs.

The proposals for the control of floods by reservoirs may be still further improved as years pass by, since stream flow data covering longer periods of time will be at hand. The added data will permit new analyses to be made that will offer greater assurance of accuracy than is possible at present and through closer study made possible by additional data, no doubt improvements may be devised in the construction of the reservoir operating diagrams. It is certain that much improvement may be made in the part of the diagrams pertaining to snow-water floods.

In the analysis herein, the part of the diagrams pertaining to snow-water floods is constructed using indices of rainfall. Since snow-water floods pertain more to the amount of snow-on-the-ground at any time, rather than upon the total of previous seasonal precipitation, it is evident that, were data of snow-on-the-ground available, superior results could be obtained. This is indicated on Plate XXIV, p. 119, and Plate XXV, p. 131, which show the effect on reservoir stage of controlling floods on the Mokelumne and San Joaquin rivers by the reservoir operating diagrams described in Chapter V. In reviewing these plates, it is noticeable in many instances, that space is held in reserve for flood control during the latter part of June and the first part of July, when, by the indications of subsequent stream flow, the snow in the mountains must have been too far melted to produce floods. Since these reservations of reservoir space are held nearly to the close of the run-off season, they result in the reservoir failing to fill to the point that it otherwise would, had space not been reserved for flood control, and cause a slightly reduced yield thereby. While in these two instances the differences in reservoir yield with and without flood control are small, nevertheless, it is believed that a noticeable improvement could be made in the part of the work relating to snow-water floods, if data relating to snow-on-the-ground were available. It is believed that superior results could be obtained by constructing the part of the reservoir operating diagram relating to snow-water floods upon indices of snow-on-the-ground instead of upon indices of precipitation. The rainfall indices apparently indicate the general character of the season fairly well so far as rain-water floods are concerned, but, in failing to incorporate the effect of weather conditions subsequent to precipitation upon the amount of unmelted snow remaining on the ground, lead to the unnecessary reservation of reservoir space for the control of snow-water floods almost up to the close of the run-off season. If indices of snow-on-the-ground at some suitable mountain station were used both in constructing and applying the part of the reservoir operating diagrams relating to snow-water floods, the Pardee and Temperance Flat reservoirs undoubtedly would have filled to the same point each year both with and without flood control and there would not have been even the slight reduction in reservoir yield with the inclusion of flood control that is noted in the tests of the reservoir operating diagrams on these two streams. (See pp. 121 and 130.)

Indices of snow-on-the-ground could not be used in constructing the reservoir operating diagrams for the Mokelumne and San Joaquin rivers because records suitable for this purpose are not available. So far as known, the only records of snow-on-the-ground of any length are at points in the Sacramento River drainage basin. Since snow melts earlier in the season in the Sacramento than in the San Joaquin basin, these records are not adapted for use on the Mokelumne and San Joaquin rivers.

CHAPTER VIII.

TABLES OF MONTHLY SUMMARIES OF WATER AND POWER YIELD OF RESERVOIRS ON THE FOUR ILLUSTRATIVE STREAMS.

Yield computed on a daily basis to show the effect of inclusion of the flood control feature upon the yield of the "Coordinated Plan."

KENNETT RESERVOIR ON SACRAMENTO RIVER.

Height of dam 420 feet. Capacity of reservoir 2,940,000 acre-feet.

PARDEE RESERVOIR ON MOKELUMNE RIVER.

Height of dam 345 feet. Capacity of reservoir 222,000 acre-feet.

TEMPERANCE FLAT RESERVOIR ON SAN JOAQUIN RIVER.

Height of dam 595 feet. Capacity of reservoir 1,071,000 acre-feet.

SAN GABRIEL RESERVOIR ON SAN GABRIEL RIVER.

Heights of dams 383 and 425 feet. Capacity of reservoirs 180,000 and 240,000 acre-feet.

ASSUMPTIONS EMPLOYED IN COMPUTING WATER AND POWER YIELD OF KENNETT RESERVOIR ON SACRAMENTO RIVER ON DAILY BASIS.

1. Water supply at dam site is the flow at the Red Bluff gaging station of the United States Geological Survey unimpaired by upstream diversions, less 25.9 per cent which is estimated to originate on the average on the drainage area between the dam site and gaging station, and less the unimpaired flow of the Pit River at Bieber. No deductions are made for prior rights downstream from the dam.

2. Daily stream flow at the dam site on any day within a month bears the same relation to the monthly mean at the dam site as the measured mean daily discharge of the same date at the Red Bluff gaging station of the United States Geological Survey bears to the corresponding measured monthly mean at this station.

3. The reservoir is full on June 1, 1895, the opening date of the estimates. Run-off index of season 1894–1895 is 124. The reservoir fills in 1925 with a run-off index of 81.

4. The net evaporation from the reservoir surface equals 3.5 feet depth per annum, divided among the months as follows:

Month	*Depth in feet*	*Per cent of seasonal total*
April	0.32	9.2
May	0.44	12.6
June	0.52	15.0
July	0.62	17.8
August	0.58	16.6
September	0.45	12.7
October	0.34	9.6
November	0.23	6.5
	3.50	100.0

5. The total seasonal demand for irrigation water is divided among the months as follows:

Month	*Demand in per cent of total seasonal use*
January	0
February	0
March	1
April	5
May	16
June	20
July	22
August	20
September	12
October	4
November	0
December	0
Total	100

6. The seasonal irrigation yield is that which can be obtained during the period with a deficiency on the average not oftener than one year in ten.

7. Power is generated at a plant near the base of the dam with a power factor of 0.80 and load factors as noted.

8. Primary power yield is the energy that can be generated without fail through every season from 1871 to 1926, divided among the months as follows:

Month	*Electric power consumption in per cent of annual total (state-wide average)*
January	7.3
February	6.9
March	7.8
April	7.9
May	8.8
June	9.0
July	9.4
August	9.5
September	8.7
October	8.5
November	8.0
December	8.2
Total	100.00

9. The secondary power yield is the energy that can be generated intermittently by the installed capacity of the power plant in addition to the primary output.

10. The overall plant efficiency is 75.0 per cent at full reservoir level, increases to 77.4 per cent at 0.8 depth and then decreases to 75.0 per cent at 0.6 depth of a full reservoir.

11. The elevation of the tail race rises 26 feet when 100,000 second-feet are passing the dam, 17 feet when 50,000 second-feet are passing, 10 feet when 25,000 second-feet are passing and corresponding amounts for other flows.

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TABLE 1a. KENNETT RESER

WATER AND POWER YIELD, OPERATING PRIMARILY FOR BOTH

WITH AND WITHOUT FLOOD CONTROL

Monthly Summary of Computa

(For corresponding yearly sum

Height of dam 420 feet. Capacity of reservoir 2,940,000 acre-feet.

Year and month	Estimated run-off at dam site in acre-feet	Without flood control								
		Stage of reservoir at beginning of month in acre-feet	Power draft through turbines in acre-feet		Evaporation in acre-feet	Waste over spillway in acre-feet	Average power head in feet	Average power yield in kilowatts (Load factor=0.75)		
			Primary	Secondary				*Primary	Secondary	Total
1896										
Jan.	1,980,000	2,256,000	238,000	98,000	0	960,000	389	97,400	40,500	137,900
Feb.	474,000	2,940,000	218,000	173,000	0	83,000	408	98,400	78,000	176,400
Mar.	738,000	2,940,000	245,000	215,000	0	278,000	410	104,200	91,100	195,300
April	891,000	2,940,000	249,000	231,000	7,000	404,000	408	109,000	101,000	210,000
May	1,194,000	2,940,000	279,000	219,000	10,000	686,000	407	117,500	92,500	210,000
June	536,000	2,940,000	283,000	196,000	12,000	80,000	410	124,200	85,800	210,000
July	313,000	2,905,000	298,000	151,000	14,000	0	407	125,400	63,700	189,100
Aug.	268,000	2,755,000	304,000	102,000	13,000	0	400	126,700	42,500	169,200
Sept.	258,000	2,604,000	282,000	101,000	10,000	0	394	120,000	42,800	162,800
Oct.	262,000	2,469,000	278,000	75,000	7,000	0	388	113,400	30,500	143,900
Nov.	472,000	2,371,000	264,000	161,000	5,000	0	385	110,300	66,800	177,100
Dec.	920,000	2,413,000	267,000	246,000	0	0	392	109,400	100,600	210,000
Total or average	8,306,000		3,205,000	1,968,000	78,000	2,491,000	400	113,000	69,500	182,500
1897										
Jan.	577,000	2,820,000	229,000	129,000	0	99,000	412	97,400	55,000	152,400
Feb.	1,338,000	2,940,000	218,000	231,000	0	889,000	408	101,900	108,100	210,000
Mar.	737,000	2,940,000	247,000	251,000	0	239,000	407	104,200	105,800	210,000
April	858,000	2,940,000	249,000	231,000	7,000	371,000	408	109,000	101,000	210,000
May	554,000	2,940,000	276,000	195,000	10,000	73,000	411	117,500	82,500	200,000
June	310,000	2,940,000	283,000	73,000	12,000	0	410	124,200	32,100	156,300
July	275,000	2,882,000	298,000	90,000	14,000	0	407	125,400	37,900	163,300
Aug.	254,000	2,755,000	305,000	87,000	13,000	0	400	126,700	36,200	162,900
Sept.	247,000	2,604,000	282,000	90,000	10,000	0	394	120,000	38,200	158,200
Oct.	262,000	2,469,000	278,000	75,000	7,000	0	388	113,400	30,500	143,900
Nov.	274,000	2,371,000	265,000	97,000	5,000	0	382	110,300	40,300	150,600
Dec.	366,000	2,278,000	274,000	113,000	0	0	380	109,400	45,200	154,600
Total or average	6,052,000		3,204,000	1,662,000	78,000	1,671,000	401	113,400	59,100	172,500
1898										
Jan.	257,000	2,257,000	243,000	0	0	0	380	97,400	0	97,400
Feb.	478,000	2,271,000	226,000	0	0	0	388	101,900	0	101,900
Mar.	380,000	2,523,000	248,000	0	0	0	397	104,200	0	104,200
April	274,000	2,655,000	253,000	0	7,000	0	400	109,000	0	109,000
May	300,000	2,669,000	281,000	0	10,000	0	401	117,500	0	117,500
June	304,000	2,678,000	287,000	0	11,000	0	401	124,200	0	124,200
July	237,000	2,684,000	301,000	0	14,000	0	400	125,400	0	125,400
Aug.	225,000	2,606,000	307,000	0	12,000	0	396	126,700	0	126,700
Sept.	198,000	2,512,000	284,000	0	9,000	0	390	120,000	0	120,000
Oct.	221,000	2,417,000	279,000	0	7,000	0	386	113,400	0	113,400
Nov.	217,000	2,352,000	265,000	21,000	5,000	0	383	110,300	8,800	119,100
Dec.	217,000	2,278,000	274,000	0	0	0	380	109,400	0	109,400
Total or average	3,308,000		3,248,000	21,000	75,000	0	392	113,400	700	114,100
1899										
Jan.	605,000	2,221,000	239,000	0	0	0	388	97,400	0	97,400
Feb.	253,000	2,587,000	222,000	0	0	0	398	101,900	0	101,900
Mar.	900,000	2,618,000	249,000	65,000	0	264,000	404	104,200	27,300	131,500
April	456,000	2,940,000	247,000	174,000	7,000	28,000	411	109,000	76,300	185,300
May	330,000	2,940,000	276,000	44,000	10,000	0	412	117,500	18,800	136,300
June	302,000	2,940,000	282,000	59,000	12,000	7,000	411	124,200	25,700	149,900
July	240,000	2,882,000	298,000	55,000	14,000	0	407	125,400	23,100	148,500
Aug.	224,000	2,755,000	304,000	58,000	13,000	0	400	126,700	24,200	150,900
Sept.	197,000	2,604,000	282,000	40,000	10,000	0	394	120,000	16,900	136,900
Oct.	252,000	2,469,000	278,000	65,000	7,000	0	388	113,400	23,500	136,900
Nov.	645,000	2,371,000	264,000	187,000	5,000	0	386	110,300	77,900	188,200
Dec.	646,000	2,560,000	265,000	243,000	0	0	398	109,400	100,600	210,000
Total or average	5,050,000		3,206,000	990,000	78,000	299,000	400	113,400	34,900	148,300

*Total primary power production in February of leap years taken the same as in other years.

VOIR ON SACRAMENTO RIVER.

POWER GENERATION WITH INCIDENTAL IRRIGATION

BY RESERVOIR OPERATING DIAGRAM.

tions Carried out on a Daily Basis.
mary, see Table 1, page 108.)

Installed capacity of power plant 400,000 k.v.a. P. F. = 0.80

Coordinated with flood control by reservoir operating diagram
Maximum controlled flow at Red Bluff 125,000 sec.-ft. Maximum reservoir space required 454,000 ac.-ft.

Stage of reservoir at beginning of month in acre-feet	Power draft through turbines in acre-feet		Evaporation in acre-feet	Release through flood control outlets in acre-feet	Waste over spillway in acre-feet	Average power head in feet	Average power yield in kilowatts (Load factor=0.75)			Year and month
	Primary	Secondary					*Primary	Secondary	Total	
										1896
2,256,000	242,000	118,000	0	1,367,000	0	383	97,400	47,200	144,600	Jan.
2,509,000	231,000	51,000	0	50,000	0	396	98,400	22,300	120,700	Feb.
2,651,000	247,000	49,000	0	0	153,000	405	104,200	20,400	124,600	Mar.
2,940,000	249,000	231,000	7,000	0	404,000	408	109,000	101,000	210,000	April
2,940,000	279,000	219,000	10,000	0	686,000	407	117,500	92,500	210,000	May
2,940,000	283,000	196,000	12,000	0	80,000	410	124,200	85,800	210,000	June
2,905,000	298,000	151,000	14,000	0	0	407	125,400	63,700	189,100	July
2,755,000	304,000	102,000	13,000	0	0	400	126,700	42,500	169,200	Aug.
2,604,000	282,000	101,000	10,000	0	0	394	120,000	42,800	162,800	Sept.
2,469,000	278,000	75,000	7,000	0	0	388	113,400	30,500	143,900	Oct.
2,371,000	264,000	161,000	5,000	0	0	385	110,300	66,800	177,100	Nov.
2,413,000	268,000	247,000	0	223,000	0	390	109,400	100,600	210,000	Dec.
	3,225,000	1,701,000	78,000	1,640,000	1,323,000	398	113,000	59,700	172,700	Total or average
										1897
2,595,000	238,000	174,000	0	252,000	0	392	97,400	71,000	168,400	Jan.
2,508,000	228,000	242,000	0	846,000	0	385	101,900	108,100	210,000	Feb.
2,530,000	251,000	130,000	0	75,000	0	398	104,200	53,200	157,400	Mar.
2,811,000	249,000	186,000	7,000	2,000	285,000	408	109,000	81,400	190,400	April
2,940,000	276,000	195,000	10,000	0	73,000	411	117,500	82,500	200,000	May
2,940,000	283,000	73,000	12,000	0	0	410	124,200	32,100	156,300	June
2,882,000	298,000	90,000	14,000	0	0	407	125,400	37,900	163,300	July
2,755,000	305,000	87,000	13,000	0	0	400	126,700	36,200	162,900	Aug.
2 604,000	282,000	90,000	10,000	0	0	394	120,000	38,200	158,200	Sept.
2,469,000	278,000	75,000	7,000	0	0	388	113,400	30,500	143,900	Oct.
2,371,000	265,000	97,000	5,000	0	0	382	110,300	40,300	150,600	Nov.
2,278,000	274,000	113,000	0	0	0	380	109,400	45,200	154,600	Dec.
	3,227,000	1,552,000	78,000	1,175,000	358,000	396	113,400	54,300	167,700	Total or average
										1898
2,257,000	243,000	0	0	0	0	380	97,400	0	97,400	Jan.
2,271,000	226,000	0	0	0	0	388	101,900	0	101,900	Feb.
2,523,000	248,000	0	0	0	0	397	104,200	0	104,200	Mar.
2,655,000	253,000	0	7,000	0	0	400	109,000	0	109,000	April
2,669,000	281,000	0	10,000	0	0	401	117,500	0	117,500	May
2,678,000	287,000	0	11,000	0	0	401	124,200	0	124,200	June
2,684,000	301,000	0	14,000	0	0	400	125,400	0	125,400	July
2,606,000	307,000	0	12,000	0	0	396	126,700	0	126,700	Aug.
2,512,000	284,000	0	9,000	0	0	390	120,000	0	120,000	Sept.
2,417,000	279,000	0	7,000	0	0	386	113,400	0	113,400	Oct.
2,352,000	265,000	21,000	5,000	0	0	383	110,300	8,800	119,100	Nov.
2,278,000	274,000	0	0	0	0	380	109,400	0	109,400	Dec.
	3,248,000	21,000	75,000	0	0	392	113,400	700	114,100	Total or average
										1899
2,221,000	241,000	45,000	0	2,000	0	387	97,400	18,400	115,800	Jan.
2,538,000	223,000	0	0	0	0	396	101,900	0	101,900	Feb.
2,568,000	249,000	57,000	0	278,000	0	399	104,200	23,900	128,100	Mar.
2,884,000	246,000	140,000	7,000	0	7,000	412	109,000	61,500	170,500	April
2,940,000	276,000	44,000	10,000	0	0	412	117,500	18,800	136,300	May
2,940,000	282,000	59,000	12,000	0	7,000	411	124,200	25,700	149,900	June
2,882,000	298,000	55,000	14,000	0	0	407	125,400	23,100	148,500	July
2,755,000	304,000	58,000	13,000	0	0	400	126,700	24,200	150,900	Aug.
2,604,000	282,000	40,000	10,000	0	0	394	120,000	16,900	136,900	Sept.
2,469,000	278,000	65,000	7,000	0	0	388	113,400	26,500	139,900	Oct.
2,371,000	264,000	187,000	5,000	0	0	386	110,300	77,900	188,200	Nov.
2,560,000	266,000	244,000	0	108,000	0	396	109,400	100,600	210,000	Dec.
	3,209,000	994,000	78,000	388,000	14,000	399	113,400	35,000	148,400	Total or average

TABLE 1a (Continued). KENNETT

WATER AND POWER YIELD, OPERATING PRIMARILY FOR BOTH

WITH AND WITHOUT FLOOD CONTROL

Monthly Summary of Computa

(For corresponding yearly sum

Height of dam 420 feet. Capacity of reservoir 2,940,000 acre-feet.

Year and month	Estimated run-off at dam site in acre-feet	Without flood control								
		Stage of reservoir at beginning of month in acre-feet	Power draft through turbines in acre-feet		Evaporation in acre-feet	Waste over spillway in acre-feet	Average power head in feet	Average power yield in kilowatts (Load factor=0.75)		
			Primary	Secondary				*Primary	Secondary	Total
1900										
Jan.	1,299,000	2,698,000	232,000	247,000	0	578,000	405	97,400	103,500	200,900
Feb.	391,000	2,940,000	217,000	134,000	0	40,000	410	101,900	62,500	164,400
Mar.	912,000	2,940,000	245,000	242,000	0	425,000	410	104,200	102,400	206,600
April	457,000	2,940,000	246,000	183,000	7,000	21,000	412	109,000	80,300	189,300
May	413,000	2,940,000	276,000	110,000	10,000	17,000	412	117,500	46,600	164,100
June	247,000	2,940,000	282,000	11,000	12,000	0	412	124,200	4,900	129 100
July	219,000	2,882,000	297,000	35,000	14,000	0	408	125,400	14,800	140,200
Aug.	208,000	2,755,000	303,000	43,000	13,000	0	402	126,700	17,900	144,600
Sept.	201,000	2,604,000	282,000	44,000	10,000	0	394	120,000	18,800	138,800
Oct.	508,000	2,469,000	278,000	121 000	7,000	0	388	113,400	49,200	162,600
Nov.	368,000	2,371,000	264,000	145,000	5,000	0	384	110,300	59,700	170,000
Dec.	697,000	2,325,000	271,000	222,000	0	0	384	109,400	89,000	198,400
Total or average	5,720,000		3,193,000	1,537,000	78,000	1,081,000	402	113,400	54,200	167,600
1901										
Jan.	895,000	2,529,000	230,000	95,000	0	159,000	406	97,400	39,900	137,300
Feb.	1,304,000	2,940,000	218,000	223,000	0	863,000	408	101,900	104,200	206,100
Mar.	749,000	2,940,000	247,000	246,000	0	256,000	407	104,200	103,800	208,000
April	382,000	2,940,000	246,000	123,000	7,000	6,000	412	109,000	54,000	163,000
May	411,000	2,940,000	276,000	120,000	10,000	5,000	412	117,500	51,100	168,600
June	240,000	2,940,000	282,000	4,000	12,000	0	412	124,200	1,800	126,000
July	218,000	2,882,000	297,000	34,000	14,000	0	408	125,400	14,200	139,600
Aug.	206,000	2,755,000	303,000	41,000	13,000	0	402	126,700	17,100	143,800
Sept.	200,000	2,604,000	282,000	43,000	10,000	0	394	120,000	18,200	138,200
Oct.	215,000	2,469,000	278,000	28,000	7,000	0	388	113,400	11,400	124,800
Nov.	354,000	2,371,000	265,000	103,000	5,000	0	383	110,300	42,500	152,800
Dec.	550,000	2,352,000	272,000	252,000	0	0	383	109,400	100,600	210,000
Total or average	5,724,000		3,196,000	1,312,000	78,000	1,289,000	401	113,400	46,300	159,700
1902										
Jan.	227,000	2,378,000	240,000	0	0	0	386	97,400	0	97,400
Feb.	2,782,000	2,365,000	224,000	153,000	0	1,830,000	392	101,900	69,300	171,200
Mar.	1,115,000	2,940,000	248,000	253,000	0	614,000	404	104,200	105,800	210,000
April	891,000	2,940,000	249,000	232,000	7,000	403,000	408	109,000	101,000	210,000
May	765,000	2,940,000	278,000	216,000	10,000	261,000	409	117,500	91,400	208,900
June	407,000	2,940,000	282,000	164,000	12,000	7,000	410	124,200	71,700	195,900
July	254,000	2,882,000	298,000	69,000	14,000	0	406	125,400	29,000	154,400
Aug.	234,000	2,755,000	304,000	68,000	13,000	0	400	126,700	28,400	155,100
Sept.	184,000	2,604,000	282,000	27,000	10,000	0	394	120,000	11,400	131,400
Oct.	235,000	2,469,000	278,000	48,000	7,000	0	388	113,400	19,500	132,900
Nov.	829,000	2,371,000	258,000	190,000	5,000	0	396	110,300	81,100	191,400
Dec.	762,000	2,747,000	260,000	239,000	0	70,000	407	109,400	100,600	210,000
Total or average	8,685,000		3,201,000	1,659,000	78,000	3,185,000	400	113,400	58,900	172,300
1903										
Jan.	1,113,000	2,940,000	230,000	214,000	0	669,000	409	97,400	90,300	187,700
Feb.	633,000	2,940,000	218,000	231,000	0	184,000	408	101,900	108,100	210,000
Mar.	1,339,000	2,940,000	246,000	252,000	0	841,000	408	104,200	105,800	210,000
April	765,000	2,940,000	250,000	232,000	7,000	276,000	407	109,000	101,000	210,000
May	458,000	2,940,000	276,000	152,000	10,000	20,000	412	117,500	64,700	182,200
June	278,000	2,940,000	282,000	42,000	12,000	0	412	124,200	18,300	142,500
July	231,000	2,882,000	297,000	47,000	14,000	0	408	125,400	19,800	145,200
Aug.	204,000	2,755,000	303,000	39,000	13,000	0	402	126,700	16,300	143,000
Sept.	174,000	2,604,000	282,000	17,000	10,000	0	394	120,000	7,200	127,200
Oct.	199,000	2,469,000	278,000	12,000	7,000	0	388	113,400	4,800	118,200
Nov.	924,000	2,371,000	261,000	156,000	5,000	0	390	110,300	65,600	175,900
Dec.	530,000	2,873,000	259,000	238,000	0	0	408	109,400	100,600	210,000
Total or average	6,848,000		3,182,000	1,632,000	78,000	1,990,000	404	113,400	58,200	171,600

*Total primary power production in February of leap years taken the same as in other years.

RESERVOIR ON SACRAMENTO RIVER.
POWER GENERATION WITH INCIDENTAL IRRIGATION
BY RESERVOIR OPERATING DIAGRAM.

tions Carried out on a Daily Basis.

mary, see Table 1, page 108.)

Installed capacity of power plant 400,000 k.v.a. P.F. = 0.80

Coordinated with flood control by reservoir operating diagram
Maximum controlled flow at Red Bluff 125,000 sec.-ft. Maximum reservoir space required 454,000 ac.-ft.

Stage of reservoir at beginning of month in acre-feet	Power draft through turbines in acre-feet		Evaporation in acre-feet	Release through flood control outlets in acre-feet	Waste over spillway in acre-feet	Average power head in feet	Average power yield in kilowatts (Load factor=0.75)			Year and month
	Primary	Secondary					*Primary	Secondary	Total	
										1900
2,588,000	240,000	274,000	0	883,000	0	388	97,400	110,900	208,300	Jan.
2,490,000	224,000	49,000	0	29,000	0	394	101,900	22,000	123,900	Feb.
2,579,000	250,000	107,000	0	316,000	0	400	104,200	43,800	148,000	Mar.
2,818,000	247,000	77,000	7,000	0	4,000	411	109,000	33,900	142,900	April
2,940,000	276,000	110,000	10,000	0	17,000	412	117,500	46,600	164,100	May
2,940,000	282,000	11,000	12,000	0	0	412	124,200	4,900	129,100	June
2,882,000	297,000	35,000	14,000	0	0	408	125,400	14,800	140,200	July
2,755,000	303,000	43,000	13,000	0	0	402	126,700	17,900	144,600	Aug.
2,604,000	282,000	44,000	10,000	0	0	394	120,000	18,800	138,800	Sept.
2,469,000	278,000	121,000	7,000	0	0	388	113,400	49,200	162,600	Oct.
2,371,000	264,000	145,000	5,000	0	0	384	110,300	59,700	170,000	Nov.
2,325,000	271,000	222,000	0	0	0	384	109,400	89,000	198,400	Dec.
	3,214,000	1,238,000	78,000	1,228,000	21,000	398	113,400	42,900	156,300	Total or average
										1901
2,529,000	239,000	251,000	0	446,000	0	389	97,400	101,600	199,000	Jan.
2,488,000	227,000	223,000	0	801,000	0	386	101,900	99,400	201,300	Feb.
2,541,000	251,000	128,000	0	155,000	0	398	104,200	52,400	156,600	Mar.
2,756,000	249,000	0	7,000	0	0	408	109,000	0	109,000	April
2,882,000	276,000	67,000	10,000	0	0	412	117,500	28,500	146,000	May
2,940,000	282,000	4,000	12,000	0	0	412	124,200	1,800	126,000	June
2,882,000	297,000	34,000	14,000	0	0	408	125,400	14,200	139,600	July
2,755,000	303,000	41,000	13,000	0	0	402	126,700	17,100	143,800	Aug.
2,604,000	282,000	43,000	10,000	0	0	394	120,000	18,200	138,200	Sept.
2,469,000	278,000	28,000	7,000	0	0	388	113,400	11,400	124,800	Oct.
2,371,000	265,000	103,000	5,000	0	0	383	110,300	42,500	152,800	Nov.
2,352,000	272,000	252,000	0	0	0	383	109,400	100,600	210,000	Dec.
	3,221,000	1,174,000	78,000	1,402,000	0	397	113,400	40,400	153,800	Total or average
										1902
2,378,000	240,000	0	0	0	0	386	97,400	0	97,400	Jan.
2,365,000	230,000	176,000	0	2,175,000	0	381	101,900	77,100	179,000	Feb.
2,566,000	251,000	183,000	0	409,000	0	398	104,200	75,300	179,500	Mar.
2,838,000	249,000	187,000	7,000	0	346,000	408	109,000	81,500	190,500	April
2,940,000	278,000	216,000	10,000	0	261,000	409	117,500	91,400	208,900	May
2,940,000	282,000	164,000	12,000	0	7,000	410	124,200	71,700	195,900	June
2,882,000	298,000	69,000	14,000	0	0	406	125,400	29,000	154,400	July
2,755,000	304,000	68,000	13,000	0	0	400	126,700	28,400	155,100	Aug.
2,604,000	282,000	27,000	10,000	0	0	394	120,000	11,400	131,400	Sept.
2,469,000	278,000	48,000	7,000	0	0	388	113,400	19,500	132,900	Oct.
2,371,000	258,000	190,000	5,000	0	0	396	110,300	81,100	191,400	Nov.
2,747,000	264,000	241,000	0	352,000	0	400	109,400	100,600	210,000	Dec.
	3,214,000	1,569,000	78,000	2,936,000	614,000	398	113,400	55,300	168,700	Total or average
										1903
2,652,000	240,000	264,000	0	772,000	0	388	97,400	106,900	204,300	Jan.
2,489,000	226,000	222,000	0	126,000	0	390	101,900	100,100	202,000	Feb.
2,548,000	253,000	242,000	0	580,000	0	394	104,200	99,600	203,800	Mar.
2,812,000	249,000	225,000	7,000	46,000	110,000	408	109,000	98,100	207,100	April
2,940,000	276,000	152,000	10,000	0	20,000	412	117,500	64,700	182,200	May
2,940,000	282,000	42,000	12,000	0	0	412	124,200	18,300	142,500	June
2,882,000	297,000	47,000	14,000	0	0	408	125,400	19,800	145,200	July
2,755,000	303,000	39,000	13,000	0	0	402	126,700	16,300	143,000	Aug.
2,604,000	282,000	17,000	10,000	0	0	394	120,000	7,200	127,200	Sept.
2,469,000	278,000	12,000	7,000	0	0	388	113,400	4,800	118,200	Oct.
2,371,000	261,000	156,000	5,000	0	0	390	110,300	65,600	175,900	Nov.
2,873,000	263,000	229,000	0	310,000		400	109,400	95,300	204,700	Dec.
	3,210,000	1,647,000	78,000	1,834,000	130,000	399	113,400	57,800	171,200	Total or average

TABLE 1a (Continued). KENNETT

WATER AND POWER YIELD, OPERATING PRIMARILY FOR BOTH

WITH AND WITHOUT FLOOD CONTROL

Monthly Summary of Computa

(For corresponding yearly sum

Height of dam 420 feet. Capacity of reservoir 2,940,000 acre-feet.

Year and month	Estimated run-off at dam site in acre-feet	Without flood control								
		Stage of reservoir at beginning of month in acre-feet	Power draft through turbines in acre-feet		Evaporation in acre-feet	Waste over spillway in acre-feet	Average power head in feet	Average power yield in kilowatts (Load factor=0.75)		
			Primary	Secondary				*Primary	Secondary	Total
1904										
Jan.	473,000	2,906,000	229,000	188,000	0	22,000	412	97,400	80,000	177,400
Feb.	1,742,000	2,940,000	217,000	204,000	0	1,321,000	410	98,400	92,400	190,800
Mar.	2,877,000	2,940,000	248,000	254,000	0	2,375,000	403	104,200	105,800	210,000
April	1,467,000	2,940,000	252,000	235,000	7,000	973,000	402	109,000	101,000	210,000
May	914,000	2,940,000	279,000	220,000	10,000	405,000	406	117,500	92,500	210,000
June	505,000	2,940,000	283,000	196,000	12,000	48,000	410	124,200	85,800	210,000
July	377,000	2,906,000	298,000	201,000	14,000	0	406	125,400	84,600	210,000
Aug.	282,000	2,770,000	304,000	131,000	13,000	0	400	126,700	54,600	181,300
Sept.	271,000	2,604,000	282,000	114,000	10,000	0	393	120,000	48,300	168,300
Oct.	491,000	2,469,000	276,000	201,000	7,000	0	391	113,400	81,900	195,300
Nov.	379,000	2,476,000	263,000	241,000	5,000	0	386	110,300	99,700	210,000
Dec.	600,000	2,346,000	273,000	252,000	0	0	381	109,400	100,600	210,000
Total or average	10,378,000		3,204,000	2,437,000	78,000	5,144,000	400	113,000	85,600	198,600
1905										
Jan.	1,371,000	2,421,000	234,000	87,000	0	531,000	400	97,400	36,300	133,700
Feb.	1,027,000	2,940,000	218,000	231,000	0	578,000	408	101,900	108,100	210,000
Mar.	1,335,000	2,940,000	247,000	252,000	0	836,000	406	104,200	105,800	210,000
April	753,000	2,940,000	250,000	232,000	7,000	264,000	407	109,000	101,000	210,000
May	560,000	2,940,000	276.000	207,000	10,000	67,000	411	117,500	87,600	205,100
June	365,000	2,940,000	283,000	128,000	12,000	0	410	124,200	56,100	180,300
July	269,000	2,882,000	298,000	84,000	14,000	0	407	125,400	35,500	160,900
Aug.	236,000	2,755,000	304,000	70,000	13,000	0	400	126,700	29,200	155,900
Sept.	208,000	2,604,000	282,000	51,000	10,000	0	394	120,000	21,700	141,700
Oct.	221,000	2,469,000	278,000	34,000	7,000	0	388	113,400	13,800	127,200
Nov.	229,000	2,371,000	264,000	53,000	5,000	0	384	110,300	21,900	132,200
Dec.	249,000	2,278,000	270,000	0	0	0	380	109,400	0	109,400
Total or average	6,823,000		3,204,000	1,429,000	78,000	2,276,000	400	113,400	51,000	164.400
1906										
Jan.	851,000	2,257,000	237,000	0	0	0	393	97,400	0	97,400
Feb.	872,000	2,871,000	217,000	139,000	0	447,000	409	101,900	64,700	166,600
Mar.	1,646,000	2,940,000	247,000	252,000	0	1,147,000	406	104,200	105,800	210,000
April	995,000	2,940,000	250,000	233,000	7,000	505,000	406	109,000	101,000	210,000
May	817,000	2,940,000	278,000	220,000	10,000	309,000	408	117,500	92,500	210,000
June	756,000	2,940,000	284,000	196,000	12,000	265,000	409	124,200	85,800	210,000
July	362,000	2,939,000	297,000	201,000	14,000	0	408	125,400	84,600	210,000
Aug.	280,000	2,789,000	304,000	148,000	13,000	0	400	126,700	61,700	188,400
Sept.	247,000	2,604,000	283,000	89,000	10,000	0	394	120,000	37,800	157,800
Oct.	251,000	2,469,000	278,000	64,000	7,000	0	388	113,400	26,100	139,500
Nov.	256,000	2,371,000	265,000	79,000	5,000	0	383	110,300	32,800	143,100
Dec.	648,000	2,278,000	272,000	186,000	0	0	382	109,400	74,300	183,700
Total or average	7,981,000		3,212,000	1,807,000	78,000	2,673,000	399	113,400	63,900	177,300
1907										
Jan.	936,000	2,468,000	231,000	44,000	0	189,000	406	97,400	18,500	115,900
Feb.	1,636,000	2,940,000	218,000	231,000	0	1,187,000	408	101,900	108,100	210,000
Mar.	2,115,000	2,940,000	249,000	254,000	0	1,612,000	402	104,200	105,800	210,000
April	1,250,000	2,940,000	251,000	234,000	7,000	758,000	404	109,000	101,000	210,000
May	646,000	2,940,000	278,000	219,000	10,000	139,000	408	117,500	92,500	210,000
June	421,000	2,940,000	282,000	179,000	12,000	6,000	410	124,200	78,200	202,400
July	334,000	2,882,000	298,000	149,000	14,000	0	406	125,400	62,600	188,000
Aug.	291,000	2,755,000	304,000	125,000	13,000	0	400	126,700	52,000	178,700
Sept.	252,000	2,604,000	282,000	95,000	10,000	0	394	120,000	40,300	160,300
Oct.	261,000	2,469,000	278,000	74,000	7,000	0	388	113,400	30,100	143,500
Nov.	256,000	2,371,000	264,000	80,000	5,000	0	384	110,300	33,300	143,600
Dec.	479,000	2,278,000	273,000	138,000	0	0	380	109,400	55,100	164,500
Total or average	8,877,000		3,208,000	1,822,000	78,000	3,891,000	399	113,400	64,500	177,900

*Total primary power production in February of leap years taken the same as in other years.

RESERVOIR ON SACRAMENTO RIVER.

POWER GENERATION WITH INCIDENTAL IRRIGATION

BY RESERVOIR OPERATING DIAGRAM.

tions Carried out on a Daily Basis.

mary, see Table 1, page 108.)

Installed capacity of power plant 400,000 k.v.a. P. F. = 0.80

Coordinated with flood control by reservoir operating diagram

Maximum controlled flow at Red Bluff 125,000 sec.-ft. Maximum reservoir space required 454,000 ac.-ft.

Stage of reservoir at beginning of month in acre-feet	Power draft through turbines in acre-feet		Evaporation in acre-feet	Release through flood control outlets in acre-feet	Waste over spillway in acre-feet	Average power head in feet	Average power yield in kilowatts (Load factor=0.75)			Year and month
	Primary	Secondary					*Primary	Secondary	Total	
										1904
2,601,000	238,000	232,000	0	83,000	0	392	97,400	94,500	191,900	Jan.
2,521,000	236,000	165,000	0	1,332,000	0	386	98,400	70,500	168,900	Feb.
2,530,000	256,000	262,000	0	2,031,000	0	387	104,200	105,800	210,000	Mar.
2,858,000	250,000	234,000	7,000	146,000	748,000	405	109,000	101,000	210,000	April
2,940,000	279,000	220,000	10,000	0	405,000	406	117,500	92,500	210,000	May
2,940,000	283,000	196,000	12,000	0	48,000	410	124,200	85,800	210,000	June
2,906,000	298,000	201,000	14,000	0	0	406	125,400	84,600	210,000	July
2,770,000	304,000	131,000	13,000	0	0	400	126,700	54,600	181,300	Aug.
2,604,000	282,000	114,000	10,000	0	0	393	120,000	48,300	168,300	Sept.
2,469,000	276,000	201,000	7,000	0	0	391	113,400	81,900	195,300	Oct.
2,476,000	263,000	241,000	5,000	0	0	386	110,300	99.700	210.000	Nov.
2,346,000	273,000	252,000	0	0	0	381	109,400	100,600	210,000	Dec.
	3,238,000	2,449,000	78,000	3,592,000	1,201,000	395	113,000	85,100	198,100	Total or average
										1905
2,421,000	238,000	179,000	0	743,000	0	391	97,400	72,600	170,000	Jan.
2,632,000	224,000	229,000	0	607,000	0	393	101,900	103,600	205,500	Feb.
2,599,000	251,000	238,000	0	524,000	0	398	104,200	98,400	202.600	Mar.
2,921,000	249,000	231,000	7,000	29,000	218,000	408	109,000	101,000	210,000	April
2,940,000	276,000	207,000	10,000	0	67,000	411	117,500	87,600	205,100	May
2,940,000	283,000	128,000	12,000	0	0	410	124,200	56,100	180,300	June
2,882,000	298,000	84,000	14,000	0	0	407	125,400	35,500	160,900	July
2,755,000	304,000	70,000	13,000	0	0	400	126,700	29,200	155,900	Aug.
2,604,000	282,000	51,000	10,000	0	0	394	120,000	21,700	141,700	Sept.
2,469,000	278,000	34,000	7,000	0	0	388	113,400	13,800	127,200	Oct.
2,371,000	264,000	53,000	5,000	0	0	384	110,300	21,900	132,200	Nov.
2,278,000	270,000	0	0	0	0	380	109,400	0	109,400	Dec.
	3,217,000	1,504,000	78,000	1,903,000	285,000	397	113,400	53,100	166,500	Total or average
										1906
2,257,000	239,000	52,000	0	109,000	0	390	97,400	21,600	119,000	Jan.
2,708,000	222,000	141,000	0	611,000	0	398	101,900	63,700	165,600	Feb.
2,606,000	253,000	241,000	0	924,000	0	394	104,200	98,900	203,100	Mar.
2,834,000	249,000	232,000	7,000	136,000	235,000	408	109,000	101,000	210,000	April
2,940,000	278,000	220,000	10,000	0	309,000	408	117,500	92,500	210,000	May
2,940,000	284,000	196,000	12,000	0	265,000	409	124,200	85,800	210,000	June
2,939,000	297,000	201,000	14,000	0	0	408	125,400	84,600	210,000	July
2,789,000	304,000	148,000	13,000	0	0	400	126,700	61,700	188,400	Aug.
2,604,000	283,000	89,000	10,000	0	0	394	120,000	37,800	157,800	Sept.
2,469,000	278,000	64,000	7,000	0	0	388	113,400	26,100	139,500	Oct.
2,371,000	265,000	79,000	5,000	0	0	383	110,300	32,800	143,100	Nov.
2,278,000	272,000	186,000	0	0	0	382	109,400	74,300	183,700	Dec.
	3,224,000	1,849,000	78,000	1,780,000	839,000	397	113,400	65,100	178,500	Total or average
										1907
2,468,000	239,000	247,000	0	430,000	0	389	97,400	100,300	197,700	Jan.
2,488,000	229,000	243,000	0	1,122,000	0	384	101,900	108,100	210,000	Feb.
2,530,000	254,000	259,000	0	1,314,000	0	392	104,200	105,800	210,000	Mar.
2,818,000	249,000	234,000	7,000	178,000	460,000	406	109,000	101,000	210,000	April
2,940,000	278,000	219,000	10,000	0	139,000	408	117,500	92,500	210,000	May
2,940,000	282,000	179,000	12,000	0	6,000	410	124,200	78,200	202,400	June
2,882,000	298,000	149,000	14,000	0	0	406	125,400	62,600	188,000	July
2,755,000	304,000	125,000	13,000	0	0	400	126,700	52,000	178,700	Aug.
2,604,000	282,000	95,000	10,000	0	0	394	120,000	40,300	160,300	Sept.
2,469,000	278,000	74,000	7,000	0	0	388	113,400	30,100	143,500	Oct.
2,371,000	264,000	80,000	5,000	0	0	384	110,300	33,300	143,600	Nov.
2,278,000	273,000	138,000	0	0	0	380	109,400	55,100	164,500	Dec.
	3,230,000	2,042,000	78,000	3,044,000	605,000	395	113,400	71,400	184,800	Total or average

TABLE 1a (Continued). KENNETT

WATER AND POWER YIELD, OPERATING PRIMARILY FOR BOTH

WITH AND WITHOUT FLOOD CONTROL

Monthly Summary of Computa

(For corresponding yearly sum

Height of dam 420 feet. Capacity of reservoir 2,940,000 acre-feet.

Year and month	Estimated run-off at dam site in acre-feet	Without flood control								
		Stage of reservoir at beginning of month in acre-feet	Power draft through turbines in acre-feet		Evaporation in acre-feet	Waste over spillway in acre-feet	Average power head in feet	Average power yield in kilowatts (Load factor=0.75)		
			Primary	Secondary				*Primary	Secondary	Total
1908										
Jan.	904,000	2,346,000	234,000	48,000	0	28,000	400	97,400	20,200	117,600
Feb.	970,000	2,940,000	217,000	246,000	0	507,000	409	98,400	111,600	210,000
Mar.	669,000	2,940,000	246,000	251,000	0	172,000	408	104,200	105,800	210,000
April	527,000	2,940,000	247,000	225,000	7,000	48,000	411	109,000	98,100	207,100
May	492,000	2,940,000	276,000	187,000	10,000	19,000	411	117,500	79,600	197,100
June	340,000	2,940,000	283,000	103,000	12,000	0	410	124,200	45,100	169,300
July	260,000	2,882,000	298,000	75,000	14,000	0	407	125,400	31,600	157,000
Aug.	229,000	2,755,000	304,000	63,000	13,000	0	400	126,700	26,200	152,900
Sept.	205,000	2,604,000	282,000	48,000	10,000	0	394	120,000	20,400	140,400
Oct.	235,000	2,469,000	278,000	48,000	7,000	0	388	113,400	19,500	132,900
Nov.	257,000	2,371,000	264,000	81,000	5,000	0	384	110,300	33,800	144,100
Dec.	267,000	2,278,000	273,000	15,000	0	0	380	109,400	5,900	115,300
Total cr average	5,355,000		3,202,000	1,390,000	78,000	774,000	400	113,000	49,500	162,500
1909										
Jan.	3,260,000	2,257,000	236,000	185,000	0	2,156,000	396	97,400	76,200	173,600
Feb.	2,526,000	2,940,000	221,000	235,000	0	2,070,000	400	101,900	108,100	210,000
Mar.	977,000	2,940,000	248,000	253,000	0	476,000	404	104,200	105,800	210,000
April	756,000	2,940,000	249,000	231,000	7,000	269,000	408	109,000	101,000	210,000
May	581,000	2,940,000	276,000	216,000	10,000	79,000	410	117,500	91,500	209,000
June	410,000	2,940,000	282,000	171,000	12,000	3,000	410	124,200	74,900	199,100
July	308,000	2,882,000	298,000	123,000	14,000	0	406	125,400	51,700	177,100
Aug.	264,000	2,755,000	304,000	98,000	13,000	0	400	126,700	40,900	167,600
Sept.	246,000	2,604,000	282,000	89,000	10,000	0	394	120,000	37,800	157,800
Oct.	284,000	2,469,000	278,000	97,000	7,000	0	388	113,400	39,400	152,800
Nov.	538,000	2,371,000	264,000	174,000	5,000	0	384	110,300	72,500	182,800
Dec.	721,000	2,466,000	265,000	244,000	0	0	396	109,400	100,600	210,000
Total or average	10,871,000		3,203,000	2,116,000	78,000	5,053,000	400	113,400	74,800	188,200
1910										
Jan.	708,000	2,678,000	231,000	69,000	000	146,000	407	97,400	29,000	126,400
Feb.	847,000	2,940,000	217,000	230,000	0	400,000	410	101,900	108,100	210,000
Mar.	1,239,000	2,940,000	247,000	251,000	0	741,000	407	104,200	105,800	210,000
April	665,000	2,940,000	249,000	232,000	7,000	177,000	408	109,000	101,000	210,000
May	415,000	2,940,000	276,000	128,000	10,000	1,000	412	117,500	54,400	171,900
June	282,000	2,940,000	282,000	46,000	12,000	0	412	124,200	20,100	144,300
July	254,000	2,882,000	297,000	70,000	14,000	0	408	125,400	29,400	154,800
Aug.	236,000	2,755,000	304,000	70,000	13,000	0	400	126,700	29,200	155,900
Sept.	214,000	2,604,000	282,000	57,000	10,000	0	394	120,000	24,200	144,200
Oct.	231,000	2,469,000	278,000	44,000	7,000	0	388	113,400	17,900	131,300
Nov.	274,000	2,371,000	265,000	97,000	5,000	0	383	110,300	40,300	150,600
Dec.	436,000	2,278,000	273,000	184,000	0	0	380	109,400	73,400	182,800
Total or average	5,801,000		3,201,000	1,478,000	78,000	1,465,000	401	113,400	52,300	165,700
1911										
Jan.	700,000	2,257,000	240,000	0	0	0	385	97,400	0	97,400
Feb.	848,000	2,717,000	217,000	187,000	0	221,000	409	101,900	88,100	190,000
Mar.	1,278,000	2,940,000	246,000	248,000	0	784,000	408	104,200	104,400	208,600
April	962,000	2,940,000	250,000	232,000	7,000	473,000	406	109,000	101,000	210,000
May	671,000	2,940,000	278,000	219,000	10,000	164,000	408	117,500	92,500	210,000
June	431,000	2,940,000	282,000	182,000	12,000	13,000	410	124,200	79,600	203,800
July	287,000	2,882,000	298,000	102,000	14,000	0	406	125,400	42,900	168,300
Aug.	244,000	2,755,000	304,000	78,000	13,000	0	400	126,700	32,500	159,200
Sept	231,000	2,604,000	282,000	74,000	10,000	0	394	120,000	30,700	150,700
Oct.	246,000	2,469,000	278,000	59,000	7,000	0	388	113,400	24,100	137,500
Nov.	241,000	2,371,000	264,000	65,000	5,000	0	384	110,300	26,900	137,200
Dec.	244,000	2,278,000	273,000	0	0	0	380	109,400	0	109,400
Total or average	6,383,000		3,212,000	1,446,000	78,000	1,655,000	398	113,400	51,500	164,900

*Total primary power production in February of leap years taken the same as in other years.