SAFE YIELD STUDY OF THE
COMPLETE DEVELOPMENT OF THE
WATERS OF THE SAN DIEGO RIVER,
SURFACE AND UNDERGROUND.

F.E.GREEN JANUARY 7, 1929.

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THE SAN DIEGO RIVER AS RELATED TO THE CITY'S WATER NEEDS

San Diego County has an area of approximately 3000 square miles between the divide along the mountain range and the Pacific Ocean to the west. Of these 3000 square miles, 2117 square miles are drained by the principal streams of the county, making it possible to conserve the runoff from approximately two-thirds of the county by developing reservoirs on these streams. But at the present time only 748 square miles of water shed, exclusive of that above Hodges Dam, have been so developed, leaving 1369 square miles of this area tributary to the principal streams from which practically all of the runoff still goes to waste. Of this undeveloped area, 356 square miles is within the San Luis Rey River watershed, 96 square miles on the Santa Margarita below the county line, 307 square miles above Hodges Dam, 375 square miles in the San Diego River and 235 square miles on the Cottonwood above Marron damsite. The San Diego River, therefore, represents more than one-fourth of the undeveloped main watersheds in the county.

According to Diagram "B", however, the San Diego River produces approximately thirty-seven per cent of the undeveloped water in the main streams, exclusive of the Tijuana River below Marron damsite. There is more undeveloped water on the San Diego River than on any other river in the county, there being at least twenty per cent more than there is now remaining on the San Dieguito River. With this stream flowing practically through the city, it represents the best possible, most feasible, most accessible and most productive water assets remaining to the city at the present

time. When one examines the water resources of the county, as fairly well portrayed in Diagram "B", he is confronted with the astounding fact that out of all of this water once available to the city exclusive of the Tijuana River, we have acquired at the present time only thirteen per cent, and that the very most we can ever hope to acquire, even after annexing National City and the Sweetwater system, is less than sixty per cent. Since water is the prime necessity, and since fully seventy-five per cent of the population and the wealth of the county is located within the city, it is plainly evident that as a city we have been careless in providing water for our future growth.

During the past ten years, the record shows that in spite of an increase in daily consumption of 7.5 m. g. d., as shown in Diagram "F", there was lost from our available water resources three times as much water as was developed by the building of Barrett and Otay dams during this period. The twenty or twenty-five million gallons of water daily developed by the building of the Henshaw dam was rejected by the city and it was afterwards sold for agricultural purposes and is now gone forever as far as the city is concerned. If we do no better during the next ten years in taking care of our water, eventually we will be compelled to pay the city of Los Angeles whatever price they may ask for the surplus water they may have from their Colorado River development. At the present rate of growth, it is a matter of but twenty-five or thirty years until the water requirements of the city have exceeded the entire resources of our present supply plus the total resources of the San Diego and San Dieguito Rivers. And in the mean time we should begin on plans to develop the water in these two rivers to their greatest possible yield. This should be done at the least possible cost, as the time of much more costly water will be upon us all too soon.

WATER RESOURCES OF THE SAN DIEGO RIVER

The discussion of this subject has been arranged under five general heads, as follows:

1. Rainfall.
2. Runoff.
3. Evaporation.
4. Water bearing gravels.
5. Safe yield studies of various proposed reservoirs.

RAINFALL

Runoff from a watershed depends not only upon the amount of rainfall, but also upon the intensity of the rainfall, and to some extent upon the character of the one or two preceding seasons. Good rainfall records therefore are essential for a comprehensive study of the hydrography of a watershed especially where runoff records are more or less meager and incomplete. San Diego county has an abundance of good long term rainfall records, as everyone is interested in rainfall on account of it being such a vital factor in our economic life in this semi-arid country. In addition to the several stations maintained under cooperation with the U.. S. Weather Bureau, under Mr. Dean Blake, there are numerous gages maintained by the city, water companies, the San Diego Consolidated Gas & Electric Company, and by private individuals. The geographic range covered by these stations makes it possible to plat an accurate map of each rainstorm, showing its variations and progress or decline. Means from these long term records also make it possible to plat a very accurate isohyetose map. Diagram "D" is a very good presentation of the long term seasonal records in San Diego county, as plotted in relation to altitude. A separate line or curve has been drawn to indicate the character of each watershed the top line marked San Luis Rey River Basin having the most rain, and the bottom line marked Santa Margarita River Basin and beyond the Mountain Range having the least rain. The San Diego River watershed, therefore, is exceeded as a rain producer, or catcher by only the San Luis Rey, the average seasonal difference being about two and one-half inches.

The three great rain producing peaks in the county are the Cuyamaca peaks, Volcan Mt. and Palomar Mountain, Palomar being the greatest of the three. It is too bad there is not a Palomar in the Campo section of the county also, so as to make a San Luis Rey River out of the Cottonwood Creek.

The rainfall quickly diminishes to little or nothing east of the mountain tops, being the same condition found behind other ranges on the coast. Therefore, points in the San Luis Rey Basin around the Warner Ranch, and in the Cottonwood Basin above Barrett are plotted as beyond the mountain range.

The great unsolved mystery in connection with our rainfall records is the cause, or causes, back of the seasonal variations and so-called "cycles". The wet seasons seem to come in groups of three and the dry seasons in groups of three or four, with a "flood" season of extreme intensity about every ten or eleven years. This matter has been the subject of a great deal of study and research, not only in this country but all over the world, as these so-called

climatic cycles seem to be general everywhere. The irregularity of the cycles is the great stumbling block in the way of a satisfactory explanation, and is the cause of so many scientists denying their existence. The most popular explanation at the present time is the influence of the sun-spots. These are plotted, as given by Prof. Hale, in connection with the rainfall and runoff in Diagram "C". Sun-spots do not recur at regular intervals - 11.2 years is the average over the observed period of record. There is also a large variation in intensity. In connection with this line of research, the Smithsonian Institute has established a solar observatory in South Africa, in addition to those already maintained in Chile and Arizona. The French astronomer, Abbe Gabriel, arrived at the conclusion after 60 years research that there was a solar cycle of 744 years, and which he further divided into two periods of 372 years each, and into four periods of 186 years each. The 744 year cycle includes 67 periods of sun-spots.

In Diagram "A", the results of Dr. McEwen's ocean temperature observations have been plotted against the mean of five rainfall stations in San Diego County, those used being Cuyamaca or Julian, Ramona, Escondido, Fallbrook or Valley Center, and San Diego. The year given opposite each point in the diagram is the year during which the ocean temperatures were taken, and in plotting was referred to the rainfall of the following winter. The points for the years 1921, 1925 and 1926 are very much out of line on account of the following winter in each case being unusually wet, while for 1924 the reverse is true. Ocean temperatures in 1928 indicate a normal rainfall for 1928-29. The significant fact in this data, however,, is the lack of conformity in the wet years, which Dr. McEwen accounts for by the wild cat storms, monsoons or sonoras from the south, since San Diego lies in the district of overlapping influence from the high pressure areas of the tropical and the low pressure areas of the north. Therefore, the data would be more applicable to points further north, which seems to have been proven in the past.

Although many different systems of long range weather forecasting have been developed, as yet there is none that is dependable. Father Ricard with his sun-spot forcasts has a great following on this coast. The long rangers all agree, however, that the climatic changes are due to variations in solar radiations. When the components existing in the sun's variations, therefore, are reduced to a mathematical equation our wet and dry cycles should be solved, and the regularity of the irregularity established.

The point of vital interest to our community, however, is when and how often to expect extreme droughts such as occurred between 1895 and 1904. "Tree ringology", as Mr. Savage expresses it, or the study of tree rings, has been carried back over a period of three or four thousand years in the case of the redwoods, and for over 200 years for the trees in San Diego County. The resulting diagrams and records show variations in seasonal growth from 25% to 300%

of the average, occurring every few years at irregular intervals. The record of every tree has a large per cent of subnormal years, sometimes in small groups of two or three and sometimes in groups of five to eight. The evidence is plain that these droughts are as much a part of our regular climate as the wet periods. To establish the order of their frequence, however, is another matter. Prof. Douglas, of the University of Arizona, has attempted to establish a harmonious relation between the tree rings, sun-spots, rainfall, volcanic eruptions, crops, levels in the Caspian Sea, etc. He has done a great deal of work along this line from data gathered from all over the world, and his published reports are very interesting indeed.

In the light of all of this "dry" or drought evidence, in this land of "little rain" we should capture and conserve every drop of it.

RUNOFF

Since the water caught and stored in the surface and underground reservoirs is almost entirely from the surface runoff, reliable records of this runoff are of first importance in estimating a river's average yield. The seasonal variations are so great, ranging from nothing to 700% and 800% of the normal, and the wet or flood years, during which occurs the major part of the runoff over a long period of years, are so infrequent that a record of twenty years or more is necessary to establish a reliable index for the stream. Interpolations and extensions are resorted to in cases of short term records, the nearest station of similar geographic conditions having a long term record being used for comparison. Very good restorations can be made from rainfall records, but they always contain inaccuracies due to the unknown departure from the rainfall index during the very wet and the very dry seasons. This is plainly evident from the Diagram "C", some seasons producing more runoff than other seasons with greater rainfall, and vice cersa. One method used in overcoming this condition in making runoff restorations is to make allowance for the character of the two preceding seasons. But where ever possible the restorations should be made by comparison of synchronous runoff.

The runoff records in San Diego County begin with the building of Sweetwater and Cuyamaca dams in 1887 and 1888, these records being continuous up to date. The records at

the Diverting Dam on the San Diego river begin with 1898-99 and are complete up to date, and furnish the best criterion of runoff in the county, on account of the geographical position at the foot of the mountain range and above the gravel beds and the excellent control offered by the dam. Then there is a twelve years record at Pala beginning with 1903-4, at Pamo on the San Dieguito from 1905-06 to 1921-22, eleven years at Lakeside beginning with 1905-06, at Old Mission Dam from 1912-13 to date, and records from various other places beginning at about 1911-12. Practically all of the stream gaging has been done by or under the supervision of the U. S. Geological Survey engineers, Mr. F. C. Ebert and Mr. H. D. McGlashan. Photographs of several of the gaging stations are given in this report. A gaging station with full equipment has either a natural or an artificial control with a water stage recorder for obtaining a continuous record. Estimates of runoff at stations with no control must be based largely on current meter measurements of the stream flow. Rating curves, if used, will be changed more or less with every change in the discharge, on account of the shifting channel opposite the gage. Discharge observations then should be frequent enough to cover all the fluctuations so that a fairly accurate hydrograph can be plotted. A rating curve for a station with a control, however, under goes very little change, except for the low flows of a few second feet, which usually are free from fluctuations in discharge. The essential point is to arrive at the daily average flow. The two extremes in each change in flow should be known, either from gage height or measured discharge. A continuous record from a water stage recorder tells the whole story of the extent and the duration of the fluctuations, covering all of the breaks, large and small, which would be impossible from a series of miscellaneous staff gage readings. A tracing from such a record is shown in Diagram "E", covering the storm of February 1927, on the Santa Margarita River near Fallbrook. The tracing was made on the same kind of paper and on the same scale as used in the instrument. The instrument functioned perfectly, with no damage whatever to the gage house or well, which is unusual for a flood stage of over sixteen feet in depth. During the same storm, the gage house at Mission Gorge was swamped, as can be seen from the drift shown in the photograph in the back of this report. The importance of flood records is realized from the fact that on the three days, February 15, 16 and 17, at Fallbrook, three times as much water passed down the river as occurs in an average year. That is, the runoff of three years roared by in three days. The discharge on February 15 was 18,728 acre feet; February 16, 43,077 acre feet and on February 17, 5,713 acre feet, or a total of 67,518 acre feet, or almost twice the amount in the St. Francis dam disaster. Several photographs in the back of this report show the San Diego river during flood stages. The enormous destruction of these floods can be prevented only by dams and reservoirs.

On the other hand, reliable runoff records during the dry seasons are also of vital importance, as they represent the additions to the last of the reserves being drawn upon during these dry or so-called "critical

periods. That is, a runoff of, say 1000 acre feet, during this limiting or critical period will increase the safe yield of a reservoir from 400 acre feet to 800 acre feet annually, depending on when this runoff occurs and thus how long it has to be held in storage. Very slight overestimates of the runoff during this period will affect the safe yield estimate of reservoir operation materially. This fact is well illustrated by the effects of the upper reservoirs on the yields from the lower reservoirs. Inaccuracies in the runoff record during the critical period will affect the yield of all reservoirs, regardless of size, while inaccuracies for a flood year will affect the yield only of those reservoirs too large to spill. That is, in the case of the smaller reservoirs, the inaccuracy is wiped out by the fact of the spill. The yield from a reservoir too large to spill, however, will be materially affected by the size of the inflow during these flood periods because this determines to a large extent, the amount remaining in storage at the beginning of the critical period. Therefore, the making of runoff estimates and restorations calls for expert care and consideration.

Runoff estimates at the following places were necessary in making this study.

Cuyamaca Dam
Diverting Dam
South Fork Creek
El Capitan
San Vicente Creek
Mission Gorge

The runoff at Cuyamaca Dam was taken from the

Cuyamaca Water Company's records.

The runoff at the Diverting Dam also was taken from the Cuyamaca Water Company's records. For the period 1898-9 to 1914-15 the data was compiled by the company's engineer,, W. S. Post, and subsequently published in Water Supply Paper #446. For the period 1892-3 to 1897-8 it is by J. S. Longwell, in a report on the San Diego River to the Reclamation Bureau, and are the results he obtained from a curve of relationship between the runoff per square mile at the Diverting Dam and at Cuyamaca Dam. Restorations for the period 1883-4 to 1891-2 were made from the runoff indices given for the San Diego River on page 277, of the state blue book, "Flow in California Streams", and also by comparison with Sweetwater Dam. The estimate for the important season 1883-4 is 116.34% of the estimated flow in 1915-16, which is according to the relations between these two seasons on the San Diego River as established by the engineers working up the data in the state blue book. There has been some confussion in the records of the runoff at the Diverting Dam on account of draft water from Cuyamaca Dam sometimes being included in the record, but the figures as given in this report do not include any draft water from Cuyamaca.

The restorations made by Mr. Longwell in the runoff from South Fork Creek were based on comparisons with Cuyamaca Dam, Diverting Dam and the Sweetwater River at Descanso, and undoubtedly are quite reliable.

The runoff restorations in the El Capitan record

for the period 1883-4 to 1891-2 were made from the runoff indices in the State blue book and by comparison with Sweetwater Dam, the season 1883-4 being 116.34% of the estimate for 1915-16, as explained above. For the period 1892-3 to 1918-19 the restorations are from a comparison with the Diverting Dam and Sweetwater Dam, as shown by the curve in Diagram "P". The Geological Survey record of the flow at Lakeside for the period 1905-06 to 1915-16 was not used in making these extensions as the Diverting Dam record was considered much more reliable and accurate on account of the absolute control of the river by the dam which acts as a weir, and also on account of the much longer period of the record. At Lakeside, however, the channel is deep shifting sand, subject to deep scouring at high water, and the peak of the 1916 storm overflowed the north bank for a distance of over one thousand feet, making worthless for estimate purposes any readings on the staff gage. The result of the gagings at Lakeside also are not applicable to El Capitan because the station was located over a deep valley fill, this gravel basin extending up and down stream for several miles, and would have to be saturated before any continuous surface flow could take place. While the El Capitan station is located in a narrow rocky channel well up above gravel beds and valley fills, Neither the measured nor restored runoff at El Capitan contains any allowance for diversions by the Cuyamaca Water Company at the Diverting Dam and on South Fork Creek. This in part accounts for the zero runoff during the critical period. This same method was followed in handling the runoff at Mission Gorge.

The restorations in the runoff from San Vicente Creek were made by comparison with the Diverting Dam, as shown in Diagram "Q". The steeply ascending lower end of the curve indicates poor runoff production in subnormal years as compared with the Diverting Dam.

The restorations in the runoff record for Mission Gorge were obtained by comparison with the Diverting Dam and Sweetwater Dam, as shown in Diagram "O", except for the period 1883-84 to 1886-87, for which the runoff indices from the State blue book were used. The estimate for 1915-16 is from a comparison between the two flood seasons 1915-16 and 1921-22 as observed at Sutherland damsite and at the Diverting Dam. At Sutherland the 1915-16 runoff was 202% of that in 1921-22; at the Diverting Dam it was 173%, and the estimate at Mission Gorge is 167%, a little lower per-centage than the other two on account of the much greater absorption in the valley fills in 1915-16. A comparison also was made with the long term means, as follows, the 1915-16 runoff being given over the long term mean in acre feet:

Sutherland	95116/14021	678%
Diverting Dam	126000/18413	684%
Sweetwater Dam	160590/18634	862%
Cuyamaca Dam	22355/ 4987	448%
State Blue Book	200600/35400	567%
Mission Gorge	280000/35235	795%

By this comparison the estimate for Mission Gorge is considerably under that for Sweetwater Dam, but much higher than those for the other stations, being a little above the mean between Sweetwater and Diverting Dam. Runoff at the lower stations, like Sweetwater and Mission Gorge, shows much wider fluctuations above and below normal

than is shown at the upper stations like Sutherland and Diverting Dam. That is, the amount above normal is greater at the lower stations for a wet season, and the amount below normal is greater for a dry season than at the upper stations.

The estimate for 1915-16 at Mission Gorge is very important because it forms the basis of making the restoration for 1883-4, the runoff from which season is one of the vital factors in the operation of the big Mission Gorge reservoirs.

The estimate for 1883-4 at Mission Gorge is 116.34% of that for 1915-16, according to the runoff indices of the State blue book as explained in the discussion of the Diverting Dam runoff.

The measured flow at Mission Gorge, from 1912-13 to date, is all from observations made by the Cuyamaca Water Company in cooperation with the Geological Survey.

EVAPORATION

Since the big water crop in the county occurs only every five or ten years, water stored in reservoirs undergoes a great loss from evaporation during the intervening seasons. The relation of the evaporation losses to consumption out of the various reservoirs is shown graphically in Diagram "HH", and in tabulated form as follows, the seasonal evaporation losses being given over the seasonal draft in acre feet.

El Capitan	139200	ac.	ft.	res'r.	4350/13600	32.0 %
Mission Gorge No. 3	44225	"	"	"	1978/ 5600	35.3 %
" " " "	121000	"	"	"	6202/10000	62.0 %
" " " "	295000	"	"	"	18746/16500	113.6 %
" " " 2	87000	"	"	"	6700/ 5600	119.6 %
" " " "	295000	"	"	"	18706/14000	133.6 %

From this tabulation it is seen that there is lost by evaporation into the atmosphere from one-third to one and one-third times the amount of water actually used from the reservoirs. When the evaporation losses amount to the same proportion as the draft, or even greater, the situation, indeed, becomes serious, both as to the reduction by waste in our water resources and also as to the resulting increased cost of water remaining for actual consumption. The consideration of evaporation, therefore, is of vital importance.

In general, there are four kinds of evaporation records from open water surfaces, three of which are from pans either on top of the ground, buried in the ground, or floating in water, and the fourth from a lake surface. In San Diego county we have examples of all four, The records given in this study from Pamo and Lake Hodges were obtained from pans buried in the ground, while the records from Morena and Murray were from

floating pans. A 207 day period is given from observations of lake surface levels at Lake Hodges. Not included in this report are long term records from a standard U. S. Weather Bureau pan in the air at the Chula Vista salt works at the head of San Diego Bay, and a record of the gage readings at Elsinore Lake by the Geological Survey. A summary of these results is given below.

Place	Kind of Pan	Length of Record	Mean Annual Evaporation
Morena	In water	11 years	68.85 inches
Murray	" "	10 "	61.69 "
Pamo	" ground	9 "	59.44 "
Hodges	" "	9 "	52.94 "
Chula Vista	" air	8 "	61.25 "
Elsinore	Lake surface	6 "	54.00 "

This record shows an annual evaporation loss of from 54 to 69 inches, or from 4½ to 6 feet. A pan in the air, such as the Chula Vista pan, usually is considered as showing the greatest evaporation, and this seems to be indicated by comparison with Hodges, Elsinore and Pamo. Exposure has a great deal to do with the evaporation, whether from pan or lake. Anything affecting the three regulating factors of temperature, wind and humidity will affect the evaporation results. The relative importance of these three controlling factors may be roughly estimated as temperature 70%, wind or air movement 15% and humidity 15%. Prof. N. W. Cummings of the San Diego State College, together with Dr. McEwen, has carried on quite extensive researches and experiments in evaporation in San Diego County, and one of his conclusions was that air temperatures could be used as a fairly reliable index for evaporation losses. Evaporation losses at Lakes Morena and Cuyamaca are materially increased by the high wind movement, coming mostly from the north and the east, these records being the highest in the county. Elevation may enter into the results also to some extent. The relatively high evaporation at Murray may be due to the dry warm winds that sweep up Alvarado Canyon from Mission Valley, with a comparatively low humidity. The same explanation also applies to Hodges, where the pan shows 14% and 13% respectively greater results than similar pans at San Dieguito Reservoir and Hodges Bridge, the relative humidity being greater at the bridge near the east end of the lake, and at the San Dieguito Reservoir several miles closer to the coast.

There has been much discussion as to the relation existing between evaporation from a standard pan and a large lake surface. There have been occasional periods during the operation of our artificial reservoirs in which there was no runoff nor draft, or if so, in negligable quantities, making it possible to compare reservoir gage readings with synchronous results from nearby pans.

A tabulation is given below of the results obtained from such periods:-

Reservoir	Days	Evaporation in % of Lake to pan	Conditions
Upper Otay	120	100.20	Floating pan at Murray
Henshaw	5	104.90	Floating pan at dam
Hodges (a)	207	105.40	Ground pan at dam
Cuyamaca (1915)	60	98.50	Floating pan at dam
Cuyamaca (1916-22)	102	109.00	" " " "
Cuyamaca (1923)	16	106.60	Ground pan at dam
Cuyamaca weighted			

Reservoir, cont.	Days	Evaporation in % of Lake to pan	Condition
mean)	178	105.07	
Weighted mean	510	104.06%	

(a) Pan results adjusted by comparison with pans at Hodges Bridge and Murray.

These observations indicate that the true lake evaporation is but slightly above the results obtained from a standard pan, whet er floating in the water or buried in the ground, and while each observation covered but a fraction of a year mostly in the summer months, the results quite likely could be taken as applying generally throughout the year.

The results obtained from pans floating in water and buried in the ground on the whole seem to correspond quite closely in seasonal totals, but the floating pans, of course, are better suited for obtaining the daily or monthly evaporation losses from a lake or reservoir. Temperature at the water surface in ground pans has been noted as high as 87.0 degrees, which was rather unusual, as the average surface temperature during the day time in the summer would be from 75 to 80 degrees. While a lake surface is seldom above 70, 71 or 72 degrees. The temperature of the deep water in lakes seems to remain nearly constant, corresponding to the mean air temperature at the time of the runoff. The change from surface to bottom temperature is not gradual, but seems to undergo a sudden decrease rather close to the surface. At Lake Hodges on April 22, 1921, Mr. E. A. Bartl showed the following observations: Air temperature 68 degrees, water at surface, 67 degrees, 17 feet down, 64 degrees, 20 feet down, 61 degrees and 70 feet down or bottom, 58 degrees. This same sudden change at about 20 feet below the surface was noted in several other observations at later dates, indicating a turnover of a surface layer of about 20 feet due to changes in temperature. That is, as water is chilled at the surface by a lowering in air temperatures, it sinks to a zone of equal temperature and is replaced at the surface by warmer water. This same explanation applies to the custom of keeping drinking water in uncorked vessels. If corked tightly the purifying process is prevented which otherwise would take place when the cooling of the air above the water causes this turn over between top and bottom.

Transpiration losses from surface storage reservoirs is another source of loss that sometimes amounts to considerable proportions. The hundreds of varieties of acquatic plants that thrive in veritable hot beds in shallow water up to about twelve feet deep are constantly throwing off moisture into the atmosphere, their branches acting as wicks and their leaves and flowers as exhaust ventilators. The variety of this growth is myriad, coming under such general plant classifications as willows, sedges, rushes, tules, grasses, moss, algae, docks, plantains, lilies, etc. Experiments in the county have shown that water sustaining such swamp growths will suffer a fifty per cent greater loss than water without them. Reservoirs with flat shore lines will have a large acreage of this marginal swamp growth, sometimes hundreds of acres. The tendency in this direction is indicated by the reservoir mean depth. The large Mission Gorge reservoirs would develop large marginal swamp areas, as shown by the curves in Diagram "GG". This

condition helps to make Cuyamaca Reservoir the most wasteful in the county, the growth on the surface during shallow water stages in the summer being so dense it is almost impossible to handle the oars in rowing a boat. Henshaw and Morena reservoirs also have large marginal swamps, Henshaw especially. Observations during the summer of 1923 at Torrey Pines lake on the city pueblo lands showed the pond evaporation to be twenty-two per cent greater than that from a pan buried in the ground nearby, the pond being shallow with about half of its surface area of five or six acres covered with plant life.

Two tabulations have been included in this report, entitled "Comparative Evaporation", which compare the results of observations in San Pasqual Valley during 1923 and 1924 with pans of different size. The pan of 9 square feet was the standard 3x3 foot pan. These three pans have equal depths, of about 24 inches, and the water level was maintained to within three or four inches of the top of the pan. They were buried in the ground within a few feet of one another. These results cannot be taken as conclusive for general application because the pans were so close together and also to other equipment at the station that they may have been affected by heat radiation and absorption. The heat conductivity of the sand and silt soil around each pan also may have varied in each case. For more definite results, the pans should have been thermetically insulated and separated by at least 15 feet. But this data is an interesting check on the curve drawn by R. B. Sleight, Denver, 1915-16, showing the relation between evaporation and diameters of pan. Results from the small San Pasqual pan coincide with Sleight's curve, but those from the largest pan do not. His experiments showed that when the diameter of the pan was increased the evaporation decreased, up to a pan 12 feet in diameter, beyond which the relation remained constant. His 12 foot pan would give true lake surface evaporation, while the standard 3x3 foot pan burried in the ground he shows would give 125%, the same pan floating in water 109.9%, and U. S. Weather Bureau pan in the air 151.51% of true lake surface evaporation. These conclusions, of course, apply only to the experiments carried on by him, but would indicate in a general way what may be expected from similar experiments elsewhere. It is to be expected different results would be obtained in Southern California, especially in the low altitudes near the coast. It is not to be understood, however, that the relation between true lake evaporation and that from a standard pan is as shown in Sleight's curve, although such is his deduction. Data from actual lake levels would have to be included to make a proper comparison, as there are many factors in a lake not represented in a pan, no matter how large, such as depth, volume, relation of perimeter to area, side walls, plant and animal life, marginal areas, wind movement, waves, currents, etc.

The subject of evaporation losses from storage reservoirs is very important, indeed, in this country of predestined water shortage, and should be given due consideration in planning future reservoirs.

WATER BEARING GRAVELS

The underground water resources of the San Diego River are shown by examinations made under the following general heads:

1. The extent and depth of the gravel beds
2. Physical characteristics of the gravel beds.
3. Indications of absorption of runoff.
4. Fluctuations in water levels.
   a. Well records.
   b. Hydraulic profiles.
5. Pumping records and yield estimates.

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1. The Extent and Depth of the Gravel Beds.

Leaving the Mission Valley basin for a later discussion, the water bearing gravels of the upper river extend from the old Mission Dam in a continuous body for fourteen miles up stream, or almost to the lower El Capitan Damsite. In the San Vicente Creek above its mouth is another gravel bed two miles in length, while there is also more or less storage in the delta of Los Coches Creek and opposite the mouth of El Cajon Valley. Ten representative cross sections of the river valley were made from the Geological Survey contour map to show the general outlines of the valley walls and bottom. With the areas of these cross sections as end areas, the volume of each intervening section was computed, as shown in Tables No. 1 and No. 2. The points at which these cross sections were made are marked on the map in the back of the report "A", "B", etc., and the sections are shown to scale in Diagrams "EE" and "FF". Areas and mean depths were not planimetered, but were taken from sections each 100 feet horizontally. In computing the volume of the beds in acre feet the mean distance of the water plane below the bed of the stream was taken on each cross section from well records, and the acre foot totals for each section corrected accordingly. This is on the assumption that stream bed elevations have not changed materially since the making of the contour map, the filling of one peculiar season balancing the scouring of another.

The places chosen for cross sections are between points of high elevation on each side of the valley, as these, as a rule, are of massive granite formation in an undisturbed state, and therefore best indicate the general confines of the valley. Profiles across wide valley fills, however, show the general slope of the deposits washed down from the more distant elevations, and would not be a true indication of the depths down to bed rock. Profiles "G" and "H" are of this character, and of course indicate little scouring with a corresponding shallow fill. The alluvial fill in this particular wide section, however, is also water bearing, as shown by wells, and of course will feed more or less water into the river gravels.

The greatest depths are indicated at the El Monte contraction and on down to section "D" above the Lakeside bridge. Maximum depths here seem to be from 165 feet to 195 feet. C. H. Lee, in Water Supply Paper 446, has listed

the logs of various wells in this section with depths up to 129 feet with none ending in granite or bed rock, except possibly those designated L. 77, the Lakeside Farm wells, which at 70 and 80 feet seem to run into the slope of the hill on that side of the river. These wells are on the edge of the valley fill, well L. 80, in the center of the valley 1400 feet south, ending in coarse gravel and boulders at 76 feet. The Cuyamaca Water Company in 1926 put down several wells in the river opposite their El Monte pumping plant to a depth of 125 feet, ending in coarse boulders, and the town of Lakeside at about the same time put down a well just above the bridge over 80 feet deep, ending in coarse gravel, with the first 40 feet in clean sand. Lee's log of well L. 85 at Riverview shows it ends in gravel at 90 feet. Wells in the same vicinity put down by the city of San Diego in 1926 end in coarse gravel from 80 to 120 feet down.

The bottom layers of the valley fill in this area are composed of the coarser materials, running from coarse gravel up to huge boulders, and in spots mingled into a conglomerate of sand, rock, clay, silt and decomposed granite. It is unsorted material worked over by running water, with the heavy boulders on the bottom. The well logs and profiles along the cross sections indicate this bottom layer is from 40 to 70 feet thick.

A. J. Ellis, on page 71 of Water Supply Paper No. 446, says: "The valleys of our principal streams were excavated during a period in which the land stood possibly 800 or 1000 feet higher than it does at present, and the streams were able to cut their valleys to a depth between 100 and 200 feet below the levels of the present valley floors before the beginning of the submergence that obliged the streams to aggrade their valleys. The alluvium (of this valley fill) is composed of sand, clay and gravel derived from the drainage basins of the streams. The beds of the ancient channels underlying the alluvium are generally characterized by coarse boulder deposits. Overlying the boulders are alternate layers of gravel, sand and clay, sand being predominant, especially at the surface." This corresponds to the observations of two previous geological surveys in San Diego county, one by H. W. Fairbanks in 1893, and one by F. J. H. Merrill in 1913. The only deep wells in the valley of the San Diego river are the two oil wells in Mission Valley, each being over 5000 feet deep. According to the logs the Balboa well went through the boulders at the bottom of the valley fill at a depth of 146 feet.

The depths, therefore, of these valley fills as shown in the cross sections in Diagram "EE" and "FF", are believed to be conservative. They probably are underestimated rather than overestimated, especially so at section "I" on the San Vicente Creek, according to the nearby well logs.

The depth of the gravel beds below the Riverview contraction gradually decreases until the lower end of the beds is reached at Old Mission Dam. This is shown by the cross section profiles "E" to "H" on Diagram "FF". The maximum depth shown at section "E" just above the Riverview contraction is 120 feet while at section "F" just below the contraction the maximum depth is 90 feet or a decrease of 30 feet in half a mile.

Between "F" and "G", however, the decrease in depth is not so rapid, being 40 feet over a distance of 6400 feet which is about one-half the rate between "E" and "F". Between "G" and "H" the maximum depths indicated are 50 feet and 20 feet respectively, or a decrease of 30 feet in 8200 feet which is about one-half the rate between "F" and "G". In other words, below the Riverview contraction there is a marked flattening in the grade of the gravel beds. This condition also is true of the present valley floor and river channel and of the hydraulic grade of the water plane. The results of the computation of gravel bed volumes in Table No. 1 show there are ~~over~~ only one-third the volume of gravels below Riverview contraction as there is above when compared with the respective lengths of the valley sections. That is, over a distance of 45,300 feet from the upper end of the gravels to the Riverview contraction, the computation shows a volume of 147,818 acre feet or on the average of 3.3 acre feet per mile, while for the distance of 2760 feet between the contraction and Old Mission Dam there is shown a total volume of 27902 acre feet, or an average of one acre foot per mile. Above the narrows the gravel beds are deep and narrow, while below they are shallow and wide.

The log of a well 125 feet deep on the Scripps Fanita Ranch as given by C. H. Lee shows decomposed granite was struck at a depth of 60 feet, again at 85 feet and the bottom of the well at 125 feet was in decomposed granite. The intervening material was worked over sand and cobbles with no clay. This well is about half way between sections "G" and "H" in the center of the valley. The logs of three other wells he gives in this section show a deep bed of marl or clay at a depth of 30 to 40 feet, which was not penetrated at a depth of 173 feet.

Geologists are of the opinion that when the valley filling began in this section below the narrows the deposits were laid down under water, the coarser material being deposited above the narrows and the finer material, marl, clay, sand, etc., being carried out into the lake. This lake, or arm of the sea, covered practically all of El Cajon valley, as shown by the underlying beds of clay. The water bearing gravels of the valley fill are the more recent deposits laid down on top of these older lacustrian silts. Therefore, in showing the depths of the gravel beds below the Riverview narrowsthey were kept above these mud and clay deposits.

The estimated depths as used in this section are believed to be quite conservative, as there is no evidence to show that the underlying clay deposits form a continuous layering, and if so to what depth.

The total area covered by these water bearing gravels from above Cape Horn to Old Mission dam, and including San Vicente Creek, is 5427 acres, from the data contained in Tables No. 1 and No. 2. C. H. Lee's estimate is 3120 acres with 2180 acres as the effective area. Effective volumes have been considered in this report, however, in place of effective areas, depths along the cross sections decreasing from maximum to zero. Areas in the Mission Valley section will be given later.

The total of the cubic contents of these gravel beds as given in Tables No. 1 and No. 2 is 202293 acre feet. If this were all water, what a prize it would be as a part of the city water system!

2. PHYSICAL CHARACTERISTICS OF THE GRAVEL BEDS

In physical characteristics the gravel beds above Old Mission Dam may be divided into four parts, as follows:

1. Cape Horn Basin, above the Monte contraction.
2. El Monte Basin, to below mouth of San Vicente Creek
3. Lakeside Basin, to Riverview narrows
4. Santee Basin, to Old Mission Dam.

A panoramic photograph in the back of this report gives a very good view of the Cape Horn basin, to the right in the photo, and of the Monte basin to the left. The photograph was ~~was~~ taken from a point near the flume above the Cuyamava Water Company's El Monte pumping plant. The dividing point or contraction between the two basins is opposite the rough granite mountain a little to the right of the center of the picture. The Monte pump house in use at that time can be seen in the foreground of the second section from the left. Deep well pumps installed in 1926 now pump into a sump. Nearly all of the cultivated area seen in this part of the picture was flooded in February 1927. There is no back water during floods above the junction with the San Vicente Creek, as the outlet below is unobstructed. In 1927, however, overflow from the San Vicente Creek covered all the flat area seen in the distance in section two of the panorama.

This overflow area also is shown in section one of the other panoramic view, which is of the Lakeside-Santee Basins. The lower half of section two in this picture is the willow growth between the Lakeside bridge, seen in section three, and the hill back of the Thum Cactus Ranch. The river channel, dimly seen in section one, is to the left, or east of this hill. The picture was taken looking south toward Lakeside, the lake being seen, a little out of place, in sections two and three. The large shed shown in the field in the last section at the right is the Lakeside Farms upper pumping plant. This section also shows the Riverview narrows with the Santee basin in the distance.

None of these four basins is a closed basin. At no place between the upper end of the gravels below the El Capitan damsite and Old Mission dam at the lower end does bedrock come to the surface, or near the surface. The water in the gravels flows freely from the upper basins into the lower. And at no place are there sufficient deposits of silt to form a dam across the valley. One might expect such deposits above Lakeside near the mouth of San Vicente Creek and below the Thum hill, but apparently there is not sufficient disturbance of the velocity at high water here to cause silt deposition. Silt deposits, however, will be found in overflow areas, such as that between the Thum cactus ranch and the lake at Lakeside, on the south side of the river on the upstream side of the Thum Hill, on the overflow land on both sides of the river above and below Riverview, and in the delta overflows of Los Coches and San Vicente Creeks. This silt, however, is in thin layers and offers no substantial ~~hind~~ hindrance to the free percolation of the ground water. There is no indication anywhere of hydraulic pressure in any of the basins, as would happen in a closed basin or in one with dense layers of silt on top of coarse water bearing gravel, and with considerable difference in elevation between the upper and lower ends of the beds.

The Monte and Riverview contractions, however, do cause a disturbance in the hydraulic grade, as shown in the

profile in Diagram "V". When the river is flowing, or the water plane is near the surface, the hydraulic grades above and below the Monte contraction are practically on the same slope but the average seasonal elevation of the water plane above the contraction shows a hydraulic grade 1.3 feet less per mile than that below. Or, in other words, because the water plane at the upper end of the Cape Horn basin fluctuates as much as 10.5 feet during the season, with little or no fluctuation at the lower end in the Monte narrows, we know that the water in the upper gravels has drained out faster than could be handled by the gravel area at the narrows, so a surface flow results that is nearly continuous throughout the year. The narrowing of the granite side walls, and probably to some extent a rise in the granite bottom, so reduces the area of the cross section that the gravel beds capacity for percolation is also reduced. This fact is well illustrated in Diagram "W", which exhibits a veritable water fall from the contraction into the pump draw down cone, the depression and extension downstream of the cone indicating the pumps drew more water then came down through the contraction from the upper basin.

The relatively steep and uniform hydraulic grade between the Monte and Riverview narrows indicates an unobstructed channel with uniform bedding of gravels and freedom of percolation. But below Riverview the hydraulic grade changes from 19.2 feet per mile to 15.0 feet per mile. This is not a sudden drop, but the grade gradually flattens out until the Old Mission dam is reached. The condition here is just the reverse of that at the Monte contraction, where there is back water, as it were, above the contraction, while here the back water effect is below the contraction. This change in grade below Riverview is not caused by any condition in the contraction, as at the Monte, but is caused by the widening of the valley floor below the contraction with considerably shallower depths as pointed out above. This has caused the river to build up beds of fine silts. With a much larger area to cover the storm waters lose in velocity and drop big portions of their silt load, making a dumping ground out of this basin. Flood control channels would overcome this condition to some extent, while on the other hand, if Old Mission dam were raised 50 or 60 feet, say from elevation 280 to 340, Santee in time would become the center of a big silt delta.

There is no continuous surface flow at the Riverview narrows as there is at the Monte, although the cut along the eastern toe of the hill on the north side of the river opposite Riverview will carry a small surface flow and standing water late into summer. This is drainage or percolating water from the wide alluvial flats on that side of the river and the long canyon northwest of Lakeside Farms, as well as rising water from the main river channel. This cut or wash evidently is of long standing, judging from the willows, swamp growth, and remains of an old dam. Undoubtedly at one time it was a watering place for the Indians.

Of the four basins, the Monte and the Lakeside basins have by far the greatest ground water capacity. The relation of their respective capacities, according to the volumes given in Table No. 1, is as follows:

Cape Horn Basin	29413 ac. ft.	or value 1.11
Monte Basin	60236 ac. ft.	or value 2.27
Lakeside Basin	58169 ac. ft.	or value 2.19
Santee Basin	27902 ac. ft.	or value 1.05
San Vicente Basin	26573 ac. ft.	or value 1.00
Total	202293 ac. ft.	

If the Monte basin, however, is credited with the San Vicente basin its value becomes 3.27 in place of 2.27. That is, it would have three times the capacity of the Santee or Cape Horn basins and 50% greater than the Lakeside basin. To effectively draw on the San Vicente basin, pumps in the Monte basin should be somewhere near the Thum hill.

Pumps installed in the river near Thum hill would draw upon the Monte, San Vicente and Lakeside basins. But if seeking to make an exhaustive draft on these three basins, the pumps should be distributed at scattered points throughout the basins so as to reduce to a minimum the slow process of percolation into the pump draw-down cones, and thus reduce the lift.

As under ground storage reservoirs these four basins should be operated in pairs, the two upper together and the two lower together. Better control of water levels could be obtained this way. Pumping from the Cape Horn basin alone would in time exhaust that basin while the contents of the Monte basin in the meantime have been evaporating and draining out below. The ideal method would be to keep the water plane in all four basins drawn down below the point of surface losses by evaporation. Heavy pumping at one spot materially increases the cost on account of the greater lift from a deeper draw down cone, and on account of the resulting loss in pump efficiency.

Sites above the Monte and Riverview narrows undoubtedly are ideal for under ground collection galleries, if the basins above and their yield were large enough to warrant the expense. That is, a long pumping period each year might warrant such an expense.

The Santee basin undoubtedly will yield more water than is shown by the cross section figures in Table No. 1. This basin not only receives the drainage of all the other basins up the river, which, judging from the area of the cross section at the Riverview narrows, would amount to 50 inches or more, but also receives lateral drainage from the wide alluvial slopes on the north side of the river and all the drainage of El Cajon valley, with its watershed of granite hills. Individual wells here may not develop much capacity but this could be met by increasing their number.

Table No. 11

Safe Net Yields at Mission Gorge No. 3, 295200 Ac. Ft.
San Vicente Dam 59230 Ac. Ft. or more
Seasonal Draft 12300 Ac. Ft. (1043 Ac. Ft. short)
Use 12200 Ac. Ft. or 10.89 m.g.d.

October 1 to March 31

Seasonal	Runoff Ac. Ft.	Res'r content at beginning of period	Area Acres	Evaporation (1.33 ft) Ac. Ft.	Draft Ac. Ft.	Total Withdrawals Ac.Ft.		Net Additions or deductions Ac. Ft.
1883-4	189000	0	3000	3990	4100	8090	+	180910
1884-5	6860	238760	6200	8240	4100	12340	-	5480
1885-6	47600	212270	6000	7980	4100	12080	+	35520
1886-7	5390	243170	6200	8240	4100	12340	-	6950
1887-8	7910	214450	5650	7510	4100	11610	-	3700
1888-9	29400	191530	5400	7180	4100	11280	+	18120
1889-0	21000	199370	5450	7250	4100	11350	+	9650
1890-1	20300	195270	5350	7120	4100	11220	+	9080
1891-2	4200	190560	5150	6850	4100	10950	-	6750
1892-3	8400	164330	4650	6180	4100	10280	-	1880
1893-4	350	145970	4200	5590	4100	9690	-	9340
1894-5	49700	118170	4100	5450	4100	9550	+	40150
1895-6	350	159140	4400	5850	4100	9950	-	9600
1896-7	8400	130540	3950	5250	4100	9350	-	950
1897-8	70	114980	3500	4650	4100	8750	-	8680
1898-9	35	89720	2800	3720	4100	7820	-	7785
1899-0	0	67210	2050	2720	4100	6820	-	6820
1900-1	1400	47520	1400	1860	4100	5960	-	4560
1901-2	350	32560	650	865	4100	4965	-	4615
1902-3	4200	18827	300	399	4100	4499	-	299
1903-4	35	11567	130	173	4100	4273	-	4238
	404950					195167		

Table No. 11

Safe Net Yield at Mission Gorge No. 3, 295200 Ac. Ft.
San Vicente Dam 59230 Ac. Ft. or more
Seasonal Draft 12300 Ac. Ft. (1043 Ac. Ft. short)
Use 12200 Ac. Ft. or 10.89 m.g.d.

April 1 to September 30

Season	Runoff	Res'r content at beginning of period	Area	Evaporation	Draft	Total with-drawals	Net Additions or deductions
	Ac. Ft.		Acres	Ac. Ft.	Ac.Ft.	Ac.Ft.	Ac. Ft.
1883-4	81000	180910	5600	14950	8200	23150	+ 57850
1884-5	2940	233280	5900	15750	8200	23950	- 21010
1885-6	20400	247790	6300	16820	8200	25020	- 4620
1886-7	2310	236220	5950	15880	8200	24080	- 21770
1887-8	3390	210750	5400	14410	8200	22610	- 19220
1888-9	12600	209650	5500	14680	8200	22880	- 10280
1889-0	9000	209020	5450	14550	8200	22750	- 13750
1890-1	8700	204350	5350	14290	8200	22490	- 13790
1891-2	1800	183810	4900	13080	8200	21280	- 19480
1892-3	3600	162450	4450	11880	8200	20080	- 16480
1893-4	150	136630	3900	10410	8200	18610	- 18460
1894-5	21300	158320	4600	12280	8200	20480	+ 820
1895-6	150	149540	4100	10950	8200	19150	- 19000
1896-7	3600	129590	3750	10010	8200	18210	- 14610
1897-8	30	106300	3150	8410	8200	16610	- 16580
1898-9	15	81935	2450	6540	8200	14740	- 14725
1899-0	0	60390	1750	4670	8200	12870	- 12870
1900-1	600	42960	1050	2800	8200	11000	- 10400
1901-2	150	27945	400	1068	8200	9268	- 9118
1902-3	1800	18528	210	561	8200	8761	- 6961
1903-4	15	7329	70	187	8200	8387-	8372
	173550					386376	short 1043
	404950					193167	
	1043 short						
	579543					579543	

3.-Indications of Absorbtion of Runoff

The water bearing gravels of the San Diego River Valley are replenished by the flood runoff from the San Vicente Creek and the upper watershed of the main river and by runoff from the adjacent hills. The manner in which the replenishment occurs is illustrated in certain features by Diagram "X", the major or complete replenishments occuring in the wet seasons of 1914-15, 1915-16, 1921-22 and 1926-27, with more or less partial replenishment during each of the intervening seasons. The record of this well L 5 shows the highest water levels were in 1916 but the greatest absorption or replenishment occurred in 1922 as shown by the difference between the minimum and maximum levels.

Theamount of runoff absorbed by the gravel beds can be arrived at by two different methods, first, by the measured stream flow above and below the gravel beds, and second, by the rise in the water plane as indicated in observation wells.

Nine seasons of measured runoff are given in Table No. 4, covering the stream flow from El Capitan to Old Mission Gorge. The estimated runoff from the 125 square miles as given in column No. 3, is believed to be low rather than high, as no runoff is given for the dry years and comparatively small amounts for the seasons nearly normal. This area includes small creeks like Los Coches, Barona, El Cajon, Sycamore, etc. all of which produce flood torrents during the heavy rainfall in wet seasons, washing out bridges, highways, etc., in much the same manner as the main river. The nine year mean in this tabulation shows an absorption by the gravels between El Capitan and Old Mission dam of 6080 acre feet, ranging from 1355 acre feet in seasons of little or no runoff to 14726 acre feet in very wet seasons. Reduced to a long term mean the amount is 4045 acre feet by comparison with the long term mean of the San Vicente Creek, and 4[illegible]58 acre feet compared with the long term mean at El Capitan That is, on the average over a long period, 4000 or 5000 acre feet of water would be absorbed each season by these gravels. The amount absorbed during seasons of complete or maximum, replenishment is shown to be from 16000 to 17000 acre feet.

There are several synchronous measurements by actual observation on record that indicate the manner of this absorption, as follows:

March 31 and April 3, 1915, by C. H. Lee: 51 second feet at El Capitan, 45 second feet at Lakeside and 38 second feet at Old Mission dam, representing a loss of 13 second feet plus any pick up along the way, except San Vicente Creek, which was excluded from the total. May 15, 1926, there was flowing at El Capitan 6.7 second feet and but 1.2 second feet at Lakeside. December 11, 1926, El Capitan 127 second feet, Lakeside, 12 second feet, Mission Gorge, 29 second feet. While for the month of December, 1926, there was a flow of 3166 acre feet at El Capitan and but 601 at Mission Gorge. And in January 1927, there was a flow of 795 acre feet at El Capitan and but 53 acre feet at Mission Gorge. The runoff from San Vicente Creek and the additional 123 square miles of area would have to be added to obtain the total absorption. On December 20, 1921, the flow at the Lakeside bridge at 9:00 a.m.

was 1800 second feet, 1000 second feet of which was from the San Vicente Creek, while at 3;00 p.m. the flow had dropped to 600 second feet, all but one second foot of which was from the San Vicente Creek, indicating very pronounced absorption. As pointed out above from Diagram "[illegible]", this season of 1921-22 showed the greatest absorption on record.

In Table No. 5, the average range in the fluctuation of the water plane has been used to show the runoff absorbed in the gravel beds. This average range was taken from different points along the profiles of the maximum and minimum elevations of the water plane as plotted from well observations in Diagram "V". The resulting mean range for the entire gravel bed area is 3.07, as compared with 4.28 feet used by Lee for the period 1912-13 to 1914-15. Lee's porosity estimate of 38% was used and an average absorption of 3991 acre feet obtained, compared with 5074 acre feet obtained by Lee with his greater average range. Lee's well data, however, covered the area only between Lakeside and the Monte contraction. Lee added to his result two estimated quantities, one of 1040 acre feet for runoff absorbed during the period of decline in the water plane and which consequently would not be manifest in the well levels, and one of 2016 acre feet for water lost from the gravels by evaporation and transpiration during the period of rising levels and which also would not be manifest in the well levels. With the addition of these estimated quantities, using the proper percentage for the second, the results in Table No. 5, compared with Lee's are 6690 acre feet from Table No. 5, and 8130 acre feet from Lee. During seasons of complete replenishment the range in the water plane fluctuation would be twice the average amount used above, showing with Lee's addition a total absorption of 11997 acre feet.

Thus, there is shown by the two methods of using runoff and water plane observations that the gravel beds above Old Mission dam have absorbed during an average season 6080 acre feet of water according to runoff records, and 6690 acre feet according to water plane observations, or a mean of the two of 6385 acre feet. This would amount to 5.7 million gallons daily throughout the year. Part of this water has been put to beneficial use by pumping for irrigation, but the greatest part has been lost by evaporation and transpiration. The pumping done by the Cuyamaca Water Company at El Monte, and by the city at Riverview is very small, indeed, compared with this average seasonal total loss of 5.7 m.g.d. The total pumping at these points since 1919 averages 1 m.g.d. distributed over the nine years. But the effect of this pumping on the water levels was too small and limited in area to have had any effect on the data used above. Therefore, most of the 5.7 m.g.d. can be considered as water wasted through the processes of nature, and that a large part of it could be saved by pumping it into the city during the spring and early summer months when the water plane is highest and consequently the losses greatest.

There is a third method by which the amounts absorbed by the gravel beds can be estimated and that is by showing the amount of water lost each season by evaporation from the soil and

by plant transpiration in the area underlain by the gravel beds. In making such a study, there should be outlined on a map of the valley floor the various areas of soil and plant conditions, such as sand, gravel, silt and loam areas, and all plant growth should be indicated, such as grass, willows, swamps, alfalfa, grain fields, orchards, etc. Then for each area the average distance at which the water plane stands beneath the surface should be determined, and the various rates of evaporation for each condition then could be applied to obtain the amount of water lost each season from this underground water. The results of various soil evaporation experiments are available, such as the one by Lee in Owens Valley 1908 to 1911, R. B. Sleight at Denver in 1915 and 1916, Samuel Fortier and S. H. Beckett at Davis since 1907, Ralph L. Parshall at Fort Collins, and various others, including two by the writer at Henshaw Reservoir and San Pasqual Valley in 1923 and 1924. If the loss from the ground waters as determined by this method should prove to average two feet in depth annually over an effective area of 3000 acres, the losses would amount to 6000 acre feet.

4. FLUCTUATIONS IN WATER PLANE LEVELS

a. Well records.

The Geological Survey and the Cuyamaca Water Company began making observations of the ground water fluctuations along the valley of the San Diego river in 1912, and have continued these observations to date. In 1926 the city of San Diego also began a systematic record of water plane observations. Most of the observation wells now in use by all parties have been marked on the map in the back of this report. Several photographs also are given showing how some of these wells were put down. The usual practice, however, has been to use a private or domestic well. The domestic wells in nearly every case sooner or later are destroyed by floods, filled up or closed against inspection. The most useful records are those for a long term period from one well or from one immediate vicinity such as that from Well L, 5, since 1912. Rounds of observations are made with sufficient frequency to make it possible to plot an accurate hydrograph of the fluctuations, such as given in Diagram "X". More frequent measurements sometimes are made when daily, weekly, or monthly changes are desired. Diagram "W" is from monthly readings, to show the progressive effects of pumping.

Having the necessary well observations, hydrographic levels, contours and profiles can then be plotted for examination and study.

The detailed records of several wells have been given in Diagrams "X" to "DD".

b. Hydraulic profiles.

Several longitudinal profiles of the water plane are given in Diagrams "R" to "W". Diagrams "R" and "S" show the effects from the city pumps at Riverview in 1927 and 1928 were limited largely to a radius of about 1000 feet from the pumps, the effects gradually disappearing at about 2000 feet. The effects seem to extend a little further down stream than upstream. The average elevation of the water level in the pump basin at the end of the 1927 pumping season was 354.5 feet, and the

amount pumped was 1221 acre feet while at the end of the 1928 season the average elevation was 352.5, with 1533 acre feet pumped. This is 25% more water pumped in 1928 than in 1927, with an increase in depression of two feet, which is also 25% of the total drop of 8.5 feet in 1927, the total drop in 1928 being 10.5 feet. Similar comparisons of amounts pumped with the resulting drop in the water plane may be made from the record given in Diagram "W" of the Monte pumps and water levels, but in both cases the amount pumped was too small and the effects too limited to offer any satisfactory conclusion as to what the effects would be if the pumping were very materially increased. There would also enter into such a comparison the amount of the underground flow, which would vary with the head, or the elevation of the water plane, and would vary with the character of the season, as for instance, it was much greater in 1927, following the wet winter than it was in 1928, following a subnormal year. The natural seasonal drop also would have to be considered in such a comparison.

In Diagram "V" are shown the minimum levels in Well L 85 at Riverview narrows, as observed by Lee and Alverson in 1912 and 1914, and while it is interesting to note that the low level of December 1928, was 2½ feet higher than that in November 1914, in spite of the pumping at Riverview, the most interesting fact, however, is that the low level of 1914 was as high as it was since the runoff during the preceding five seasons had been very much subnormal. Or, in other words, following a long dry spell of five consecutive seasons, the water plane at Riverview was only 2½ feet lower than it was in 1928, following a wet season of complete replenishment and after a summer in which 1535 acre feet were pumped from the river at Riverview. In this connection, C. H. Lee says in Water Supply Paper 446, page 141, "The only water level observation available for the protracted period of drought from 1897-98 to 1903-4 is a measurement at well number L 85 at Riverview, reported by Mr. C. S. Alverson. This measurement was made November 22, 1904, at practically the end of the dry period, and indicated a level several feet higher than the minimum of 1914. This measurement indicated that with natural conditions a protracted drought results in only a minor depression of the water table, a conclusion that is also confirmed by the statements of cattlemen, who, during this same dry period, found it possible to obtain water for stock at many points in the river beds by merely scooping out basins 2 to 4 feet deep. The only unusual depressions of the water table reported in this period were in the immediate vicinity of pumping plants making heavy drafts."

These are very important facts as they illustrate some of the important features in these gravel bed storage basins. First, they show that there is no material loss from the basins due to seepage or draining out at the lower end, as Mr. Freeman contended, and second, they show that the evaporation and transpiration losses are reduced to little or nothing by a lowering

of the water plane. Mr. Freeman's opinion was based on the theory that the underground flow of 100 to 200 inches, estimated at the rate of 5 feet a day, would practically drain the basins to exhaustion during a protracted drought. He pictured the basins as a saucer or trough filled with sand and water and tilted so the water content drained out over the lower edge. This sounds plausible, if it were not for the fact that the resistance of the silt and sand particles is not so easily overcome by the low hydraulic heads found in the basins. The hydraulic head above the Monte contraction is 35 feet and is sufficient to cause rising water, and the hydraulic head above the Riverview narrows is 80 feet, with possibly a very little rising water on the north side. The hydraulic head between Riverview narrows and Old Mission dam is 70 feet. Any drainage out of the basin comes to the surface here at the bedrock at Old Mission dam. This natural seepage from the twenty miles of gravel beds above, as well as from all the adjacent hills and canyons and from El Cajon valley, results in a more or less constant summer flow of about 10 inches. A stream flowing 10 inches of water or 144 acre feet a year, is not going to exhaust the water from beds holding thousands of acre feet.

The underground flow in the basins, or the movement downstream of the ground water, is the attempt at equilibrium in trying to overcome the losses from the lower ends of the basins due to evaporation and drainage out into the next lower basin. In other words, the water is moving downstream underground first, to establish an equilibrium, second, to offset evaporation and transpiration losses, and third, to offset the drainage out into the basin below.

Diagram "V", therefore, portraying the hydraulic profiles from Cape Horn to Old Mission dam, is a very good picture of the range in the water plane fluctuations from Cape Horn to Old Mission dam. The two general noteworthy facts are, first, the maximum range from complete saturation to extreme low level following a group of dry years, is about 7 feet, and second, the increased depression at the Monte and Riverview pumping plants following pumping periods was comparatively small. Another interesting point is to note how quickly the Monte pumps draw down cone of November 30, 1928 was absorbed or refilled by December 6 further evidence that such a large draw down cone would not be necessary if the pumps were distributed over a wider area.

5. PUMPING RECORDS AND YIELD ESTIMATES

The pumping records in Tables No. 6 and No. 7 show that during the thirteen years since 1916 there has been pumped by the Cuyamaca Water Company and the city of San Diego from the gravel beds of the San Diego River, including Mission Valley, a total of 21518 acre feet, or an average of 1655 acre feet a year, or 1.5 million gallons daily. If the four years of little or no pumping are excluded, however, the average amount pumped was 2326 acre feet a year or 21 m.g.d.

Excluding from the totals for 1927 and 1928 the amount

pumped at Mission Valley, there was pumped by the two upper plants in 1927 a total of 1729 acre feet or 1.5 m.g.d. and in 1928, 2933 acre feet, or 2.6 m.g.d. making a total for the two years of 4662 acre feet, or 4.16 m.g.d. The average for 1927 and 1928 is 2331 acre feet or 2.08 m.g.d.

According to the record as compiled in Table No. 7, the amounts pumped by the Cuyamaca Water Company during the pronounced drought from 1898 to 1904 were quite modest compared with the combined totals in 1928 and 1928 of over 4000 acre feet in each year. D ring this drought period there was considerable pumping done by the city of San Diego at the Old Town plant, but there seems to be no available record of the operation.

In other words, during the greatest drought on record the water bearing gravels of the upper river remained practically untouched. Pumping done by the Cuyamaca Water Company amounted to 7210 acre feet for this 7 year period, while the total runoff at El Capitan during the period was 11350 acre feet. The year of heaviest pumping by the Cuyamaca Water Company, according to the record, was 1926 when an average of 2.49 m.g.d. was pumped, but in 1928 the total pumped by the Monte and Riverview plants averaged 2.6 m.g.d.

Table No. 5

GRAVEL BED ABSORPTION OF RUNOFF

FROM FLUCTUATION IN WATER PLANE

PLACE	Mean Fluctuation (a) at pt.	In section	Area of Section Acres	Ac.Ft.	38% A. Ft.
Head of Basin	0				
		4.25	88.4	375.7	142.8
Cape Horn	8.5				
		7.50	107.9	809.3	307.5
"A"	6.5				
		4.50	284.7	1281.2	486.9
"B"	2.5				
		2.75	257.1	707.0	268.7
"C"	3.0	3.25	304.4	989.3	375.9
"D"	3.5				
		3.00	528.9	1586.7	602.9
"E"	2.5				
		2.50	114.7	286.8	109.0
"F"	2.5	2.75	356.3	979.8	372.3
"G"	3.0				
		3.20	574.2	1837.4	698.2
"H"	3.4				
		1.70	402.9	684.9	260.3
O. M. Dam	0				
Total		3.84 (3.07)	3019.5	9538.1	3624.5
					366.3
					3990.8

(a) From Hydraulic profile, Diagram "Y"

SAN VICENTE CREEK

Head	0				
		1.00	90.0	90.0	34.2
I	2.0				
		2.75	317.8	874.0	332.1
J (L15)	3.5				
			407.8	964.0	366.3

Table No. 3

AREAS ABOVE GRAVEL BEDS

(From tables No. 1 & 2.)

SECTION	Av. width	Length	Area sq. ft.	Area acres
Head of Basin				
	550	7000	3,850,000	88.4
Cape Horn				
	1000	4700	4,700,000	107.9
"A"				
	1550	8000	12,400,000	284.7
"B"				
	1750	6400	11,200,000	257.1
"C"				
	1950	6800	13,260,000	304.4
"D"				
	2375	9700	23,037,500	528.9
"E"				
	1850	2700	4,995,000	114.7
"F"				
	2425	6400	15,520,000	356.3
"G"				
	3050	8200	25,010,000	574.2
"H"				
	1350	13000	17,550,000	402.9
			131,522,500	3019.5
O. M. Dam				

SAN VICENTE CREEK

Head of Basin				
	700	5600	3,920,000	90.0
"I"				
	1775	7800	13,845,000	317.8
"J"				407.8 Ac.
				3019.5 Ac.
				3427.3 Ac.

Table No. 4

RUNOFF ABSORPTION ABOVE OLD MISSION DAM

FROM MEASURED FLOW - ACRE FEET

Season	At El Capitan 177 sq. mi.		From San Vicente Cr. 75 sq. mi.		Remaining Area Above Mission Gorge 123 sq. mi. (c)		Total Amount Reaching Gravel Beds above Mission Gorge	Flow at Mission Gorge 375 sq. mi.		Absorption 4 - 5
	Runoff	Per sq. mi.	Runoff	Per sq. mi.	Runoff	Per sq. mi.		Runoff	Per sq. mi.	
	1.		2.		3.		4.	5.		6.
1919-0	23624	135	2518	34	3690	.30	29832	21882	58	7950
1920-1	1535	9	0	0	0	0	1535	180	0	1355
1921-2	100231	566	36302	484	47232	384	183765	168039	448	15726
1922-3	12999	73	394	5	369	3	13762	10100	27	3662
1923-4	2589	15	39	0	0	0	2628	16	0	2612
1924-5	2951	17	76	0	0	0	3027	72	0	2955
1925-6	16192	91	5506	73	6150	50	27848	25939	69	1909
1926-7	100700	569	32669	436	41328	336	174697	159823	426	14874
1927-8	4700	27	279	4	0	0	4979	1299	4	3680
TOTAL	265521		77783		98769		442073	387350		54723
9 yr. mean	29502		8642		10974		49119	43040		6080
Long term Mean	23078		7138		(a) 9064 (b) 9877		(a) 39280 (b) 40093	35235		(a) 4045 (b) 4858

(a) By comparison with San Vicente
(b) " " " El Capitan
(c) " " " San Vicente & Mission Gorge

RESERVOIR AND RIVER CONTROL

There are several good reservoir and dam sites on the San Diego River. San Diego County as a whole is overstocked with reservoir sites and understocked with the water with which to fill them. To obtain the greatest yield from the river a total reservoir storage is required approximately equal to the runoff during the known wettest season, which was 1883-84 when the estimated flow at Mission Gorge was 325752 acre feet. Reservoir yields also must be considered in relation to total storage. That is, the total yield must not be sacrificed for the sake of increasing the total storage. The yield for use is the main purpose - flood control is secondary. Increased storage does not always mean increased yield, owing to the element of evaporation. If there were an over-abundance of water available to the city, then the first object would be flood control. But we need every drop of water that falls in the county, and our problem is how to catch and hold it for use.

The answer to this problem as related to the San Diego River has been worked out under two heads, first, the yield of the water bearing gravels, and second, the yield from reservoir storage. The results of the study of the water bearing gravels already have been given, and now the study of the reservoirs will be taken up.

Table No. 9 was prepared to give the individual characteristics of each reservoir, with its dam. The areas capacities, etc., are from the area and capacity curves as given in this report. The estimated costs are explained in the

in the foot notes and are from the engineering offices of the city of San Diego and the Cuyamaca Water Company. The annual interest charges are based on the estimated costs as given forming a common basis of comparison. They do not include operating, maintenance or depreciation charges and hence the figures in the last two columns in the tabulation do not represent the total cost of the water.

SAFE YIELD STUDIES

A large number of safe yield studies was made of reservoir units and combinations. The results are given in Table No. 10, and partly in Table No. 9. They are the result of a vast amount of time and work. The preliminary work was done with mass curves and the final work by tabulations. The mass curves usually indicate the period to be covered by the estimate, but the results obtained from the tabulated method are much more reliable, accurate and consistent, and also on the whole they give a greater yield.

Diagram "LL" gives the mass runoff at Mission Gorge, together with lines of gross and net yields. The tendency of the curve to flatten out during the critical period indicates the controling feature in the reservoir operation.

Table No. 11 is a sample of one of the safe yield computations, being for the 295,200 acre feet Mission Gorge No. 3 reservoir. In dividing the operation into winter and summer periods, the winter period from October 1 to March 31 was given 70% of the seasonal runoff, one-third of the seasonal total depth in net evaporation, and one-third of the seasonal draft. This is the usual method in such computations. The evaporation losses for each period were obtained by applying the evaporation rate against the area of the reservoir as represented by the mean contents during the period. The mean contents of the reservoir were obtained by adding to or substracting from the amount already in storage one half of the additions or withdrawals from the reservoir

during the period. Several trials usually are necessary to make these results balance, on account of the evaporation loss varying with the amount in storage. Usually the first estimate used for the seasonal draft is too large or too small, which is not apparent until the computation is finished, when everything on the sheet must be erased except the runoff and the computation repeated with the new draft. This process must be repeated until the right draft is found that works out with an immaterial reservoir shortage or surplus.

A net seasonal evaporation depth of four feet was used at all the reservoirs except Cuyamaca. The gross evaporation at each reservoir would be practically the same, or from 55 to 60 inches - probably above the average during the dry critical period. The normal seasonal rainfall at Mission Gorge is 12.85 inches, and 16.47 inches at Fletcher Reservoir at the head of the river. During the drought period, however, it was much less, or 9.96 inches at Mission Gorge and 12.13 inches at Fletcher Reservoir. Thus, there would be approximately one foot of average rainfall to offset approximately five feet of annual evaporation, leaving a net evaporation of four feet, the amount used throughout the studies. Deducting the rainfall from the gross evaporation is equivalent to an increase in the runoff into the reservoir. That is, a seasonal rainfall of 12 inches falling on a reservoir covering, say, 1000 acres would produce 1000 acre feet of water, which consequently would reduce the evaporation losses by that much. Sometimes the practice is followed of deducting only from 95% or 85% of the rainfall from the evaporation, the remaining 5% or 15% being considered as already having been taken care of in the runoff record. That is, 5% or 15% of the rainfall falling on the reservoir area before the dam was built and this area flooded, would be considered as showing up as runoff at the damsite and hence would be included in the runoff records and estimates. Lee gives the average percentage of rainfall appearing as runoff from the watershed above the Diverting Dam as 8.1%, and at the Sweetwater Dam 4.9%. This percentage varies sometimes as much as several hundred per cent, according to whether the season is wet or dry. Rainfall on a lake surface, however, is 100% runoff, and the only question to answer would be whether to allow for the 5% to 15% that might have appeared as runoff before the dam was built.

The evaporation records all have been adjusted for rainfall - a rain gage usually is operated alongside the pan. Otherwise the places of heavy rainfall would show the least evaporation.

In these safe yield computations, therefore, all reservoirs have been subjected to the same net evaporation losses, and hence in this respect have been placed upon an equal footing.

Safe yield studies were worked out as described above for the various reservoirs under various conditions. Diagrams "GG" to LB" illustrate some of the peculiar features of the reservoirs. Diagram "GG" is a graphic illustration of the relation between reservoir area and capacity, and hence will indicate indirectly the percentage

evaporation loss bears to reservoir content. In this diagram the greater the mean depth, the smaller the percentage of evaporation losses. The smallest percentage of loss by evaporation is shown by the Fletcher Reservoir, with San Vicente Reservoir next. These two reservoirs are in narrow, rocky, steep sided gorges, with comparatively small storage as compared with the height of dam. The height of the dam, however, has nothing to do with the mean depth. The large storage in the big Mission Gorge reservoirs is spread out over a flat saucer-like basin with a low-shore line. The curve for Mission Gorge No. 3 indicates where back water from the dam begins to spread out in the saucer-like basin above the gorge. This begins when the amount in storage has reached 10,000 acre feet from which point on the high mean depths of the storage in the lower gorge are gradually offset until the capacity of 70000 acre feet is reached, when their effect becomes indirect. Out of a toal area flooded by the big Mission Gorge No. 3 reservoir of 7100 acres, about 200 acres are in the deep gorge section, while the depth of the water within the gorge is 295 feet at the dam and 73 feet at the head of the gorge, making a total storage of over 36000 acre feet, within the gorge. This combination of storage above the gorge and within the gorge, gives the effect of a double reservoir or two reservoirs in one, a large, shallow reservoir of large storage and big evaporation losses, and a small deep reservoir of very small evaporation losses. This double reservoir might be compared with Henshaw Reservoir if the Hodges Lake were added to it in the river gorge below. Mission Gorge No. 3 reservoir contains 259,000 acre feet above the gorge with a mean depth of $37\frac{1}{2}$ feet, and 36,000 acre feet within the gorge with a mean depth of 180 feet. The mean depth of Hodges Reservoir however, is but 28.6 feet, of Henshaw Reservoir 33.8 feet and of Mission Gorge No. 2, 40.3 feet. A reservoir holding 36,000 acre feet and with a mean depth of 180 feet is far superior in evaporation economy to any reservoir or proposed reservoir in the county.

Diagram "HH" also refers to evaporation losses from reservoirs, by a comparison with the safe net yield. This shows that large storage in the Mission Gorge reservoirs is very wasteful, indeed, as more than one-half of the water is lost through evaporation.

Diagram "II" is a comparison of the safe net yields of Mission Gorge Reservoirs No. 2 and No. 3 of equal capacities, by curves drawn through points obtained by safe yield computations. Mission Gorge No. 3 shows an increase of 2.5 m.g.d. over No. 2 owing to its deep water storage.

Diagram "JJ" is another graphic illustration of the yields from Mission Gorge reservoirs No. 2 and No. 3, as related to equal contour elevations. No. 3 yields approximately 4.0 m.g.d. more than No. 2 does with storage to the same elevation. This also is owing to the deep water storage possessed by No. 3. In other words, the yield from the river is increased outright by 4.0 m.g.d. by moving the dam $1\frac{1}{2}$ miles down the river. This fact is one of the most vital importance, as 4.0 m.g.d. is too much water to waste or to overlook in this land of little rain.

Diagram "KK" is another comparison of the yields from Mission Gorge No. 2 and No. 3, as obtained by Mr. Freeman, Mr.

Savage and by the writer. These comparisons are based on reservoirs of equal capacities as in Diagram "II". All three results show No. 3 to have from 2.0 m.g.d. to 2.5 m.g.d. greater yield than No. 2. The yield by Mr. Savage for both reservoirs are considerably greater than those by the writer because of the larger runoff used in his computations, as shown by the mass curves represented by the irregular dotted lines. The yields by Mr. Freeman come about half way between those by Mr. Savage and by the writer. Quite likely Mr. Freeman used the runoff estimates by Mr. Savage but his method of doing the work was somewhat different.

Diagram "LL" is another comparison of the yields from Mission Gorge No. 2 and No. 3, shown with the mass curve of the runoff. The effect of the deep water storage in No. 3 again is apparent, in each sized reservoir. The enormous proportions of the gross yield as compared with the net yield also are apparent in the lines of yield for the larger reservoirs, indicating the importance of the problem of planning for reservoir storage with the least loss from evaporation.

DIVERSION POSSIBILITIES

Diagram "MM", in six sheets, is a series of hydrographs showing the measured mean daily runoff at El Capitan from 1919 to date. The original records from which these sheets were made were used in making an estimate of possible diversions at El Capitan from a diversion dam with no storage through three different sized pipe lines or conduits, one of 15.5 second feet, one of 50 second feet and one of 100 second feet capacity. The capacity of the present El Capitan pipe line, gravity flow, is about 15.5 second feet. A tabulation of the diversion possibilities under these three conditions is given on each sheet of the hydrographs, and Table No. 8 is a summary of the entire results, except for the wasted amounts, which appear only in the tabulations on the hydrograph sheets.

These hydrographs tell the story of the manner in which the runoff from the San Diego River occurs. This 9 year period included two normal years, two wet years, and five dry years, or seasons. The period of storm runoff is of short duration, about five months being the limit, as in 1921-22, while the dry seasons like the previous season of 1920-21, practically had no period of flood runoff. The length of the diversion period varies from 4 to 8½ months, or with an average of over 6 months in length, and with an average diversion through a pipe line of the capacity of the present line of 2.86 m.g.d. At 10¢ per 1000 gallons the value of this water is $104,240, which represents interest returns at 6% on an investment of $1,737,330. The results from the larger sized pipe lines or conduits are much greater, with no increase in the diversion period, however, Diversions at these rates, which are greater than our daily consumption, would call for storage reservoirs somewhere along the line. These figures are very interesting, indeed, and with slight reductions they would apply equally as well to Mission Gorge as to El Capitan. Table No. 17 gives the total seasonal diversions by the Cuyamaca Water Company since 1886-87, and of the seasonal average of 5256 acre feet, about 4000 acre feet were diversions from stream flow through the flume, the operating capacity of which is about 27 second feet. This record, therefore, is another good criterion of diversion possibilibilities either at

El Capitan or Mission Gorge.

PLANS FOR DEVELOPMENT

In Table No. 12 the various reservoirs on the river have been arranged in twenty-nine different combinations or plans for development, each reservoir in each plan being given with its total storage and safe net yield. The flume diversions of 2.5 m.g.d. is the safe yield estimate for the present Cuyamaca flume based on the records as contained in Tables No. 17 and No. 7. Table No. 17 shows a total diversion during the 9 years drought period of 35650 acre feet, 7210 acre feet of which was pumped water, according to Table No. 7, leaving a balance of 28,440 acre feet of gravity water, or 2.82 m.g.d. Since there was some draft water from Cuyamaca Reservoir during this period, 2.5 m.g.d. was taken as the safe yield of the flume under present conditions. With the Chocolate siphon increased to adequate capacity, however, the safe yield of the flume system would be increased materially. Storage in Murray or some other reservoir at the lower end of the flume of course is essential to the operation of the flume. That is, the main water crop is diverted during the winter and spring months and stored in Murray for constant draft throughout the year.

THE CUYAMACA FLUME

One of the first questions to be answered in devising a scheme for the comprehensive development of the San Diego river is what to do with the Cuyamaca flume. If retained, its economic value must be commensurate with its cost of operation, maintenance and replacement charges and storage must be had at the head of it. If abandoned, sufficient water by some other method must be furnished the present consumers at a cost comparable with continued flume production. In other words, the flume should not be retained if it has outlived its usefulness - it should make way for a more complete and economic development. But it should not be discarded at the expense of less water at an unreasonably higher cost to its present patrons. Another question that must be answered at the same time is how best to meet the future increased needs of the flume system.

To discard the flume would mean to replace its water supply by new development further down the river, either at El Capitan, San Vicente, Mission Gorge or by wells in the gravel beds. El Capitan reservoir would be ideal for this purpose if its yield were more in keeping with its cost, and also if its yield were large enough to take care of both the claims against its water by the city of San Diego and the requirements of the Cuyamaca service. But with a yield of 13.1 m.g.d. and an annual interest charge of $600,000, according to Table No. 9, water from this reservoir would cost the Cuyamaca consumers 13.55¢ per 1000 gallons, plus pumping costs of 4.80¢, and plus purification, transmission and distribution costs, which would bring the total cost up to something like 25¢ or 30¢ per 1000 gallons. In Table No.

14, Mr. R. H. Wueste, Supervisor of the city impounding system, has shown the total cost of the city water in 1925 to be 28.38¢ per 1000 gallon, the water from the Cottonwood system costing 26.9¢ per 1000 gallons. With the interest charges alone on the El Capitan water amounting to 13.55¢ per 1000 gallons, it is evident the total cost would be fully as great or greater than the Cottonwood water.

A comparison of these figures with the present meter rates of the Cuyamaca company, as contained in Tabulation No. 15, shows the cost of the El Capitan water would be about double the present costs for the average consumer, and over three times the cost to the present large consumers. And in addition to this high cost, by pumping the water for the flume supply from El Capitan, only 9 miles of the over 30 miles of flume would be eliminated. With El Capitan dam built, the El Monte gravel basin below could not be expected to deliver over 1 m.g.d. continuous pumping, so that the main flume supply would have to come from El Capitan reservoir. This plan, then, appears to be decidedly impracticable and undesirable.

Considering the San Vicente reservoir as an alternative for the present flume system, its low safe net yield of 3.4 m.g.d. would necessitate pumping the major part of the regular flume supply from the gravel beds, which, on the contrary, by all means should be held as sources of reserve supply to the surface storage reservoirs. In other words, the main responsibility for security of supply should rest on adequate surface storage, with the gravel bed storage as secondary. San Vicente as a controlling or major unit in this case, then, is out of the question.

Considering the Mission Gorge reservoirs next as an alternative flume supply, there would be either the large reservoir with no other dam on the river, or the small reservoir with El Capitan and San Vicente dams built, as outlined in Plans "H" 1 and 3 and Plan "F" 1. The small reservoir would not answer the purpose on account of its low yield of 3.0 m.g.d., while the large reservoir with the greatest yield, as in Plan "H" 3, would have ample water with which to supply the flume from its safe yield of about 16.0 m.g.d. including the flume diversions, but the cost of this water would be 5.13¢ per 1000 gallons at the reservoir, plus 4.6¢ for pumping and plus about 16¢ for purification, transmission and distribution, or a toal of 25.79¢ per 1000 gallons. This water, then, would cost the average consumer twice the present service rates for the flume water, and, therefore, pumping from the Mission Gorge reservoirs would not be a satisfactory alternative for the flume supply. Plan "F", already referred to, calls for El Capitan, San Vicente and the small Mission Gorge reservoirs, and the objections to furnishing the flume supply from any of these reservoirs have been given. Consequently, the solution of the problem must be sought for in some other combination of reservoirs. Or in other words, costs and yields from the river with continued operation of the flume with storage at its head to take care of future increased needs must next be investigated.

FEASIBILITY OF CONTINUED FLUME SERVICE

Plan "I" 4 calls for Fletcher reservoir, flume

diversions and the big Mission Gorge No. 3 reservoir, and produces the most and cheapest water of any plan on the "I" page, and calls for a comparatively small total outlay of money. This plan also appears much superior to the "H" and "F" plans, already discussed and discarded in this discussion of what to do with the Cuyamaca flume. Its nearest rival seems to be Plan "G" 2, which has twice the total cost with practically an equal yield, but with 3 m.g.d. less water pumped from the gravels - undeniably an advantage, because what is not pumped from the gravels remains as standby reserve storage. Plan "G" 2 also calls for the Fletcher reservoir with flume diversions, so by examining this feature in either plan, the results will apply to both plans. The comparative merits of the two plans as a whole can be taken up later.

These plans call for the building of Fletcher dam and the continued operation of the flume, and thus would continue the present service at the present cost with the addition of 4.3 m.g.d. from Fletcher reservoir, at a cost of 4.11¢ per 1000 gallons at the reservoir, the cheapest water on the river, according to Table No. 9. That is, to the yield of the present Cuyamaca system of 3.5 m.g.d. is added 4.3 m.g.d. at an increased cost of an annual interest charge of $63774 (Table No. 9), which makes the total supply of 7.8 m.g.d. cost 2.24¢ per 1000 gallons. The economy of this plan speaks for itself. The cost of this gravity water is less than one-half of what the pumping costs alone would be for water pumped from El Capitan or Mission Gorge. The 4.3 m.g.d. of additional water from Fletcher reservoir at a unit cost of 4.11¢ is as cheap as the 1.0 m.g.d. safe yield from Cuyamaca reservoir. Capitalized at $200,000, the annual interest charges at 6% for Cuyamaca Reservoir would be $12,000, and plus $3,000 for operation and maintenance expenses, makes a total annual charge of $15,000, which, when applied against the safe yield of 1.0 m.g.d. for the reservoir, shows a unit cost of 4.11¢ per thousand gallons, or exactly the same unit cost as the Fletcher reservoir water.

Allowance for the rebuilding of the flume, however would have to be included in the costs of this proposed plan, as follows: The estimated unit cost of rebuilding the flume is $3.50 per foot, making the total cost for about 30 miles of flume $554,400. Annual interest charges on this amount at 6% would be $33,264. This amount added to annual charges against Fletcher reservoir of $63,774, gives a total of $97,038 to apply against the total safe yield of 7.8 m.g.d., thus making the unit cost 3.41¢ per 1000 gallons. Again, this is very much cheaper water than that pumped from El Capitan or Mission Gorge.

The answer, then, to the question of what to do with the Cuyamaca flume seems to be from an economic standpoint that the most feasible plan is to rejuvinate the system by rebuilding the flume and double the system's resources with a small reservoir at the head of it. Such progressive, well founded improvements would readily attract the necessary financial backing.

This question, however, cannot be so simply and easily disposed of, as there are many important angles and related issues that must be considered, the most important of which are

as follows:

1. The economic effect of Fletcher reservoir on the El Capitan and Mission Gorge reservoirs.

2. Comparative merits of reservoir storage above the gravel beds of the lower river, such as the Fletcher and El Capitan reservoirs, and reservoir storage below these gravels beds such as Mission Gorge reservoir.

3. The greatest beneficial use that might be obtained from full development of the resources of the San Diego River.

4. Possible effects of legal issues now pending concerning water rights on the river.

1. As to the effect of Fletcher reservoir on the yields from El Capitan and Mission Gorge, the safe yield results as given in Table No. 10 show the effects would be as follows: An increased yield from the river of 2.0 m.g.d. with the smaller, and 1.8 m.g.d. with the larger El Capitan reservoir, and at Mission Gorge No. 3, an increased yield of 2.9 m.g.d. with the small reservoir, 2.8 m.g.d. with the medium size, and 0.8 m.g.d. with the large reservoir. This remarkable considerable gain in increased yield from the water crop of the river certainly is no drawback to the building of Fletcher dam and the continued operation of the flume.

2. Comparative merits of storage in the upper and lower reservoirs give the upper reservoirs a decided advantage in having no gravel bed losses to pay for. That is, the water stopped at Fletcher or El Capitan is thus prevented from becoming a part of the 6000 to 8000 acre feet lost annually in the gravel beds below through evaporation and plant growth. The buidling

of the upper dams has the effect of lowering the water plane in these gravel beds and thus reduces the evaporation and transpiration losses. In water logged land, the water table often is lowered by drainage ditches and by pumping. If these gravel beds were extensive enough in length and breadth, there would be little or no runoff resulting at their lower end. Such a condition is found on the San Jacinto and Santa Margarita Rivers. Controling the water level in these basins, then, is to increase the total yield of the river, andther undeniable advantage in favor of storage up the river.

3. The greatest beneficial use to which the fully developed waters of the river could be put would be domestic, of course, with crop irrigation secondary. Domestic use, however, includes cultivated gardens around the home sites, parks, sewers and anything pertaining to a civic life. As the cost of water increases, as it naturally will in this county on account of increasing demand and limited supply, the point eventually will be reached when the high water rate will make commercial irrigation prohibitive to a large extent. The San Diego river water is largely predestined for domestic use - there is no other way out of it. It might have been otherwise if we had not made a Christmas present of the 20 or 25 m.g.d. of Henshaw water to the handful of people living around Vista. The La Mesa, Lemon Grove and Spring Valley Irrigation District, who are the present owners of the Cuyamaca system, will be the first and last irrigation district ever to divert water from the San Diego River, and if subdivision units

and urban growth continue to increase within the district as rapidly as they are at present, the irrigation use of water will decrease accordingly. That is, lands in the district now using water at irrigation rates, will automatically be transferred to domestic rates when they are subdivided. Fully 50% of the expected future growth of San Diego will be located between East San Diego and La Mesa, and to this section, then, will go 50% of our increased water supply. Undoubtedly the San Diego River is the most feasible place from which to obtain this water, and the only reservoir site of sufficient elevation to furnish a gravity supply is at the head of the flume. This, then is further undeniable evidence of the need of this reservoir and the rebuilding of the flume.

4. The present court action concerning the water rights of the San Diego River can have but one, or possibly two results: first, to whom belongs the right to build the dams and develop the water of the river; and possibly second, will the City of San Diego be obliged to take over the Cuyamaca system. Conditions this court action will not affect in the least are: the amount of water available in the river, and the population and area where this water will be used - these conditions are predestined as already mentioned. If the city wins the court decision to all the water in the river and then seeks complete development by the large storage in Mission Gorge, the large urban population east of the city with its increasing demands for water will not thus be wiped off the map. They will continue to grow with the rest of the city as one of its units and will expect a full supply of water the same as the rest of the city, and it already

has been shown that the most economical plan for providing this water is by gravity from the upper river. The economic necessity of this dam and reservoir is in no way affected by the lawsuit. The spread of the metropolitan area of the city eastward establishes a positive demand for this development of the upper river, and also thereby increasing the total yield of the river by over 2 m.g.d.

Having considered this flume question from every possible angle, including the rights and requirements of its present patrons, the rights and necessities to the river water of the city of San Diego, the outcome of the present court action, and the most productive and economic development of the entire river, the one answer or solution indicated by the entire outlay of facts is the economic feasibility and necessity of a reservoir at the head of the flume, with the continued operation of the flume.

Table No. 14

CITY OF SAN DIEGO

OPERATING DEPARTMENT

WATER IMPOUNDING BUREAU

COST OF WATER

COMBINED SYNOPSIS SHEET

(All values based on actual 1925 use)

July 20, 1926 R. H. Rueste, Supervisor

Source	1925 Use Thousands of gallons	Unit Cost Cents	Extension
Production			
Purchase			
Purification			
Transmission			
Cottonwood-Otay System	3,632,562	14.7	534,000
San Dieguito System	618,279	29.2	180,675
Cuyamaca Water Co.	170,631	14.7	25,083
Mission Valley Pumping Plant	251,959	4.2	10,582
Totals & Averages	4,673,431	16.1	750,340
Distribution			
All sources	4,673,431	10.4	488,971
Commercial Expenses			
All sources	4,673,431	0.8	36,975
General Overhead			
All sources	4,673,431	1.0	50,000
TOTALS	4,673,431	28.38	$1,326,286

Table No. 15

LA MESA, LEMON GROVE & SPRING VALLEY IRRIGATION DISTRICT

MONTHLY METER RATES - 1928

INSIDE THE DISTRICT

0 to 1,000 cubic feet	15¢ per 100 cu. ft.	or 20.0¢ per 1000 gal.
1000 to 3,000 " "	10¢ per 100 " "	or 13 1/3¢ per 1000 gal.
Allover 3,000 " "	6¢ per 100 " "	or 8.0 ¢ per 1000 gal.

OUTSIDE THE DISTRICT

0 to 1,000 cubic feet	25¢ per 100 cu. ft.	or 33 1/3 ¢ per 1000 gal.
1,000 to 3,000 " "	15¢ per 100 " "	or 20.0 ¢ per 1000 gal.
All over 3,000 " "	8¢ per 100 " "	or 10 2/3 c per 1000 gal.

Table No, 16

COMPARISON OF TWELVE BEST PLANS ON AN EQUAL PUMPING BASIS

Plan	Total Yield m.g.d.	Pumped Water m.g.d.	Total yield with only 3 m.g.d. pumped water m.g.d.	Total storage Ac. Ft.	Total cost
G 4	26.6	3	26.6	316,497	$ 14,126,900
G 2	25.6	3	25.6	254,156	12,095,900
I 4	25.0	6	22.0	323,901	5,662,900
A 4	24.3	5	22.3	383,131	7,095,900
H 3	24.2	6	21.2	306,795	4,600,000
H 4	23.8	6	20.8	366,025	6,033,000
F 2	23.6	3	23.6	237,050	11,033,000
E 1	23.6	3	23.6	272,272	12,526,900
C 3	23.6	3	23.6	254,686	14,562,900
C 2	23.4	3	23.4	212,126	12,662,900
I 1	23.2	6	20.2	324,161	6,371,900
D 2	23.0	3	23.0	272,366	12,964,000

COMPREHENSIVE DEVELOPMENT
BY
TWENTY-NINE DIFFERENT PLANS.

To accomplish the purpose for which this report has been made, which is to obtain the best plan for the complete development of the entire river, all possible reservoirs were arranged into various combinations, with changes also in the capacity of each reservoir. In each case tabulations were prepared showing reservoir spills and remaining runoff for the lower reservoirs contained in the plan. The whole operation called for a multiplicity of detail and safe yield studies, which, nevertheless, were worked out for each plan. The results as contained in Table No. 12, therefore, are believed to be mathematically correct and reliable, the same basic data being used throughout as given in this report. A study of the river made in this way, should indicate not only the greatest possible yield from the river and how it is best developed, but also it should indicate the economical procedure of development, so that duplication, waste and the costly changing of plans can be avoided.

The details of these 29 different plans are contained in the nine sheets of Table No. 12, while in Table No. 13 the results have been summarized and reduced to unit costs for ready analysis. The 29 plans have been arranged under nine general heads, lettered from "A" to "I", each of the nine plans calling for a certain combination of reservoirs. In examining these plans, the process of selection and elimination has been based on the following points:

1. Total amount of safe net yield.
2. Total storage.
3. Cost, unit and total,
4. Geographical distribution of reservoirs.
5. Initial development.

These five requirements represent the scales in which the different plans are to be weighed - what one plan may lack in one respect it may make up in another.

The twelve plans with the greatest production have been reduced to an equal basis as regards pumped water, and the results are given in Table No. 16. The outstanding fact in this table is the continued superiority of Plans "G" 2 and "G" 4. Plan "H" 3, on account of its single reservoir, shows the cheapest unit cost development of anything on the river, but must be eliminated because of its low yield and because it does not take care of the Cuyamaca flume supply in the most economical way, the necessity for which has been explained at length. Plans "H" 4, "F" 2 and "D" 2 are also eliminated for the same reasons. Plans "E" 1, "C" 2 and "C" 3 are eliminated on account of comparatively low yields at high costs. Plan "I" 1 is eliminated on account of low yield.

Of the four remaining plans, "I" 4 and "A" 4 look very attractive indeed as to low unit cost, total outlay of money, total storage and production. But they both call for the large Mission Gorge reservoir, flooding 7000 acres and extending up to Lakeside, and since considerable attention in the diagrams and elsewhere has been given to show the poor economy of this reservoir as compared with the smaller reservoirs, these two plans also will have to be discarded. In other words, to retain these plans on account of their low unit cost, would mean to sacrifice or waste over 4.5 m.g.d. of water out of the river, which otherwise could be saved by better storage on the river.

MOST FEASIBLE COMPLETE DEVELOPMENT

In Plans "G" 2 and "G" 4 is found the most feasible, economic and complete development of the river, as they produce by far the greatest yield, have large storage, the unit cost, while not the lowest, is moderate, the geographical distribution of storage could not be better, and the building of the two smaller reservoirs first would place the initial development where most needed and at the least expense.

These two plans are identical except that "G" 4 calls for a 100 second feet canal leading from El Capitan to San Vicente, with double the storage in San Vicente.

The exceptionally large yield of 25.6 and 26.6 m.g.d. is made possible by reservoirs of most excellent evaporation economy and by storage above the gravel beds, where it has been shown from 6000 to 8000 acre feet of water otherwise would go to waste annually. By complete ownership and control of these gravel beds it is possible even to increase this yield by 1 or 2 m.g.d.

The total storage of 254,000 and 317,000 acre feet easily could be increased 42,000 acre feet if necessary by raising the Mission Gorge dam 20 feet to elevation 350,

and without excessive flooding of the Santee basin, as is seen from the 350 foot, contour on the map. This would give a total storage of 296,000 and 359,000 acre feet.

While the total outlay of money called for is quite a sum, the unit cost is very reasonable, and the expense is more than compensated by the unusual advantages. The cost in Plan "G" 2 is 9.62¢ per thousand gallons or $475,000 for each million gallons daily, while in Plan "G" 4 the cost is 10.65¢ per thousand gallons or $531,000 for each million gallons daily.

The geographical distribution of the reservoirs in these two plans makes it possible to overcome to a large extent the losses from the gravel beds, at the same time leaving sufficient runoff below El Capitan and San Vicente for ordinary replenishments. The geographical distribution also is such that the maximum gravity water is obtained from the river, making it possible to place this water by gravity anywhere within the city or in the suburban district to the east.

The initial development for these two plans would be the two smaller reservoirs, Fletcher and Mission Gorge, calling for a total outlay of about $5,000,000 with next, probably a diversion dam at El Capitan, followed by the San Vicente reservoir. Then eventually when needed, complete development at El Capitan. This program, consuming several years, would ease the expense burden, especially if the initial development at El Capitan is confined to diversion. The building of Fletcher dam should not materially reduce the amount of these diversions as it would spill nearly every year and there is 86 square miles of good drainage area between Fletcher and El Capitan.

The bonds already voted by the city for El Capitan are sufficent for the initial development of the diversion dam and the Mission Gorge dam. Very little money would be needed for additional pipe lines. Flooding the four miles of El Capitan pipe line in Mission Gorge would do no harm, as submerged lines often are used. This part of the line could be moved, however, if necessary.

Except eventually it may be found advisable for greater storage to build the El Capitan-San Vicente pipe line, otherwise none of the water under this development will have to be transferred to secondary storage, other than to local distribution reservoirs. A big reservoir like Mission Gorge for instance, or Henshaw, would be excellent for impounding water in flood years, to be lowered by gravity later to more economic storage. It certainly is too bad this cannot be done with the big Mission Gorge reservoir. Murray reservoir, of course, would have to be operated in conjunction with Fletcher reservoir and the flume.

The development of these four fine storage reservoirs on the San Diego River, the most accessible to the city of any in the county, will provide excellent storage facilities for any water we may secure from the Colorado River, or for diversion from the San Dieguito watershed, or from the San Luis Rey River, if any is ever to be had again from this

source. Storing our valuable water supply in these four deep, steep-walled reservoirs would be like placing our money in the best bank in ~~two~~ town for safe keeping - we would never worry about any losses. All of these four reservoirs sites are fit for nothing else but basins in which to store water. In their natural state, they would remain forever largely as rocky, barren wastes. But occupied by deep lakes of fresh water, nestling in their canyon cradles beneath the rising mountains, they will become beauty spots of pleasure and health giving recreation. The reservoir in Mission Gorge, especially, with its towering picturesque dam being only 8 miles from the city could be developed through concessions into a popular lakeside resort with good financial returns.

FLOOD CONTROL

With these four dams built, the disastrous floods on the San Diego River will be a thing of the past. Alfalfa fields, truck gardens, dairy farms, highways, etc., can then be developed in the rich bottom lands on a permanent basis.

The rights of riparian owners along the river will have to be taken care of as the occasion demands. A special commission, skilled in land and water values and the handling of real estate, may be best suited for handling this matter. These riparian owners will lose none of their rights as a result of the lawsuit now pending. The initial development, however, of the dam in the gorge and the diversion dam at El Capitan will not seriously disturb any of these rights. The delivery of water in return for grants and privileges should be scrupulously avoided wherever possible, as the city will never have any water to trade away to be used outside of the city.

All four of the damsites in question have been investigated by experts in the past in great detail and pronounced suitable for dams. There may be some argument as to the most practicable and economic type of dam, but this occurs with every development no matter where.

REPORTS BY H. N. SAVAGE & J. R. FREEMAN

There have been excellent reports in the recent past on the San Diego River by two foremost authorities, the first by Mr. H. N. Savage, and the second by Mr. John R. Freeman, The recommendation by Mr. Savage was for a single reservoir, the large Mission Gorge No. 2, with which Mr. Freeman concurred, but with the additional recommendation of San Vicente, El Capitan "many years hence," and a second dam in Mission Gorge at the No. 3 site to partially offset the waste of the shallow storage in No. 2, which he called "extremely extravagant". In this connection he said: "The great drawback (to Mission Gorge No. 2) is the enormous waste by evaporation in a reservoir of 10 square miles of evaporating surface in a land of little rain on the reservoir surface. Four feet (of evaporation) in depth in 10 square miles is equivalent to about 23 million gallons per day. I earnestly sought means for lessening this waste and this led me to the San Vicente site. After one has worked

out mass curves and tables of comparative yield for Mission Gorge No. 2 and El Capitan with reservoirs of equal capacity at each, there afe found results that at first view are unbelievable, in which, for example the project having more than double the tributary drainage area is found producing the smaller yield; simply because of the vastly greater evaporation in a shallow reservoir of about 3,700 acres compared with a deep reservoir of 1,500 acres. Because of depth, area and steep rocky shores, the San Vicente is the best reservoir site of all, and Mission Gorge No. 2 the poorest reservoir site of all."

In spite of these positive convictions, however, Mr. Freeman recommended the development of Mission Gorge No. 2, but advised "the immediate purchase of the San Vicente damsite and reservoir lands," and later a dam at Mission Gorge site No. 3, about which he said: "This No. 3 site is uncommonly favorable for building a high dam in hard bare bed rock and exceptional narrowness of gorge,, with remarkably small loss from evaporation because of the remarkably small area of its canyon reservoir and its great depth. The time will surely come when such large loss by evaporation as is caused by the 3,700 or 6,200 acres of Mission site No. 2 must be economized." There is no question about the soundness of the conclusion, but because he considered the high dam at Mission Gorge No.3 too expensive, he recommended the development of Site No. 2 with its lower dam and enormous evaporation losses, which he sought to overcome by building three additional dams, namely, San Vicente, El Capitan and later, at Gorge Site No. 3, so in the end, the economy sought in dam construction proves to be just the reverse. Or, in other words, the best ultimate development, which is what we are striving for, does not call for a dam at Mission Gorge Site No. 2.

The curves, diagrams and safe yield studies in this report, as well as in those by Mr. Savage and Mr. Freeman, all show that a reservoir at Mission Gorge Site No. 3 develops 4.0 m.g.d. more water than does a reservoir at Site No. 2 built to the same contour elevation. At 10¢ per 1000 gallons, 4.0 m.g.d. is worth $146,000 annually, which is 6% on $2,433,333, or 5% on $2,920,000. That is, this increased yield of 4.0 m.g.d. is worth from 2½ to 3 million dollars, and as an extreme value, which Mr. Savage places at 1 million dollars per 1.0 m.g.d., it is worth $4,000,000. This $4,000,000, added to the cost of a dam at site No. 2, should be ample to build the safest kind of a dam at Site No. 3 up to the 350 foot or even 360 foot contour. Mr. Freeman's estimate of the cost of an earth and rock fill dam at site No. 3 up to elevation 365, which is 10 or 15 feet higher than necessary, is $4,756,390, or slightly more than the value of the 4.0 m.g.d. increased yield. His estimate of the cost of gravity concrete dam at Site No. 2 built to elevation 365, is $1,275,000. The difference between the estimated cost of these two dams is $3,481,390, or over ½ million dollars less than the value of the increased gain in water at

Site No. 3. Therefore, the superiority in economy and advisability of Site No. 3 over Site No. 2 is plainly evident.

Plans "G" 2 and "G" 4 were chosen as representing the best complete development of the river only after a thorough examination of all the conditions. These two plans overcome the enormous evaporation losses of Mission Gorge No. 2 reservoir, which so upset Mr. Freeman, they include the San Vicente reservoir, which he highly recommended, they provide reservoir storage at the head of the flume, which has been a long-felt want, and finally they provide for the development of El Capitan reservoir, which has been the great favorite of so many city officials.

San Diego, California
January 7, 1929.

Maj. Gen'l. Joseph E. Kuhn,
800 A,
Coronado, Calif.

My dear Sir:

no - not mine but Col. Fletcher!

At your request several months ago, I undertook to gather all the available data at my command pertaining to the water resources of the San Diego River, both as to runoff available for reservoir storage and as to contents of water bearing gravels. From this data I constructed curves, diagrams, tabulations and safe yield studies, patiently working out twenty-nine different plans for the complete and ultimate development of the river, bearing in mind the three most important essentials of greatest total yield, low unit cost and accessibility of stored water to service areas.

As a result of this work, I discovered that the greatest yield cannot be obtained from the San Diego River with one reservoir, but that four are necessary for this purpose, namely, El Capitan, San Vicente, Mission Gorge No. 3, and a small reservoir at the head of the Cuyamaca flume. Fletcher (?) The peculiar conditions that make this combination of reservoirs necessary are as follows:

1. A reservoir in Mission Gorge large enough to control the river would produce 4.5 m.g.d. less water than the combination of reservoirs. 8.9 m.g.d

2. The storage at El Capitan is limited to 139,000 acre feet on account of the Cuyamaca flume, and, therefore

the additional storage of other reservoirs is needed, including the deep San Vicente reservoir.

3. A dam at Mission Gorge Site No. 3, holding from 44,000 to 90,000 acre feet is necessary for complete control and development of the river.

4. Investigation of costs and yields proved it best to continue the present gravity supply of the Cuyamaca flume service, and this calls for the development of the Fletcher reservoir.

This combination of reservoirs gives a safe yield of 26.6 m.g.d., 3.0 m.g.d. of which is pumped water from the water bearing gravels.

The unit cost of this water is 10.65¢ per 1000 gallons, exclusive of the yield from Cuyamaca Reservoir and the flume diversions. That is, water from the new development would cost 10.65¢ per 1000 gallons at the reservoir. If the transmission, purification and distribution expenses in the city limits are added, ~~said~~ which costs average about 16¢ per 1000 gallons, according to Mr. Wueste's figures as the present cost of the city of San Diego's water supply, the total unit cost of this water would be about 27¢ per 1000 gallons, or a little less than the cost Mr. Wueste shows for the water from the present city system. This water then, could be sold on an even basis with the present city water, and probably a little cheaper on account of shorter transmission lines.

I feel confident the estimated yield from the gravel beds of 3.0 m.g.d. is quite conservative, as this is meant to include the Mission Valley basin as well as the upper basins. But it must be remembered this estimated yield is for a period of 9 consecutive years of protracted drought, or the same conditions under which the safe yield of the reservoirs was obtained. During the early period of development, however, before El Capitan and San Vicente dams are built, the gravel beds should yield more than 3.0 m.g.d. and their development should be one of the first steps in the program for complete development. That is, the initial development should be the building of Mission Gorge and Fletcher dams and the development of the gravel beds, and next, diversion at El Capitan. This program of initial development will produce 15.0 m.g.d. of cheap water.

These gravels, therefore, represent a valuable asset as water storage basins. They represent at least 11% of the total yield of the river, which, applied against the total cost of this plan of development of $14,126,900 would make their value $1,593,232. Or, at the rate of 10¢ per 1000 gallons their estimated safe yield of 3.0 m.g.d. would produce $109,500 worth of water each year, which sum is 6% on $1,825,000. Therefore, it can be truthfully said, that eventually, when developing the ultimate resources of the river, the city can afford to spend from $1,500,000 to $2,000,000 on developing these water bearing gravels. Mr. Freeman, in his report, suggested a comprehensive and quite reasonable plan for doing this.

The complete plan of development, as selected from

the 29 plans, is as follows:

Unit	Storage Ac. Ft.	Yield M.G.D.
Cuyamaca Reservoir	11,595	1.0
Flume Diversions		2.5
Fletcher Reservoir	17,106	4.3
El Capitan Reservoir (a)	122,000 dam 190' high	9.4
San Vicente Reservoir	121,571	3.4
Mission Gorge No. 3 Reservoir	44,225 dam 230' high	3.0
El Monte Pumps		1.0
Riverview Pumps		1.0
Mission Valley Pumps		1.0
Totals	316,497	26.6

(a) With 100 Second feet canal to San Vicente. Without the c anal, the yield is 1.0 m.g.d. less.

Very truly yours

F. E. Green

F. E. Green

THE OLD MISSION DAM AND CONDUIT

The Old Mission dam and conduit, of which several photographs are given in this report, were built by the Mission fathers in about the year 1805, according to Bancroft, who says a famine producing drought during the period between 1801 and 1803 probably caused the construction of this water system for the purpose of irrigating crops on the cultivated land around the Mission. The mission originally was established at Old Town in 1769, but on account of the lack of water for irrigation it was moved in 1774 about 5½ miles up the river to its present location. The Mission records do not mention the construction of this water system, but Bancroft says as the records refer to skilled labor from Mexico being used on other Mission work at this time it probably also was used on this.

The dam is located about 6 miles above the present mission at the outlet of El Cajon Valley, where the ledge of porphyry makes an excellent foundation. Seepage from the 18 miles of river gravels above comes to the surface here, forming an average flow during the dry summer months of 10 or 15 inches. The dam was 224 feet long, 12 feet wide and 14 feet high and was built from field boulders, broken rock, gravel and tile, cemented together with home made mortar. Near the south end of the dam an opening 13 or 14 feet wide was built, probably for a sluice gate. The short section of the dam between this gate and the south bank was reinforced downstream by a buttress wall extending back 15 or 20 feet

to a high ledge of porphyry. This end of the dam remained practically intact until the flood of January, 1916.

The conduit keeps along the right bank of the river not far above high water level, the flood of 1916 evidently being the first water to reach this high. Many sections of the conduit when covered with debris are still in perfect condition. Two of these are shown after excavation in the photos. The conduit was lined on the bottom with tiles similar to roofing tiles as used today, being twenty-two inches long, and six to ten inches wide, with one end always a little wider. The joint between the tiles evidently was not grouted. The ditch was from two to three feet wide inside at the top, and from twelve to eighteen inches deep. A peculiar form of construction in the walls in many places are the thin slabs of granite which had scaled or blistered off from boulders. The ditch probably could not have carried more than 25 to 50 inches of water.

There is nothing in the records concerning to what extent this water system was used, but undoubtedly when the missions were secularized in 1834 by the Mexican government, the system was abandoned, if still in use at that time. During the intervening thirty odd years no great amount of water could have been diverted through the ditch for the following reasons: first, the cultivated area as indicated by the remnants of the old adobe brick wall fence still standing was quite small, not more than from 20 to 40 acres; second, with transmission losses undoubtedly as high as 40% or 50%, and with an available flow at the dam during the irrigation period of not more than 10 or 20 inches, the supply for irrigation could not have been more than 5 or 10 inches; third, there is no evidence of any storage reservoir at the outlet of the conduit. If the idea of a storage reservoir were considered by the builders of the ditch, they evidently considered the construction of the necessary high line ditch or conduit beyond their resources. The conduit as built was on the natural bench above the right river bank where very little excavation and trestle work was necessary. However, the system undoubtedly furnished a fine incentive for the many pioneer water works constructed by the ranchers during those early days.

In the spring of 1912 the U. S. Geological Survey in cooperation with the Cuyamaca Water Company established a gaging station at the Old Mission dam, with the dam as the control and the sluice gate as the low-water opening. In 1913 the sluice gate was equipped with a concrete weir with steel crest and sides, as shown in the photos. This weir was partially destroyed on February 2, 1915, and further damaged in January 1916. The flood of 1916 also carried out a large section of the south end of the dam, thus providing another outlet for the low water flow. In the fall of 1920, the Geological Survey, in cooperation with the Cuyamaca Water Company built the present gaging station at the old Loop diversion dam 1.3 miles down stream, where the control is much better and more permanent but the

channel upstream very rough with masses of large boulders.

The outlet of the Old Mission dam was through a 4 inch clay pipe set about 12 feet in from the north end of the dam. A mysterious feature of the dam is the parapet-like extension on the lower side a short distance north of the sluice gate, and which can be seen in each of the large photos under the over-hanging willow tree. This extension also contained a 4 inch clay pipe set vertically in the center and may have been used for a second outlet into the conduit, taking the water over the top of the dam in place of through it as the outlet on the north side did. If such were the case, the tile pipe probably was laid along the lower toe of the dam for making connections with the conduit, there being sufficient head for this purpose. This parapet would have been the logical place for the outlet on account of the forebay of clear water which could be maintained above the sluice gate, while the north outlet would be covered with silt and sand.

SAFE YIELD FROM THE WATER BEARING GRAVELS

In considering the yield of the gravel beds of the river above Old Mission Dam, the subject was examined under four general heads as follows:

1. Gross volume.
2. Effective porosity.
3. Percentage of water content recoverable by pumping.
4. Runoff absorbed by the gravels during the yield period.

The gross volumes contained in these gravels beds as shown in detail in Tables No. 1 and No. 2, amount to 202,293 acre feet.

The porosity of the material forming these fills in the major valleys of San Diego county C. H. Lee found ranged from 39 to 41% for coarse sand and from 50% to 54% for fine sandy loam. While his tests for effective porosity, or amount of water content recoverable as related to total volume, showed 41% for sand and 16% for fine sandy loams, with an average for six typical conditions of 34%. That is, the percentage of the water content which remained unrecoverable in the sands was 5%, and in the fine sandy loams, 36%. His effective porosity tests, however, showed 38% for the upper gravel beds in all of the major valleys, and 33% for the lower gravels beds of the SanDieguito, San Diego and Sweetwater valleys, 32% for the lower San Luis Rey, and 31% for the lower Tijuana. But in estimating the safe yield of these various gravel beds, however, during a period when the water level was to be lowered from 30 to 50 feet by pumping the effective porosity used on the upper San Diego River gravels was only 25%. The reason for thus so greatly reducing the effective porosity undoubtedly was that pumping on such a large scale would lower the water table faster than the entire water content of the gravels could drain out. That is, such an unnatural, accelerated lowering of the water table would be effective on only 25% of the volume of the gravel beds. This figure, therefore, can be considered safe and conservative, and will provide an ample margin of safety in taking care of minor factors not considered in the safe yield computations, such as the small drainage out of the basin and losses due to

evaporation and transpiration at the beginning of the pumping period.

Having determined what part of the volume of these gravel beds is water, and next, what part of this water content the sands could be expected to release by pumping, the next question is, what part of the water bearing gravels as a body would remain unaffected by pumping. That is, after every possible drop has been recovered by pumping, how much water would still remain in the lower depths of the beds untouched. In arriving at the answer to this question it is assumed that the gravel beds are fully covered with an adequate distribution of wells. That is, that no water will remain unrecovered for the sake of more or deeper wells. Just as the sands cannot be sucked dry by pumping any more than a saturated cloth can be made dry by running through the wringer, so the entire water content of the gravel beds cannot be lifted out by a complete system of wells. These eighteen miles of gravel beds might be compared to an immense trough filled with tubes more or less parallel and horizontal, something like the tubes in a boiler, and interlaid with the rock, sand etc., the water content slowly traveling through these tubes or channels toward the lower end. If this trough of gravel beds could be stood on end like a boiler would be stood on end, it might be expected the entire water content would run out, but to accomplish this complete drainage while the beds are lying in their natural state, holes would have to be punched in the rock bottom like a sieve throughout its length with an imaginary cavity below for catching the water. In other words, by standing the basin on end, or by knocking out its bottom, the full force of gravity is utilized in overcoming the resistance, the gravels offer to the draining out of the water, and also all depressions or pockets within the basin would thus be emptied. While on the other hand, the depression in the water plane surrounding a well being pumped has increased the effect of gravity only to a limited extent in overcoming the resistance of the gravels. That is, the hydraulic grade of the water flowing into a pump draw-down cone is quite steep only in the immediate vicinity of the pump, and flattens out rapidly in the affected area beyond.

All gravel basins and wells have peculiarities of their own, which become manifest with the development of pumping. One peculiar ity of these upper gravel beds of the San Diego River is the constant hydraulic grade running from 13 feet to 19 feet per mile, and the absence of any artesian pressure. The ideal pumping basin is a gravel bed that is practically closed at the lower end and with its water content under artesian pressure, such as the Santa Ana, San Gabriel and Los Angeles River basins. The artesian pressure in these basins which is caused by the weight of the water in the higher and distant areas, cooperates with the force of gravity in overcoming the resistance of the gravels, and

the hydraulic grade is very flat on account of the outlets being practically closed. Artesian conditions would be approached above the El Monte and Riverview contractions if bedrock were present to the surface or the contractions much narrower. The Mission Valley basin approaches the ideal condition, as it is in almost a balanced state with some artesian pressure from deep wells. The hydraulic grade here is about nine feet per mile.

COLLECTION GALLERIES

The high hydraulic grade of nineteen feet per mile in the upper gravel beds, however, could be well utilized by concrete collection galleries sunk across the channel at advantageous points such as the El Monte and Riverview contractions. Such galleris would not be practicable in the lower gravel beds of our streams, such as Mission Valley and Tijuana Valley on account of the low hydraulic grade, as to be effective they would have to be of immense length. Collection galleries at the El Monte and Riverview narrows undoubtedly would reduce the cost of pumping materially. Such a gallery, 1000 feet in length and 20 feet in diameter, would hold 2,355,000 gallons, to empty which each day would mean an inflow of 200 miner's inches or 4 second feet. Operation of such a gallery at the Riverview contraction would be quite feasible, indeed, as there have been periods when twice this amount of water was pumped daily by the city at the Riverview pumping plant, without materially affecting the water levels below the contraction. The effective surface of such a gallery could be increased by laterals as often is done in dug wells. In operation, pumping costs would be reduced by a lower lift, by part-time operation of the pumps at high capacity, the gallery refilling in the meantime, and by permanency of the plant. A saving in operation costs of $7,000 annually would justify the building of the gallery, as this is 7% on $100,000, which sum should be ample for the building of the gallery.

AMOUNT OF WATER RECOVERABLE

Making proper allowance, therefore, for these two factors of hydraulic gradient with resistance by the gravels, and individual pockets or depressions within the basins which would not be affected by pumping, a conservative estimate of what portion of the available water content of the gravels could be extracted has been taken as 50%. That is, out of the 50,573 acre feet of effective volume, one-half is considered as remaining beyond the reach of the pumps, leaving 25,287 acre feet for duty during the safe yield period. This surely should be quite within the margin of safety when it is considered that the total volume of gravels being considered is over 202,000 acre feet.

This estimate also is borne out by C. H. Lee as his possible maximum lowering of the water plane of 30 feet is one-half of the mean depth of the gravel beds, the mean depth being the total volume divided by the surface area, or 202,293/3427, or 59 feet.

The runoff into these upper gravels beds during the

safe yield period is shown in the tabulation below:

RUNOFF REACHING THE UPPER RIVER GRAVELS

Acre Feet

Season	From El Capitan	From San Vicente	From 123 sq. mi. below El Capitan and San Vicente (a)
1895-6	500	0	0
1896-7	12000	1700	2000
1897-8	0	0	0
1898-9	0	0	0
1899-0	0	0	0
1900-1	1600	100	75
1901-2	1750	200	150
1902-3	8000	700	900
1903-4	0	0	0
Total	23850	2700	3125

(a) By comparison of drainage area and rainfall with San Vicente.

The safe yield of the water bearing gravels above Old Mission Dam, therefore, based on the facts as outlined above, would be as follows:

Gross volume of gravel beds	202293 acre feet
25% - effective porosity	50573
50% - estimated limit to which the beds could be exhausted by pumping.	25287
Plus runoff during 9 seasons of critical period:	
(a) With no dam constructed (39675 Ac. Ft.)	54962
(b) With all dams constructed (3125 Ac. Ft.)	28412

Safe yield during 9 years critical period:

(a) With no dams built $\frac{54962}{9}$ 6107 ac. ft. or 5.5 m.g.d.

(b) With all dams built $\frac{28412}{9}$ 3157 ac. ft. or 2.8 m.g.d.

This, indeed, is a remarkable showing considering the ultra-conservatism of the manner in which these results were obtained, and considering the favorable comparison with surface storage reservoirs. Five and one-half m.g.d. is a greater yield than that from Fletcher reservoir, or from San Vicente or the smaller Mission Gorge reservoir, while 2.8 m.g.d. under complete development of the river compares quite favorably, with the yield from the Mission Gorge reservoirs under the same conditions. In other words, the complete development of these gravel beds would be the equivalent of adding another Mission Gorge reservoir to the resources of the river.

JAMACHA AND SAN PASQUAL

In this connection a similar condition on the Sweetwater River might be cited where the Jamacha gravel beds above Sweetwater reservoir absorb and evaporate on the average from 2000 to 3000 acre feet of water ever year, over an area of some 1000 acres. The yield from Sweetwater reservoir, therefore, is reduced correspondingly, and the water company for several years has been considering building a dam above these gravels to overcome to some extent these losses. Another similar case is the San Pasqual valley above Lake Hodges, where the water wasted each year from an area of about 2000 acres will average 5000 or 6000 acre feet, thus reducing the yield from Lake Hodges correspondingly. Reservoir storage up the river, with systematic pumping from the valley, largely would overcome these great losses, and thus, as on the San Diego River, would add

another storage unit to the water resources of the river.

RIPARIAN OWNERS AND CULTIVATED LANDS

Consideration of the complete ultimate development of the San Diego River must also include the rights of riparian owners and the rights and needs of present users of water from the river. A map has been prepared showing the valley lands between Cape Horn and Old Mission dam, a photostatic reduction of which is contained herein. The areas of these lands and their classifications are as follows:

Condition	Acres	Per cent of the whole
Alfalfa	659	15.6
Corn	417	9.9
Grain	477	11.3
Pasture	488	11.6
Sand and willows	2172	51.6
TOTAL	4213	100.0

These areas practically are as colored on the map, but also include the entire valley of the San Vicente, one arm extending up to Foster's and the other up the alluvial valley to the northwest, and which are not shown on this map. The total area of 4213 acres is outlined in most cases by a dotted line which is meant to represent the limits of the water-bearing gravel. This area is 786 acres larger than the area used in arriving at the volume of the gravel beds, and is further indication of the conservativeness of that estimate. That is, in this 4213 acres were included the little side valleys or pockets and overflow lands and widened areas of the valley floor which were eliminated by the straight lines used in the former computation, and which consequently would be more or less outside of the actual gravel basin.

It is interesting to note that out of these 4213 acres, only 56.8% are cultivated, while 51.6% are waste sand and willow lands, subject to the ravages of the winter floods. With the upper dams acting as flood controls, fully one-half of these waste lands could be reclaimed, thereby increasing their value $100 per acre or more, or a total saving to these property owners of over $100,000.

A little over 1000 acres of these river bottom lands are under more or less irrigation from individual wells. While in addition there are 400 acres within the recently formed Lakeside Irrigation District not included in the above total of 4213 acres and which gets its water supply from a well above the bridge opposite the town.

Across the river from Lakeside is another concern known as the Lakeside Farms Mutual Water Company, and comprising about 810 acres, part of which, practically all of the alfalfa land, was included in the areas on the map. This company's water supply comes from two pumping plants in the river sands of several connected well units, high and low pressure storage reservoirs being located on the adjacent hills.

The Riverview Farms Mutual Water Company's lands of about 1000 acres also were not included in the areas on this map, as they lie almost entirely on the hillsides south of the river. The small acreage of river bottom lands within this company's district that have been under cultivation was destroyed by the flood of February 1927.

This company also pumps its water supply from two plants in the river bottom into high and low pressure reservoirs on the hills. Their upper plant, however, was destroyed by the 1927 flood.

The Winchester Mutual Water Company comprises some one or two hundred acres on the north side of the river at Riverview, part of which area is shown as grain land on the map. The water supply is from a plant near the north bank of the river constructed 15 or 20 years ago, with a gas engine as the first power unit. A large part of this land at one time was under alfalfa, but at the present time this practically has all disappeared. The finishing touches to the alfalfa and also to part of the water mains were added by the flood of 1927.

The La Mesa Irrigation District recently has acquired much additional bottom land for pumping purposes above and below their El Monte pumping plant, while the City of San Diego, in addition to the Riverview property, has acquired some acreage a short distance below the Lakeside bridge, a very excellent location for pumping.

These concerns mentioned above, together with the private users up and down the river, and including the County Poor Farm lands at Santee, represent the body of riparian owners and users of water from the river gravels which would have to be considered when exhaustive pumping from these gravels is resorted to by the City of San Diego. The extent of the damage or the effect from such pumping will depend upon the amount pumped, upon the character of the season, upon the location of each property and upon the rate of pumping. It would seem best that pumping units be added gradually, the operation of units already installed indicating where best to locate additional units. In the meantime, however, steps could be taken to acquire all necessary lands, retaining full ownership or selling or leasing the land back minus the water rights. The handling of this business would properly come under the supervision of the engineer in charge of the water development work for the city, as he would be the official most familiar with all of the donditions and requirements. It is safe to say, however, that no matter how extensively the city may go in for pumping, as Mr. Freeman pointed out, there always will be sufficient water for irrigating crops in these valley lands whether supplied by the private individual wells or by the city from its deep wells. In other words, these lands will continue to produce their crops year after year as in the past, while the city extracts a portion of the water from the gravels underneath. That is, because, for instance, 2000 acre feet are needed for a summer's irrigation of 1000 acres of alfalfa and corn land, it would not be necessary for this purpose to cease all other pumping while there still remains untouched in the gravels a large quantity of water, or several thousand acre feet. The handling of these matters all will work out in time under the supervision of the engineer in charge.

THE MISSION VALLEY BASIN

No special detailed study of the Mission Valley basin was made for this report, first, because no definite prediction of the maximum amount of water recoverable by pumping could be made with any certainty on account of the proximity of sea water,

and second, because the possible yield from the Mission Valley gravels was considered as an additional factor of safety in connection with the estimated yield of the upper gravels. The area of the Mission Valley floor is about 2400 acres, and well logs show excellent water bearing gravels down to a depth of 146 feet, with good artesian water from a depth of 350 feet. The basin, however, should be good for at least 1.0 m.g.d., which is a little less than 100 miner's inches continuous flow.

Table No 1

GRAVEL BED VOLUMES, EL CAPITAN TO OLD MISSION DAM

Section	Distance between sections ft.	Width at sections ft.	mean depth at section ft.	Area of section sq. ft.	Mean area of sections sq. ft.	Volume between Sections Cu. Ft.	Ac. Ft.	Volume below Mean Level of Water Plane: Mean depth of water table	Ac. Ft.	
Head of basin		500	0	0				0		
	7000				9000	63,000,000	1446.3		1060.6	o to C.H.
Cape Horn		600	30	18000				22		
	4700				47000	220,900,000	5071.2		4413.0	C.H. to A
"A" below Cape Horn		1400	54	76000				49		
	8000				136000	1,088,000,000	24977.0		23939.4	A to B
"B" El Monte Narrows		1700	115	196000				113		
	6400				188125	1,204,000,000	27640.0		26938.5	B to C
"C" Thum hill ab. San Vicente cr.		1800	100	180250				97		
	6800				220765	1,501,202,000	34462.9		33297.5	C to D
"D" Thum hill bel. San Vicente Cr.		2100	124	261280				120		
	9700				233705	2,266,938,500	52041.7		50186.8	D to E
"E" Above Riverview narrows		2650	78	206130				75		
	2700				134065	361,975,500	8309.8		7981.9	E to F
"F" Riverview narrows		1050	59	62000				56		
	6400				94500	604,800,000	13884.3		12694.2	F to G
"G" Santee		3800	33	127000				30		
	8200				75625	620,125,000	14236.1		12461.9	G to H
"H" above Sycamore Canyon		2300	10.5	24250				8		
	13000				12125	157,625,000	3618.6		2745.6	H to O.M. Dam
Old Mission Dam		400	0	0				0		
Total	72900 (13.9 mi.)					8,088,566,000	185688		175719.4	Total
					Volume in Total	San Vicente Creek	27760		26573.3	S.V.
							213448		202292.7	

Table No 2.

GRAVEL BED VOLUMES IN SAN VICENTE CREEK

Section	Distance between sections Ft.	Width of section Ft.	Mean depth at section Ft.	Area of section Ft. (sq).	Mean area of sections sq. ft	Volume between sections Cu. ft.
Head of basin at dam-site above Foster		200	0	0		
	5600				15005	84,028,000
"I" below Foster		1200	25	30010		
	7800				144255	1,125,189,000
"J" near mouth		2350	110	258500		
Total	13400					1,209,217,000
				Ac. Ft.		27,760

After allowing for one-half of mean fluctuation of water ~~flume~~ Plane Ac Ft 26,573

Table No 6

WATER PUMPED FROM THE SAN DIEGO RIVER

BY THE CITY OF SAN DIEGO

SINCE 1915

From Monthly Reports
By D. W. Vincent

F. E. GREEN

	1916 Mission Valley		1917 Mission Valley		1918 Mission Valley	
	Mill. Gal.	Ac. Ft.	Mill. Gal.	Ac. Ft.	Mill. Gal.	Ac. Ft.
Jan.	0	0	0	0	0	0
Feb,	34.217	105	0	0	0	0
Mar.	116.688	358	8.848	27	0	0
Apr.	134.181	412	2.587	8	0	0
May	141.776	435	0	0	4.133	13
June	38.768	119	2.129	7	14.910	46
July	94.463	290	8.536	26	52.801	162
Aug.	31.213	96	0	0	0	0
Sept.	0	0	5.049	16	0	0
Oct.	0	0	1.217	4	0	0
Nov.	0	0	0	0	0	0
Dec.	0	0	0	0	0	0
TOtal	591.306	1815	28.366	88	71.844	221

	1919		1920		1921	
Jan.	.569	2	5.363	17	20.202	62
Feb.	0	0	39.755	122	0	0
Mar.	0	0	44.131	135	40.721	125
Apr.	45.926	141	44.484	137	22.979	71
May	70.854	217	39.442	121	0	0
June	55.149	169	19.615	60	0	0
July	53.694	165	0	0	0	0
Aug.	0	0	0	0	0	0
Sept.	0	0	82.169	252	0	0
Oct.	0	0	0	0	0	0
Nov.	0	0	18.642	57	0	0
Dec.	0	0	63.759	196	33.316	102
Total	226.192	694	357.360	1097	117.218	360

	1924 Mission Valley		1925 Mission Valley		1926 Mission Valley	
	Mill. Gal.	Ac. Ft.	Mill. Gal.	Ac. Ft.	Mill. Gal.	Ac. Ft.
Jan.	0	0	0	0	0	0
Feb.	0	0	0	0	0	0
Mar.	2.745	8	0	0	0	0
Apr.	0	0	0	0	0	0
May	16.538	51	5.185	16	56.949	175
June	42.613	131	55.530	170	98.190	301
July	41.535	127	96.415	296	98.382	302
Aug.	44.610	137	89.669	275	102.339	314
Sept.	21.909	67	5.160	16	78.253	240
Oct.	1.219	4	0	0	0	0
Nov.	0	0	0	0	10.478	32
Dec.	0	0	0	0	0	0
Total	171.169	525	251.959	773	444.589	1364

1927

	Mission Valley		Riverview		Total
	Mill. Gal.	Ac. Ft.	Mill Gal.	Ac. Ft.	Ac. Ft.
Jan.	0	0	0	0	0
Feb.	0	0	0	0	0
Mar.	0	0	0	0	0
April	0	0	0	0	0
May	69.516	213	0	0	213
June	107.593	330	0	0	330
July	94.972	291	86.555	266	557
Aug.	38.923	120	156.172	479	599
Sept.	0	0	119.747	367	367
Oct.	24.185	74	35.605	109	183
Nov.	0	0	0	0	0
Dec.	6.000	18	0	0	18
Total	341.189	1046	398.079	1221	2267

1928

	Mission Valley		Riverview		Total	
	Mill. Gal.	Ac. Ft.	Mill. Gal.	Ac. Ft.	Ac. Ft.	
Jan	0	0	0	0	0	
Feb.	0	0	0	0	0	
Mar.	23.071	71	0	0	71	
Apr.	106.086	326	0	0	326	
May	8.570	26	99.290	305	331	
June	84.918	261	168.464	517	778	
July	61.318	188	155.810	478	666	
Aug.	81.176	249	60.980	187	436	
Sept.	57.367	176	15.140	46	222	2830
Oct.						
Nov.						
Dec.						
Total						

Table No 6

The pumping plant at Old Town, with various units of wells and pumps up the river, was operated from 1892 to 1906.

There was no pumping during the years 1922 and 1923.

Abs. av = {6080 - ac ft runoff comparison
{6690 - " " - water plane fluc.
mean 6385 " " = 5.7 mgd
Since this min net yr

Table No. 7

WATER PUMPED FROM THE SAN DIEGO RIVER GRAVELS

F. E. GREEN

	YEAR	BY CUYAMACA WATER CO. FROM COMPANY RECORDS		BY CITY OF SAN DIEGO	TOTAL	M. G. D.	
		Acre Feet					
	1894	0					
	1895	0					
	1896	0					
	1897	0					
0 -	1898	630					
0 -	1899	1271					
0 -	1900	1872					
1600	1901	648					
1750	1902	657					
8000	1903	854					
0	1904	1278	7210				
27000	1905	0					
	1906	0					
	1907	0					
	1908	0					
	1909	0					
	1910	0					
	1911	0					
	1912	0					
	1913	63					
	1914	166					
	1915	0					
	1916	0		1815	1815	1.6	
	1917	0		88	x 88	.08	
	1918	0		221	x 221	.2	
	1919	356		694	1050	1.0	
	1920	0		1097	1097	1.0	
	1921	917		360	1277	1.1	
	1922	0		0	x 0	0	
	1923	272		0	x 272	0.2	
	1924	1255		525	1780	1.6	
	1925	1822		773	2595	2.3	
	1926	2784	= 2.49	1364	4148	3.7	error
	1927	508		2267	2775	2.5	(1.5)
	1928	(1400)		(3000)	(4400)	3.9	(2.6)

13 yrs. mean 1655 - 1.5
9 " " 2326 - 2.1

Table No. 8

POSSIBLE DIVERSION AT EL CAPITAN

Through Pipe Lines or Conduits of 15.5 Sec. Ft., 50 Sec. Ft., and 100 Sec. Ft. Capacity

From Record of Daily Discharge

	SEASON	Length of Diversion Period	At 15.5 Sec. Ft.			At 50 Sec. Ft.			At 100 Sec. Ft.		
		Days	Ac. Ft.	M.G.D.	M.G.D. for diversion period	Ac. Ft.	M.G.D.	M.G.D. for diversion period	Ac. Ft.	M.G.D.	M.G.D. for diversion period
N	1919-20	113	2690	2.40	7.76	6518	5.82	18.80	9830	8.78	28.35
D	1920-21	134	1155	1.03	2.81	1469	1.31	3.57	1469	1.31	3.57
W	1921-22	256	6365	5.68	8.10	18109	16.17	23.05	32037	28.60	40.78
D	1922-23	243	4824	4.31	6.47	9931	8.87	13.32	12030	10.74	16.13
D	1923-24	183	1496	1.34	2.66	2231	1.99	3.97	2420	2.16	4.31
D	1924-25	212	1632	1.46	2.51	2388	2.13	3.67	2824	2.52	4.34
N	1925-26	120	1523	1.36	4.14	3033	2.71	8.26	4471	3.99	12.14
W	1926-27	243	5460	4.87	7.32	13688	12.22	23.25	21670	19.35	29.06
D	1927-28	213	3649	3.26	5.58	4541	4.05	6.95	4591	4.10	7.02
	Total	1717	28794	25.71	47.35	61908	55.27	104.84	91342	81.55	145.70
	Mean	191	3199	2.86	5.26	6879	6.14	11.65	10149	9.06	16.19

Table No. 9

DAMS AND RESERVOIRS

Reservoir	Height of Dam Feet	Elev. of Res'r Top Contour Feet	Area Flooded Acres	Mean Depth of Res'r Feet	Capacity Ac. Ft.	Estimated cost of development	Safe Net Yield Independently m.g.d.	Safe Net Yield Independently Ac. Ft. Annually	Annual Interest charges 6%	Interest charges in relation to Yield Per Ac. Ft.	Interest charges in relation to Yield Per 1000 gal
Cuyamaca	41	4625	978	11.9	11,595		1.0	1120			
Fletcher	150	990	268	63.8	17,106	(a) $1,062,900	4.3	4760	$63,774	$13.40	4.11
El Capitan	190	743	1625	75.0	122,000	(b) 8,000,000	10.7	11994	480,000	40.02	12.28
El Capitan	200	753	1800	77.3	139,200	(b) 10,000,000	12.1	13589	600,000	44.15	13.55
El Capitan Site No. 3	160	750	586	41.7	24,430	(e) 1,868,000	3.4	3814	112,080	29.39	9.02
San Vicente	150	610	855	69.3	59,230	(c) 1,433,000	3.4	3845	85,980	22.36	6.86
San Vicente	175	635	993	83.4	82,860	(c) 1,916,000	3.4	3845	114,960	29.90	9.18
San Vicente	215	675	1185	102.6	121,571	(c) 2,964,000	3.4	3845	177,840	46.25	14.19
San Vicente	290	750	1540	145.7	224,400	(c) 4,440,000	3.4	3845	266,400	69.28	21.25
Mission Gorge No. 2	116	360	3320	26.1	86,785	(b) 3,500,000	5.0	5600	210,000	37.50	11.51
Mission Gorge No. 2	156	400	7330	40.3	295,460	(b) 5,309,000	12.50	14000	318,540	22.75	6.98
Mission Gorge No. 3	230	330	1424	31.1	44,225	(d) 1,600,000	5.00	5600	96,000	17.14	5.26
Mission Gorge No. 3	293	393	7100	41.6	295,200	(f) 4,600,000	14.7	16500	276,000	16.73	5.13
Mission Gorge No. 3	260	360	3770	32.1	121,0[illegible]	(g) 3,300,000	8.9	10000	198,000	19.80	6.08

?

(a) For multiple arch dam and Boulder Creek diversion dam and canal
(b) By H. N. Savage
(c) For Multiple arch dam and rebuilding of highway
(d) For radial cone dam and moving El Capitan Dam line
(e) For multiple arch dam, moving Indians and replacing South Fork siphon.
Cost of El Capitan-San Vicente canal, about 10 miles in length, taken as $500,000
Cost of Boulder Creek diversion dam and canal taken as $200,000
(f) Increased cost over 230 ft. dam: Reservoir lands, etc. $2,000,000, dam $1,000,000
(g) Increased costover 230 ft. dam: Reservoir lands, etc. $1,000,000, dam $ 700,000

Table No.10

RESERVOIR YIELDS
At El Capitan and Mission Gorge

F. E. Green

EL CAPITAN	SAFe Net Yield M.G.D.	Ac. Ft. Annually
El Capitan, 122000 ac. ft. Fletcher Dam not built	10.7	11994
El Capitan, 122000 ac. ft. Fletcher dam 17106 ac. ft.	8.4	9394
El Capitan 139200 ac. ft. Fletcher dam not built	12.1	13589
El Capitan, 139200 ac. ft. Fletcher Dam 17106 ac. ft.	9.6	10770
El Capitan No. 3, 24421 ac. ft. Fletcher dam not built	3.4	3814
El Capitan No. 3, 24421 ac. ft. Fletcher Dam 17106 ac. ft.	1.8	2013
MISSION GORGE NO. 2, 86785 ac. ft.		
With no other development on the river	5.0	5600
With Fletcher Dam 17106 ac. ft.	3.6	4000
With El Capitan, either height	3.2	3600
With Fletcher and San Vicente dams	3.5	3900
With San Vicente, 59230 ac. ft. or more	4.7	5300
MISSION GORGE NO. 2 295,460 ac. ft.		
With no other development on the river	12.5	14000
With Fletcher Dam 17106 ac. ft.	9.4	10500
With El Capitan either height	2.7	3000
With San Vicente 59230 ac. ft. or more	8.9	10000
With Fletcher and San Vicente	6.3	7000
MISSION GORGE NO. 3, 44225 ac. ft.		
With no other development on river	5.0	5000
With Fletcher Dam 17106 ac. ft.	3.6	4000
With El Capitan either height	3.0	3300
With San Vicente 59230 ac. ft. ore more	4.7	5300
With Fletcher and San Vicente	3.3	3700
With Fletcher and El Capitan	3.0	3300
With Fletcher, El Capitan and San Vicente	3.0	3300
With El Capitan and San Vicente	3.0	3300
MISSION GORGE NO. 3 - no other development		
44225 ac. ft. Reservoir (230 ft. dam)	5.0	5600
121095 " " " (260 ft. dam)	8.9	10000
295200 " " " (293 ft. dam)	14.7	16500
MISSION GORGE NO. 3 - 295200 ac. ft.		
With Fletcher Dam 17106 ac. ft.	11.2	12500
With San Vicente 59230 ac. ft. or more	10.9	12200
With Fletcher and San Vicente	8.1	9100
MISSION GORGE NO. 3 - 121095		
With no other development on river	8.9	10000
With Fletcher Dam 17106 ac. ft.	7.4	8300

Table No. 12
9 Sheets

PLANS FOR DEVELOPMENT

PLAN "A"

"A" 1

Unit	Storage Ac. Ft.	YIELD M. G. D.
Cuyamaca Reservoir	11,595	1.0
Flume Diversions		2.5
Fletcher Reservoir	17,106	4.3
San Vicente Reservoir	59,230	3.4
Mission Gorge No. 3 Reservoir	44,225	3.3
El Monte Pumps		1.0
Riverview Pumps		4.0
Mission Valley Pumps		1.0
	132,156	20.5

"A" 2

Unit	Storage Ac. Ft.	YIELD M. G. D.
Cuyamaca Reservoir	11,595	1.0
Flume Diversions		2.5
Fletcher Reservoir	17,106	4.3
San Vicente Reservoir	59,230	3.4
Mission Gorge No. 2 Reservoir	86,785	3.5
El Monte Pumps		1.0
Riverview Pumps		4.0
Mission Valley Pumps		1.0
	174,716	20.7

"A" 3

Unit	Storage Ac. Ft.	YIELD M. G. D.
Cuyamaca Reservoir	11,595	1.0
Flume Diversions		2.5
Fletcher Reservoir	17,106	4.3
San Vicente Reservoir	59,230	3.4
Mission Gorge No. 2	295,460	6.3
El Monte Pumps		1.0
Riverview Pumps		4.0
Mission Valley Pumps		0
	383,391	22.5

"A" 4

Unit	Storage Ac. Ft.	YIELD M. G. D.
Cuyamaca Reservoir	11,595	1.0
Flume		2.5
Fletcher Reservoir	17,106	4.3
San Vicente Reservoir	59,230	3.4
Mission Gorge No. 3	295,200	8.1
El Monte Pumps		1.0
Riverview Pumps		4.0
Mission Valley Pumps		0
	383,131	24.3

PLAN "B"

"B" 1

Unit	Storage Ac. Ft.	YIELD M.G.D.
Cuyamaca Reservoir	11,595	1.0
Flume Diversions		2.5
El Capitan Reservoir	139,200	12.1
Mission Gorge No. 3 Reservoir	44,225	3.0
El Monte Pumps		1.0
Riverview Pumps		2.0
Mission Valley Pumps		1.0
	195,020	22.6

"B" 2

Cuyamaca Reservoir	11,595	1.0
Flume Diversions		2.5
El Capitan	139,200	12.1
Mission Gorge No. 2	86,785	3.2
El Monte Pumps		1.0
Riverview Pumps		2.0
Mission Valley Pumps		1.0
	237,580	22.8

PLAN "C"

"C" 1

Unit	Storage Ac. Ft.	YIELD M.G.D.
Cuyamaca Reservoir	11,595	1.0
Flume Diversions		2.5
Fletcher Reservoir	17,106	4.3
El Capitan Reservoir	122,000	8.4
Mission Gorge No. 3 Reservoir	44,225	3.0
El Monte Pumps		1.0
Mission Valley Pumps		1.0
Riverview Pumps		1.0
	194,926	22.2

"C" 2

Cuyamaca Reservoir	11,595	1.0
Flume Diversions		2.5
Fletcher Reservoir	17,106	4.3
El Capitan Reservoir	139,200	9.6
Mission Gorge No. 3 Reservoir	44,225	3.0
El Monte Pumps		1.0
Riverview Pumps		1.0
Mission Valley Pumps		1.0
	212,126	23.4

"C" 3

Cuyamaca Reservoir	11,595	1.0
Flume Diversions		2.5
Fletcher Reservoir	17,106	4.3
El Capitan	139,200	9.6
Mission Gorge No. 2	86,785	3.2
El Monte Pumps		1.0
Riverview Pumps		1.0
Mission Valley Pumps		1.0
	254,686	23.6

PLAN "D"

"D" 1

Unit	Storage Ac. Ft.	YIELD M.G.D.
Cuyamaca Reservoir	11,595	1.0
Flume Diversions		2.5
El Capitan Reservoir	139,200	12.1
San Vicente Reservoir	59,230	3.4
El Monte Pumps		1.0
Riverview Pumps		1.0
Mission Valley Pumps		1.0
	210,025	22.0

"D" 2

Unit	Storage Ac. Ft.	YIELD M.G.D.
Cuyamaca Reservoir	11,595	1.0
Flume Diversions		2.5
El Capitan No. 2 Reservoir (a)	139,200	13.1
San Vicente Reservoir	121,571	3.4
El Monte Pumps		1.0
Riverview Pumps		1.0
Mission Valley Pumps		1.0
	272,366	23.0

(a) With 100 Sec. Ft. Canal to San Vicente Reservoir.

PLAN "E"

"E" 1

Unit	Storage Ac. Ft.	YIELD M.G.D.
Cuyamaca Reservoir	11,595	1.0
Flume Diversion		2.5
Fletcher Reservoir	17,106	4.3
El Capitan No. 2 Reservoir (a)	122,000	9.4
San Vicente Reservoir	121,571	3.4
El Monte Pumps		1.0
Riverview Pumps		1.0
Mission Valley Pumps		1.0
	272,272	23.6

"E" 2

Unit	Storage Ac. Ft.	YIELD M.G.D.
Cuyamaca Reservoir	11,595	1.0
Flume Diversions		2.5
Fletcher Reservoir	17,106	4.3
El Capitan Reservoir	122,000	8.4
San Vicente Reservoir	59,230	3.4
El Monte Pumps		1.0
Riverview Pumps		1.0
Mission Valley Pumps		1.0
	209,931	22.6

(a) With 100 sec. ft. canal to San Vicente Reservoir.

PLAN "F"

"F" 1

Unit	Storage Ac. Ft.	YIELD M.G.D.
Cuyamaca Reservoir	11,595	1.0
El Capitan Reservoir	139,200	12.1
San Vicente Reservoir	59,230	3.4
Mission Gorge No. 3 Reservoir	44.225	3.0
El Monte Pumps		1.0
Riverview Pumps		1.0
Mission Valley Pumps		1.0
	254,250	22.5

"F" 2

Cuyanaca Reservoir	11,595	1.0
Flume Diversions		2.5
El Capitan Reservoir	122,000	10.7
San Vicente Reservoir	59,230	3.4
Mission Gorge No. 3 Reservoir	44,225	3.0
El Monte Pumps		1.0
Riverview Pumps		1.0
Mission Valley Pumps		1.0
	237,050	23.6

"F" 3

Cuyemaca Reservoir	11,595	1.0
Flume Diversions		2.5
El Capitan No. 3 Reservoir (a)	24,430	4.4
San Vicente Reservoir	121,571	3.4
Mission Gorge No. 3 Reservoir	44,225	3.0
El Monte Pumps		2.0
Riverview Pumps		2.0
Mission Valley Pumps		1.0
	201,821	19.3

(a) With 100 Sec. Ft. canal to San Vicente Reservoir.

PLAN "G"

"G" 1

Unit	Storage Ac. Ft.	YIELD M.G.D.
Cuyamaca Reservoir	11,595	1.0
Flume Diversions		2.5
Fletcher Reservoir	17,106	4.3
El Capitan No. 3 Reservoir	24,430	1.8
San Vicente Reservoir	59,230	3.4
Mission Gorve No. 3 Reservoir	44,225	3.0
El Monte Pumps		1.0
Riverview Pumps		2.0
Mission Valley Pumps		1.0
	156,586	20.0

"G" 2

Cuyamaca Reservoir	11,595	1.0
Flume Diversions		2.5
Fletcher Reservoir	17,106	4.3
El Capitan Reservoir	122,000	8.4
San Vicente Reservoir	59,230	3.4
Mission Gorge No. 3 Reservoir	44,225	3.0
El Monte Pumps		1.0
Riverview Pumps		1.0
Mission Valley Pumps		1.0
	254,156	25.6

"G" 3

Cuyamaca Reservoir	11,595	1.0	
Flume Diversions		2.5	
Fletcher Reservoir	17,106	4.3	
El Capitan No. 3 Reservoir (a)	24,430	2.8	
San Vicente Reservoir	121,571	3.4	
Mission Gorge No. 3 Reservoir	44,225	3.0	
El Monte Pumps		1.0	
Riverview Pumps	218,927	2.0	
Mission Valley Pumps		1.0	21.0

(a) With 100 Sec. Ft. Canal to San Vicente Reservoir

"G" 4

Cuyamaca Reservoir	11,595	1.0
Flume Diversions		2.5
Fletcher Reservoir	17,106	4.3
El Capitan No. 2 Reservoir (a)	122,000	9.4
San Vicente Reservoir	121,571	3.4
Mission Gorge No. 3 Reservoir	44,225	3.0
El Monte Pumps		1.0
Riverview Pumps		1.0
Mission Valley Pumps		1.0
	316,497	26.6

PLAN "H"

"H" 1

Unit	Storage Ac. Ft.	YIELD M.G.D.
Cuyamaca Reservoir	11,595	1.0
Flume Diversions		2.5
Mission Gorge No. 2 Reservoir	295,460	12.5
El Monte Pumps		4.0
Riverview Pumps		1.0
Mission Valley Pumps		1.0
	307,055	22.0

"H" 2

Unit	Storage Ac. Ft.	YIELD M.G.D.
Cuyamaca Reservoir	11,595	1.0
Flume Diversions		2.5
San Vicente Reservoir	59,230	3.4
Mission Gorge No. 2	295,460	8.9
El Monte Pumps		3.0
Riverview Pumps		2.0
Mission Valley Pumps		1.0
	366,285	21.8

"H" 3

Unit	Storage Ac. Ft.	YIELD M.G.D.
Cuyamaca Reservoir	11,595	1.0
Flume Diversions		2.5
Mission Gorge No. 3 Reservoir	295,200	14.7
El Monte Pumps		4.0
Riverview Pumps		1.0
Mission Valley Pumps		1.0
	306,795	24.2

"H" 4

Unit	Storage Ac. Ft.	YIELD M.G.D.
Cuyamaca Reservoir	11,595	1.0
Flume Diversions		2.5
San Vicente Reservoir	59,230	3.4
Mission Gorge No. 3 Reservoir	295,200	10.9
El Monre Pumps		3.0
Riverview Pumps		2.0
Mission Valley Pumps		1.0
	366,025	23,8

PLAN "I"

"I" 1

Unit	Storage Ac. Ft.	YIELD M.G.D.
Cuyamaca Reservoir	11,595	1.0
Flume Diversions		2.5
Fletcher Reservoir	17,106	4.3
Mission Gorge No. 2 Reservoir	295,460	9.4
El Monte Pumps		1.0
Riverview Pumps		4.0
Mission Valley Pumps		1.0
	324,161	23.2

"I" 2

Unit	Storage Ac. Ft.	YIELD M.G.D.
Cuyamaca Reservoir	11,595	1.0
Flume Diversions		2.5
Fletcher Reservoir	17,106	4.3
Mission Gorge No. 2 Reservoir	86,785	3.6
El Monte Pumps		1.0
Riverview Pumps		4.0
Mission Valley Pumps		1.0
	115,486	17.4

"I" 3

Unit	Storage Ac. Ft.	YIELD M.G.D.
Cuyamaca Reservoir	11,595	1.0
Flume Diversions		2.5
Fletcher Reservoir	17,106	4.3
Mission Gorge No. 3 Reservoir	44,225	3.6
El Monte Pumps		1.0
Riverview Pumps		4.0
Mission Valley Pumps		1.0
	72,926	17.4

"I" 4

Unit	Storage Ac. Ft.	YIELD M.G.D.
Cuyamaca Reservoir	11,595	1.0
Flume Diversions		2.5
Fletcher Reservoir	17,106	4.3
Mission Gorge No. 3 Reservoir	295,200	11.2
El Monte Pumps		1.0
Riverview Pumps		4.0
Mission Valley Pumps		1.0
	325,901	25.0

"I" 5

Unit	Storage Ac. Ft.	YIELD M.G.D.
Cuyamaca Reservoir	11,595	1.0
Flume Diversions		2.5
Fletcher Reservoir	17,106	4.3
Mission Gorge No. 3	121,095	7.4
El Monte Pumps		1.0
Riverview Pumps		4.0
Mission Valley Pumps		1.0
	149,796	21.2

COMPARATIVE YIELDS AND COSTS OF THE DIFFERENT PLANS OF DEVELOPMENT

Plan	From Reservoirs M.G.D. (a)	From Reservoirs Cost per 1000 Gal. (b)	From Wells M.G.D.	From Wells Cost per 1000 Gal.	Total M.G.D. (a)	Total Cost per 1000 Gal. (b)	Total cost of Plan as estimated	Total Storage Acre Feet
A 1	14.5	6.12 ¢	6.0	4.6	20.5	5.58 ¢	$ 4,095,900	132,156
A 2	14.7	8.80	6.0	4.6	20.7	7.34	5,995,900	174,716
A 3	17.5	9.17	5.0	4.6	22.5	7.97	7,804,900	383,391
A 4	19.3	7.38	5.0	4.6	24.3	6.71	7,095,900	383,131
B 1	18.6	12.63	4.0	4.6	22.6	10.95	11,600,000	195,020
B 2	18.8	14.50	4.0	4.6	22.8	12.45	13,500,000	237,580
C 1	19.2	11.16	3.0	4.6	22.2	10.11	10,662,900	194,926
C 2	20.4	12.32	3.0	4.6	23.4	11.15	12,662,900	212,126
C 3	20.6	14.00	3.0	4.6	23.6	12.60	14,562,900	254,686
D 1	19.0	12.13	3.0	4.6	22.0	10.91	11,433,000	210,025
D 2	20.0	13.41	3.0	4.6	23.0	12.06	12,964,000	272,366
E 1	20.6	12.04	3.0	4.6	23.6	10.93	12,526,900	272,272
E 2	19.6	10.72	3.0	4.6	22.6	9.76	10,495,900	209,931
F 1	19.5	11.58	3.0	4.6	22.5	10.61	13,033,000	254,250
F 2	20.6	10.61	3.0	4.6	23.6	9.71	11,033,000	237,050
F 3	14.3	10.55	5.0	4.6	19.3	8.67	6,932,000	201,821
G 1	16.0	7.84	4.0	4.6	20.0	7.06	5,963,900	156,586
G 2	22.6	10.41	3.0	4.6	25.6	9.62	12,095,900	254,156 ××
G 3	17.0	9.74	4.0	4.6	21.0	8.56	7,994,900	218,927
G 4	23.6	11.55	3.0	4.6	26.6	10.65	14,126,900	316,497 ×
H 1	16.0	6.98	6.0	4.6	22.0	6.21	5,309,000	307,055
H 2	15.8	9.01	6.0	4.6	21.8	7.56	6,742,000	366,285
H 3	18.2	5.14	6.0	4.6	24.2	4.99	4,600,000	306,795
H 4	17.8	6.94	6.0	4.6	23.8	6.24	6,033,000	366,025
I 1	17.2	7.65	6.0	4.6	23.2	6.72	6,371,900	324,161
I 2	11.4	9.49	6.0	4.6	17.4	7.38	4,562,900	115,486
I 3	11.4	5.54	6.0	4.6	17.4	5.14	2,662,900	72,926
I 4	19.0	6.00	6.0	4.6	25.0	5.61	5,662,900	323,901
I 5	15.2	6.13	6.0	4.6	21.2	5.61	4,362,900	149796

(a) Including Cuyamaca Reservoir and flume diversions
(b) Excluding Cuyamaca Reservoir and flume diversions

Table No 17

TOTAL CUYAMACA FLUME SEASONAL
DIVERSIONS
FROM DIVERTING DAM, SO. FORK & PUMPS
IN ACRE FEET

	Total Diversions (a)
1886-7	0
1887-8	4950
1888-9	5500
1889-0	6000
1890-1	6100
1891-2	5300
1892-3	5400
1893-4	4600
1894-5	4000
1895-6	3800
1896-7	3850
1897-8	3250
1898-9	2750
1899-0	2500
1900-1	4900
1901-2	4000
1902-3	5250
1903-4	3350
1904-5	6700
1905-6	6731
1906-7	5996
1907-8	6896
1908-9	5817
1909-0	6371
1910-1	5393
1911-2	4617
1912-13	4236
1913-4	4100
1914-5	8696
1915-6	4780
1916-7	3988
1917-8	6548
1918-9	6106
1919-0	6639
1920-1	3625
1921-2	9221
Mean	5256

(Note: (a) from 1887-8 to 1897-8 inc. the annual diversion is computed according to method on Sheet "A".
From 1898-9 to 1919-20 inc. is from the Cuyamaca Co. records.

Table No. 18

RAINFALL ON RESERVOIR SURFACES
INCHES

F. E. GREEN

Season	Cuyamaca (a)	Fletcher (b)	South Fork (c)	Mission Gorge (d)
1886-7	21.81	11.06		11.09
1887-8	32.86	16.67		13.18
1888-9	42.26	19.43		14.74
1889-0	49.21	21.97		20.22
1890-1	51.07	15.72		14.09
1891-2	31.69	12.20		11.61
1892-3	36.41	17.40		12.39
1893-4	17.50	11.82		6.65
1894-5	45.25	21.80		15.84
1895-6	22.80	9.96	18.15	8.35
1896-7	31.22	18.56	27.31	15.78
1897-8	26.26	10.25	20.88	6.65
1898-9	19.98	9.12	11.94	7.04
1899-0	25.96	10.52	16.46	7.97
1900-1	33.42	16.86	25.28	13.96
1901-2	29.90	11.00	21.57	8.22
1902-3	29.28	16.00	(25.25)	15.78
1903-4	18.72	6.90	(13.38)	5.67
1904-5	45.85	24.84	(36.35)	19.18
1905-6	47.38	27.71	(39.37)	19.70
1906-7	32.72	22.65	(28.02)	14.25
1907-8	28.03	16.20	(21.96)	11.48
1908-9	34.17	16.43	(27.76)	13.71
1909-1	26.88	16.04	27.54	13.18
1910-1	24.93	15.66	21.65	16.05
1911-2	25.97	18.15	25.40	14.35
1912-3	26.11	10.12	16.02	6.92
1913-4	25.97	17.65	25.46	13.81
1914-5	42.28	25.75	37.16	22.02
1915-6	49.85	26.12		17.56
1916-7	28.02	15.30	25.16	15.22
1917-8	25.13	13.87	21.08	7.17
1918-9	22.77	18.12	23.47	8.83
1919-0	32.12	18.24	[illegible]	13.96
Mean	30.40	16.47	25.24	12.85

Note: (a) These quantities are 80% of the observed data at Cuyamaca Dam. The mean of observed data for 6 synchronal season at east edge of lake and dam is 30.40 inches, or 80% of mean at dam, Winter rain = 80% = summer 20%

(b) From 1899-0 to date is observed data. Winter rain = 86% Summer = 14%

(c) Descanso Record

(d) From 1912-3 to date is observed data at Murray Dam. Winter rain - 88% Summer - 12%

checked
Table No19

SEASONAL RUNOFF WITH INDICES

ACRE FEET

F. E. GREEN

SEASON	CUYAMACA DAM 12 SQ. Miles Runoff (a)	Index	SWEETWATER DAM 184 SQ. Miles Runoff (s)	Index
1887-8	2926	58.67	7048	37.82
1888-9	4376	87.75	25255	135.52
1889-0	6430	128.94	20532	110.19
1890-1	8525	170.94	21565	115.73
1891-2	4016	80.53	6198	33.26
1892-3	4498	90.19	16260	87.26
1893-4	2563	51.39	1338	7.18
1894-5	11498	230.56	73412	393.97
1895-6	2152	43.15	1321	7.09
1896-7	4216	84.54	6892	36.99
1897-8	834	16.72	4	00.02
1898-9	555	11.13	245	1.31
1899-0	260	5.21	0	0
1900-1	3031	60.78	825	4.43
1901-2	2351	47.14	0	0
1902-3	2516	50.45	0	0
1903-4	492	9.87	0	0
1904-5	6831	136.98	13760	73.84
1905-6	12785	256.37	35000	187.83
1906-7	9259	185.66	30000	161.00
1907-8	3201	64.19	4140	22.22
1908-9	7172	143.81	16007	85.90
1909-0	5148	103.23	9619	51.62
1910-1	2850	57.15	3160	16.96
1911-2	3758	75.36	5000	26.83
1912-3	2982	59.80	915	4.91
1913-4	2289	45.90	3525	18.92
1914-5	10988	220.33	27085	145.35
1915-6	22355	448.27	160590	861.81
1916-7	4752	95.29	15282	82.01
1917-8	3333	66.83	10204	54.76
1918-9	2598	52.10	4053	21.75
1919-0	6412	128.57	14943	80.19
1920-1	2225	44.62	1811	9.72
1921-2	11956	239.74	61942	332.41
1922-3	3465	69.48	9111	48.89
1923-4	2295	46.02	2818	15.12
1924-5	1606	32.20	1140	6.12
1925-6	—	—	14420	77.39
1926-7	—	—	119243	639.92
Long Term Mean	4987		18634	

(a) Cuyamaca Water Company records
(s) Sweetwater Water Company records

checked
Table No20

RUNOFF AT DIVERTING DAM (a)
Drainage Area 91 sq. mi.

Season	Index	Runoff	Spills from 17106 Ac. Ft. Reservoir	Runoff from San Vicente Creek. 75 Sq. Mi.
1883-4	800	147000	125000	56818
1884-5	35	6400		100
1885-6	243	44700	40000	17345
1886-7	26	4800		100
1887-8	40	7400	3000	2000
1888-9	78	14400	10000	6281
1889-0	139	25600	21000	9208
1890-1	130	23900	20000	12206
1891-2	82	15100	10000	5782
1892-3	58.65	10800 l	8000	1500
1893-4	36.17	6660 l		600
1894-5	271.28	49950 l	45000	24500
1895-6	18.09	3330 l		0
1896-7	60.61	11160 l	5000	1700
1897-8	9.29	1710 l		0
1898-9	4.94	909 p		0
1899-0	3.31	609 p		0
1900-1	21.85	4025 p		100
1901-2	22.39	4122 p		200
1902-3	45.38	8375 p		700
1903-4	3.46	638 p		0
1904-5	119.68	22036 p		10400
1905-6	167.47	30837 p	25000	17000
1906-7	178.22	32816 p	27000	18100
1907-8	65.67	12091 p		2200
1908-9	105.66	19455 p	18000	8000
1909-0	73.11	13461 p	8000	3000
1910-1	45.32	8345 p	5000	700
1911-2	52.25	9620 p	5000	1100
1912-3	29.21	5378 p	2000	100
1913-4	55.73	10261 p	4000	1300
1914-5	166.15	30593 p	25000	17066 c
1915-6	684.30	126000 u		46845
1916-7	98.20	18081 c		7010
1917-8	44.82	8253 c		3867
1918-9	29.90	5506 c		100
1919-0	134.98	24854 c		2518 c
1920-1	20.80	3830 c		0 c
1921-2	395.03	72736 c		56502 c
1922-3	64.29	11837 c		394 c
1923-4	20.91	3851 c		39 c
1924-5	30.98	5705 c		76 c
1925-6	85.17	15682 c		5506 s
1926-7	351.91	64798 c		52669 s
1927-8	24.76	4559 c		279 s

Mean since 1892, 18413 ac. ft. Mean 7138
Mean as extended to 18830, 21159 ac ft.
(a) Runoff includes flume diversions exclusive of draft from Cuyamaca Reservoir
(c) Cuyamaca Water Company records
(l) J. S. Longwell from Cuyamaca Water Company records
(p) W. S. Post from Cuyamaca Water Company records, W. S. Paper #446
(u) U. S. G. S.
(s) City of San Diego

checked

Table No. 21

RUNOFF AT EL CAPITAN (a)
Drainage Area 177 sq. mi.
Acre Feet

Season	With no other develeopment on River Runoff	Spills 122000 Ac. foot dam	Spills 139200 Ac. foot dam	With Fletcher Built 17106 Ac. Ft. Runoff	Spills 12200 Ac. Ft. Dam	Spills 139200 Ac. Ft. dam
1883-4	186000	47000	28000	164000	29000	10000
1884-5	8000			2000		
1885-6	56000	32000	28000	52000	28000	24000
1886-7	6000			1500		
1887-8	9000			5000		
1888-9	18000			14000		
1889-0	32000			28000		
1890-1	30000	15000	6000	26000	8000	0
1891-2	19000	3000	2000	14000	0	0
1892-3	12000			9500		
1893-4	5500			1500		
1894-5	72000	40000	34000	67000	39000	30000
1895-6	500			500		
1896-7	12000			6000		
1897-8	0			0		
1898-9	0			0		
1899-0	0			0		
1900-1	1600			0		
1901-2	1750			0		
1902-3	8000			0		
1903-4	0			0		
1904-5	27000			6000		
1905-6	55000			50000	0	0
1906-7	41130			36000	0	0
1907-8	11000			500		
1908-9	32000			31000	0	0
1909-0	16000			11000		
1910-1	8000			5000		
1911-2	10000			6000		
1912-3	2500			0		
1913-4	10000			4000		
1914-5	42000			37000	0	0
1915-6	160000					
1916-7	22663					
1917-8	8000					
1918-9	4000					
1919-0	23624 c					
1920-1	1535 c					
1921-2	100251 c					
1922-3	12999 C					
1923-4	2589 c					
1924-5	2951 c					
1925-6	16192 c					
1926-7	100700 s					
1927-8	4700 s					

Mean since 1887 by comparison with Diverting Dam and Sweetwater dam 23078 ac. ft.
Mean as intended to 1883-4, 26715 ac. ft.
(a) Net runnoff, no allowance for diversions by Cuyamaca W. co.
(c) Cuyamaca Water Co. records (s) City of San Diego.

Table No. 22

SEASONAL RUNOFF
ACRE FEET

F. E. GREEN

Season	Boulder Creek At Diverting Dam 21.5 sq. mi. (b)	South Fork 44.5 sq. mi. (n)	El Capitan 177 sq mi (d)	Lakeside 203 sq. mi (f)
1892-3	3168	2400 L	12000	
1893-4	1954	1600 L	5500	
1894-5	14655	16700 L	72000	
1895-6	977	890 L	500	
1896-7	3274	2450 L	12000	
1897-8	502	404 L	0	
1898-9	267	0 L	0	
1899-0	179	0 L	0	
1900-1	1180	1470 L	1600	
1901-2	1210	1250 L	1750	
1902-3	2457	1650 L	8000	
1903-4	187	0 L	0	
1904-5	6465	6450 L	27000	
1905-6	9047	13000 L	55000	67506U
1906-7	9627	8900 L	41130	44800U
1907-8	3547	1820 L	11000	9100U
1908-9	5708	11600 L	32000	59400U
1909-0	3949	3070 L	16000	18400U
1910-1	2448	2000 L	8000	11000U
1911-2	2823	2033 A	10000	12000U
1912-3	1578	1182 A	2500	1740U
1913-4	3011	2500 A	10000	10500U
1914-5	10450 A	8391 A	42000	49000U
1915-6	36966	35000 L	160000	194000U
1916-7	5305	2650 L	22663	
1917-8	2421	2700 L	8000	
1918-9	2990 A	1472 A	4000	
1919-0	6255 A	3954 A	23624 A	
1920-1	1486 A	347 A	1535 A	
1921-2	17510 A	23179 A	100251 A	
1922-3	4163 A	3875 A	12999 A	
1923-4	1685 A	1523 A	2589 A	
1924-5	2293 A	1137 A	2951 A	
1925-6	4406 A	4305 R	16192 E	
1926-7	16390 A	25690 R	100700 E	
1927-8	1551 A	2052 R	4700 E	
Long Term Mean	5402 C	5594 K	23078 P	

(n) Including flume diversions
(r) Cuyamaca Water Co. Records and by comparison with diverting dam & El Capitan
(a) Cuyamaca Water Company records
(b) Without draft from Cuyamaca Reservoir
(l) Restoration by J. S. Longwell
(d) Exclusive of all diversions
(f) Above junction with San Vicente Creek & without flume diversions
(c) By comparison with Cuyamaca & Diverting Dam
(k) " " " " " " " and Boulder Creek
(p) " " " Diverting Dam, Mission Gorge & Sweetwater Dam
(E) City of San Diego.

RUNOFF AT MISSION GORGE (b)
Drainage Area 375 Sq. Mi.
Acre Feet

Table No. 23

Season	With no other development on the river	With Fletcher Dam 17106 Ac. Ft. capacity	With El Capitan Dam 122000 Ac. Ft. capacity	With San Vicente Dam 59230 Ac. Ft. or more	With Flethcer & San Vicente Dams built
1883-4	325752	315752	187000	270000	260000
1884-5	9866	4000	2000	98000	4000
1885-6	85621	80000	62000	68000	62379
1886-7	7752	2000	0	7700	1950
1887-8	13389	6000	500	11300	3911
1888-9	47920	36000	2700	42000	30080
1889-0	38759	33000	2000	30000	24241
1890-1	40873	35000	27000	29000	23127
1891-2	11628	5000	500	6000	0
1892-3	13000	6000	500	12000	5000
1893-4	500	0	0	500	0
1894-5	95000	83000	63000	71000	59000
1895-6	500	500	0	500	500
1896-7	13750	8000	0	12000	6250
1897-8	100	0	0	100	0
1898-9	50	0	0	50	0
1899-0	0	0	0	0	0
1900-1	2000	0	0	2000	0
1901-2	500	0	0	500	0
1902-3	7000	1000-	0	6000	0
1903-4	50	0	0	50	0
1904-5	49000	33000	20000	39000	23000
1905-6	80000	74000	25000	63000	57000
1906-7	86000	80000	40000	68000	62000
1907-8	17000	10000	7000	15000	8000
1908-9	40000	30000	9000	32000	22000
1909-0	20000	10000	3000	17000	7000
1910-1	8000	1000	0	7500	500
1911-2	10000	2000	0	9000	1000
1912-3	1750 u	500	0	1700	450
1913-4	14170 u	4000	0	13000	2830
1914-5	82500 u	77000	40000	66000	60500-
1915-6	280000 a			231000	
1916-7	37986 u			21000	
1917-8	20493 u			20000	
1918-9	1864 c			1800	
1919-0	21882 c			20000	
1920-1	180 u			180	
1921-2	168039 u			132000	
1922-3	10100 u			10000	
1923-4	16 c			16	
1924-5	72 c			72	
1925-6	25939 c			20500	
1926-7	159823 c			127000	
1927-8	1299 c			1200	

Mean since 1887 by comparison with Diverting Dam and Sweetwater, 35235 Ac. Ft.
Mean as extended to 1883-4, 40558 Ac. Ft.

(a) By comparison of flood seasons 1915-6 and 1921-2 at Sutherland and Diverting Dam
(c) Cuyamaca Water Co. records
(u) U.S.G.S.
(b) Net runoff - no allowance for present or past diversions by Cuyamaca Water Co.

EVAPORATION FROM PAN FLOATING IN WATER AT
MURRAY RESERVOIR - ELEV. 520 FT.
INCHES

CUYAMACA WATER CO. F. E. GREEN

YEAR	JAN.	FEB.	MAR.	APRIL	MAY	JUNE	JULY	AUGUST	SEPT.	OCT.	NOV.	DEC.	TOTAL
1913	1.59	4.23	4.51	6.19	7.54	6.98	9.64	8.45	8.21	6.46	3.42	2.70	69.92
1914	2.37	2.94	6.15	6.16	5.48	7.76	9.03	8.26	6.56	4.47	4.34	2.37	65.87
1915	1.73	2.40	4.99	5.15	6.45	8.01	9.34	7.89	6.02	5.10	4.11	1.44	62.63
1916	1.85	2.75	3.98	5.77	8.33	7.65	9/90	7.87	5.81	4.89	5.54	3.09	67.43
1917	2.72	2.88	4.17	3.55	4.05	6.96	7.60	8.08	7.38	5.12	4.10	3.48	60.09
1918	----	-----	----	4.02	6.27	6.63	8.20	8.22	6.55	4.75	3.07	1.71	58.82
1919	2.00	2.95	4.05	3.99	5.48	7.12	8.29	7.64	6.36	4.64	4.67	3.07	60.26
1920	2.43	2.93	4.28	3.79	4.71	6.64	7.12	6.56	5.32	4.48	2.21	1.62	52.09
1921			2.31					7.39	7.95	4.66	3.29	3.63	
1922	2.45	2.34			6.71	6.72	7.93	7.06	6.74	4.79	2.50	3.29	57.53
1923	4.30	3.64			7.02	6.41	6.89	7.06	5.25	4.96	4.80	3.07	62.23
1924	2.65	2.84			6.61	7.62							
TOTAL	24.09	29.90	34.44	38.62	68.65	78.50	83.94	84.48	~~73.12~~ 72.13	54.32	42.05	29.47	616.87
MEAN	2.41	2.99	4.31	4.83	6.24	7.14	8.39	7.68	6.56	4.94	3.82	2.68	61.69

Table No. 24

CITY OF SAN DIEGO CALIFORNIA
OPERATING DEPARTMENT
BUREAU OF WATER IMPOUNDING
GROSS EVAPORATION
(Floating Pan)

MORENA DAM Elevation 3050

SEASON	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	SEASON TOTAL	ANNUAL TOTAL	YEAR
1915-16	5.89#	3.09	2.96	0.28	3.31	3.37	5.22	6.50	8.68	10.15	9.58	8.15	67.54	67.04	1916
1916-17	4.83	4.32	2.65	1.51	1.87	3.79	4.65	4.96	8.63	8.77	10.10	8.76	64.84	68.61	1917
1917-18	6.86	4.65	4.06	3.23	2.24	3.53	5.30	6.59	7.41	10.06	7.69	7.54	69.16	66.08	1918
1918-19	5.71	4.27	2.51	3.40	1.71	3.38	4.50	6.30	9.73	9.25	9.69	8.38	68.83	68.67	1919
1919-20	6.17	3.49	2.67	2.76	2.14	2.04	4.90	5.60	9.30#	9.92@	9.48	8.15	66.62	68.85	1920
1920-21	5.98	3.61	4.97	2.20	2.55	3.91	6.17	5.32	8.13	9.95	9.01	8.88	70.69	67.96	1921
1921-22	5.43	4.21	2.20	2.55	1.94	2.90	4.39	6.55	8.00	9.49	8.66	8.01	64.33	67.33	1922
1922-23	7.47	4.83	2.54	2.63	2.28	4.43	2.81	7.03	7.95	9.18	10.67	7.10	68.92	68.58	1923
1923-24	6.33	4.57	3.60	3.73	4.00	2.63	3.29	7.38	10.00	10.50	11.10	9.31	76.44	78.32	1924
1924-25	7.07	4.96	4.35	2.98	1.90	3.38	3.95	6.85	7.78	10.59	11.16	8.52	73.49	67.64	1925
1925-26	3.82	3.64	3.07	2.55	2.33	3.11	3.56	6.09	9.40	10.54	9.23	8.39	65.73	68.26	1926
1926-27	6.16	4.94	1.96	1.69											

MEAN FOR ELEVEN YEARS 68.85

NOTE: Figures to and including Feb. 1921 takenfrom H. N. Savage's Report, Page 251
Monthly mean value used.
@ 1/2 Month July 1920 ---4.96.

Table No. 25

Table No. 26

EVAPORATION FROM STANDARD 3 x 3 FT. PAN IN GROUND HODGES DAM

ELEV. 260 and 325

INCHES

SD.M.W. Co. F. E. GREEN

MONTH	1915	1916	1917	1918	1919	1920	1921	1922	1923 (d)	1924 (d)
JAN.	1.07	(1.30)	1.07	2.03	(b)2.03	2.78	3.52	2.81	3.00	2.66
FEB.	1.15	1.28	1.95	2.32	1.85	2.47	2.83	2.02	3.64	3.49
MAR.	3.06	2.66	3.26	2.54	2.74	2.78	4.00	3.10	4.37	3.37
APR.	2.45	3.89	3.82	3.81	3.45	5.06	6.33	4.00	3.86	3.70
MAY	3.92	5.34	3.21	4.90	4.16	5.62	4.04	4.78	6.86	6.71
JUNE	5.89	5.61	(a)5.91	5.95	7.18	7.29	5.90	5.88	7.15	8.11
JULY	6.83	6.24	6.17	6.61	8.19	8.20	7.82	6.62	7.70	8.98
AUG.	6.77	5.95	5.97	6.00	8.17	7.80	7.45	(c)8.80	7.10	
SEPT.	5.02	4.49	5.07	4.72	6.82	6.40	6.09	8.20	5.61	
OCT.	3.81	2.80	3.98	3.60	5.36	5.40	4.99	6.26	4.50	
NOV.	2.42	2.52	2.49	2.38	3.75	3.44	3.90	4.84	3.67	
DEC.	1.28	1.70	1.94	1.86	3.14	3.03	3.58	2.36	2.76	
TOTAL	43.67	43.78	44.84	46.72	56.84	60.27	60.45	59.67	60.22	

Nine year mean 52.94

(a) Pan moved 2 miles down to camp.

(b) Pan moved ½ mile down to dam.

(c) Screen over pan removed.

(d) From pan in ground at Hodges Bridge.

Table No. 27.

EVAPORATION FROM 3 x 3 Ft. PAN AT PAMO RESERVOIR SITE

ELEVATION 880

INCHES

V. L. & W. Co. F. E. GREEN.

MONTH	1914	1915	1916	1917	1918	1919	1920	1921	1922
JANUARY	2.79	1.44	0.43	1.54	2.20	2.84	2.09	2.02	2.53
FEBRUARY	2.56	2.00	(2.00)	2.25	2.56	1.98	2.99	2.40	2.26
MARCH	3.51	3.07	3.10	4.16	3.27	3.11	1.95	3.49	2.86
APRIL	3.56	5.29	5.46	3.85	4.80	3.71	4.31	5.34	4.06
MAY	4.72	4.00	7.61	4.52	5.89	6.22	6.09	4.55	6.11
JUNE	8.25	6.18	8.81	8.05	7.55	7.90	8.34	6.80	7.44
JULY	10.26	6.52	10.25	8.60	8.72	8.50	9.48	8.64	7.93
AUGUST	9.92	6.62	8.71	8.50	8.38	9.75	8.00	8.11	8.98
SEPTEMBER	6.68	5.01	7.01	9.50	6.96	8.99	6.30	6.69	7.58
OCTOBER	4.51	4.12	4.18	5.42	5.01	4.80	4.21	3.80	5.11
NOVEMBER	3.16	2.20	4.02	3.38	2.60	3.75	2.77	2.84	2.99
DECEMBER	1.40	1.22	2.54	3.22	2.97	2.21	2.27	3.07	1.80
TOTAL	61.30	47.67	64.12	60.99	60.91	63.76	58.80	57.75	59.65

Means for 9 years = 59.44

Table No. 28

EVAPORATION FROM LAKE SURFACE
COMPARED WITH THAT FROM STANDARD EVAPORATION PAN
DATA FROM HODGES RESERVOIR

F. E. GREEN

DATE	Days	Evaporation – Lake	Inches Pan	Rain in	% of Lake to Pan
May 21 to June 1, 1919	11	1.29	1.39	.33	92.81
June 1, to July 1, 1919	30	7.20	7.18	0	100.28
July 1 to Aug. 1, 1919	31	8.16	8.19	.44	99.63
Sept. 1 to Oct. 1, 1919	30	6.04	6.82	.28	88.56
Oct. 14 to Oct. 24, 1919	10	1.80	1.71	0	105.26
June 1 to June 26, 1920	25	5.59	6.09	.19	91.79
July 9 to Aug. 1, 1920	23	5.64	6.10	0	92.46
Aug. 22 to Sept. 1, 1920	10	2.04	2.20	0	92.73
Sept. 1 to Sept. 12, 1920	11	2.40	2.50	0	96.00
Oct. 1 to Oct. 16, 1920	15	2.64	3.00	0	88.00
Aug. 10 to Aug. 21, 1921	11	2.52	2.70	0	93.33
Total	207	45.32	47.88	1.24	Mean $\frac{45.32}{47.88}$ =94.65%

The lake evaporation is taken from the daily readings of a vertical enameled staff gage, graduated to 0.02 of one foot, set in the water about 800 ft. from the dam. Daily readings of this gage are on record since Feb. 1, 1919.

The evaporation pan used was the standard 3 ft. pan 18 in. deep, buried in the ground about 25 ft. above the lake near the north side of the dam. The pan was covered with a wire fencing screen of two inch mesh.

Table No. 28

The pan evaporation given for each of the thirteen periods is from actual operation of the pan without any interpolations. That is, the pan was actually filled at the beginning and end of each period. Periods where this condition did not hold were not considered. The pan has been in operation continuously since the formation of the lake.

There was no reservoir draft or runoff during the periods of the study, and in no case was a period taken immediately following a draft. Hence, there are no discrepancies arising from computations involving runoff and areas.

Since it is impossible to fully standardize the conditions under which a pan is operated, a comparison was made with the synchronous results from other standard pans at about the same elevation and distance back from the coast, the Hodges pan showing the following ratio:

107.0 % of pan floating in Murray Reservoir

113.9 % " " buried in ground at San Dieguito Reservoir

113.2 % " " " " " " Hodges Bridge, Bernardo.

Mean 111.4 %

Accepting the above mean of 111.4 % as the true index of the Hodges pan, then the ratio between lake and pan is as 45.32 is to 42.98, or 105.4%.

F E Green.

Table No. 29

COMPARATIVE EVAPORATION

From Pans of $4\frac{1}{2}$ sq. ft. area, 9 sq. ft., and 18 sq. ft.

San Pasqual Valley, 1923-24.

Date	Time	Pan $4\frac{1}{2}$ sq. ft. Evaporation Inches	Pan $4\frac{1}{2}$ sq. ft. Temperature s.Surface b.Bottom	Pan 9 sq. ft. Evaporation Inches	Pan 9 sq. ft. Temperature s.Surface b.Bottom	Pan 18 sq. ft. Evaporation Inches	Pan 18 sq. ft. Temperature s.Surface b.Bottom
July 20, 1923 -	9:00 A.	1.90	s.80.0 b.76.0	1.78	s. 77.0 b. 74.0	1.78	s. 77.0 b. 75.0
" 28, "	5:00 P.	2.26	s.86.0 b.85.0	2.04	s. 87.0 b. 86.0	2.05	s. 87.3 b. 86.0
Aug. 18, "	11:00 A.	1.92	s.80.0 b.77.0	1.80	s.79.3 b.77.0	1.86	s. 79.3 b. 78.0
Sep. 1, "	10:00 A.	1.76	s.71.5 b.70.0	1.62	s.71.8 b.70.0	1.66	s. 71.9 b. 70.9
Sep. 12, "	2:00 P.	2.18	s.74.8 b.74.0	2.04	s.74.0 b.74.0	2.14	s. 74.8 b. 74.0
" 20, "	10:30 A	1.38	s.73.4 b.68.0	1.29	s.71.0 b.68.0	1.31	s. 72.0 b. 69.0
" 27, "	1:00 P.	1.44	s.76.4 b.69.0	1.32	s.75.0 b.70.0	1.25	s. 75.7 b. 70.0
Oct. 4, "	10:00 A.	1.09	s.67.0 b.65.8	1.06	s.67.0 b.66.0	1.18	s. 67.0 b. 66.0
Oct. 12, "	2:00 P.	1.31	s.77.0 b.68.1	1.16	s.74.1 b.70.0	1.15	s. 75.0 b. 69.0
31, "	3:00 P.	2.58		2.42		2.42	
Nov. 13, "	5:00 P.	(1.49)		1.28	s.63.6 b.60.0	1.26	s. 64.0 b. 60.0
" 26, "	11:00 A.	1.38		1.19		1.19	
Dec. 6, "	4:00 P.	.99		.88		.89	
" 19, "	1:00 P.	1.13		.97		.96	
Jan. 5, 1924	11:00 A.	1.42	s.51.0 b.47.0	1.28	s.50.0 b.47.0	1.21	s. 49.9 b. 46.8
" 17, "	11:00 A.	1.25		1.16		1.00	
" 31, "	10:00 A.	1.01	s.52.9 b.49.0	.91	s.52.0 b.49.8	.91	s. 52.0 b. 49.9
Feb. 14, "	10:00 A.	1.44	s.56.2 b.51.8	1.29	s.56.0 b.52.0	1.28	s. 56.0 b. 52.0
" 28, "	11:00 A.	1.90	s.62.2 b.54.0	1.72	s.62.0 b.55.0	1.69	s. 61.0 b. 55.0
			Mean		Mean		Mean
Total		29.83	s.69.88 b.65.75	27.21	s.68.94 b.66.06	27.19	s. 69.15 b. 66.28
Ratio to 3 x 3 pan		109.63%		100 %		99.93%	
R. B. Sleight's curve		104.30%		100 %		94.61%	

Table No. 29

COMPARATIVE EVAPORATION

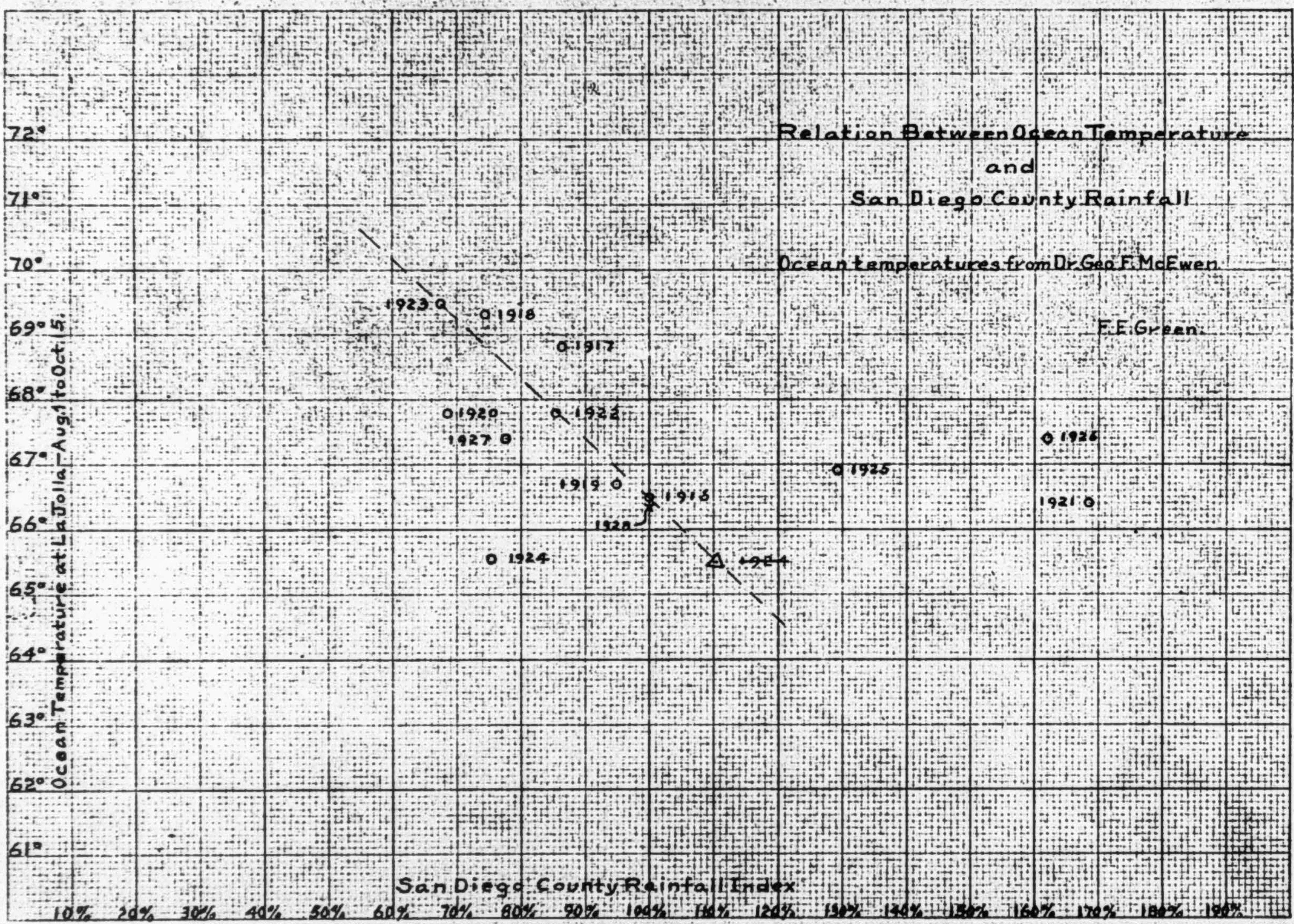
FROM PANS OF $4\frac{1}{2}$ SQ. FT., 9 SQ. FT., AND 18 SQ. FT.

San Pasqual Valley, 1923-24

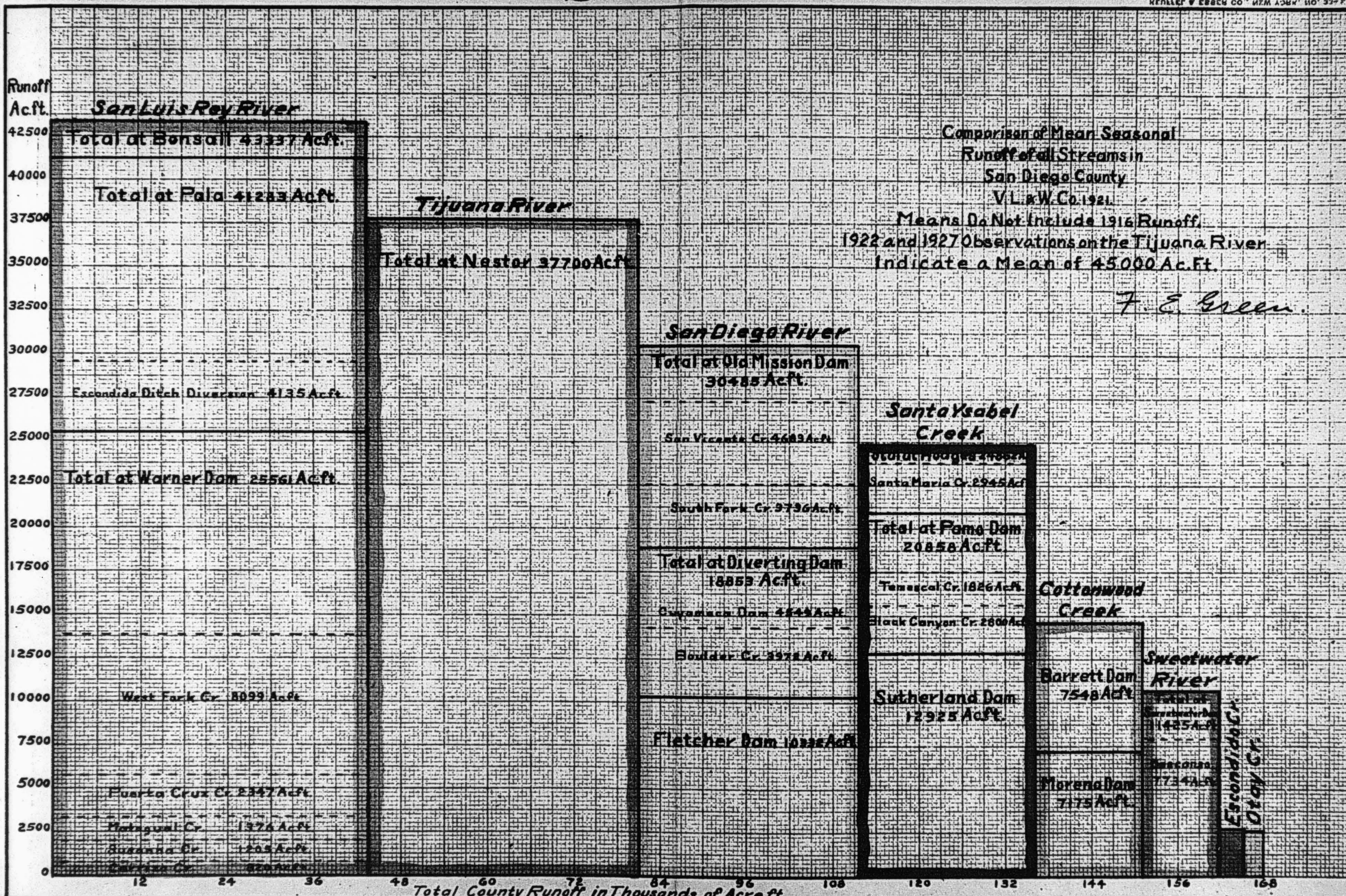
F. E. Green.

Evaporation in inches

Date	Pan $4\frac{1}{2}$ ft. sq.	Pan 9 ft. sq.	Pan 18 ft. sq.
April 8, 1924	1.35	1.32	1.29
" 30,	2.74	2.72	2.82
May 19,	3.57	3.55	3.53
June 2,	2.94	2.95	2.96
June 11,	2.30	2.29	2.34
June 23,	3.20	3.10	3.21
July 1,	2.04	1.92	2.02
July 7,	1.58	1.51	1.60
July 17,	2.66	2.56	2.78
July 23,	1.48	1.43	1.44
July 31,	2.00	1.97	2.93
Aug. 6,	1.64	1.58	1.64
Total	27.50	26.90	27.65
Ratio to 3x3 pan	102.23%	100.00%	102.83%
Evaporation July 20, 1923 to Feb. 28, 1924	29.83	27.21	27.19
Ratio to 3x3 pan	109.63%	100.00%	99.93%
Total Evaporation 1 year, 17 days	57.33	54.11	54.85
Ratio to 3x3 pan	105.95%	100.00%	101.37%
From R. B. Sleight's curve	104.30%	100.00%	94.61%

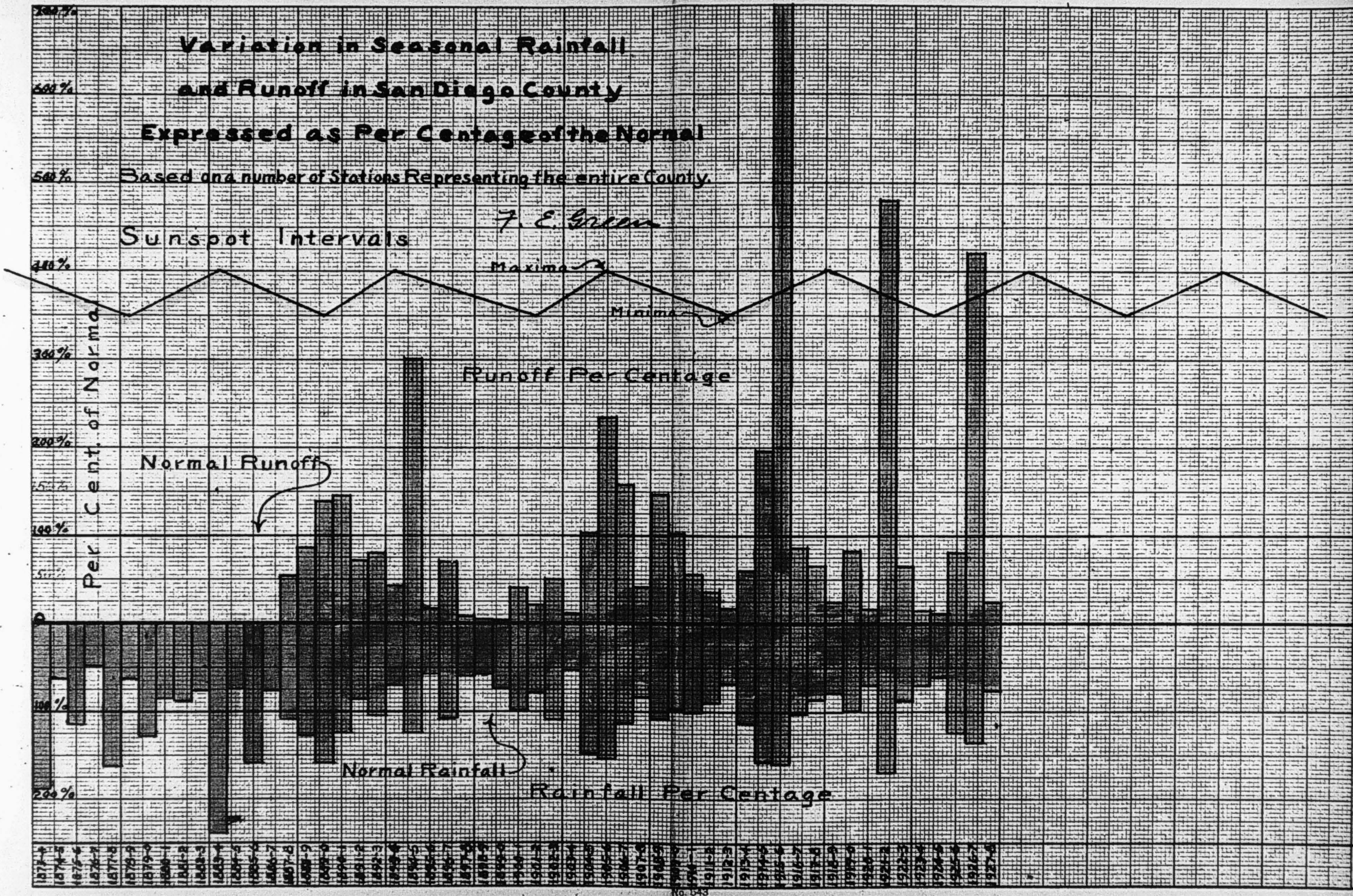

Relation Between Ocean Temperature
and
San Diego County Rainfall
Ocean temperatures from Dr. Geo. F. McEwen.
F. E. Green.
Ocean Temperature at La Jolla - Aug. 1 to Oct. 15.
San Diego County Rainfall Index
72°
71°
70°
69°
68°
67°
66°
65°
64°
63°
62°
61°
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
110%
120%
130%
140%
150%
160%
170%
180%
190%
1923
1918
1917
1920
1922
1927
1926
1925
1919
1916
1921
1928
1924

B

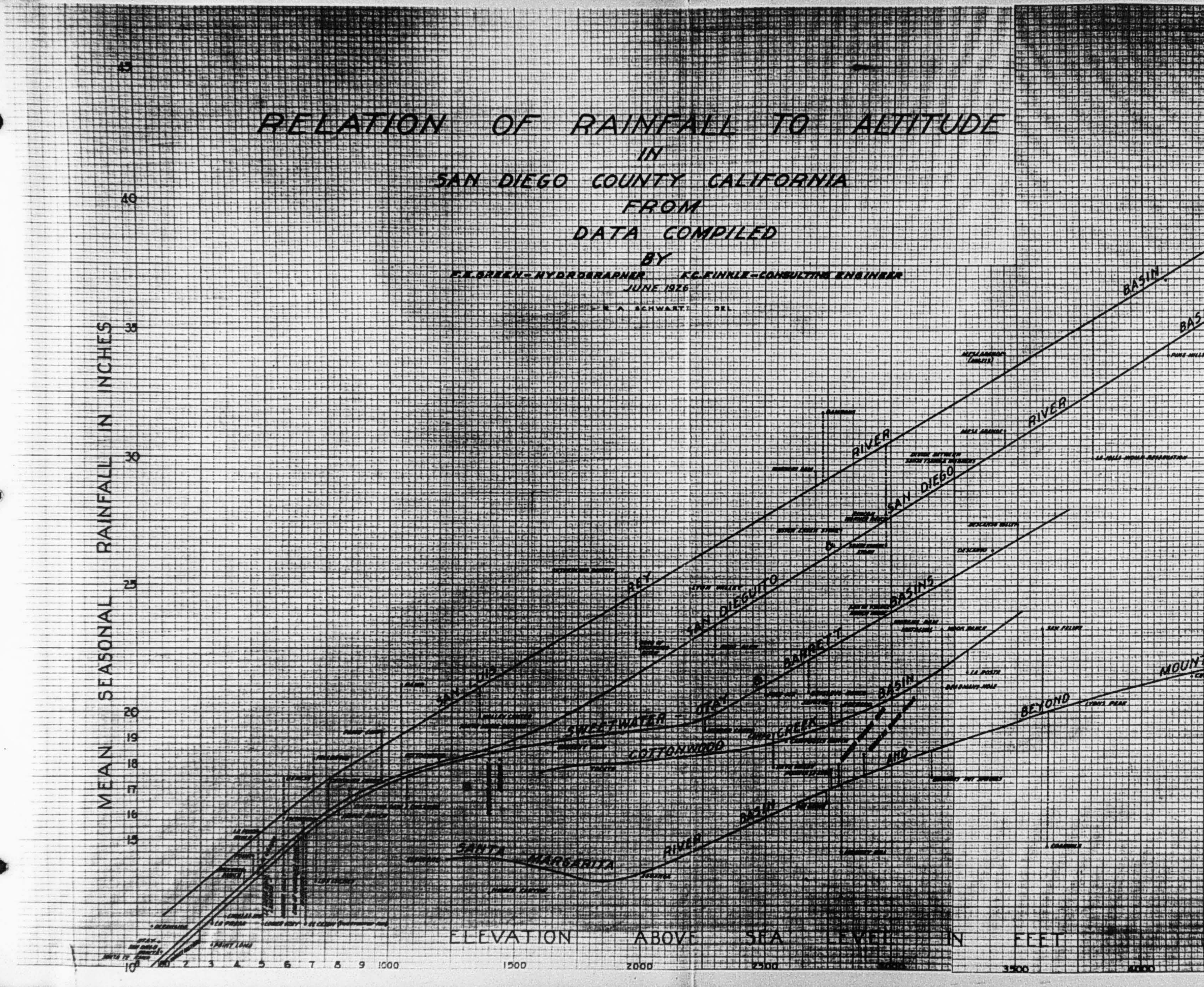


Red Green Yellow Blue Olive S. R Y

C



Variation in Seasonal Rainfall
and Runoff in San Diego County
Expressed as Per Centage of the Normal
Based on a number of Stations Representing the entire County.
F. E. Green
Sunspot Intervals
Maxima
Minima
Runoff Per Centage
Normal Runoff
Per Cent. of Normal
Normal Rainfall
Rainfall Per Centage
600 %
500 %
400 %
300 %
100 %
0
100 %
200 %
No. 543


RELATION OF RAINFALL TO ALTITUDE
IN
SAN DIEGO COUNTY CALIFORNIA
FROM
DATA COMPILED
BY
F.E. GREEN – HYDROGRAPHER
F.C. FINKLE – CONSULTING ENGINEER
JUNE 1926
R. A. SCHWARTZ DEL.
MEAN SEASONAL RAINFALL IN INCHES
ELEVATION ABOVE SEA LEVEL IN FEET
10
15
16
17
18
19
20
25
30
35
40
45
2
3
4
5
6
7
8
9
1000
1500
2000
2500
3000
3500
4000
SAN LUIS REY RIVER BASIN
SAN DIEGUITO SAN DIEGO RIVER BASIN
SWEETWATER – OTAY – BARRETT BASINS
COTTONWOOD CREEK BASIN
SANTA MARGARITA RIVER BASIN
AND
BEYOND MOUNT

L TO ALTITUDE

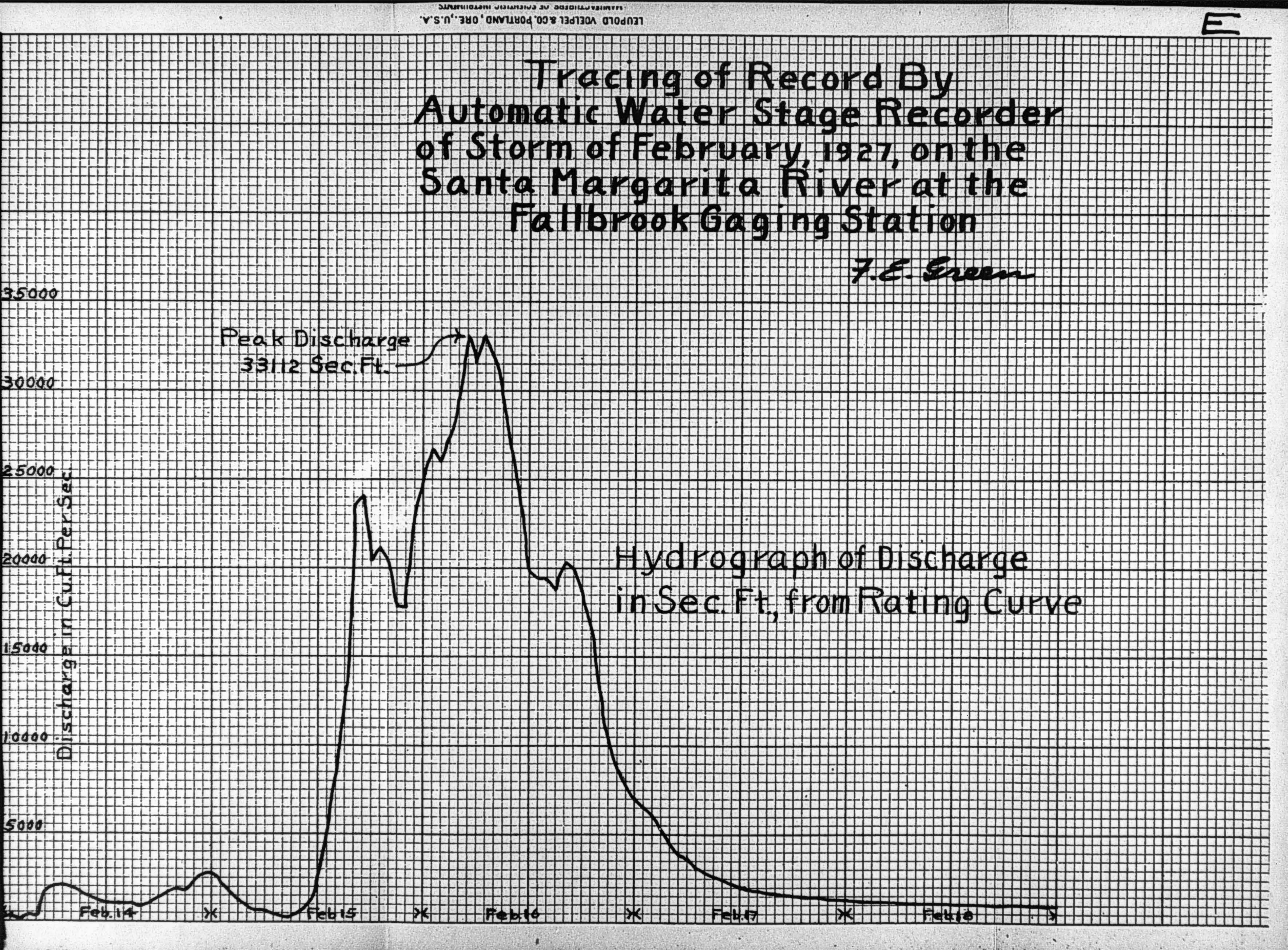
ALIFORNIA

PILED

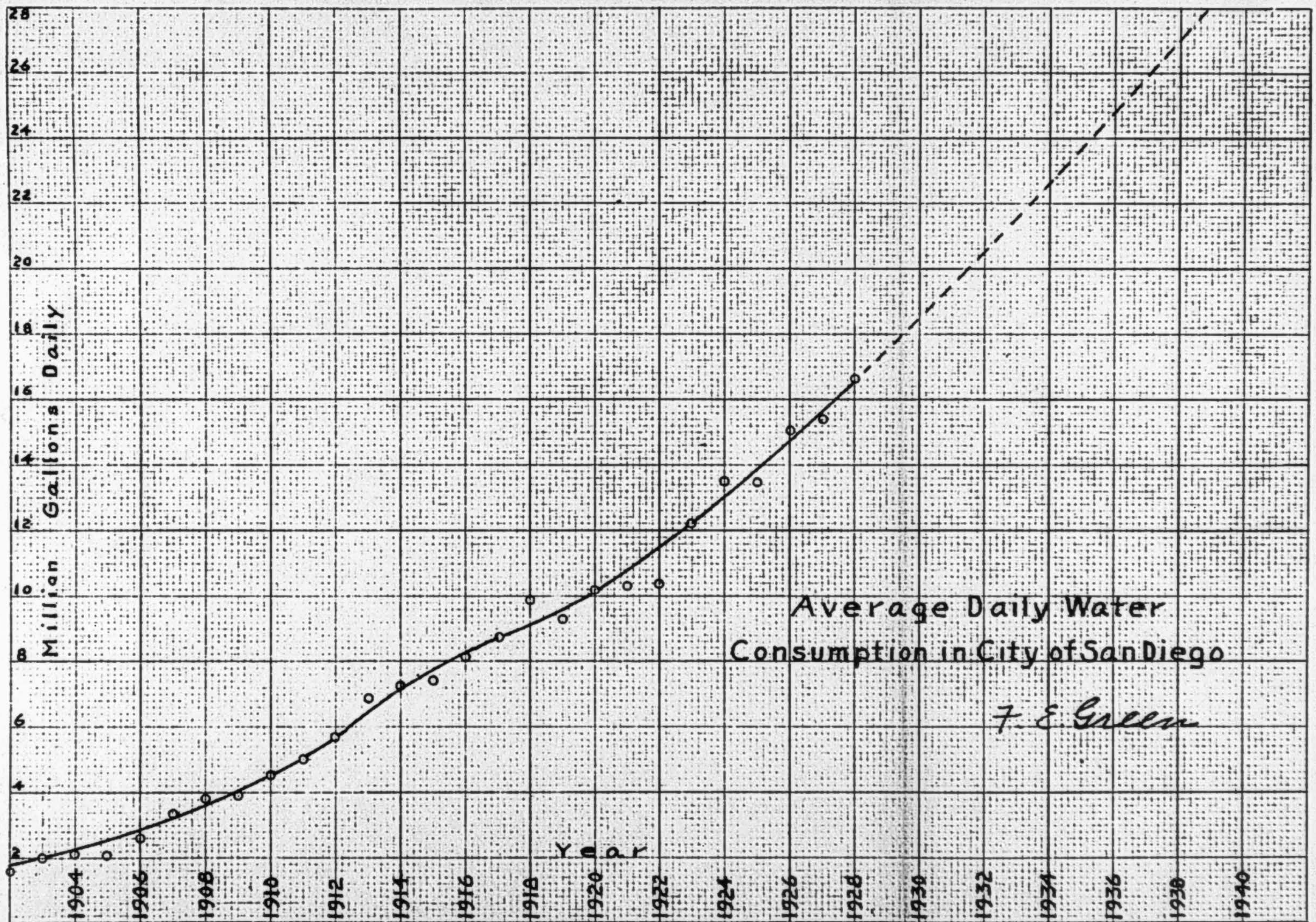
RELATION OF RAINFALL TO ALTITUDE

	SAN LUIS REY RIVER BASIN	SAN DIEGUITO & SAN DIEGO RIVER BASIN	SWEETWATER OTAY & BARRETT RIVER BASIN	COTTONWOOD CREEK BASIN	SANTA MARGARITA RIVER BASIN
PRECIPITATION INCHES	ALTITUDE FEET	ALTITUDE FEET	ALTITUDE FEET	ALTITUDE FEET	ALTITUDE FEET
10		60	80		
11		170	200		
12	100	280	300		
13	220	390	420		
14	340	500	530		2060
15	450	620	650		2290
16	580	740	770		2610
18	860	1070	1210	1850	3010
20	1200	1720	2310	2850	3700
22	1540	2070	2690	3200	4400
24	1880	2400	3020	3540	5500
26	2220	2730	3360		
28	2550	3050	3710		
30	2890	3380			
32	3230	3710			
34	3570	4030			
36	3910	4360			
38	4250	4680			
40	4590	5010			
42	4920	5340			
44	5260	5670			
46	5600	6000			

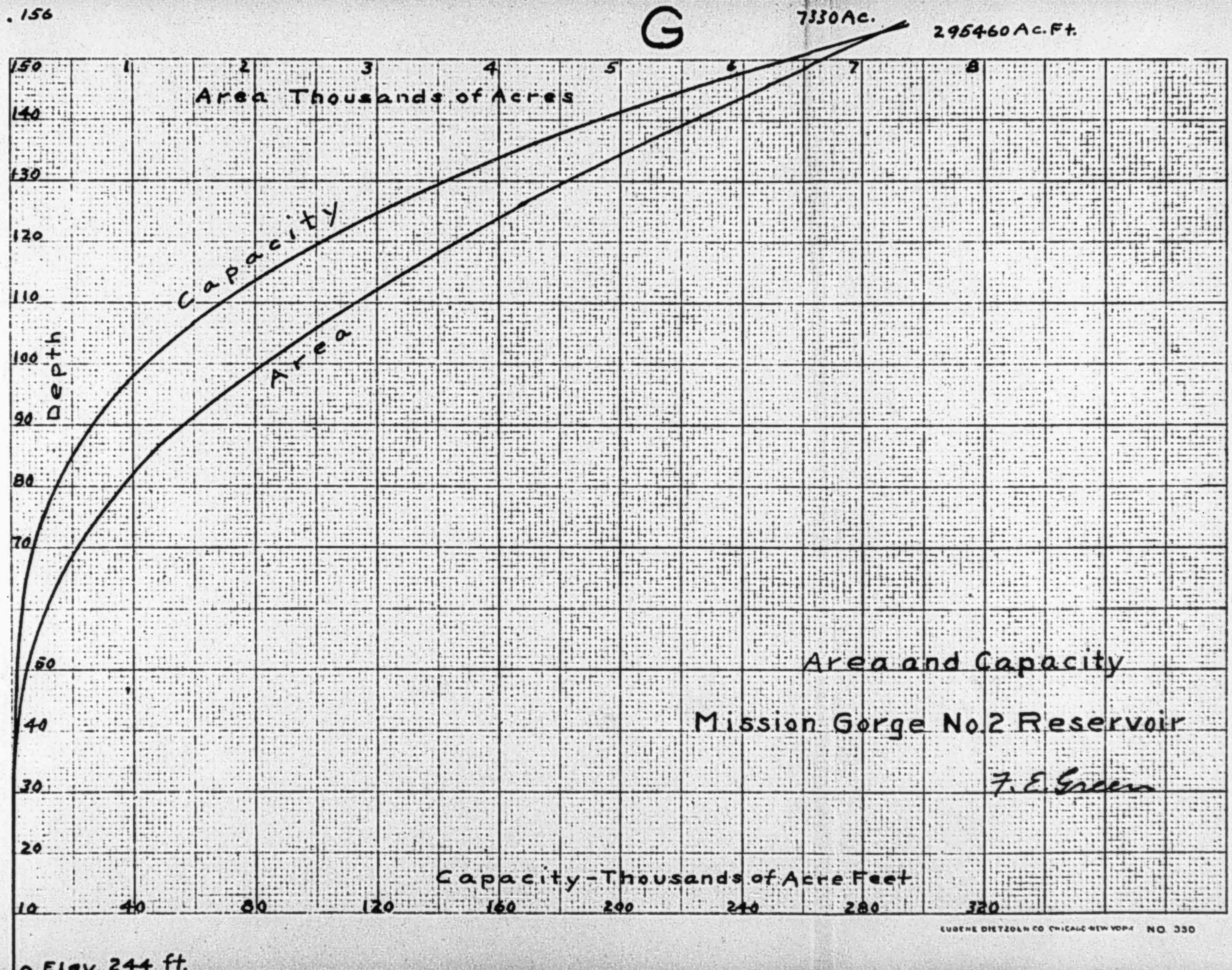
Peak No.1
G.H.4.50
Peak No.2
G.H.4.83
Reversal No.1
Reversals No's 4,5 & 6
3
Peak No.3
G.H.13.55
Peak No.4
G.H.15.90
Reversal No.8
Reversal No.2
Reversal No.7
5.00
4.00
3.00
2.00
1.00
Gage Height in Feet
35000
30000
25000
20000
15000
10000
5000
Discharge in Cu.Ft.Per.Sec.
Feb13
Feb14
Feb15
Feb16
Feb17
Feb18
Feb.14
This recorder operates on a scale of 1 to 6, 6 in. change in water level being 1 inch in the record.
The instrument automatically reverses direction at each margin of the sheet, without loss in gage height.
Tracing From Record By Automatic Water Stage Recorder


E
LEUPOLD VOELPEL & CO. PORTLAND, ORE., U.S.A.
Tracing of Record By Automatic Water Stage Recorder of Storm of February, 1927, on the Santa Margarita River at the Fallbrook Gaging Station
F. E. Green
Peak Discharge 33112 Sec. Ft.
Hydrograph of Discharge in Sec. Ft., from Rating Curve
Discharge in Cu. Ft. Per Sec.
35000
30000
25000
20000
15000
10000
5000
Feb. 14
Feb 15
Feb 16
Feb 17
Feb 18

F

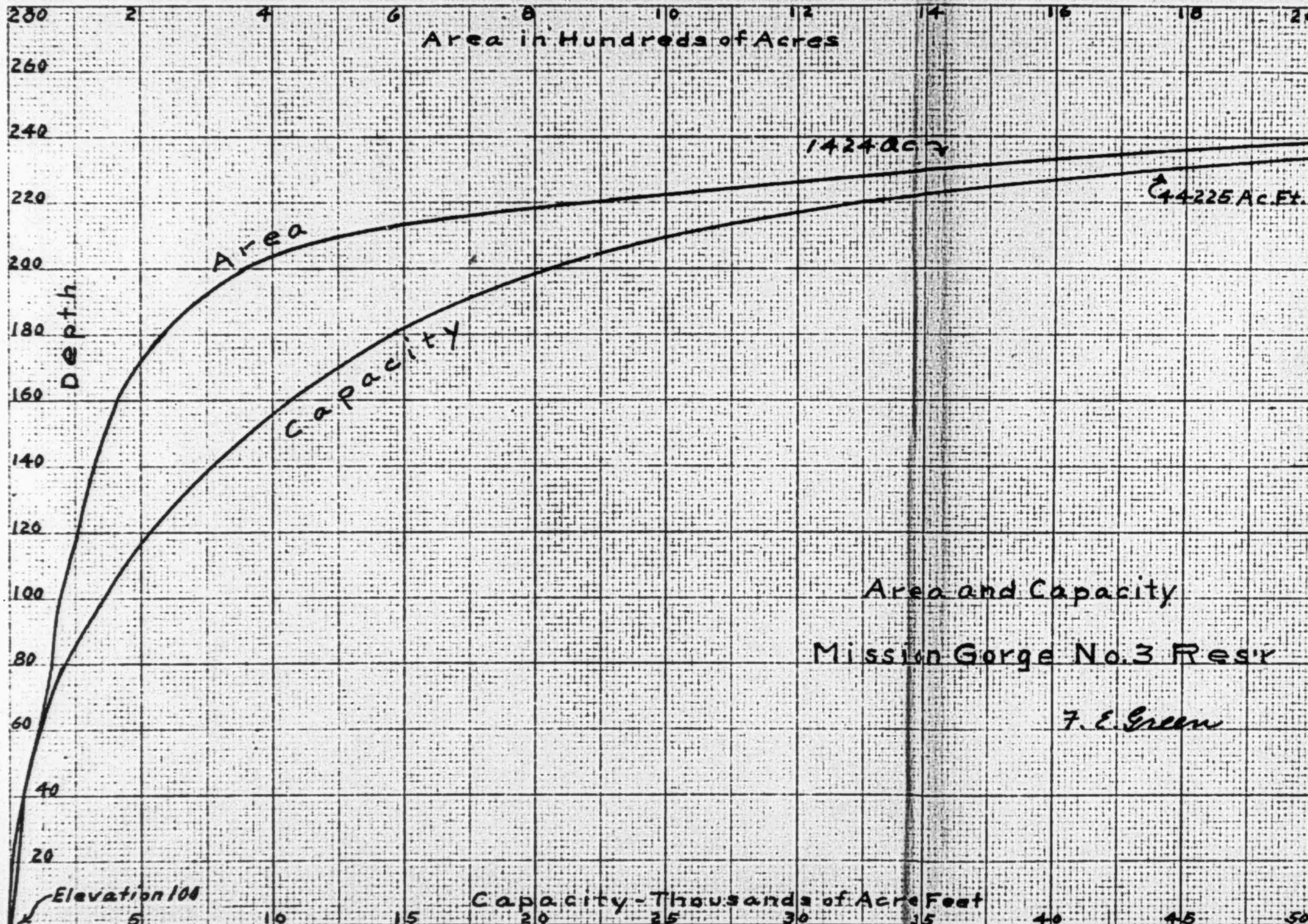


EUGENE DIETZGEN CO. CHICAGO NEW YORK NO 330

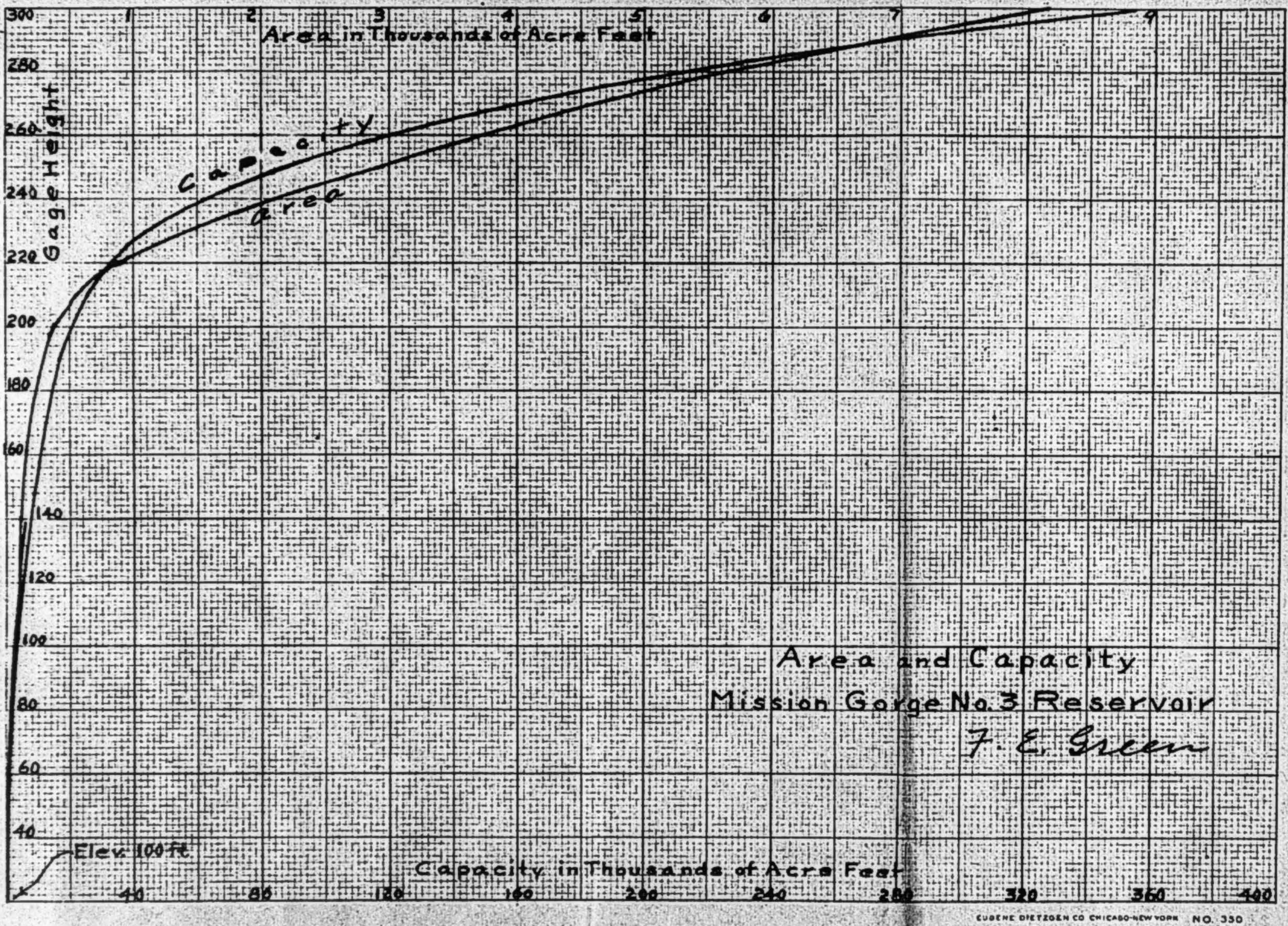


G
156
7330 Ac.
295460 Ac.Ft.
Area Thousands of Acres
1
2
3
4
5
6
7
8
150
140
130
120
110
100
90
80
70
60
40
30
20
10
Depth
Capacity
Area
Area and Capacity
Mission Gorge No. 2 Reservoir
F. E. Green
Capacity - Thousands of Acre Feet
40
80
120
160
200
240
280
320
EUGENE DIETZGEN CO. CHICAGO-NEW YORK NO. 330
Elev. 244 ft.

H

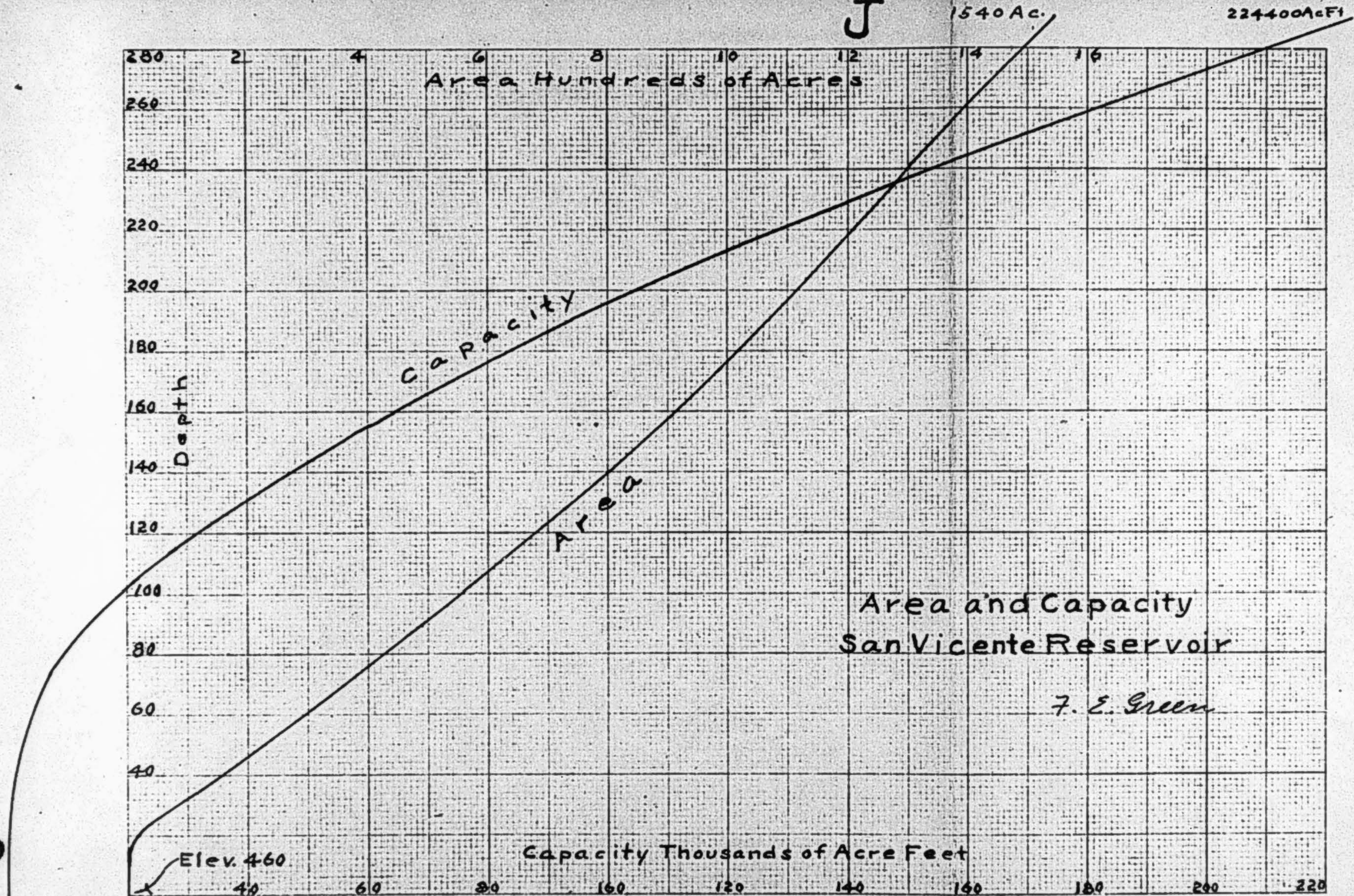

Area in Hundreds of Acres
2
4
6
8
10
12
14
16
18
20
280
260
240
220
200
180
160
140
120
100
80
60
40
20
Depth
Area
Capacity
1424 Ac.
44225 Ac.Ft.
Elevation 104
Capacity - Thousands of Acre Feet
5
10
15
20
25
30
35
40
45
50
Area and Capacity
Mission Gorge No. 3 Res'r
F. E. Green

I

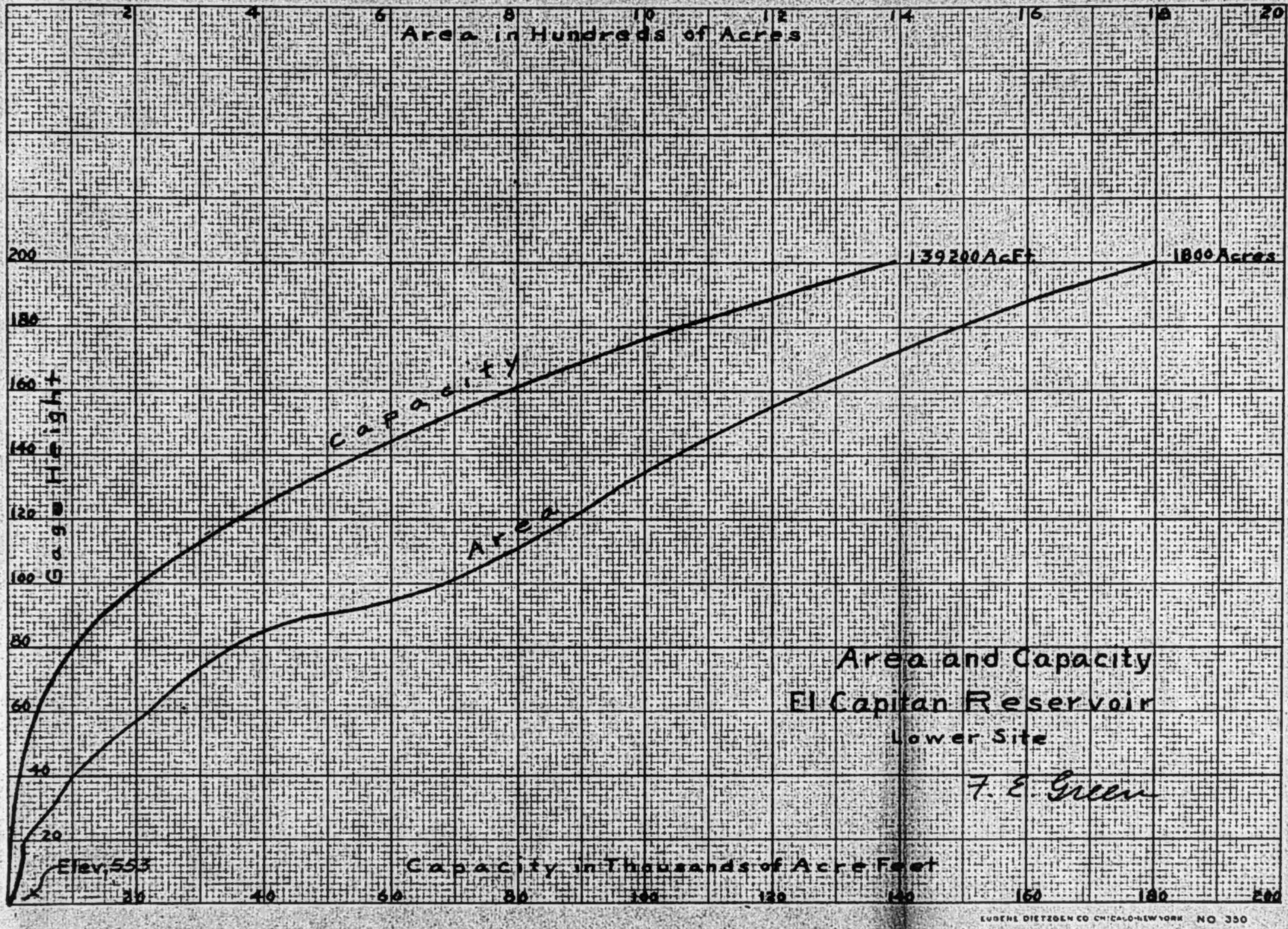


Area in Thousands of Acre Feet
1
2
3
4
5
6
7
9
Capacity
Area
Gage Height
300
280
260
240
220
200
180
160
140
120
100
80
60
40
Elev. 100 ft
Capacity in Thousands of Acre Feet
40
80
120
160
200
240
280
320
360
400
Area and Capacity
Mission Gorge No. 3 Reservoir
F. E. Green
EUGENE DIETZGEN CO. CHICAGO-NEW YORK NO. 330

J

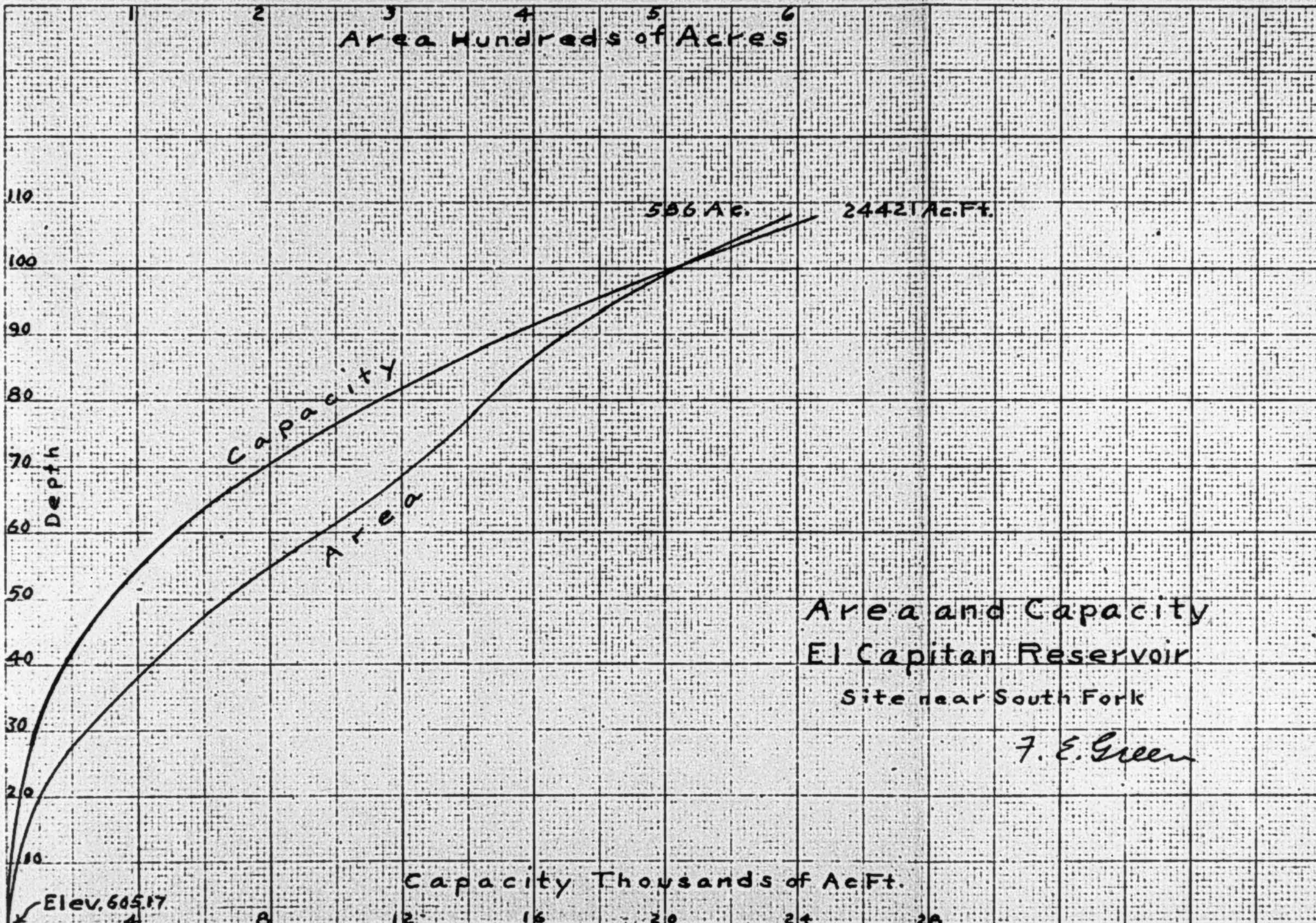

1540 Ac.
224400AcFt
Area Hundreds of Acres
2
4
6
8
10
12
14
16
280
260
240
220
200
180
160
140
120
100
80
60
40
Depth
Capacity
Area
Area and Capacity
San Vicente Reservoir
F. E. Green
Elev. 460
Capacity Thousands of Acre Feet
40
60
80
100
120
140
160
180
200
220

K

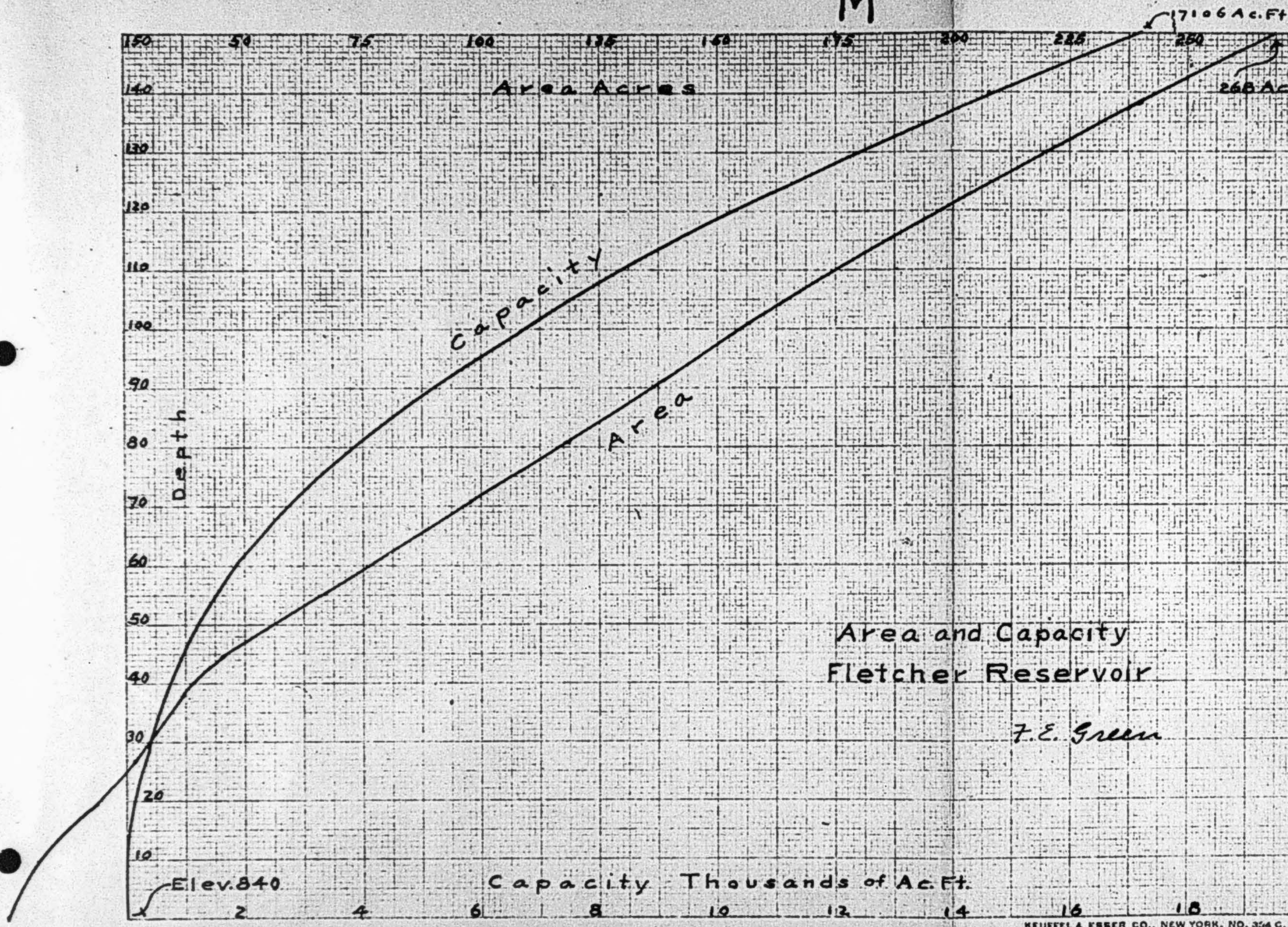


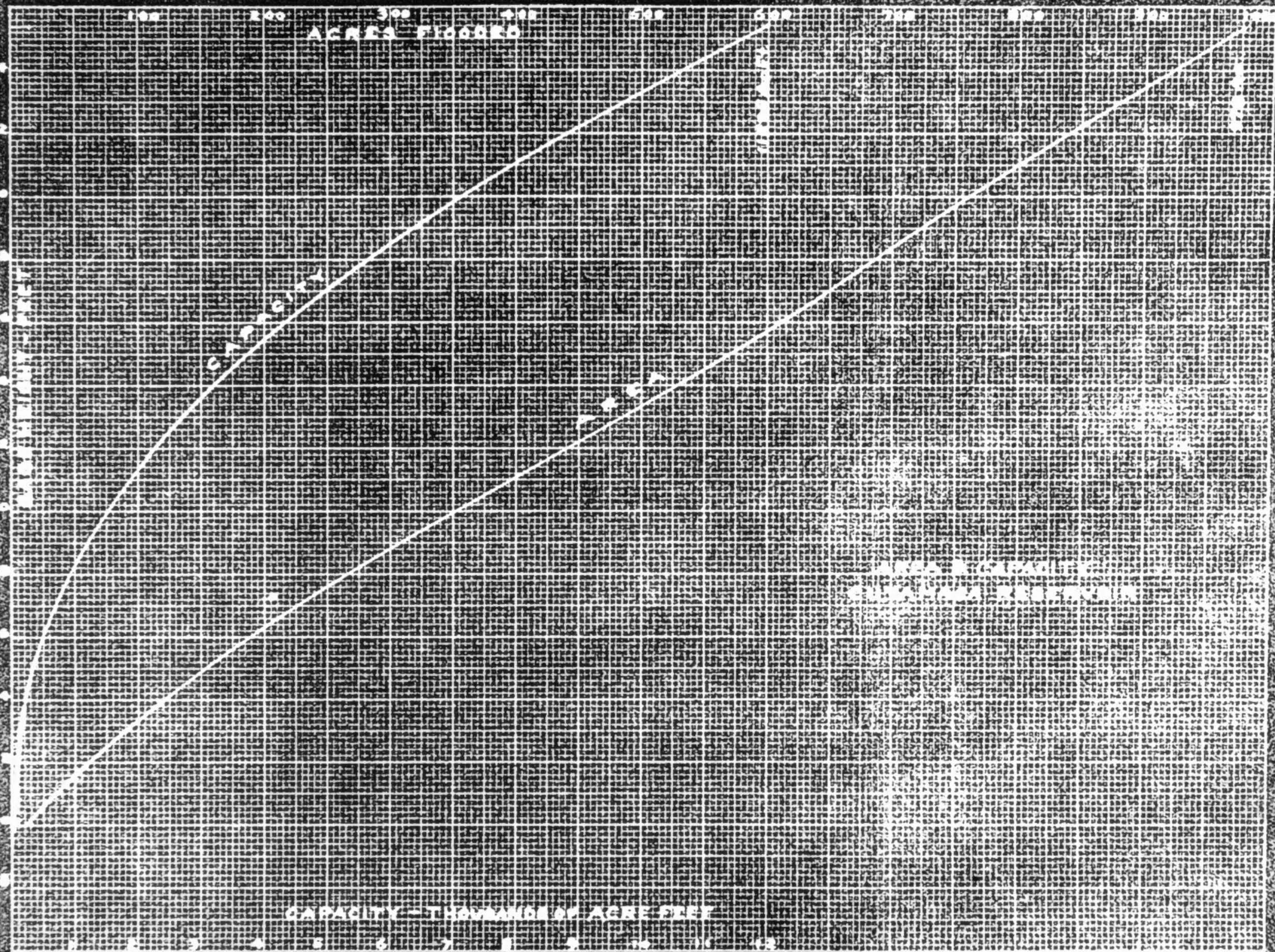
Area in Hundreds of Acres
2
4
6
8
10
12
14
16
18
20
Gage Height
200
180
160
140
120
100
80
60
40
20
139200 AcFt
1800 Acres
Capacity
Area
Elev. 553
Capacity in Thousands of Acre Feet
20
40
60
80
100
120
140
160
180
200
Area and Capacity
El Capitan Reservoir
Lower Site
F. E. Green
EUGENE DIETZGEN CO CHICAGO-NEW YORK NO 350

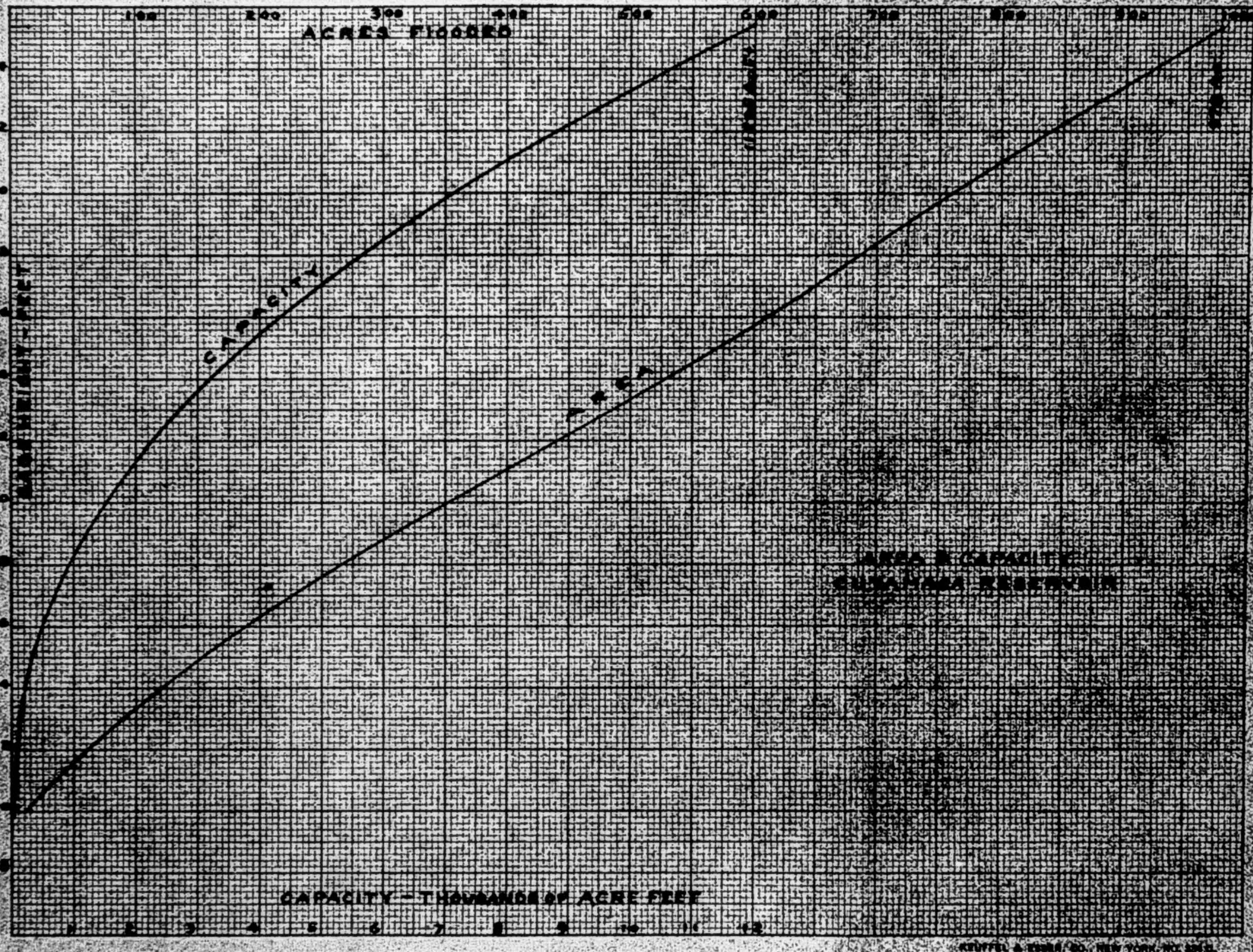
L


Area Hundreds of Acres
1
2
3
4
5
6
556 Ac.
24421 Ac.Ft.
Capacity
Area
Depth
110
100
90
80
70
60
50
40
30
20
10
Elev. 605.17
Capacity Thousands of Ac.Ft.
4
8
12
16
20
24
28
Area and Capacity
El Capitan Reservoir
Site near South Fork
F. E. Green
EUGENE DIETZGEN CO. CHICAGO-NEW YORK NO. 350

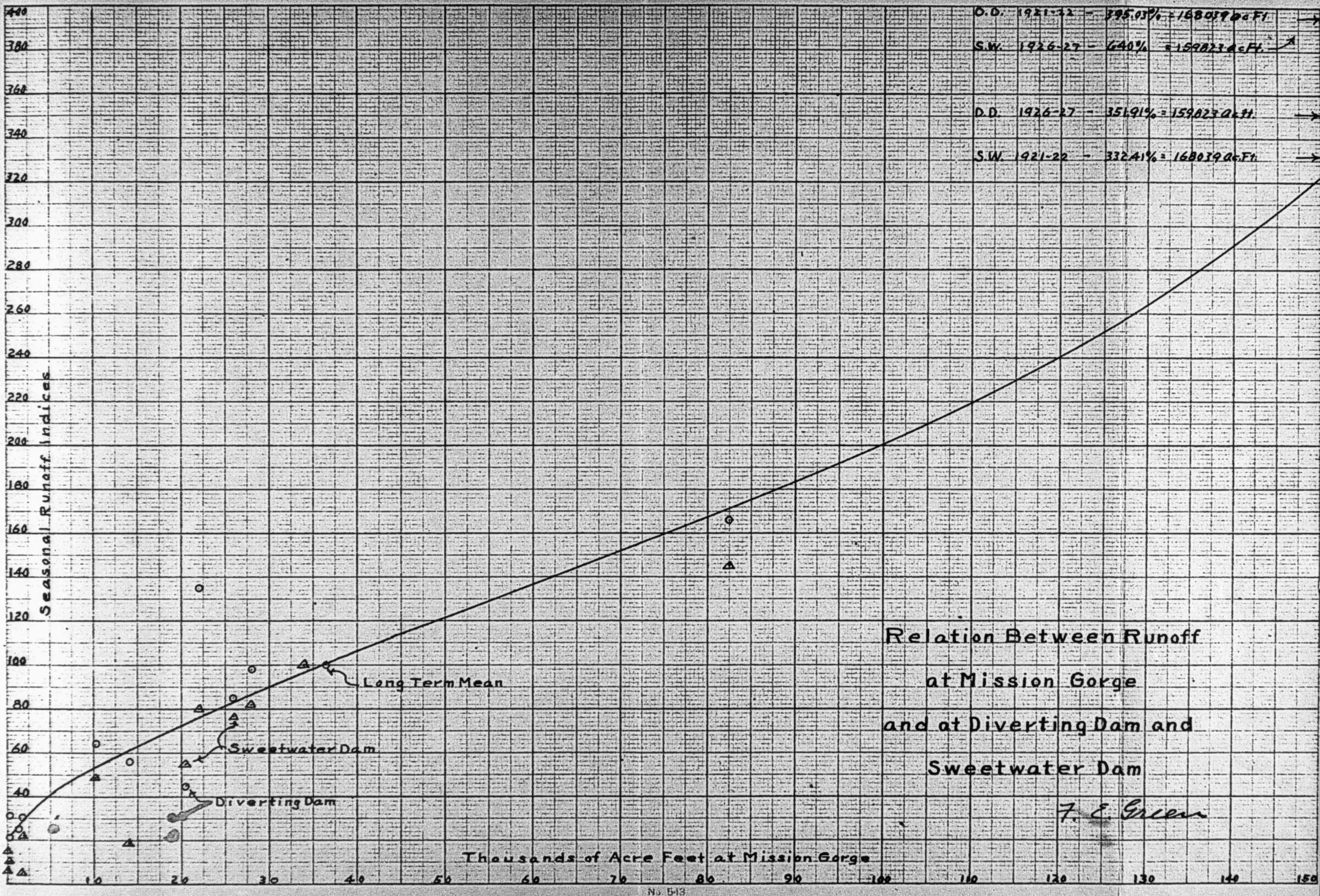
M


17106 Ac. Ft
268 Ac.
150
50
75
100
125
150
175
200
225
250
140
130
120
110
100
90
80
70
60
50
40
30
20
10
Area Acres
Capacity
Area
Depth
Elev. 840
Capacity Thousands of Ac. Ft.
2
4
6
8
10
12
14
16
18
Area and Capacity
Fletcher Reservoir
F. E. Green
KEUFFEL & ESSER CO., NEW YORK. NO. 354 C.

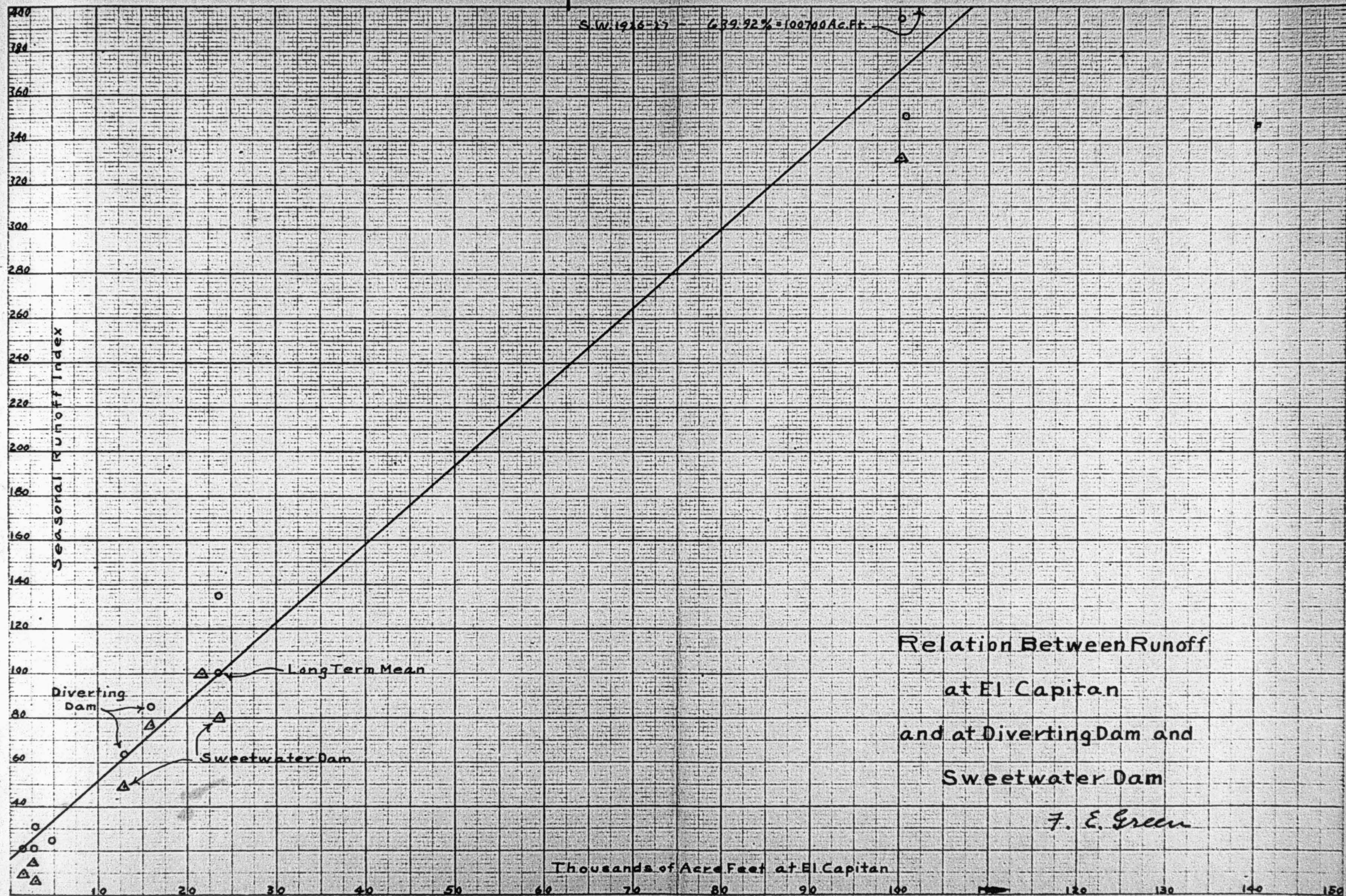

ACRES FLOODED
CAPACITY
AREA
AREA & CAPACITY
CAPACITY – THOUSANDS OF ACRE FEET



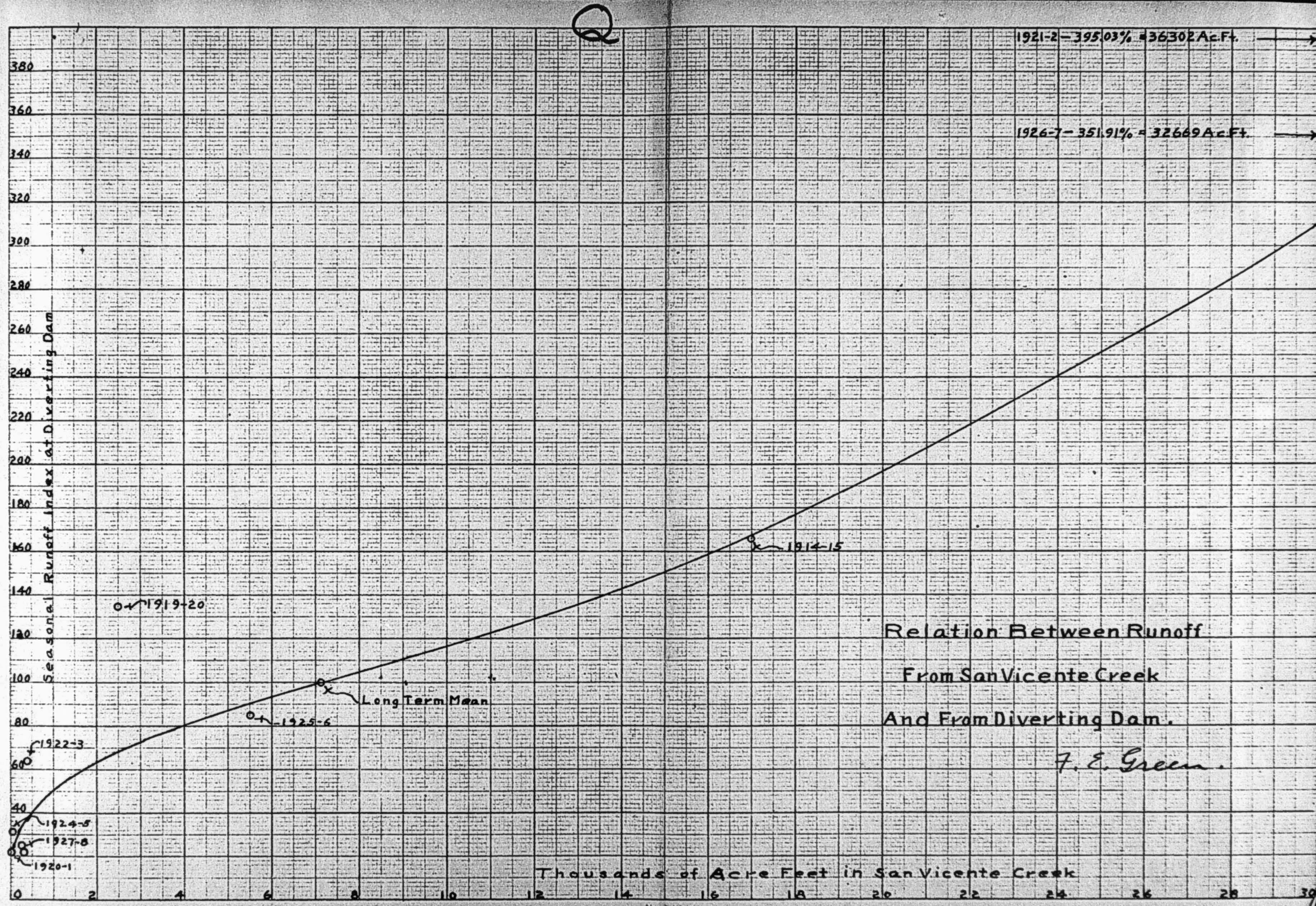
ACRES FLOODED
CAPACITY
AREA
AREA & CAPACITY
CAPACITY - THOUSANDS OF ACRE FEET


O.D. 1921-22 - 395.03% = 168039 ac.Ft.
S.W. 1926-27 - 640% = 159823 ac.Ft.
D.D. 1926-27 - 351.91% = 159823 ac.Ft.
S.W. 1921-22 - 332.41% = 168039 ac.Ft.
Seasonal Runoff Indices
Long Term Mean
Sweetwater Dam
Diverting Dam
Thousands of Acre Feet at Mission Gorge
Relation Between Runoff
at Mission Gorge
and at Diverting Dam and
Sweetwater Dam
F. E. Green
No. 513

P

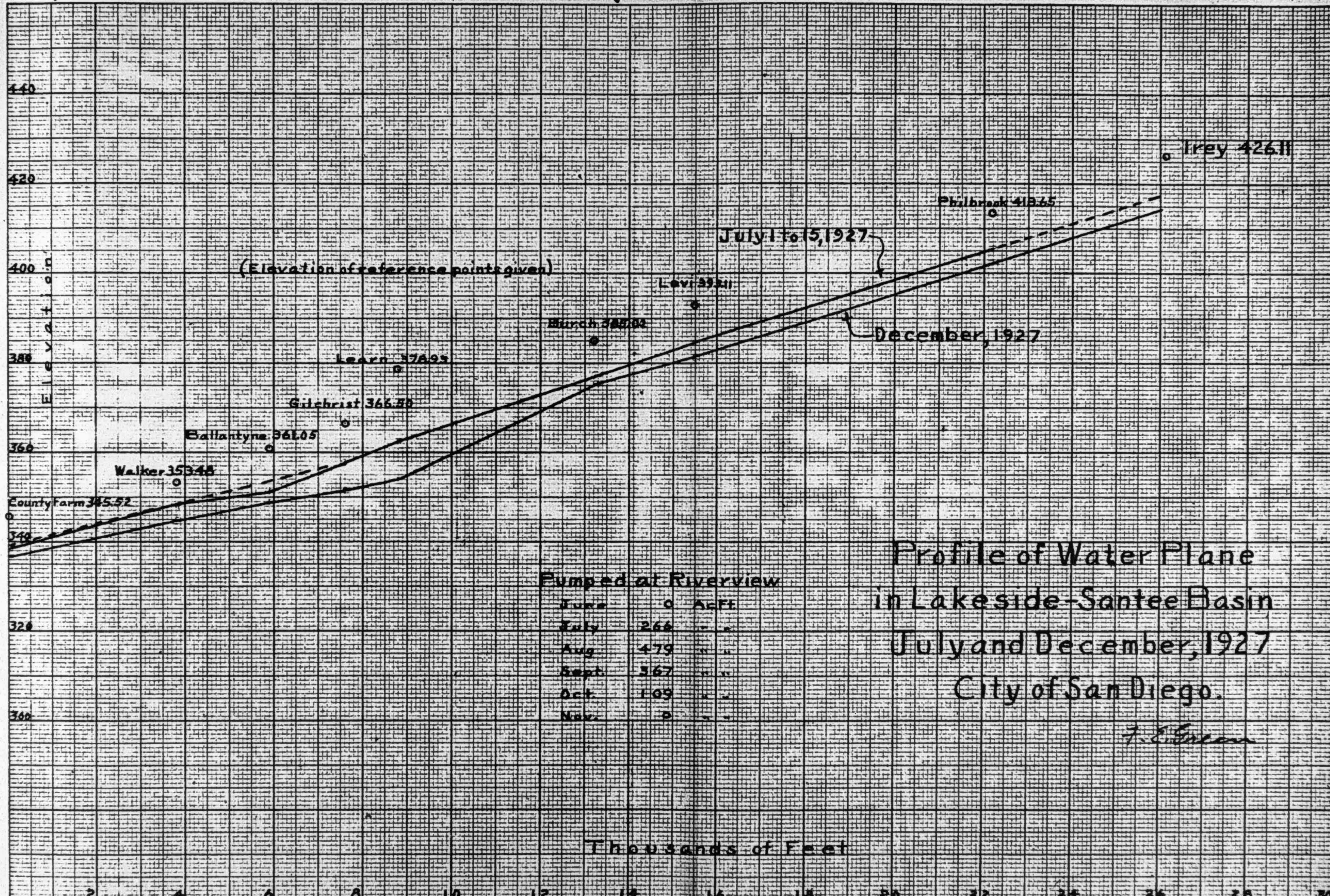


S.W. 1926-27 - 639.92% = 100700 Ac.Ft.
Seasonal Runoff Index
Long Term Mean
Diverting Dam
Sweetwater Dam
Thousands of Acre Feet at El Capitan
Relation Between Runoff at El Capitan and at Diverting Dam and Sweetwater Dam
F. E. Green



Q
1921-2 — 395.03% = 36302 Ac.Ft.
1926-7 — 351.91% = 32669 Ac.Ft.
Seasonal Runoff Index at Diverting Dam
Thousands of Acre Feet in San Vicente Creek
1914-15
1919-20
Long Term Mean
1925-6
1922-3
1924-5
1927-8
1920-1
Relation Between Runoff
From San Vicente Creek
And From Diverting Dam.
F. E. Green.

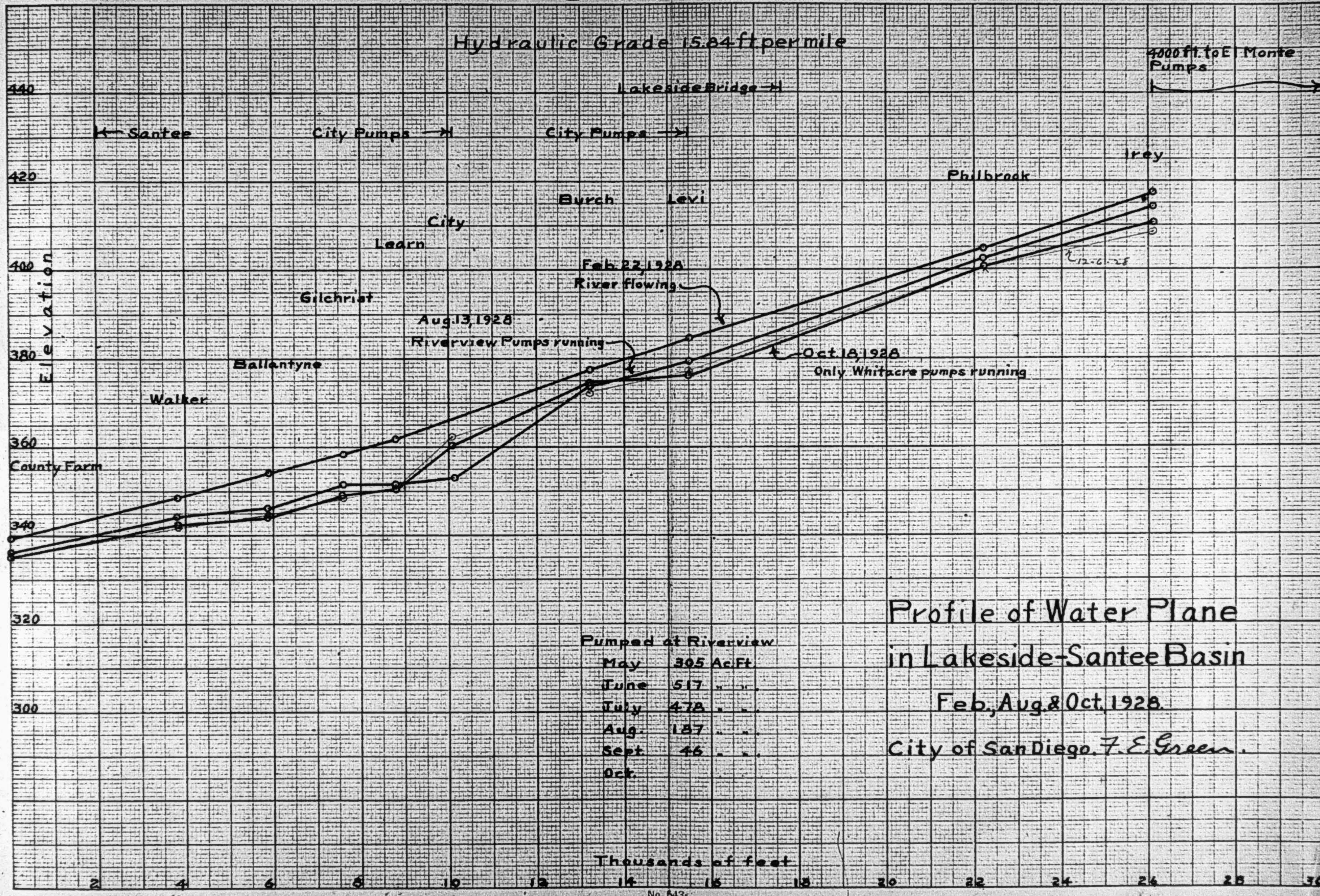
R



Trey 426.11
Philbrook 413.65
July 1 to 15, 1927
(Elevation of reference points given)
Levi 393.11
Murch 385.02
December, 1927
Learn 376.95
Gilchrist 366.50
Ballantyne 361.05
Walker 353.48
County Farm 345.52
Elevation
440
420
400
380
360
340
320
300
Pumped at Riverview
June 0 Ac.Ft.
July 266 " "
Aug 479 " "
Sept. 367 " "
Oct. 109 " "
Nov. 0 " "
Profile of Water Plane
in Lakeside-Santee Basin
July and December, 1927
City of San Diego.
F. E. Green
Thousands of Feet
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30

No. 643

S


Hydraulic Grade 15.84 ft per mile
4000 ft. to El Monte Pumps
Lakeside Bridge →|
|← Santee
City Pumps →|
City Pumps →|
Irey
Philbrook
Burch
Levi
City
Learn
Gilchrist
Ballantyne
Walker
County Farm
Elevation
440
420
400
380
360
340
320
300
Feb. 22, 1928
River flowing
Aug. 13, 1928
Riverview Pumps running
Oct. 18, 1928
Only Whitacre pumps running
12-6-28
Pumped at Riverview
May 305 Ac. Ft.
June 517 " "
July 478 " "
Aug. 187 " "
Sept. 46 " "
Oct.
Profile of Water Plane
in Lakeside-Santee Basin
Feb., Aug. & Oct. 1928.
City of San Diego. F. E. Green.
Thousands of feet
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
No. 643

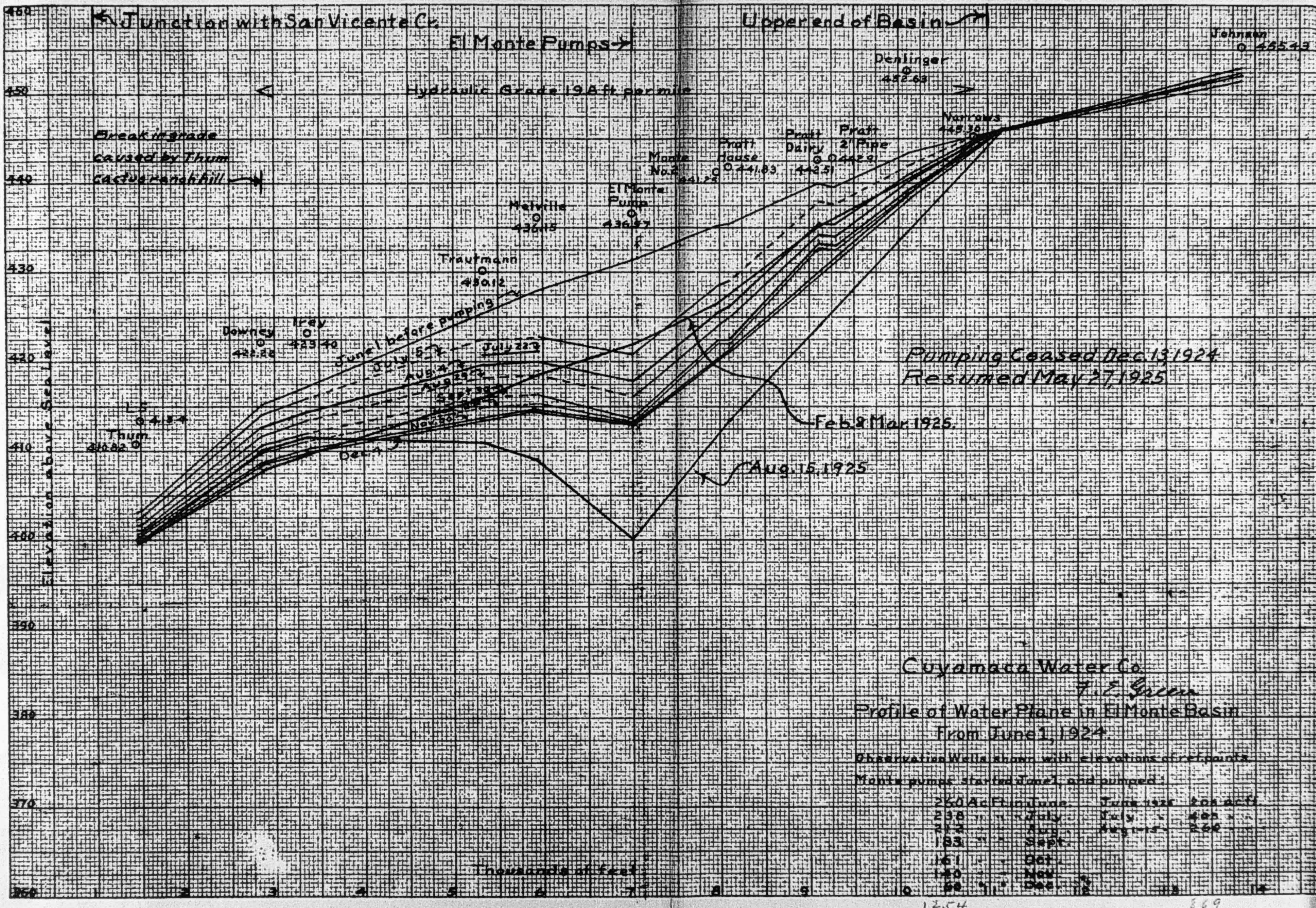
Profile of Water Plane
in Mission Valley
Apr. 30 and Dec 3, 1927
City of San Diego - F. E. Green
(Elevation of reference points given)
Jaussaud
City 54.26
Bridges 43.90
Bond 37.21
Prebisius
32.21
Madruga
30.37
Grey 28.48
Beach
10.67
April 30, 1927
Dec 3, 1927
Pumped at Mission Valley
Apr. 0 AcFt
May 213 " "
June 330 " "
July 291 " "
Aug. 120 " "
Sept. 0 " "
Oct. 74 " "
Nov. 0 " "
Dec. 18 " "
Thousands of Feet
80
70
60
50
40
30
20
10
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32

No. 543


U
Old Town Bridge
Murray Canyon Ford
City Pumps
Murphy Canyon Bridge
Hydraulic Grade 8.99 ft. per mile.
Jaussaud
April 8, 1928
City
Bridges
Oct. 17, 1928
Bond
Madruga
Grey
Beach
Elevation
Pumped at Mission Valley
March 71 Ac.Ft.
April 326
May 26
June 261
July 188
Aug 249
Sept 176
Profile of Water Plane
in Mission Valley - Apr. & Oct., 1928.
City of San Diego - F. E. Green.
Thousands of feet
No. 543


V
Santee Basin
Hydraulic Grade 13.0 ft. per mi.
Lakeside Basin
Hydraulic Grade 19.2 ft. per mi.
El Monte Basin
Hydraulic Grade 17.9 ft. per mi.
Profiles of Water Plane
Cape Horn to Old Mission Dam
City of San Diego and Cuyamaca Water Co.
F. E. Green
Oct. 11, 1925
March 27, 1922 (River flowing)
Oct. 11, 1925 (Minimum record)
June 5, 1926
Dec. 6, 1928
Dec. 4, 1924 (1254 ac. ft. pumped)
Aug. 15, 1925 (869 ac. ft. pumped)
Nov. 10, 1914 (Lee) L65
Nov. 30, 1928 (1881 ac. ft. pumped)
Nov. 18, 1926 (2532 ac. ft. pumped)
July 6, 1912 (Alverson)
Aug. 29, 1912 (Lee)
Nov. 10, 1914 (Lee)
Dr. Good
County Farm
Walker
L83
Riverview L83a
Lakeside Bridge
Philbrook
Irey
El Monte Pumps
El Monte Narrows
Cape Horn Well (200 ft. below Cape Horn and approx. 1½ mi. below head of basin.)
Thousands of Feet
(8000 ft.) Old Mission Dam
12
20
24
28
32
36
44
48
52
56
60
64
68
300
310
320
330
340
350
360
370
380
390
400
410
420
430
440
450
460
470
480
490

W



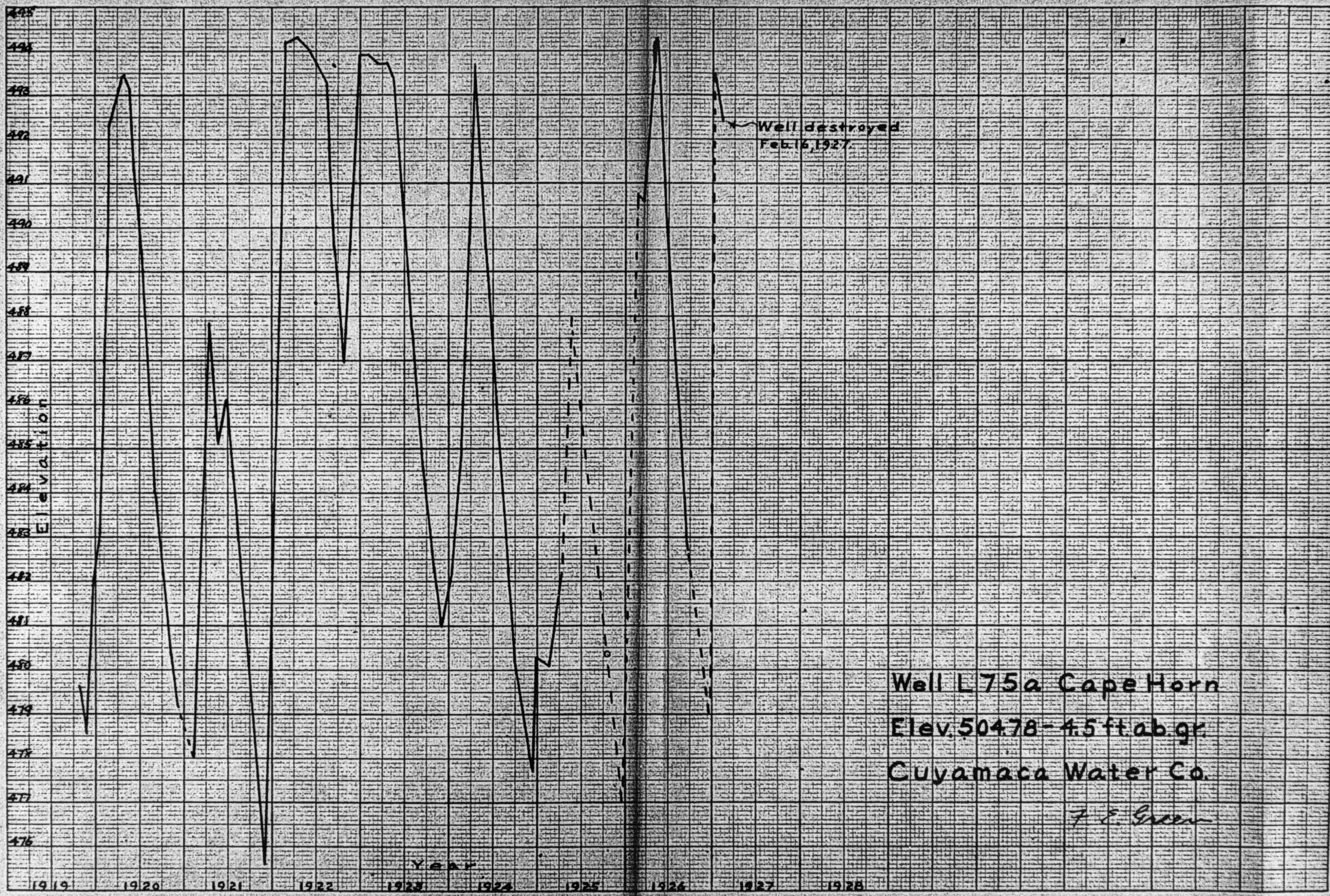
1254
869
2123

869

Monthly Rainfall at El Cajon
Rainfall Inches
Mean Normal 13.84 in.
Ground Surface
Fluctuations of Water Plane in well L65 nr. jct. of San Vicente Cr. & San Diego River. Dug well
Record after May 19, 1923, from Well L5
Cuyamaca Water Co and U.S.G.S.
Elev. L5 = 413.65-1½ ft. a.b.g.
Distance to Water Surface
Distance in ft. to water surface
Mean Normal 10.70
Year
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928

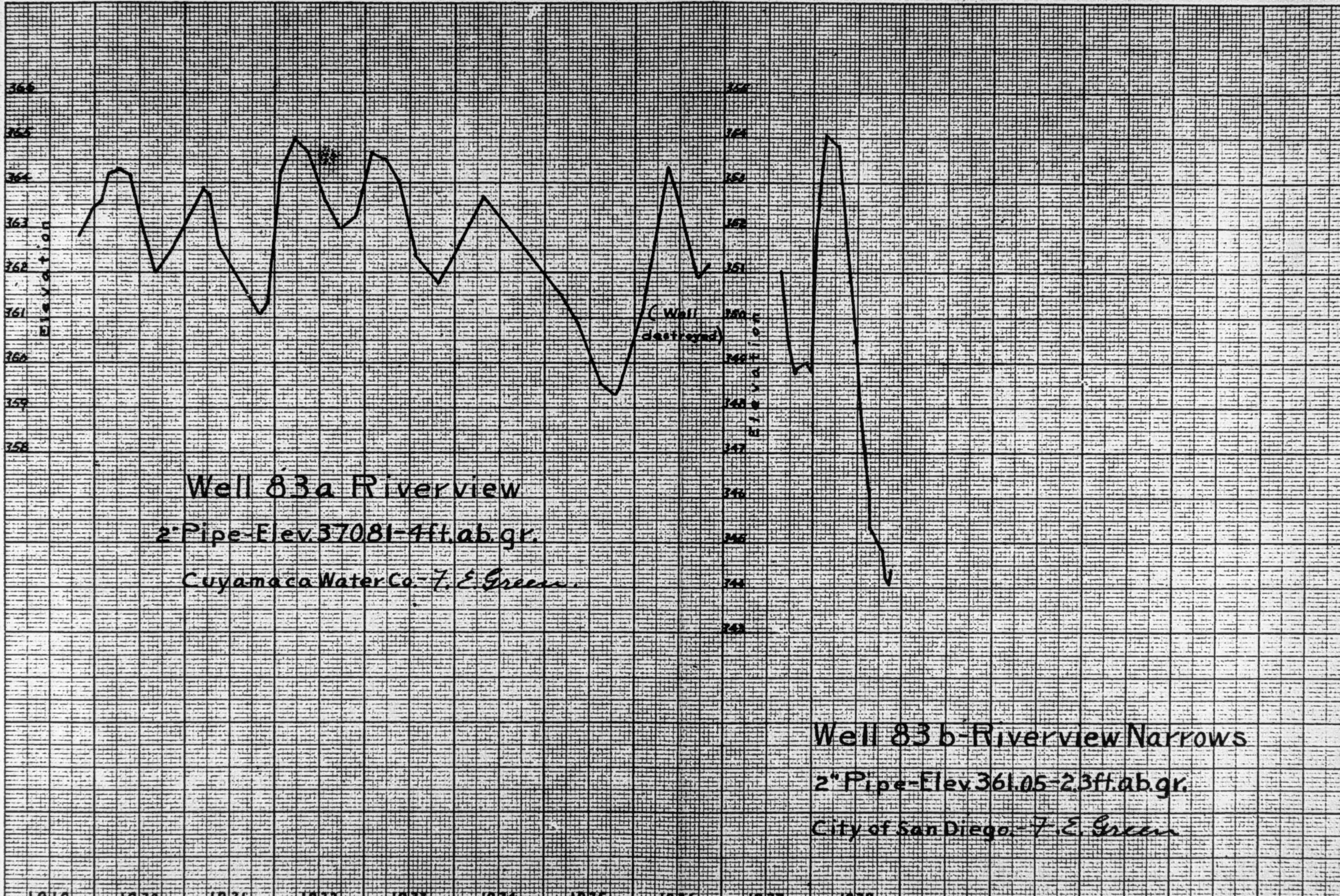
X
519
508

Y



495
494
493
492
491
490
489
488
487
486
485
484
483
482
481
480
479
478
477
476
Elevation
Year
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
Well destroyed Feb. 16, 1927.
Well L 75a Cape Horn
Elev. 504.78 - 4.5 ft. ab. gr.
Cuyamaca Water Co.
F. E. Green
No. 643

Z


366
365
364
363
362
361
360
359
358
Elevation
355
354
353
352
351
350
349
348
347
346
345
344
343
Elevation
(Well destroyed)
Well 83a Riverview
2" Pipe-Elev. 37081-4ft. ab. gr.
Cuyamaca Water Co.- F. E. Green.
Well 83b-Riverview Narrows
2" Pipe-Elev. 361.05-2.3ft. ab. gr.
City of San Diego.- F. E. Green
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928

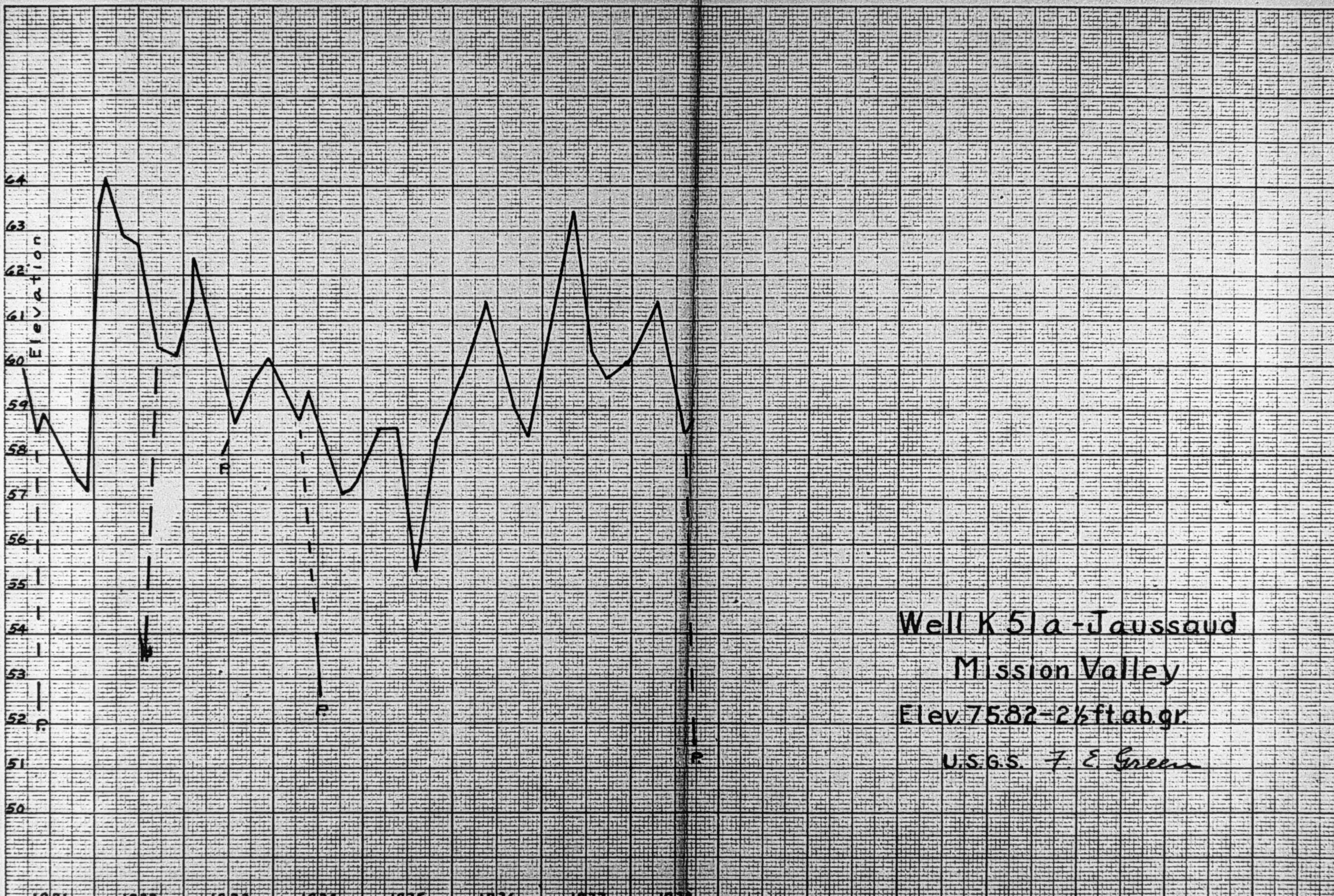
No. 543

AA

326
325
324
323
322
321
320
319
318
317
316
315
314
313
Elevation
P.
P.
P.
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
Well L85-Good-Santee
Elev. 332.94-Ground level
U.S.G.S. F. E. Green

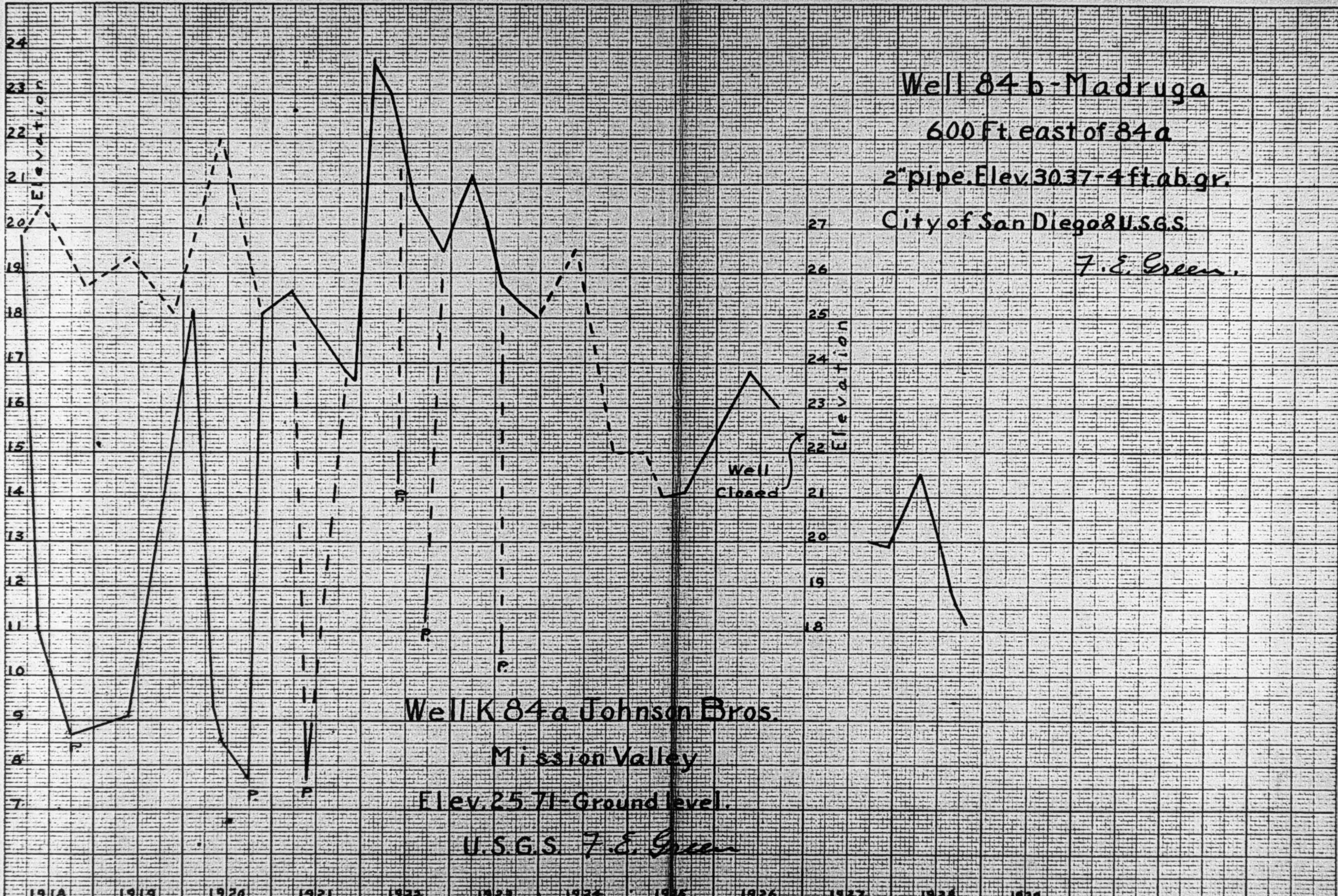
No. 643

B B


64
63
62
61
60
59
58
57
56
55
54
53
52
51
50
Elevation
P
P
P
P
P
1921
1922
1923
1924
1925
1926
1927
1928
Well K 51a - Jaussaud
Mission Valley
Elev. 75.82 - 2½ ft. ab. gr.
U.S.G.S. F. E. Green

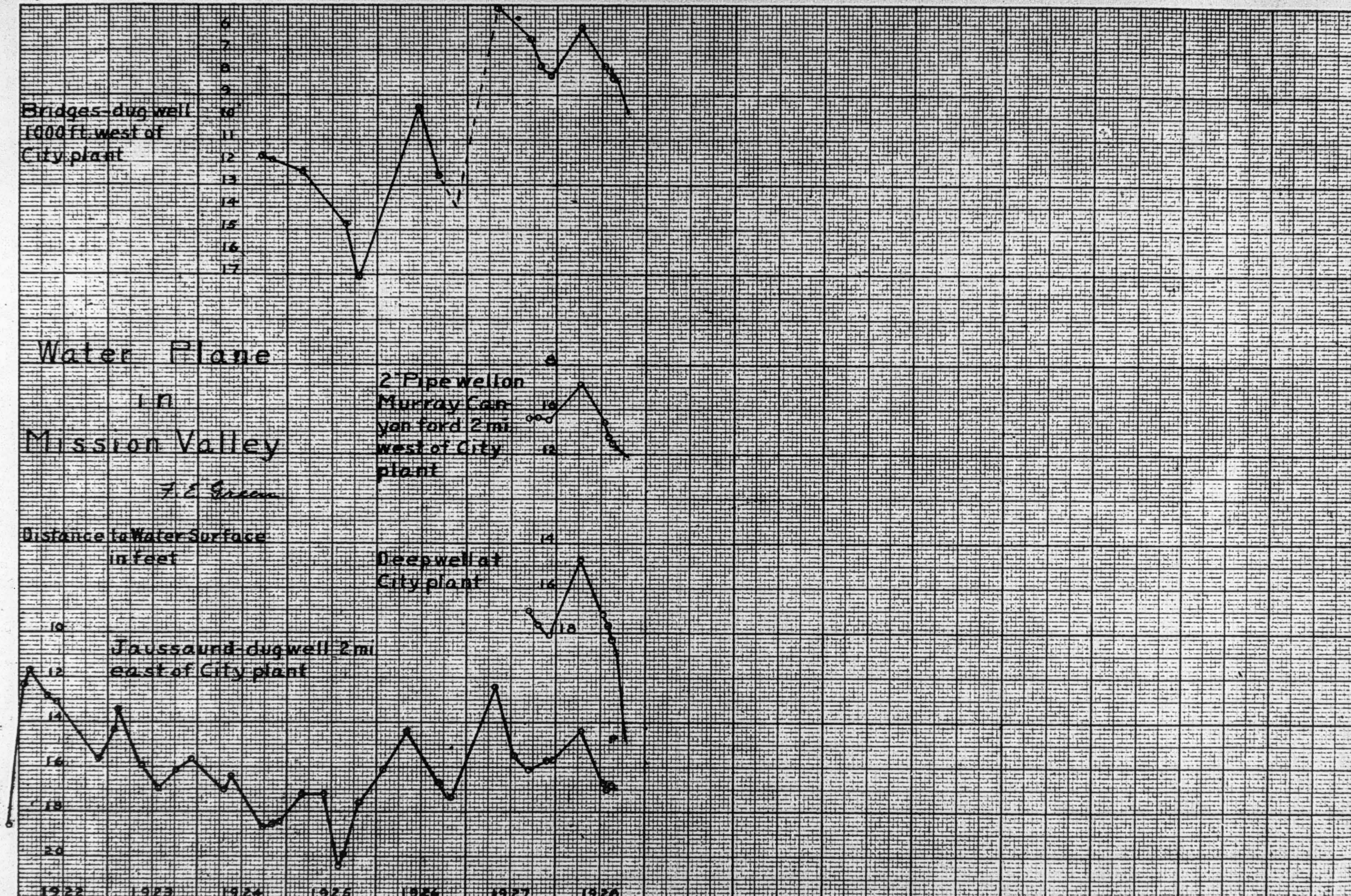
No. 543

C C



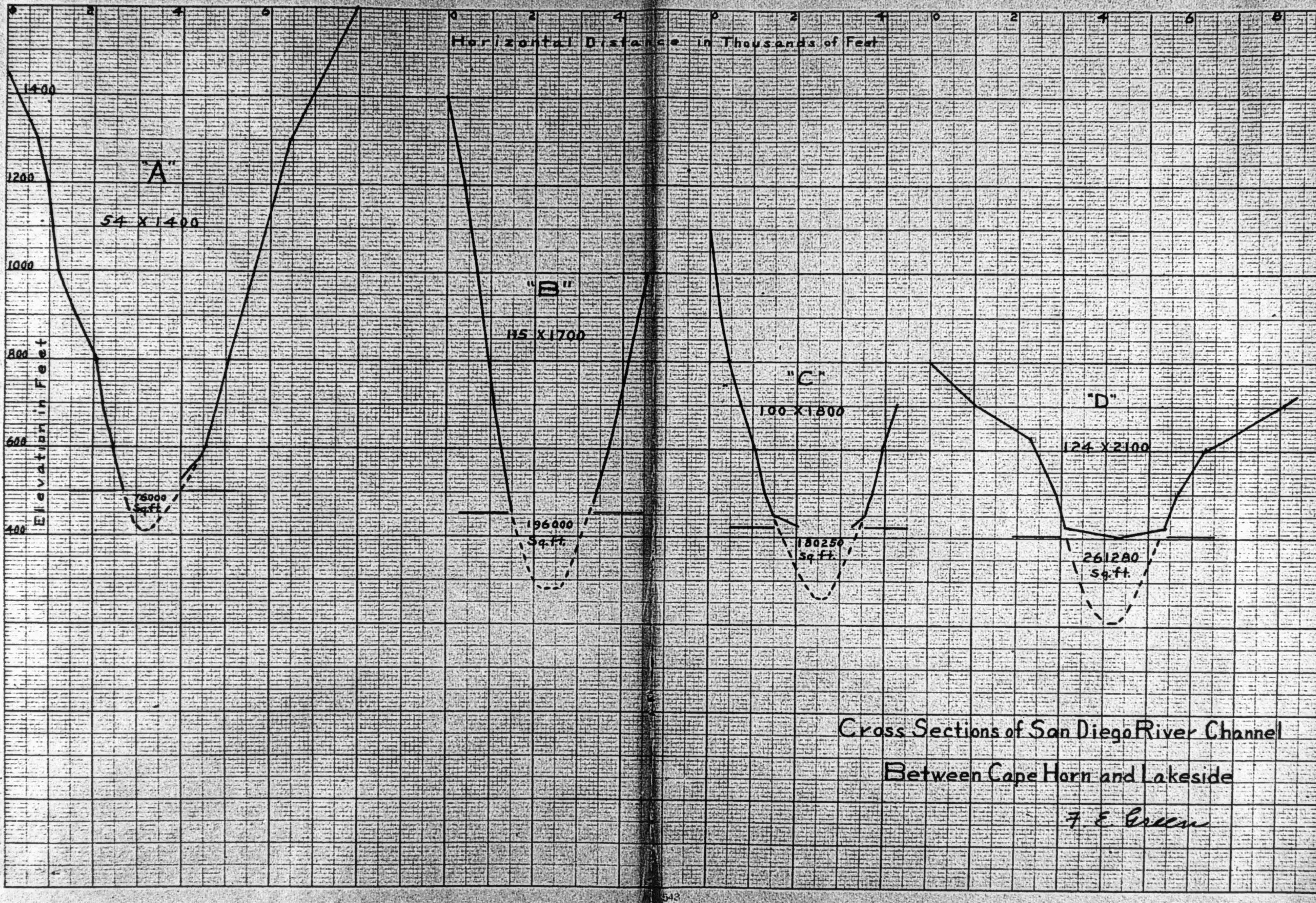
Well 84 b - Madruga
600 Ft. east of 84 a
2" pipe. Elev. 30.37 - 4 ft. ab. gr.
City of San Diego & U.S.G.S.
F. E. Green.
Well K 84 a Johnson Bros.
Mission Valley
Elev. 25.71 - Ground level.
U.S.G.S. F. E. Green
Elevation
Well Closed
P
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929

D D


Bridges-dug well 1000 ft. west of City plant
Water Plane in Mission Valley
F. E. Green
Distance to Water Surface in feet
2" Pipe well on Murray Canyon ford 2 mi. west of City plant
Deep well at City plant
Jaussaund-dug well 2 mi east of City plant
1922
1923
1924
1925
1926
1927
1928

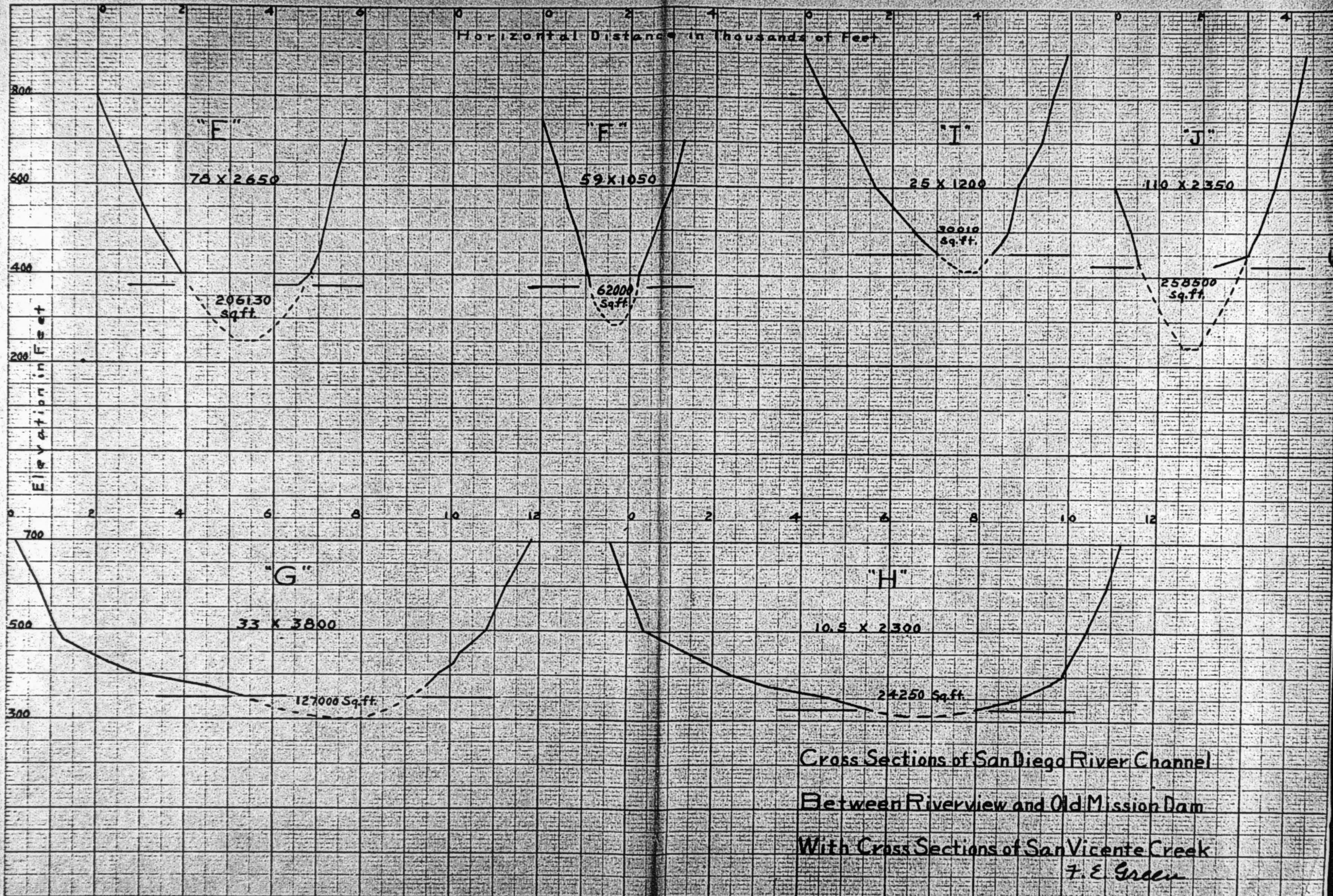
No. 543

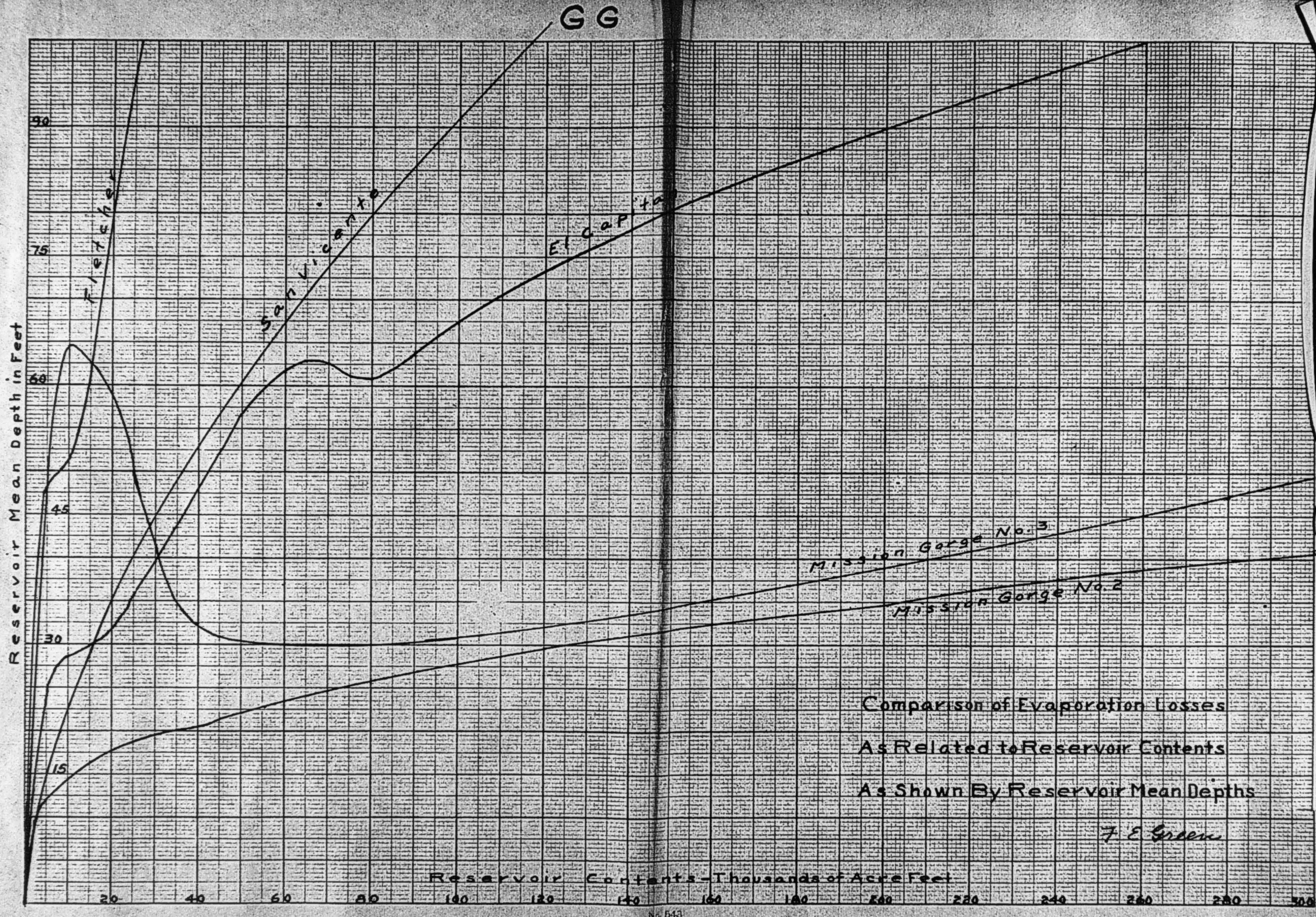
EE



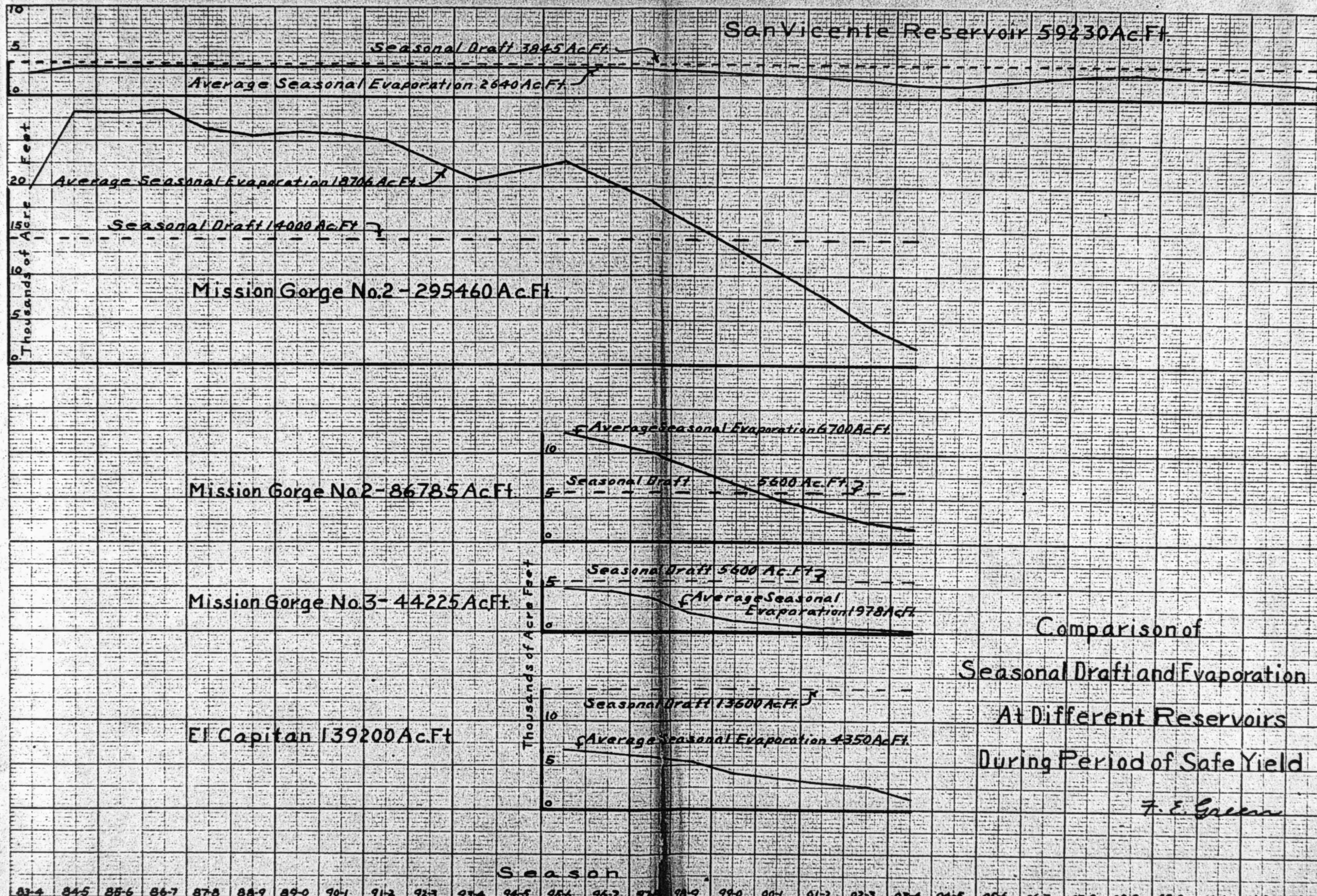
Horizontal Distance in Thousands of Feet
Elevation in Feet
0
2
4
6
8
1400
1200
1000
800
600
400
"A"
54 X 1400
76000 Sq.ft.
"B"
115 X 1700
196000 Sq.ft.
"C"
100 X 1800
180250 Sq.ft.
"D"
124 X 2100
261280 Sq.ft.
Cross Sections of San Diego River Channel
Between Cape Horn and Lakeside
F. E. Green

F F


Horizontal Distance in Thousands of Feet
Elevation in Feet
"E"
78 X 2650
206130 sq.ft.
"F"
59 X 1050
62000 Sq.ft.
"I"
25 X 1200
30010 Sq.ft.
"J"
110 X 2350
258500 sq.ft.
"G"
33 X 3800
127000 Sq.ft.
"H"
10.5 X 2300
24250 Sq.ft.
Cross Sections of San Diego River Channel
Between Riverview and Old Mission Dam
With Cross Sections of San Vicente Creek
F. E. Green

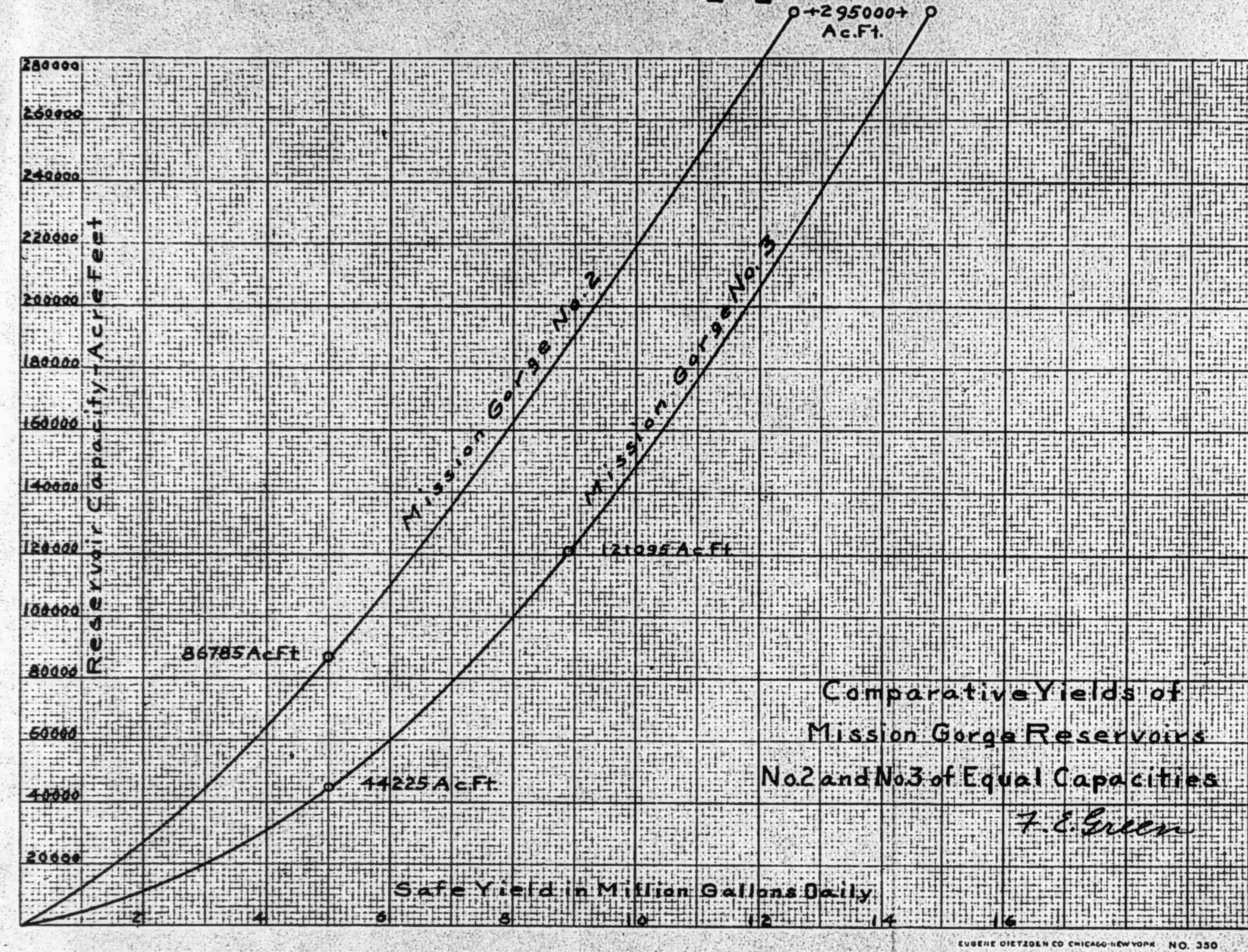

GG
Reservoir Mean Depth in Feet
90
75
60
45
30
15
Fletcher
San Vicente
El Capitan
Mission Gorge No. 3
Mission Gorge No. 2
Reservoir Contents - Thousands of Acre Feet
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
Comparison of Evaporation Losses
As Related to Reservoir Contents
As Shown By Reservoir Mean Depths
F. E. Green
No. 543

HH

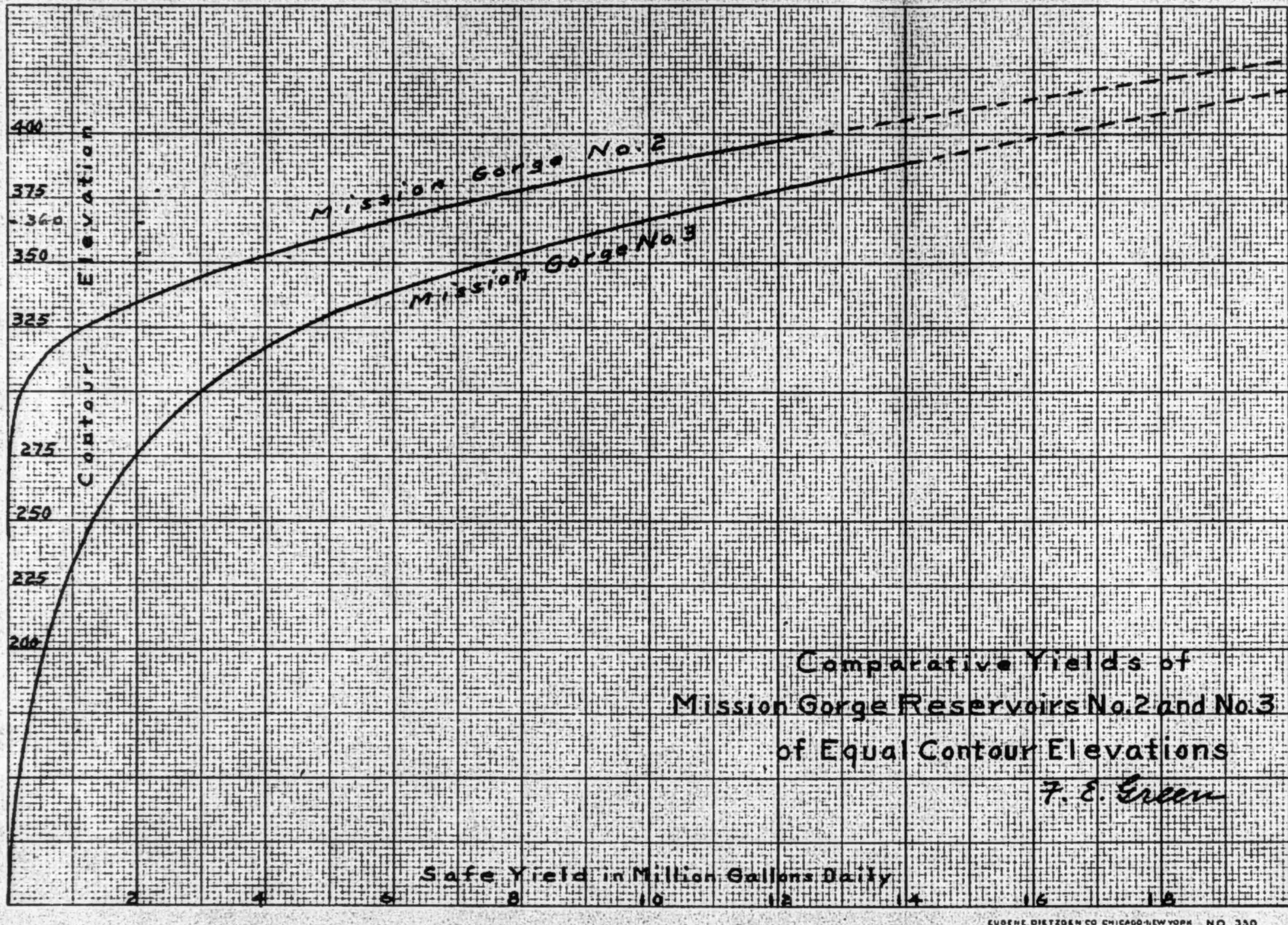


Comparison of Seasonal Draft and Evaporation At Different Reservoirs During Period of Safe Yield

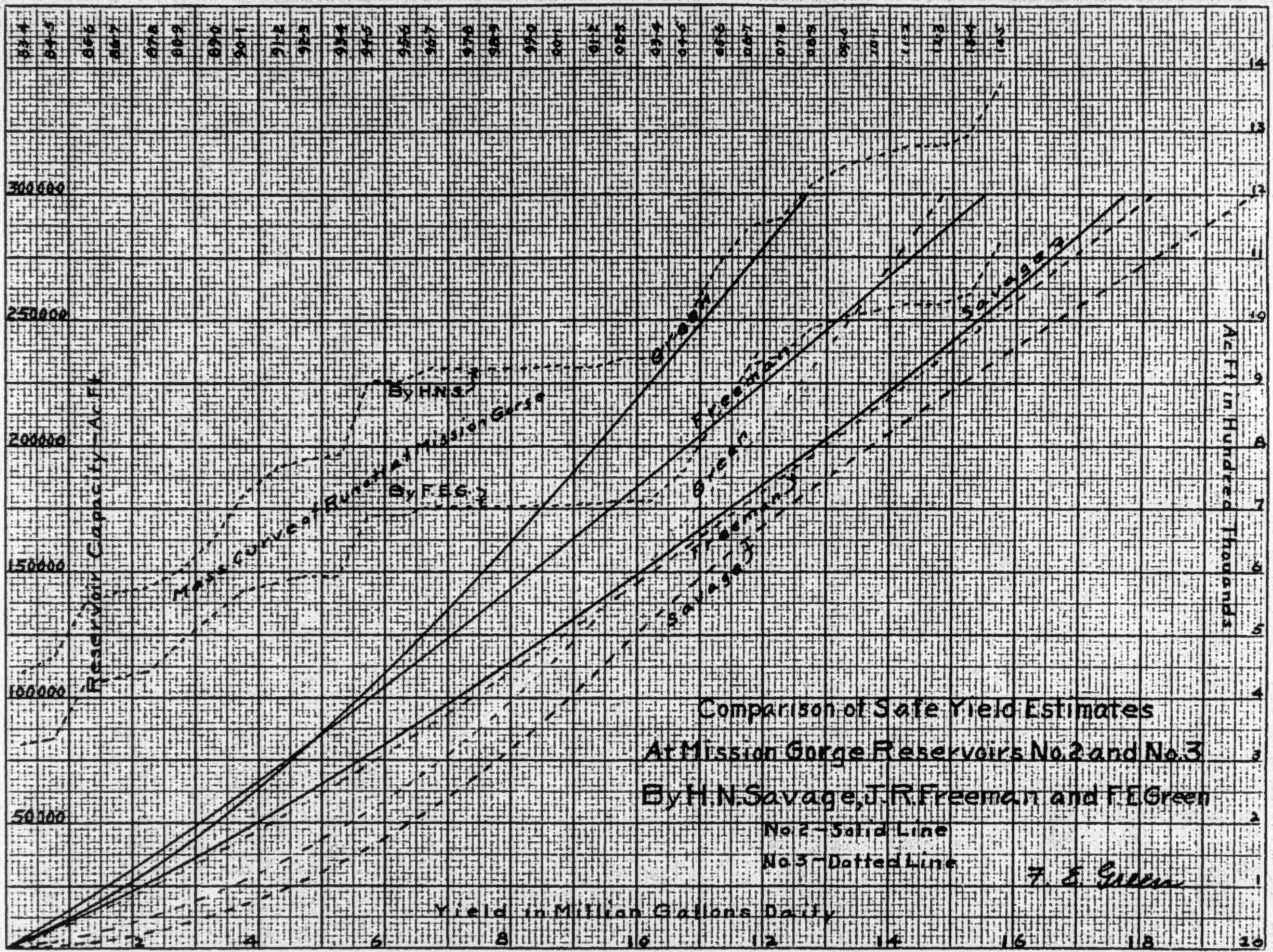
F. E. Green


+295000+ Ac.Ft.
280000
260000
240000
220000
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
Reservoir Capacity - Acre Feet
Mission Gorge No. 2
Mission Gorge No. 3
121095 Ac.Ft.
86785 Ac.Ft.
44225 Ac.Ft.
Safe Yield in Million Gallons Daily
2
4
6
8
10
12
14
16
Comparative Yields of
Mission Gorge Reservoirs
No.2 and No.3 of Equal Capacities
F. E. Green
EUGENE DIETZGEN CO CHICAGO-NEW YORK NO. 330

JJ

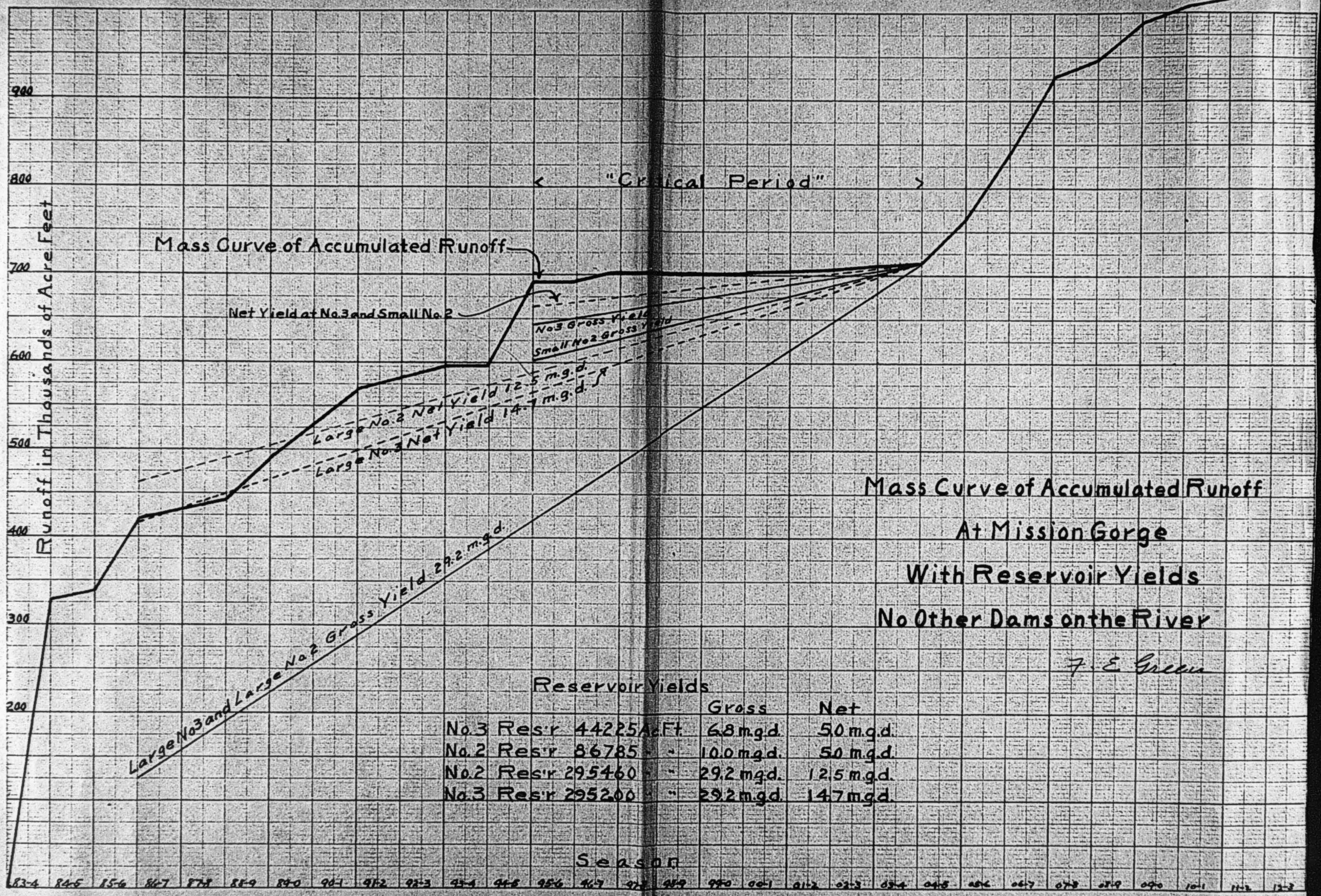

Contour Elevation
400
375
360
350
325
275
250
225
200
Mission Gorge No. 2
Mission Gorge No. 3
Safe Yield in Million Gallons Daily
2
4
6
8
10
12
14
16
18
Comparative Yields of
Mission Gorge Reservoirs No. 2 and No. 3
of Equal Contour Elevations
F. E. Green

KK



Comparison of Safe Yield Estimates
At Mission Gorge Reservoirs No.2 and No.3
By H.N.Savage, J.R.Freeman and F.E.Green
No.2 – Solid Line
No.3 – Dotted Line
F. E. Green
Reservoir Capacity – Ac.Ft.
Ac.Ft. in Hundred Thousands
Yield in Million Gallons Daily
Mass Curve of Runoff at Mission Gorge
By H.N.S.
By F.E.G.
Green
Freeman
Savage
300000
250000
200000
150000
100000
50000
2
4
6
8
10
12
14
16
18
20

LL



Mass Curve of Accumulated Runoff
At Mission Gorge
With Reservoir Yields
No Other Dams on the River
F. E. Green
Runoff in Thousands of Acre Feet
900
800
700
600
500
400
300
200
"Critical Period"
Mass Curve of Accumulated Runoff
Net Yield at No. 3 and Small No. 2
No. 3 Gross Yield
Small No. 2 Gross Yield
Large No. 2 Net Yield 12.5 m.g.d.
Large No. 3 Net Yield 14.7 m.g.d.
Large No. 3 and Large No. 2 Gross Yield 29.2 m.g.d.
Reservoir Yields
Gross Net
No. 3 Res'r 44225 Ac.Ft. 6.8 m.g.d. 5.0 m.g.d.
No. 2 Res'r 86785 " " 10.0 m.g.d. 5.0 m.g.d.
No. 2 Res'r 295460 " " 29.2 m.g.d. 12.5 m.g.d.
No. 3 Res'r 295200 " " 29.2 m.g.d. 14.7 m.g.d.
Season
83-4
84-5
85-6
86-7
87-8
88-9
89-0
90-1
91-2
92-3
93-4
94-5
95-6
96-7
97-8
98-9
99-0
00-1
01-2
02-3
03-4
04-5
05-6
06-7
07-8
08-9
09-0
10-1
11-2
12-3

MM
6 Sheets

THE FREDERICK POST CO. OF OREGON
PORTLAND OREGON

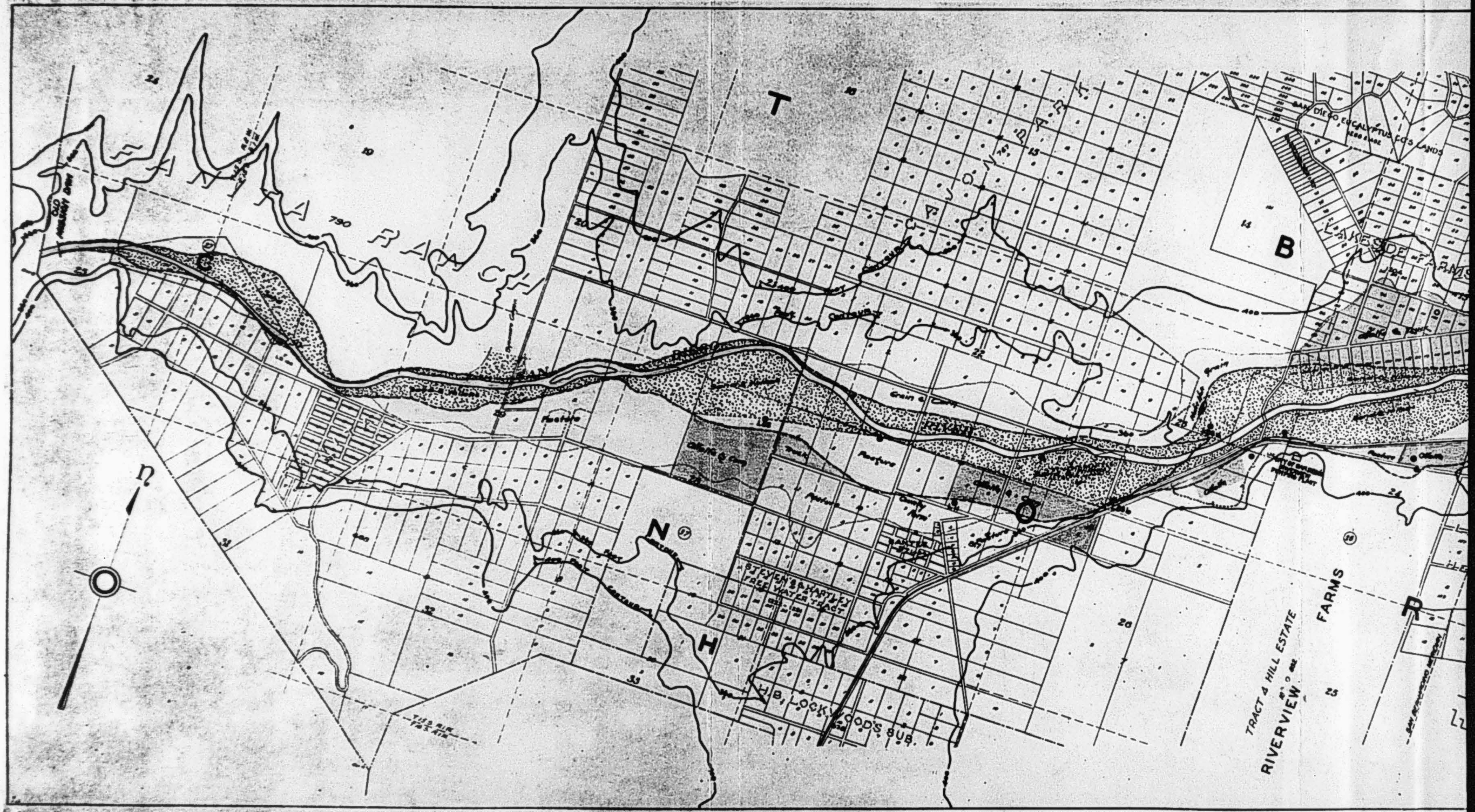
THE FREDERICK POST CO. OF OREGON
PORTLAND, OREGON

THE FREDERICK POST CO. OF OREGON
PORTLAND, OREGON


Hydrograph of Runoff
At El Capitan
Showing Possible Diversions
F. E. Green
January February March April May June July August September October November December
Cubic Feet Per Second
1921 X 1920
At 15.5 Sec.Ft.
Diverted 1155 Ac.Ft. = 1.03 m.g.d. or 2.81 m.g.d. for Div. period of 134 days
Wasted 466 " "
Total 1621 " "
At 50 Sec.Ft.
Diverted 1469 Ac.Ft. = 1.31 m.g.d. or 3.57 m.g.d. for Div. period of 134 days
Wasted 152 " "
Total 1621 " "
At 100 Sec.Ft.
Diverted 1469 Ac.Ft. = 1.31 m.g.d. or 3.57 m.g.d. for Div. period of 134 days
Wasted 152 " "
Total 1621 " "
1926 X 1925
At 100 Sec.Ft.
Diverted 4471 Ac.Ft. = 3.99 m.g.d. or 12.14 m.g.d. for Div. period of 120 days
Wasted 11721 " "
Total 16192 " "
At 50 Sec.Ft.
Diverted 3033 Ac.Ft. = 2.71 m.g.d. or 8.26 m.g.d. for Div. period of 120 days
Wasted 13159 " "
Total 16192 " "
At 15.5 Sec.Ft.
Diverted 1523 Ac.Ft. = 1.36 m.g.d. or 4.14 m.g.d. for Div. period of 120 days
Wasted 14669 " "
Total 16192 " "


Hydrograph of Runoff
at El Capitan
Showing Possible Diversions
F. E. Green
Cubic Feet Per Second
January
February
March
April
May
June
July
August
September
October
November
December
At 15.5 Sec. Ft.
Diverted 5460 [or 5468] Ac. Ft. = 4.87 m.g.d., or 7.32 m.g.d. for Div period of 243 days
Wasted 95240 " "
Total 100700 " "
At 50 Sec. Ft.
Diverted 13.688 Ac. Ft. = 12.22 m.g.d., or 23.25 m.g.d. for Div period of 243 days
Wasted 87012 " "
Total 100700 " "
At 100 Sec. Ft.
Diverted 21670 Ac. Ft. = 19.35 m.g.d., or 29.06 m.g.d. for Div period of 243 days
Wasted 79031 " "
Total 100781 " "
1927 X 1926

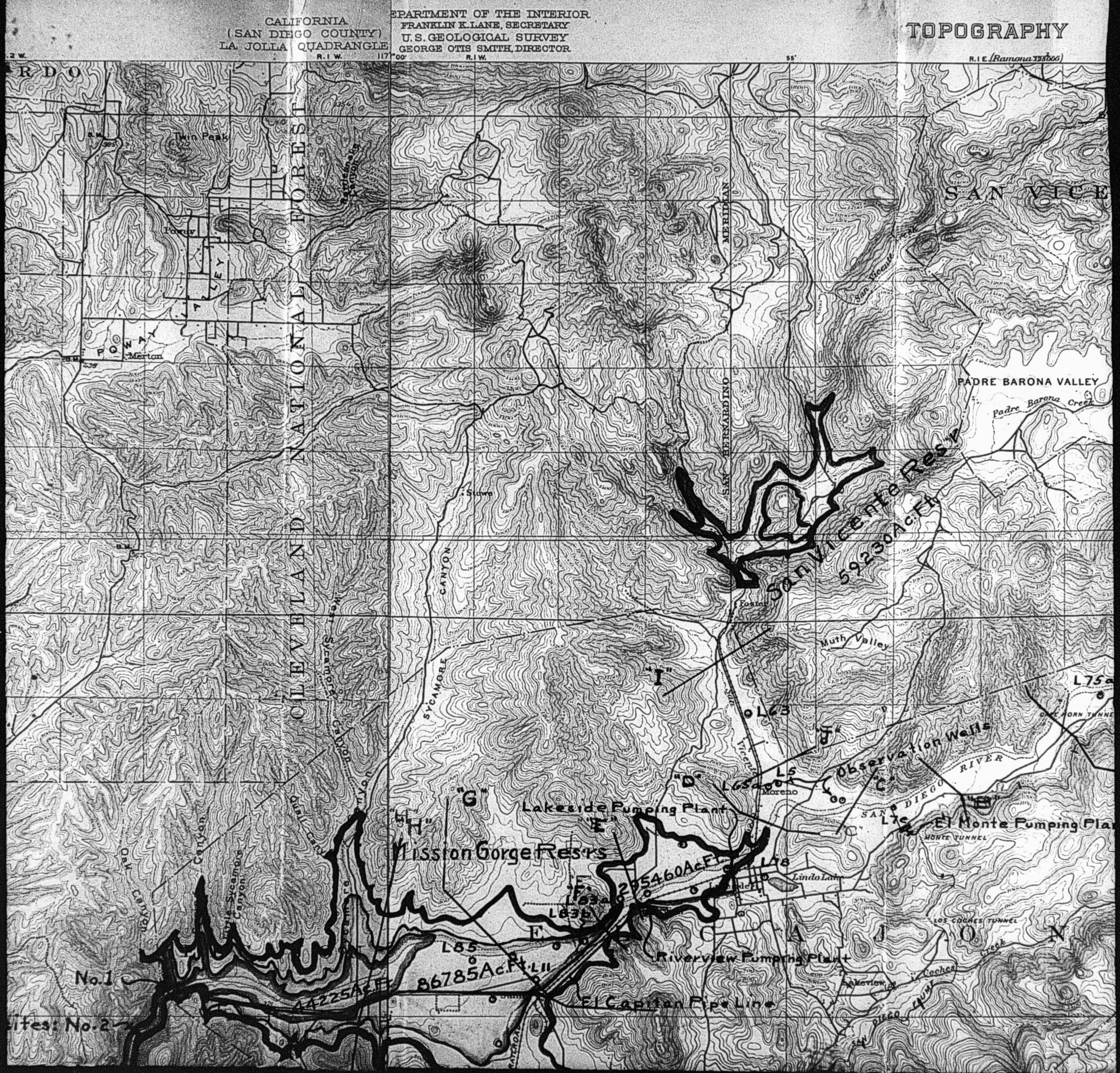

Hydrograph of Runoff
At El Capitan
Showing Possible Diversions
F. E. Green
1925 × 1924
1928 × 1927
January
February
March
April
May
June
July
August
September
October
November
December
Cubic Feet Per Second
At 15.5 Sec. Ft.
Diverted 1632 Ac.Ft. = 1.46 m.g.d., or 2.51 m.g.d. for Div. period of 212 days.
Wasted 1516 " "
Total 3148 " "
At 50 Sec. Ft.
Diverted 2388 Ac.Ft. = 2.13 m.g.d., or 3.67 m.g.d. for Div. period of 212 days.
Wasted 760 " "
Total 3148 " "
At 100 Sec. Ft.
Diverted 2824 Ac.Ft. = 2.52 m.g.d. or 4.34 m.g.d. for Div. period of 212 days.
Wasted 324 " "
Total 3148 " "
At 15.5 Sec. Ft.
Diverted 3649 Ac.Ft. = 3.26 m.g.d., or 5.58 m.g.d. for Div. period of 213 days.
Wasted 1051 " "
Total 4700 " "
At 50 Sec. Ft.
Diverted 4541 Ac.Ft. = 4.05 m.g.d., or 6.95 m.g.d. for Div. period of 213 days.
Wasted 159 " "
Total 4700 " "
At 100 Sec. Ft.
Diverted 4591 Ac.Ft. = 4.10 m.g.d., or 7.02 m.g.d. for Div. period of 213 days.
Wasted 109 " "
Total 4700 " "

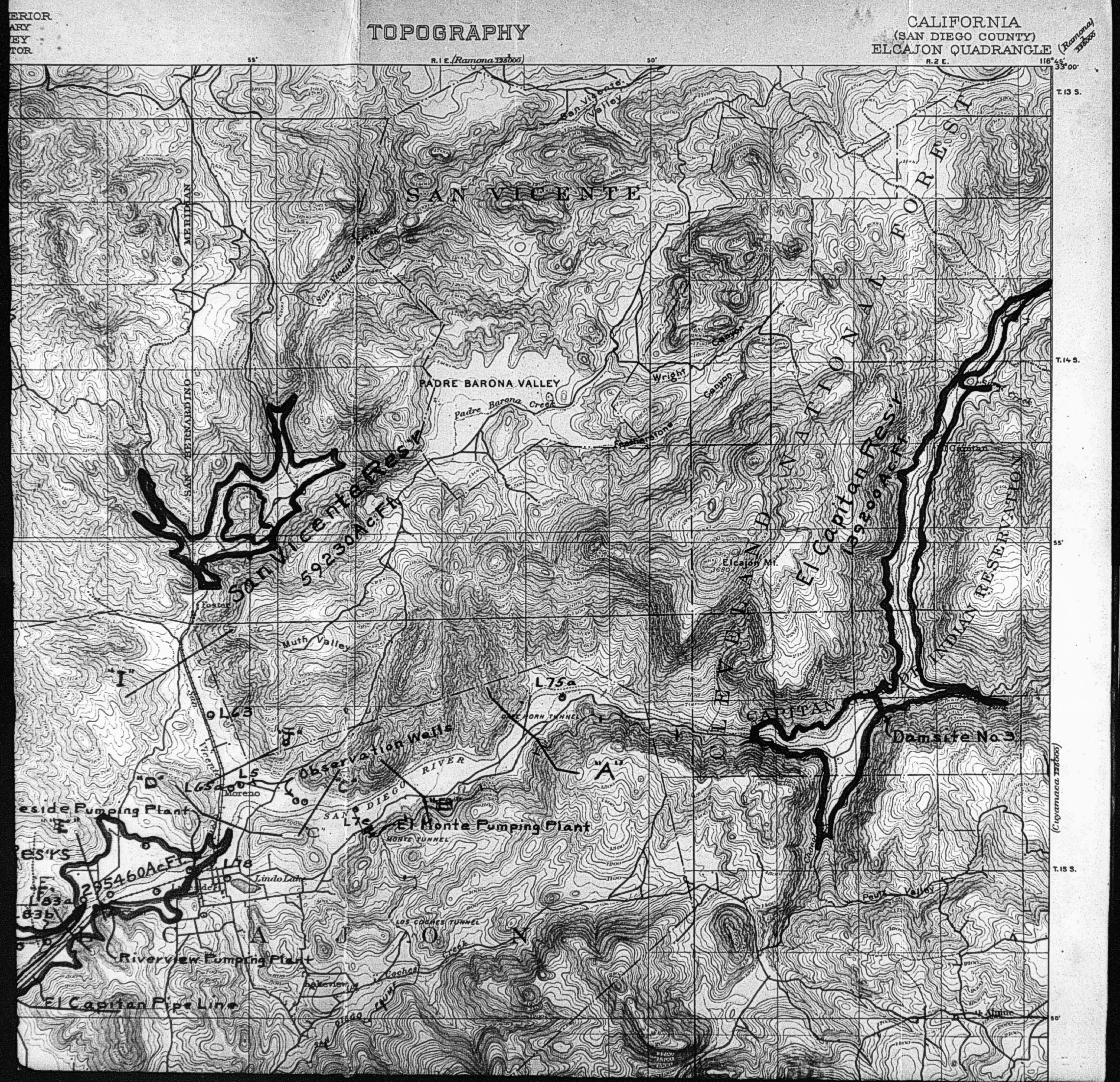


T
B
N
O
H
R
SAN DIEGO EUCALYPTUS CO'S LANDS
LAKESIDE FARMS
Pasture
STEVENS & HARTLEY FREE WATER TRACT
H.B. LOCKWOOD'S SUB.
TRACT 4 HILL ESTATE
RIVERVIEW
FARMS

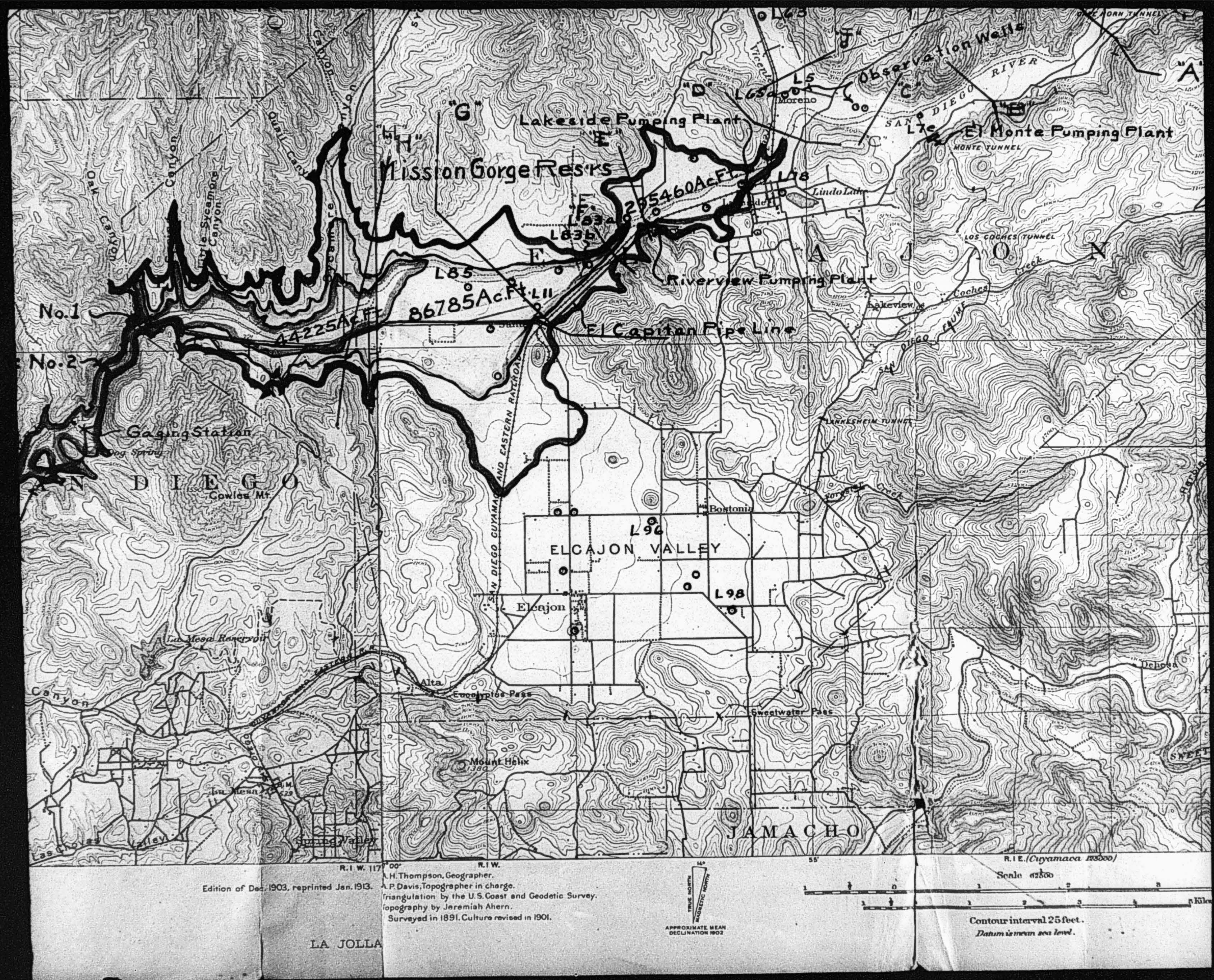

SAN DIEGO RIVER
FROM
OLD MISSION DAM TO CAPE HORN
SHOWING AREA OF WATER BEARING GRAVELS
AND
APPROXIMATE CULTIVATED AREA
SCALE
SAN DIEGO EUCALYPTUS CO'S LANDS
LAKESIDE FARMS
LAKESIDE HEIGHTS
TRACT 2 HILL ESTATE
TRACT 3 HILL ESTATE
TRACT 4 HILL ESTATE
RIVERVIEW FARMS
SAN DIEGO RIVER
EL MONTE PARK
LAKEVIEW
B
D
R
S


U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH
DIRECTOR
TOPOGRAPHY
R.4 W.
117°15'
R.3 W.
R.2 W.
(Escondido)
SAN BERNARDO
SAN DIEGUITO
RIVER
VALLEY
La Zanja Canyon
Black Mt.
Black Mountain
LOS PENASQUITOS
McGonigle Canyon
Delmar
Soledad
Valley
SURF LINE
Sorrento
Carroll
Canyon
Miramar
Linda Vista
La Laguna
PUEBLO
Selwyn
CANYON
SAN CLEMENTE
La Jolla
Soledad Mt.
Shepherd Canyon
Damsites: No.2

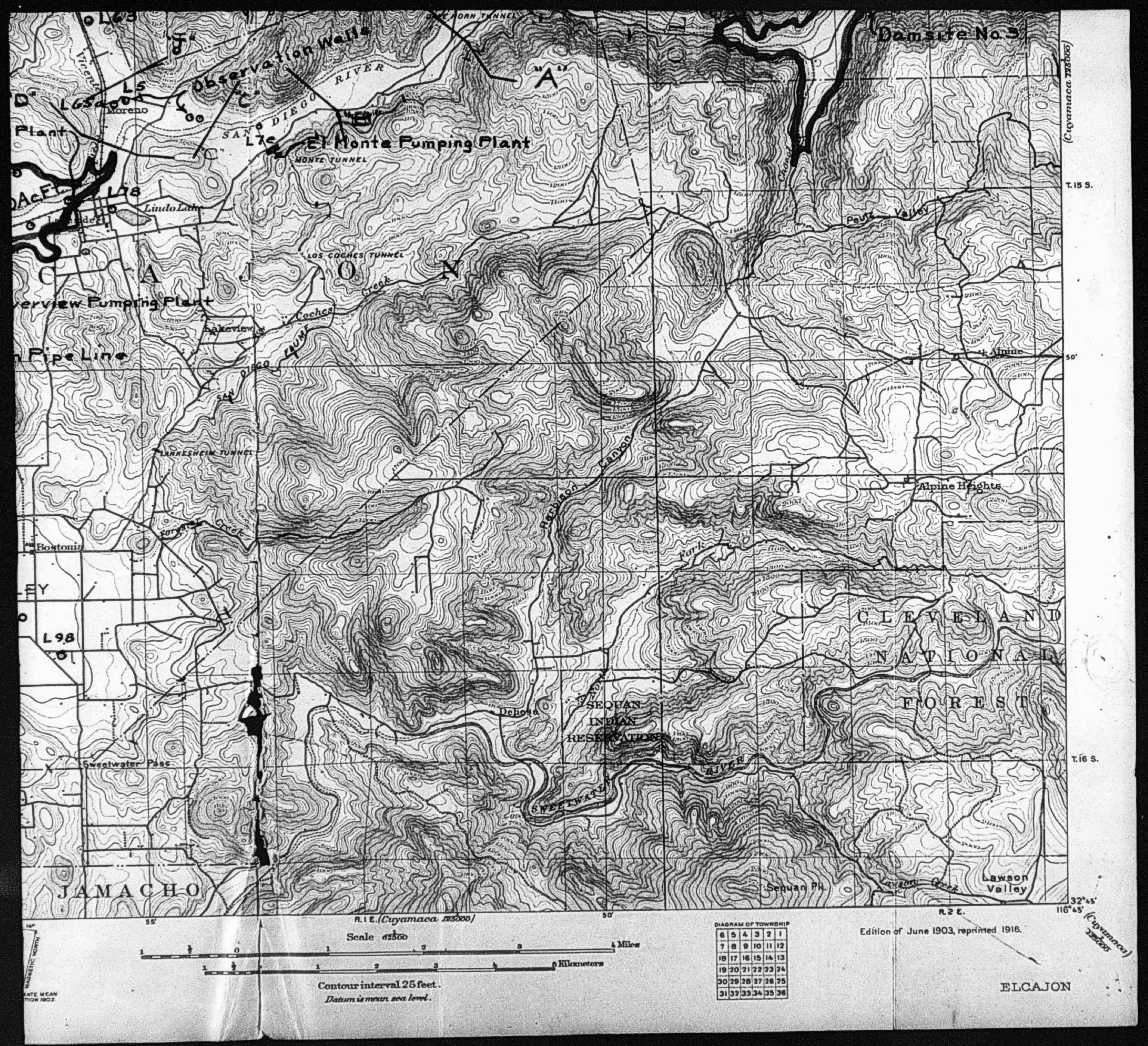

CALIFORNIA
(SAN DIEGO COUNTY)
LA JOLLA QUADRANGLE
DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, SECRETARY
U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR
TOPOGRAPHY
R.I.W.
117°00'
55'
R.I.E. (Ramona 1:125000)
Twin Peak
Poway
POWAY
Merton
CLEVELAND NATIONAL FOREST
SAN VICE
MERIDIAN
SAN BERNARDINO
PADRE BARONA VALLEY
Padre Barona Creek
San Vicente Resr
59230 Ac.Ft.
Stowe
CANYON
SYCAMORE
Foster
Muth Valley
"I"
L63
L75a
"J"
Observation Wells
SAN DIEGO RIVER
"D"
L65a
L5
Moreno
"C"
"B"
"G"
"H"
"E"
Lakeside Pumping Plant
L7c
El Monte Pumping Plant
Mission Gorge Resrs
L78
Lindo Lake
"F"
295460 Ac.Ft.
L63a
L63b
LOS COCHES TUNNEL
E
C
A
J
O
N
L85
Riverview Pumping Plant
No.1
86785 Ac.Ft.
L11
44225 Ac.Ft.
Lakeview
El Capitan Pipe Line
Sites: No.2
Oak Canyon
Canyon
Little Sycamore Canyon
West Sycamore Canyon


TOPOGRAPHY
CALIFORNIA
(SAN DIEGO COUNTY)
ELCAJON QUADRANGLE
SAN VICENTE
San Vicente Valley
San Vicente Creek
MERIDIAN
SAN BERNARDINO
PADRE BARONA VALLEY
Padre Barona Creek
Wright Canyon
Canyon
San Vicente Res'r
59230 Ac. Ft.
El Capitan Res'r
139200 Ac. Ft.
CLEVELAND NATIONAL FOREST
INDIAN RESERVATION
El Capitan
Elcajon Mt.
CAPITAN
Damsite No. 3
Foster
Muth Valley
"I"
L75a
L63
"J"
"A"
Observation Wells
SAN DIEGO RIVER
L5
"D"
L65a
Moreno
"C"
"B"
L7c
El Monte Pumping Plant
MONTE TUNNEL
Lakeside Pumping Plant
"E"
Res'rs
295460 Ac. Ft.
L78
Lindo Lake
"F"
L83a
L83b
Riverview Pumping Plant
LOS COCHES TUNNEL
Los Coches Creek
Peutz Valley
El Capitan Pipe Line
Alpine
T. 13 S.
T. 14 S.
T. 15 S.
R. 1 E.
R. 2 E.

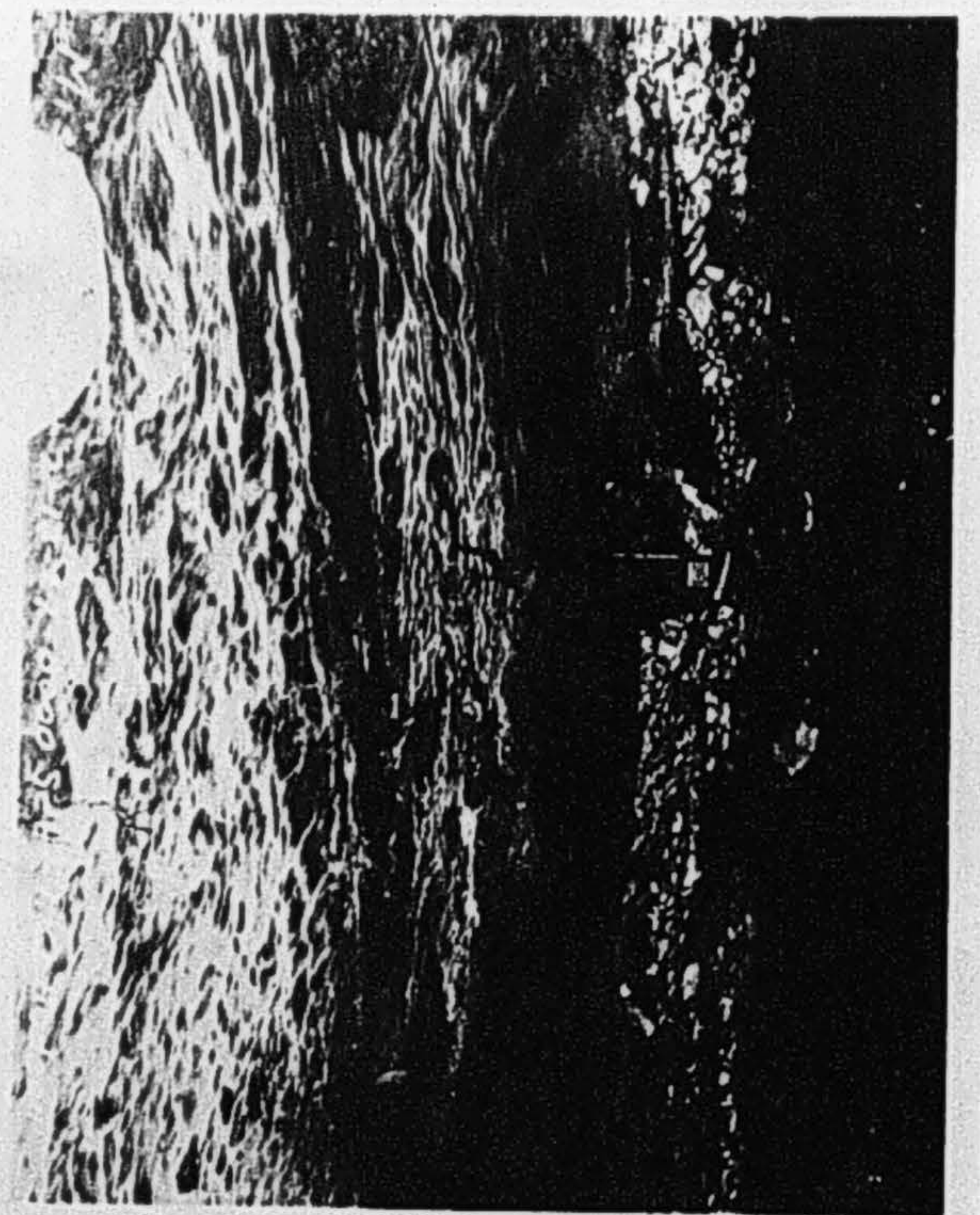
Damsites: No.2
No.1
No.3
EX MISSION SAN
Mission Valley Pumping Plant
K84
K33
K51
MISSION VALLEY
SAN DIEGO
PACIFIC OCEAN
La Jolla
Soledad Mt
La Laguna
Linda Vista
Selwyn
SAN CLEMENTE
CANYON
Rose Canyon
Ladrillo
Atwood
Pacific Beach
False Pt.
False Bay
Bay Pt.
Dunkville
Morena
Medanos Pt.
Old Town
North San Diego
Rosedale
Murray Canyon
Murphy Canyon
Shepherd Canyon
Grantville
Gravilla
EX MISSION SAN DIEGO
Alvarado Canyon
Las Choyas
(San Diego)
117°15'
32°45'
R. U. Goode, Geographer in charge.
Triangulation by U.S. Coast and Geodetic Survey and A.P. Davis.
Topography by J. E. Rockhold.
Surveyed in 1901-1902.
APPROXIMATE MEAN DECLINATION 1902.
Scale
Miles
Kilometers
Contour interval 25 feet.
Datum is mean sea level.



Observation Wells
"A"
"B"
"C"
"D"
"E"
"F"
"G"
"H"
"J"
SAN DIEGO RIVER
Moreno
L5
L65
L7e
L78
L63a
L63b
L85
L11
L96
L98
Lakeside Pumping Plant
El Monte Pumping Plant
MONTE TUNNEL
Mission Gorge Res'rs
295460 Ac.Ft.
86785 Ac.Ft.
44225 Ac.Ft.
Lindo Lake
LOS COCHES TUNNEL
Riverview Pumping Plant
El Capitan Pipe Line
Lakeview
Coches Creek
SAN DIEGO FLUME
LANKERSHEIM TUNNEL
No.1
No.2
Oak Canyon
Sycamore Canyon
Quail Canyon
Gaging Station
Dog Spring
SAN DIEGO
EL CAJON
Cowles Mt.
SAN DIEGO CUYAMACA AND EASTERN RAILROAD
Bostonia
ELCAJON VALLEY
Elcajon
Forester Creek
La Mesa Reservoir
Alta
Eucalyptus Pass
Sweetwater Pass
Dehesa
Canyon
Mount Helix
La Mesa
Spring Valley
Las Chollas Valley
JAMACHO
R.I.W. 117° 00'
R.I.W.
55'
R.I.E. (Cuyamaca 125000)
Edition of Dec. 1903, reprinted Jan. 1913.
A.H. Thompson, Geographer.
A.P. Davis, Topographer in charge.
Triangulation by the U.S. Coast and Geodetic Survey.
Topography by Jeremiah Ahern.
Surveyed in 1891. Culture revised in 1901.
TRUE NORTH
MAGNETIC NORTH
14°
APPROXIMATE MEAN DECLINATION 1902
Scale 62500
Contour interval 25 feet.
Datum is mean sea level.
LA JOLLA

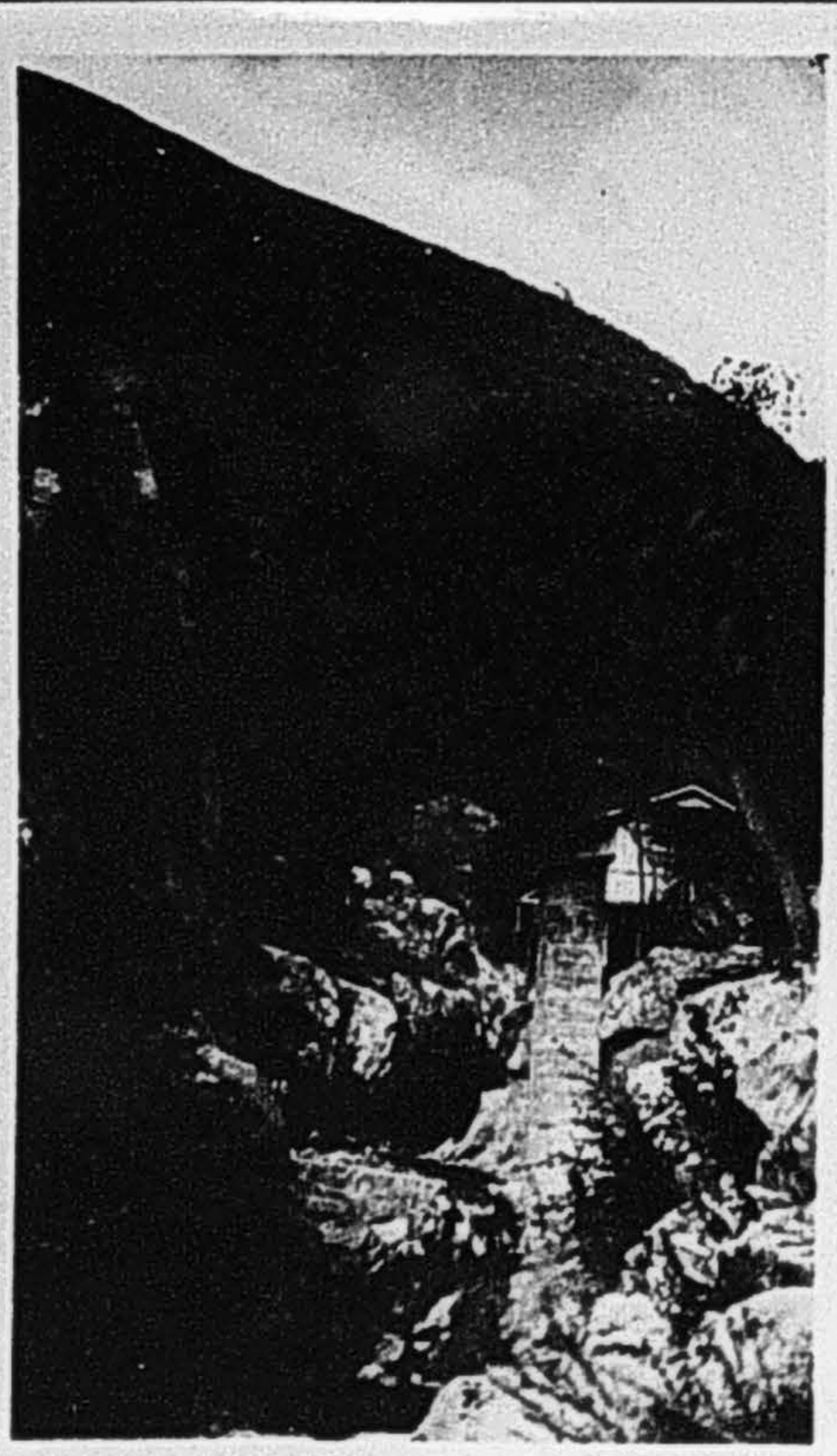

Damsite No. 3
Observation Wells
El Monte Pumping Plant
SAN DIEGO RIVER
Moreno
Plant
Lindo Lake
LOS COCHES TUNNEL
MONTE TUNNEL
EL CAJON
verview Pumping Plant
Lakeview
Coches Creek
n Pipe Line
SAN DIEGO FLUME
LAKESHEIM TUNNEL
Peutz Valley
Alpine
T. 15 S.
50'
Harbison Canyon
Alpine Heights
Bostonia
Forester Creek
L98
CLEVELAND NATIONAL FOREST
Dehesa
SEQUAN INDIAN RESERVATION
SWEETWATER RIVER
Sweetwater Pass
T. 16 S.
JAMACHO
Sequan Pk.
Lawson Creek
Lawson Valley
32°45'
116°45'
55'
R.1 E. (Cuyamaca 1:125000)
R.2 E.
(Cuyamaca 1:125000)
Scale 1/62500
4 Miles
6 Kilometers
Contour interval 25 feet.
Datum is mean sea level.
DIAGRAM OF TOWNSHIP
Edition of June 1903, reprinted 1916.
ELCAJON

Flood water during the storm of December, 1921, at the Mission Gorge Gaging Station on the San Diego River.

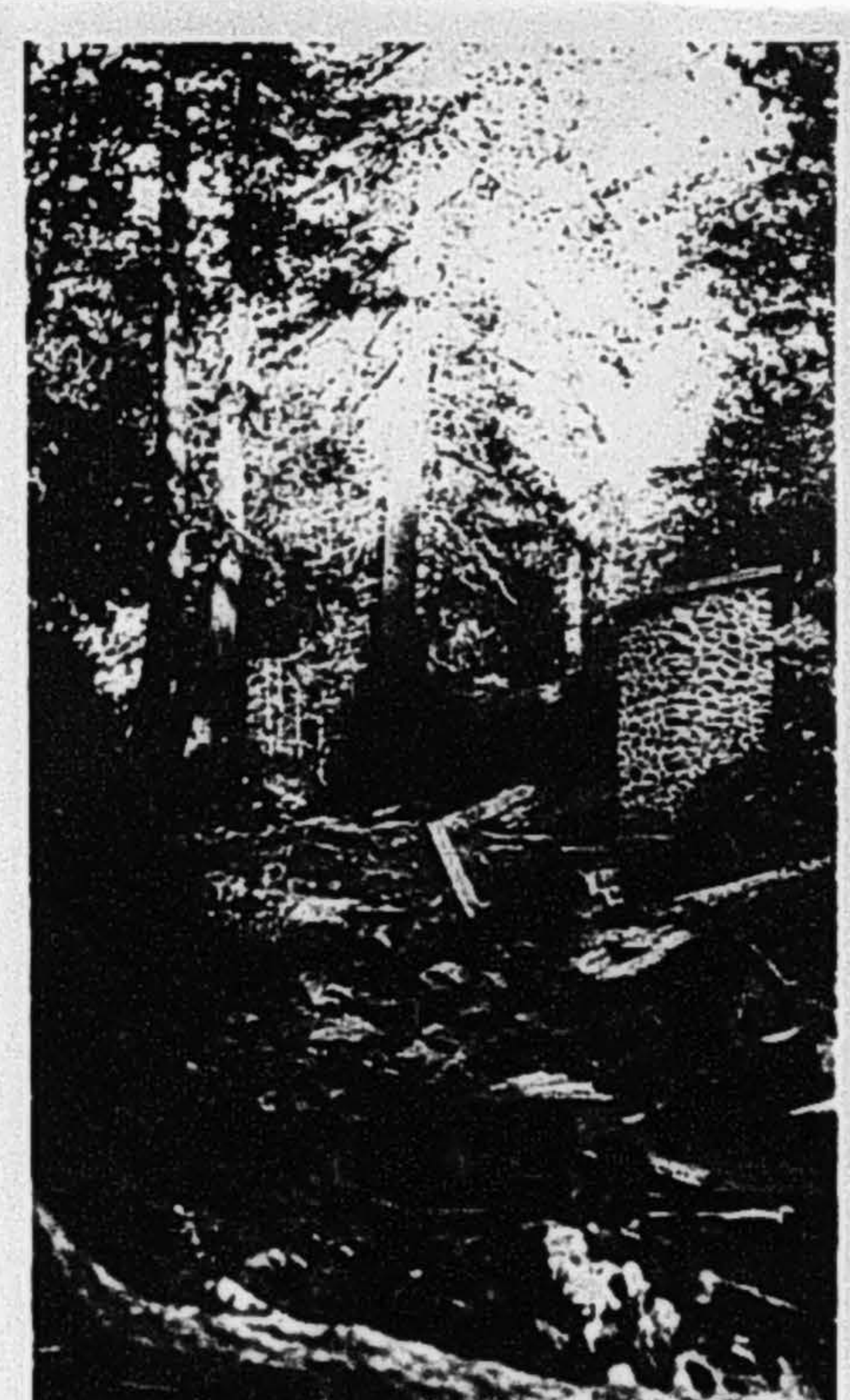


Flood stage during February, 1927, Mission Gorge Gaging Station, San Diego River.

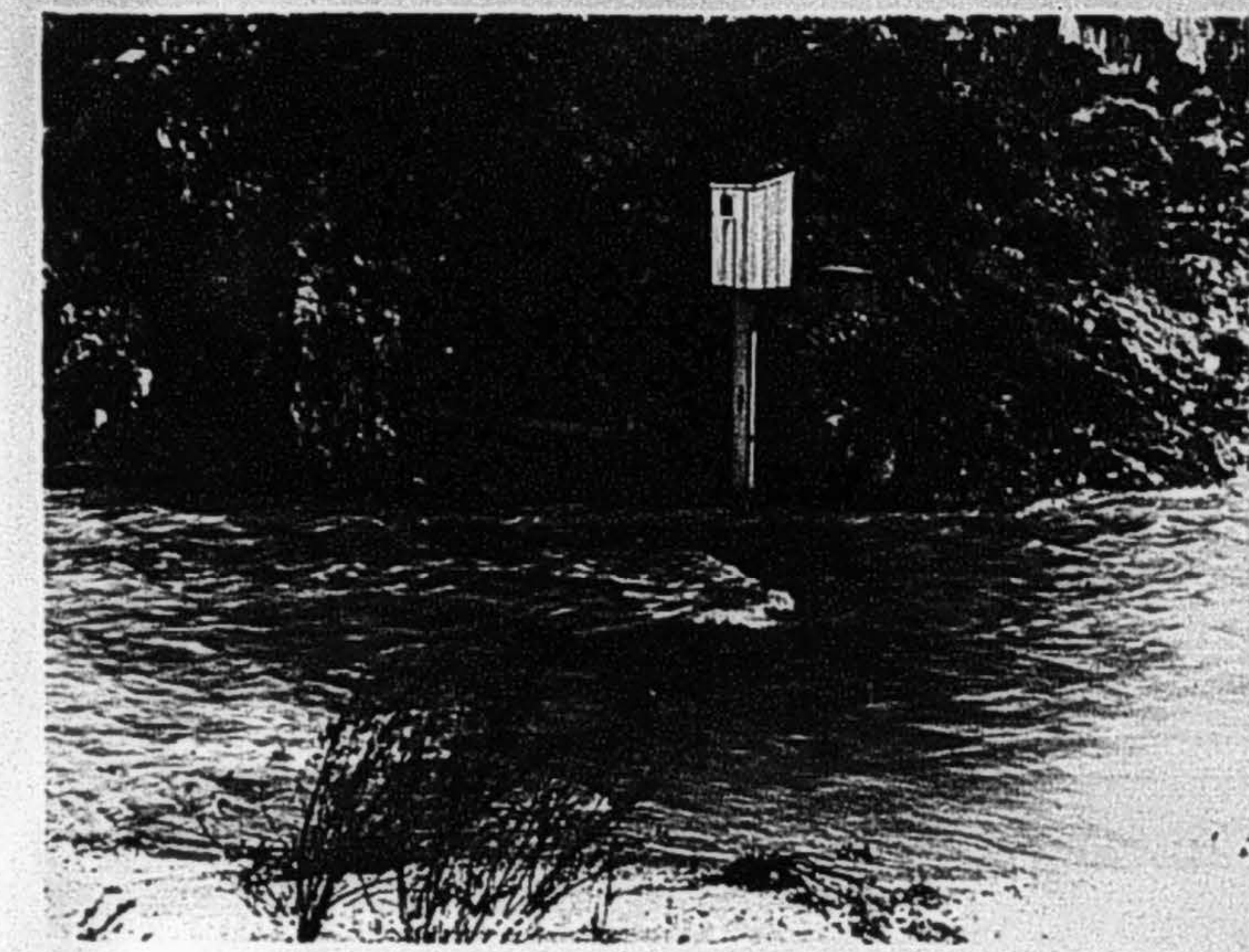
1.



Gaging station near the mouth of Pauma Creek, Palomar Mt., built by the S.D.Con. Gas & Elextric Company.

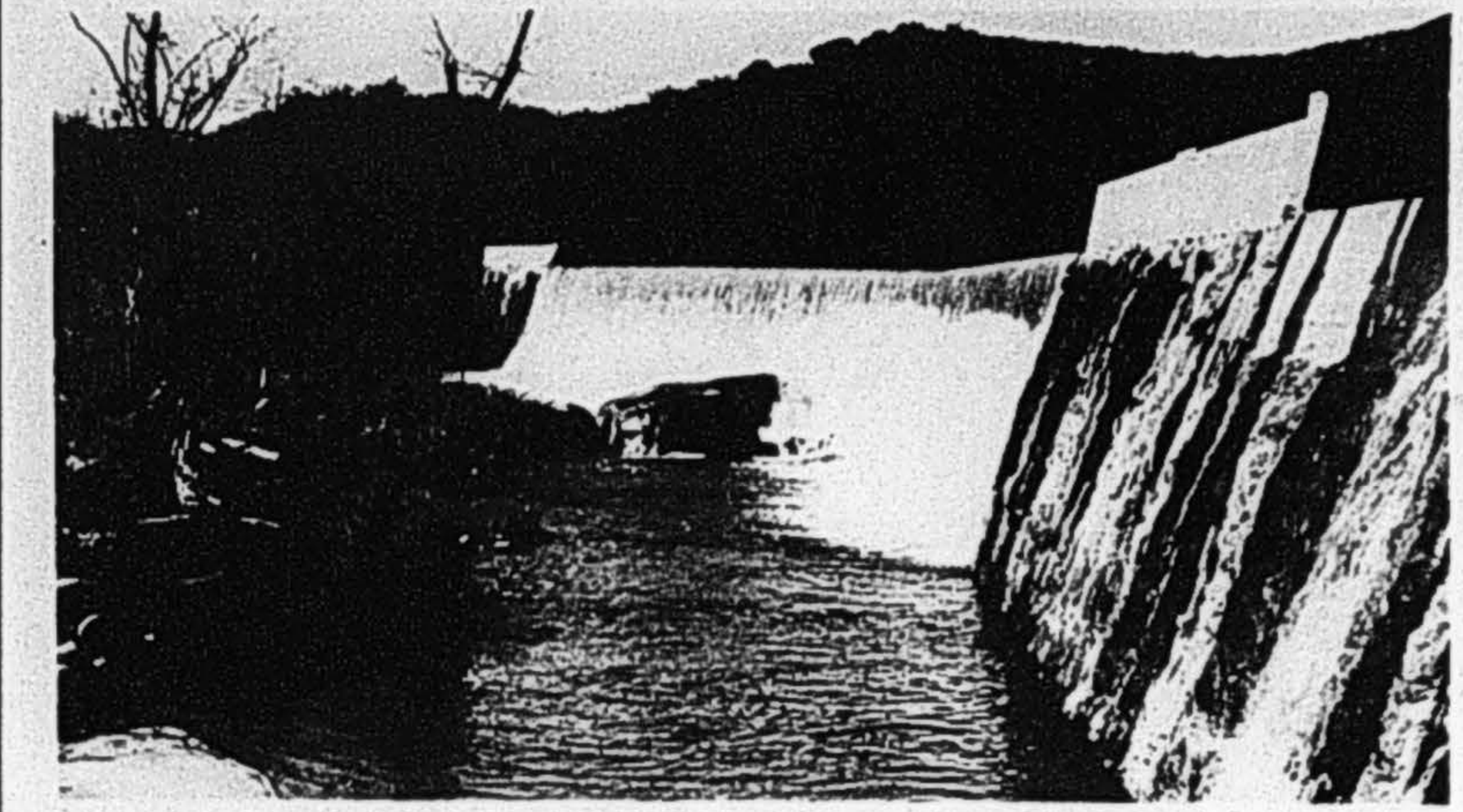


Gaging station at the outlet of Doane Valley, Palomar Mt., Built by the S.D.Con, Gas & Electric Company.



Gaging station at the head of Nigger Canyon on the Santa Margarita River, during storm of April 8th, 1926.

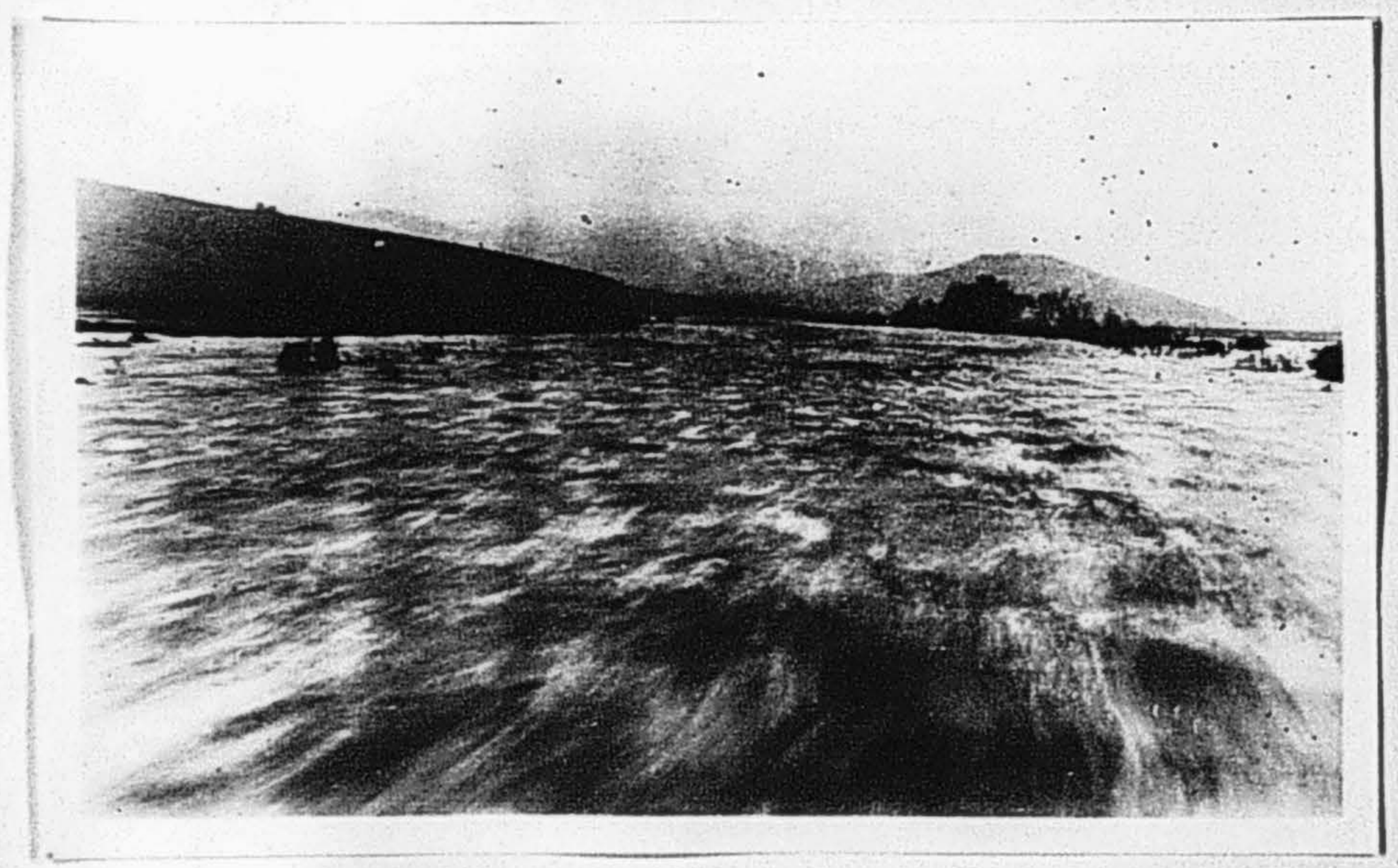
Concrete gage house can be seen in central back part of picture - looking downstream.



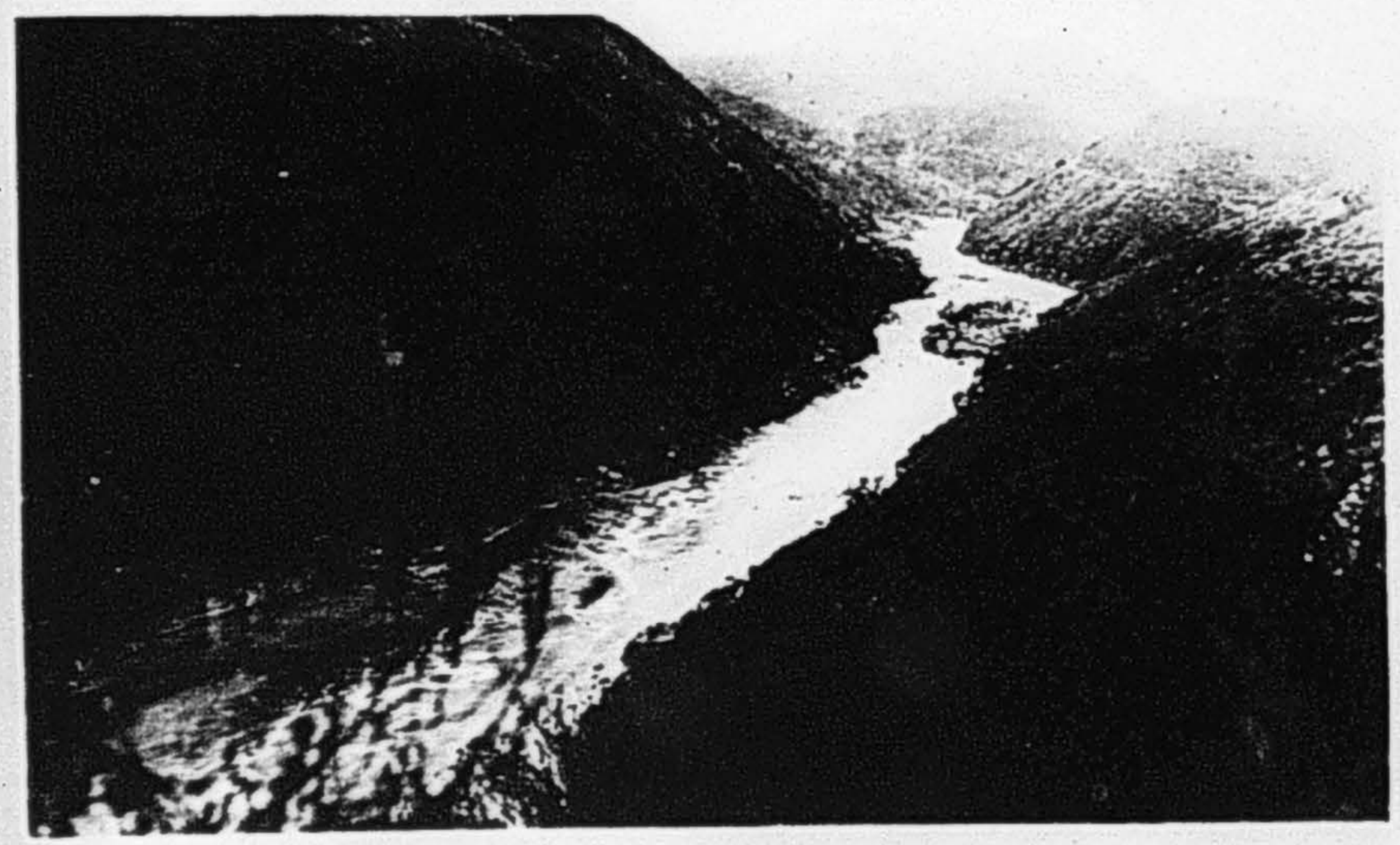
1922 Flood at the Diverting Dam on the San Diego River.

Looking upstream on the San Diego River toward the El Capitan damsite, Viejas Mt. in the distance.

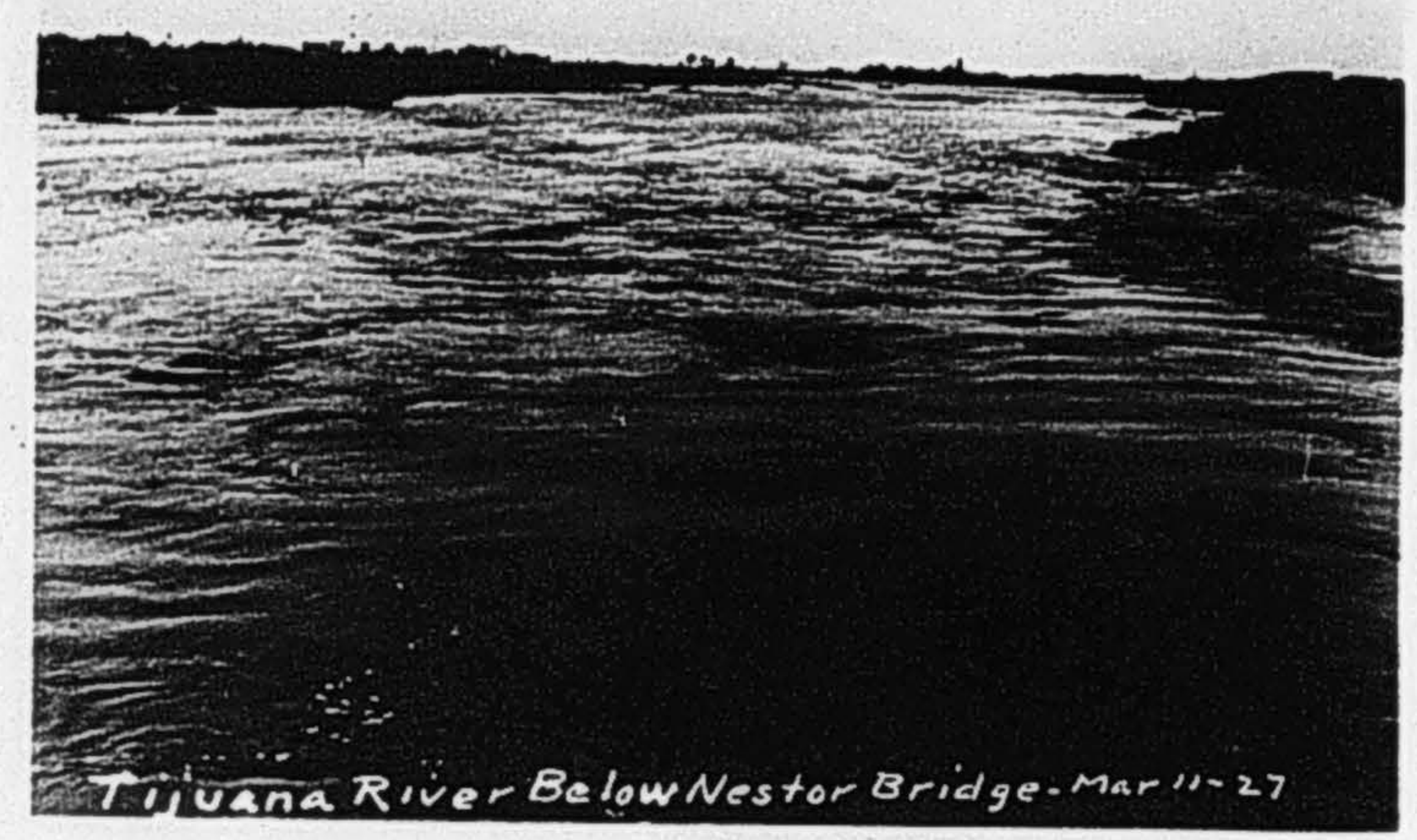
Looking downstream from Lakeside bridge during storm of December, 1921.

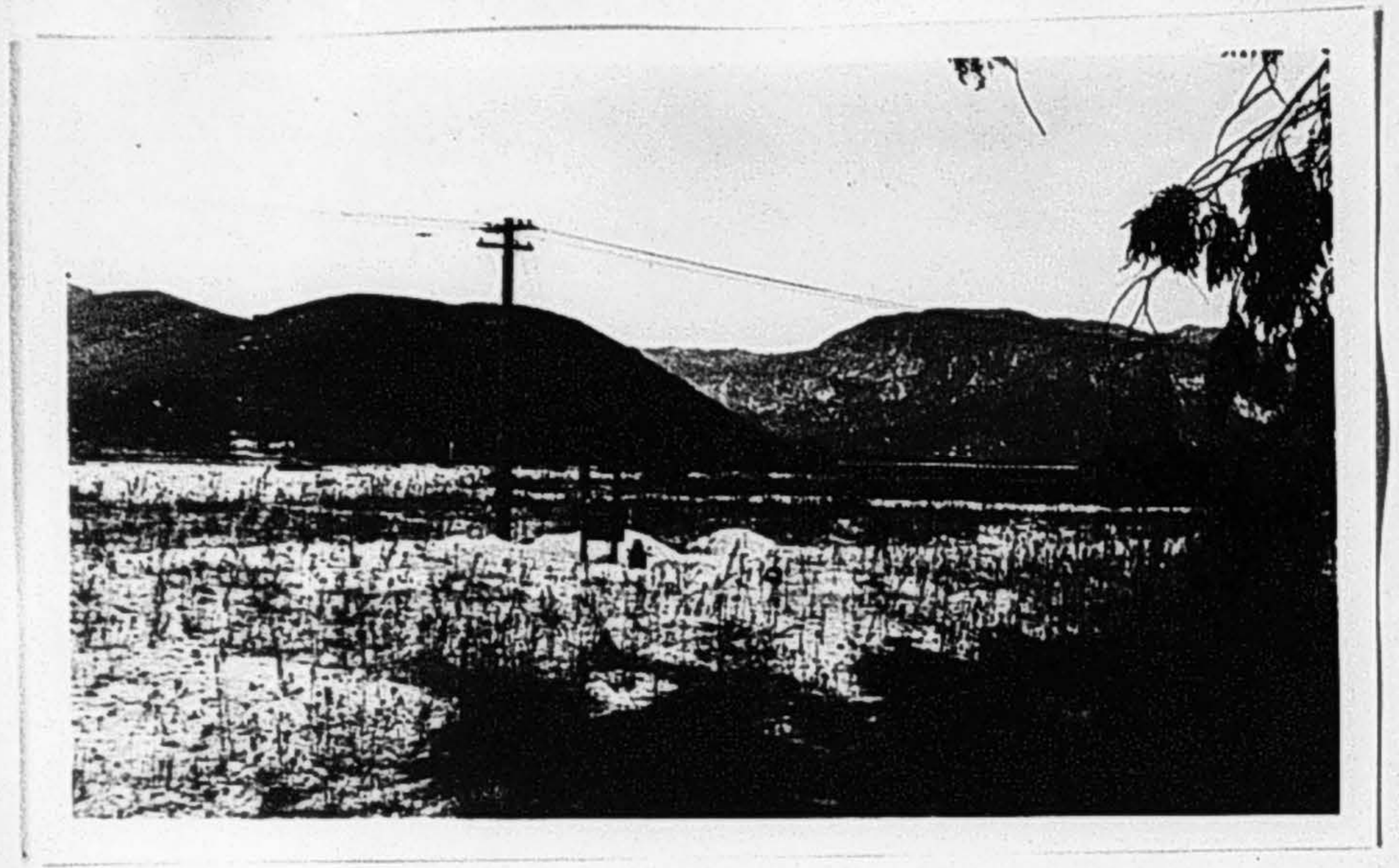


Looking upstream on San Vicente Creek from the bridge during the storm of December, 1921.

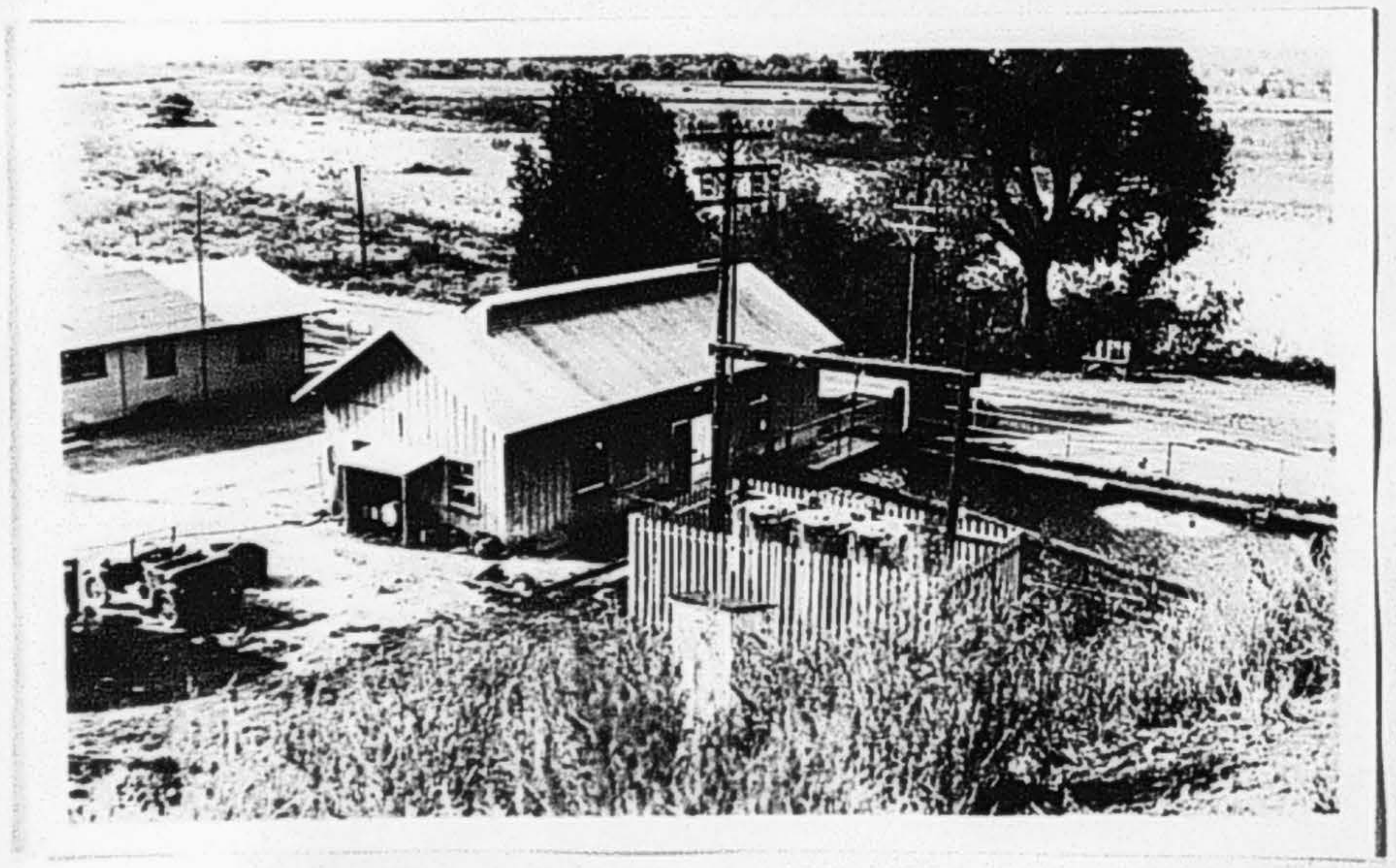


Looking upstream at Mission Gorge Damsite No. 3, during storm of December, 1921.

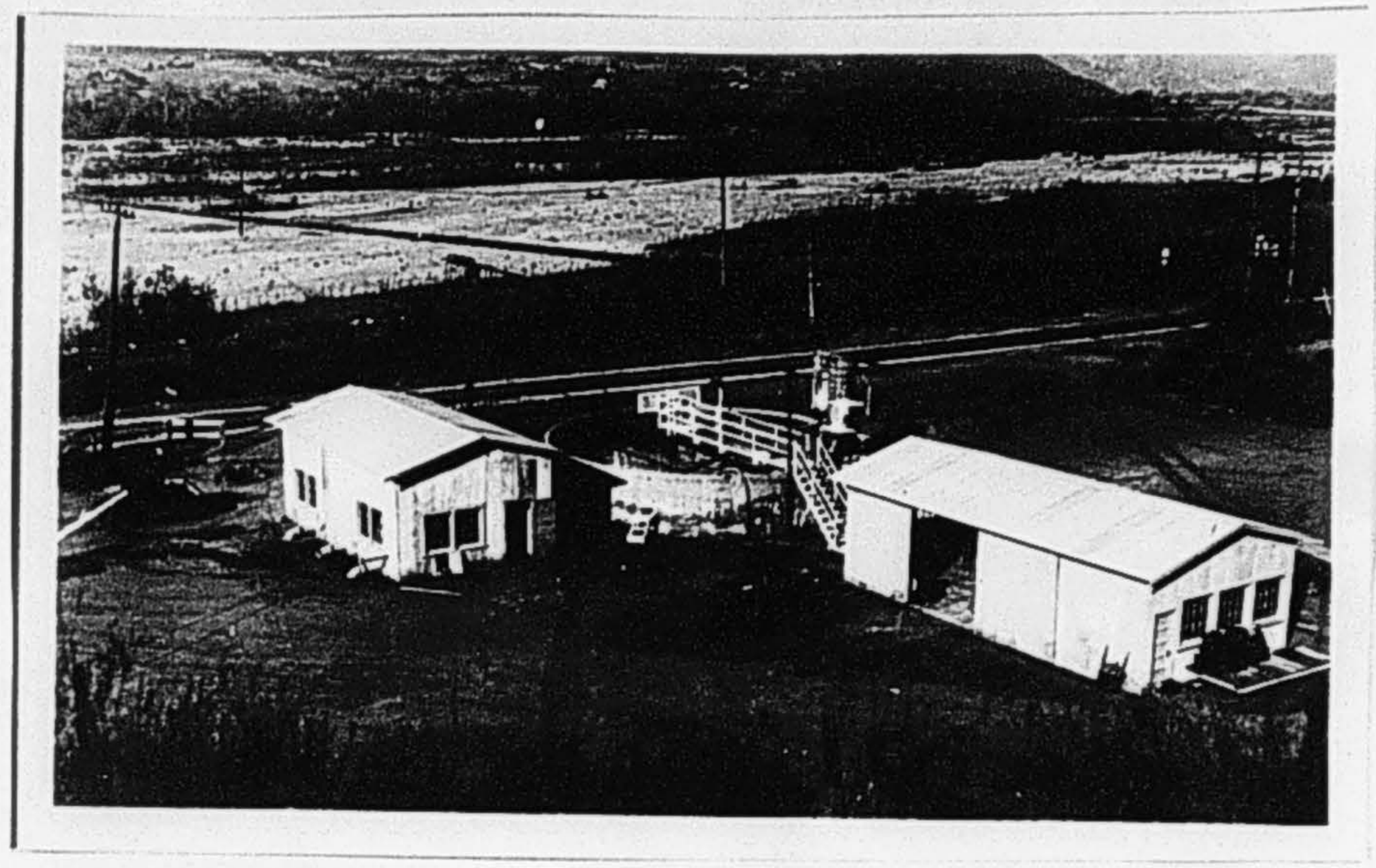




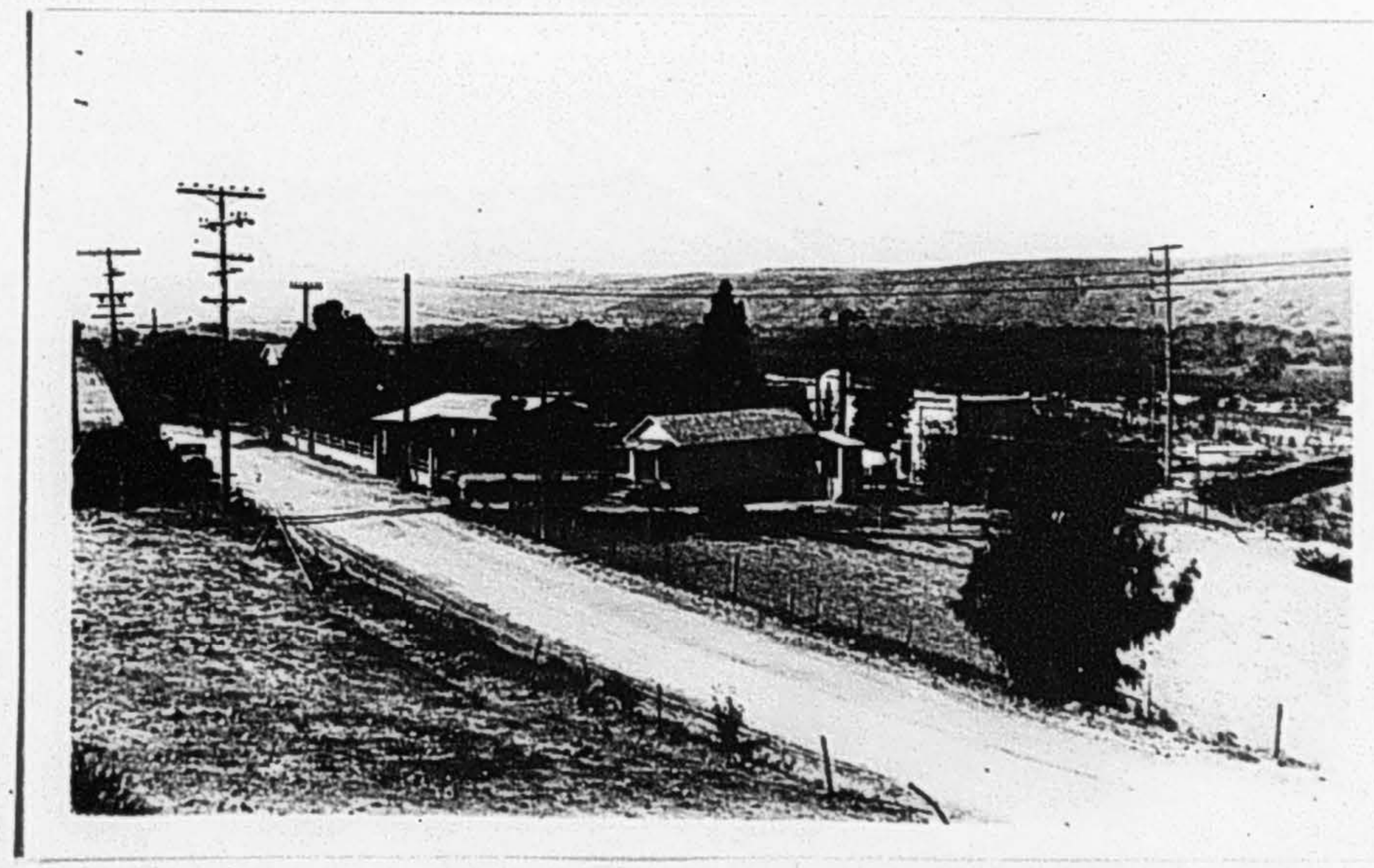
Pump and well at the Lakeside plant of the City of San Diego about one-half mile below the Lakeside bridge.



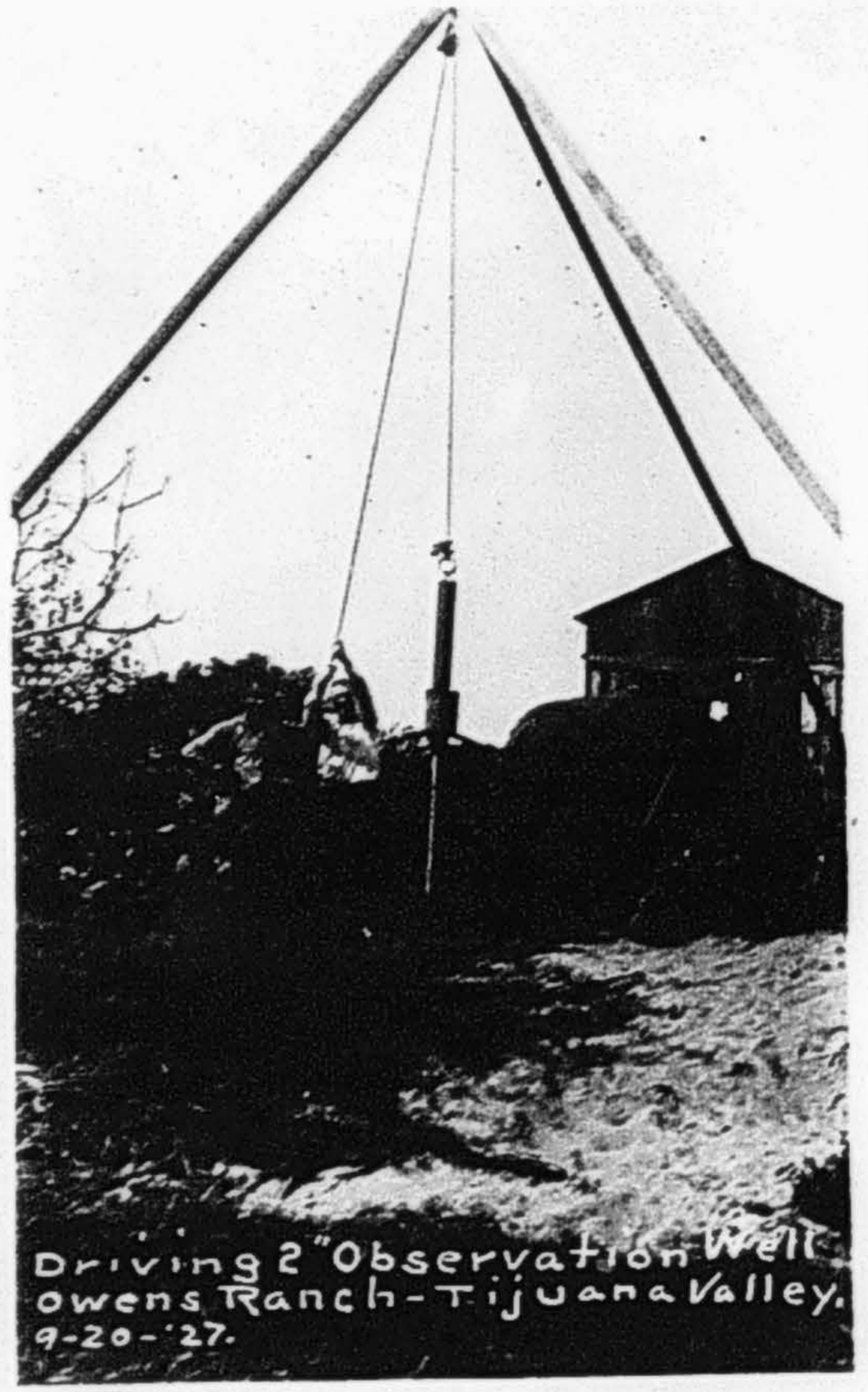
El Monte Pumping Plant of the Cuyamaca Water Company.

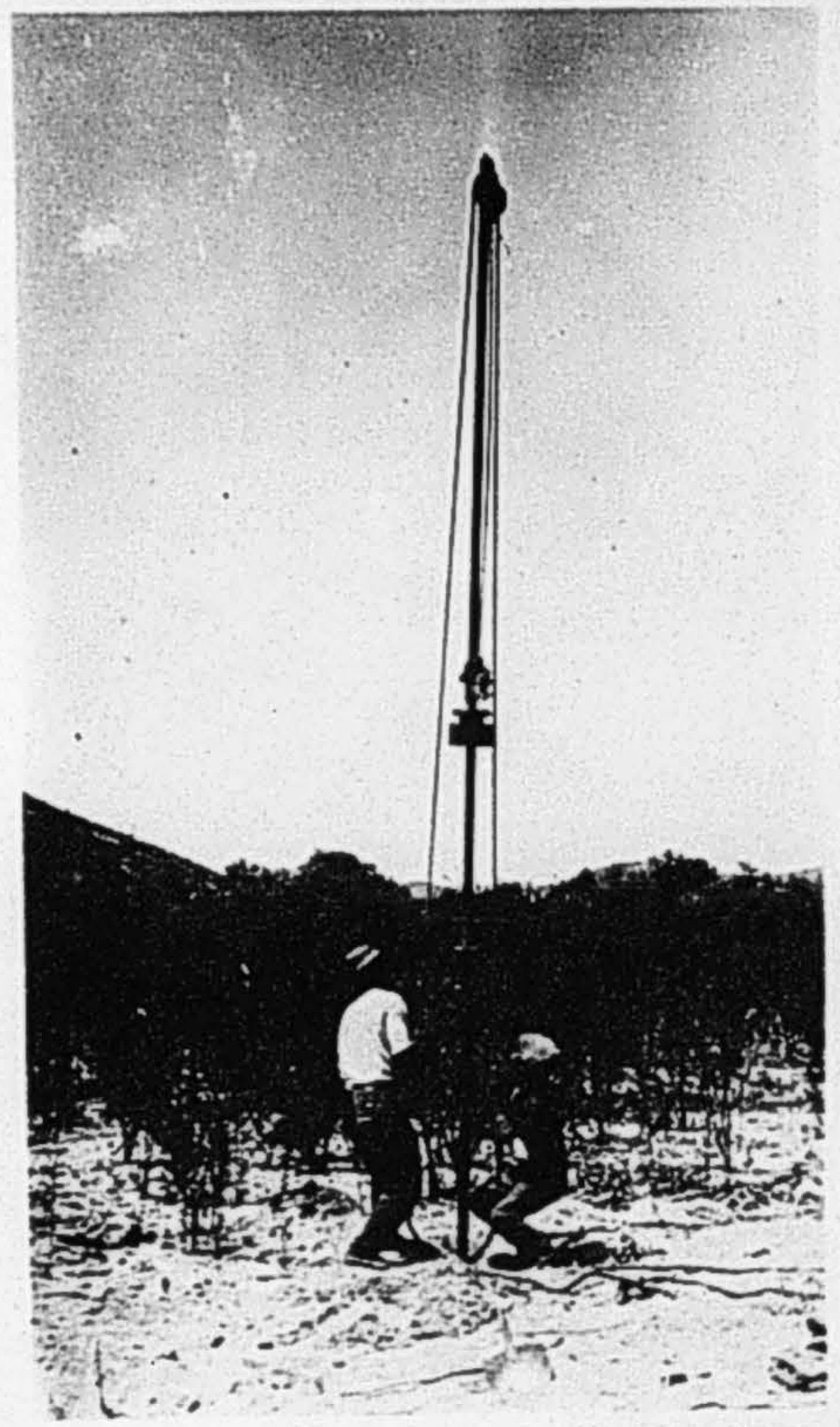


City of San Diego's Riverview Pumping Plant on the San Diego River near Lakeside.

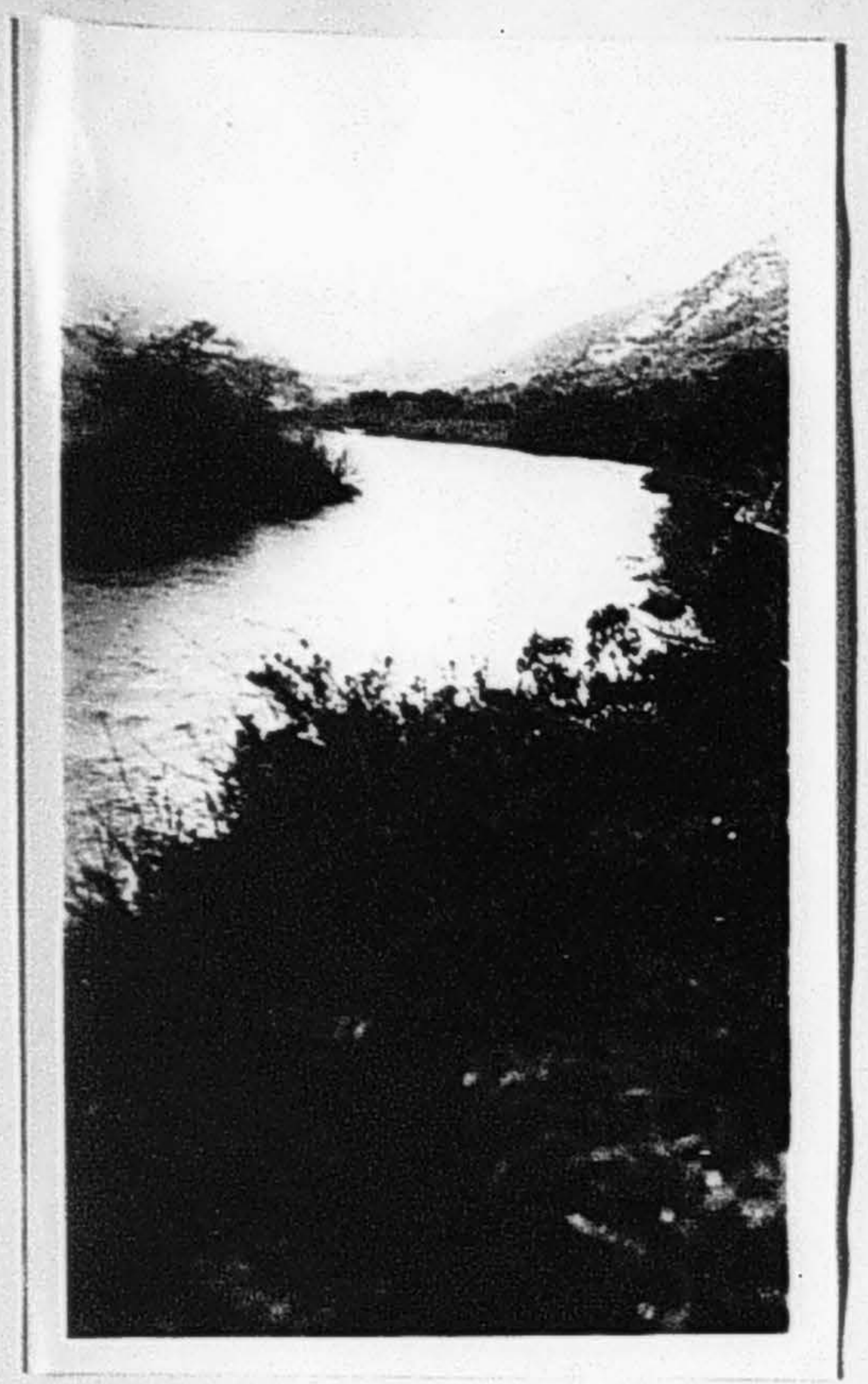


Mission Valley Pumping Plant of the City of San Diego.

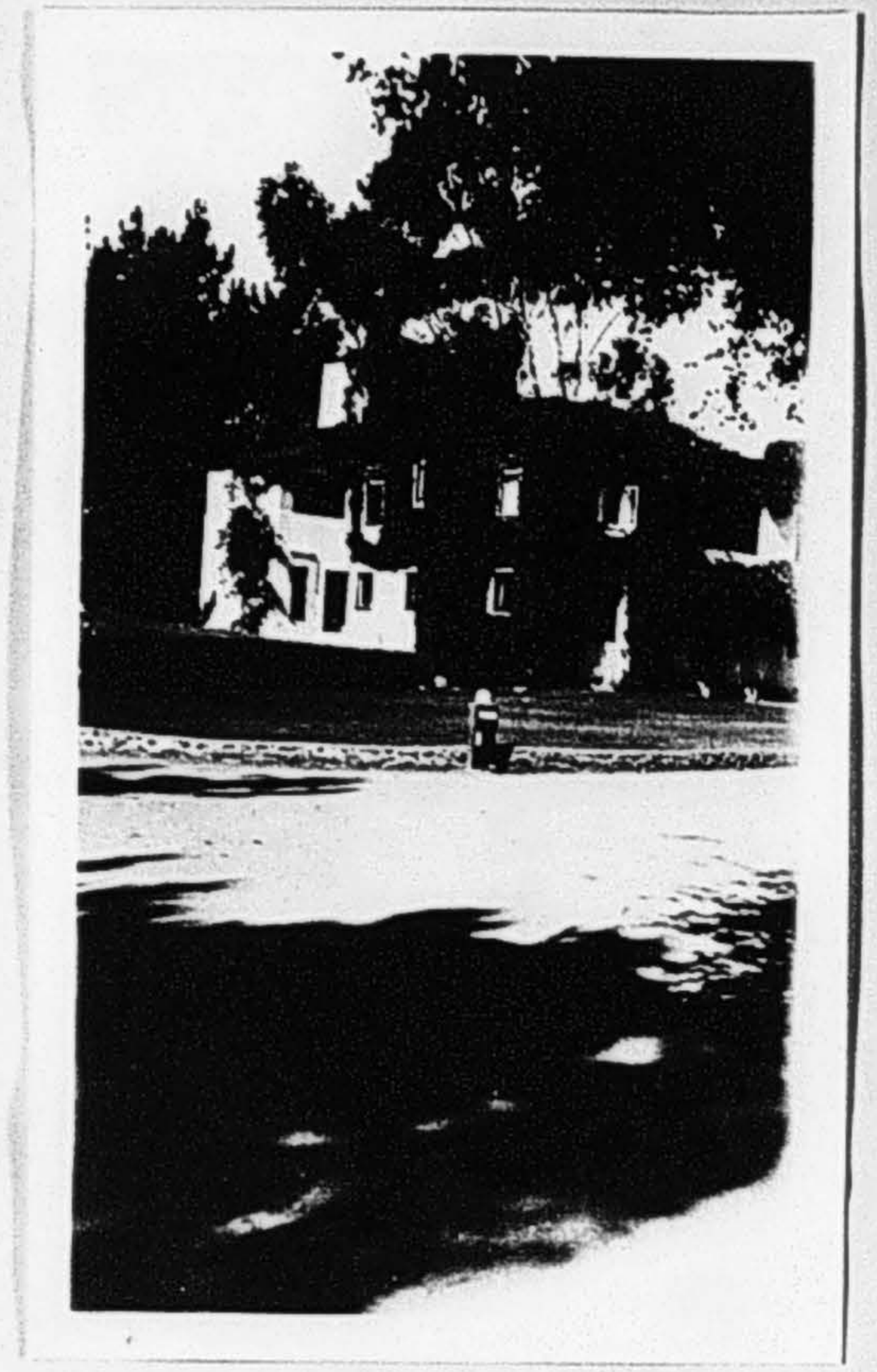




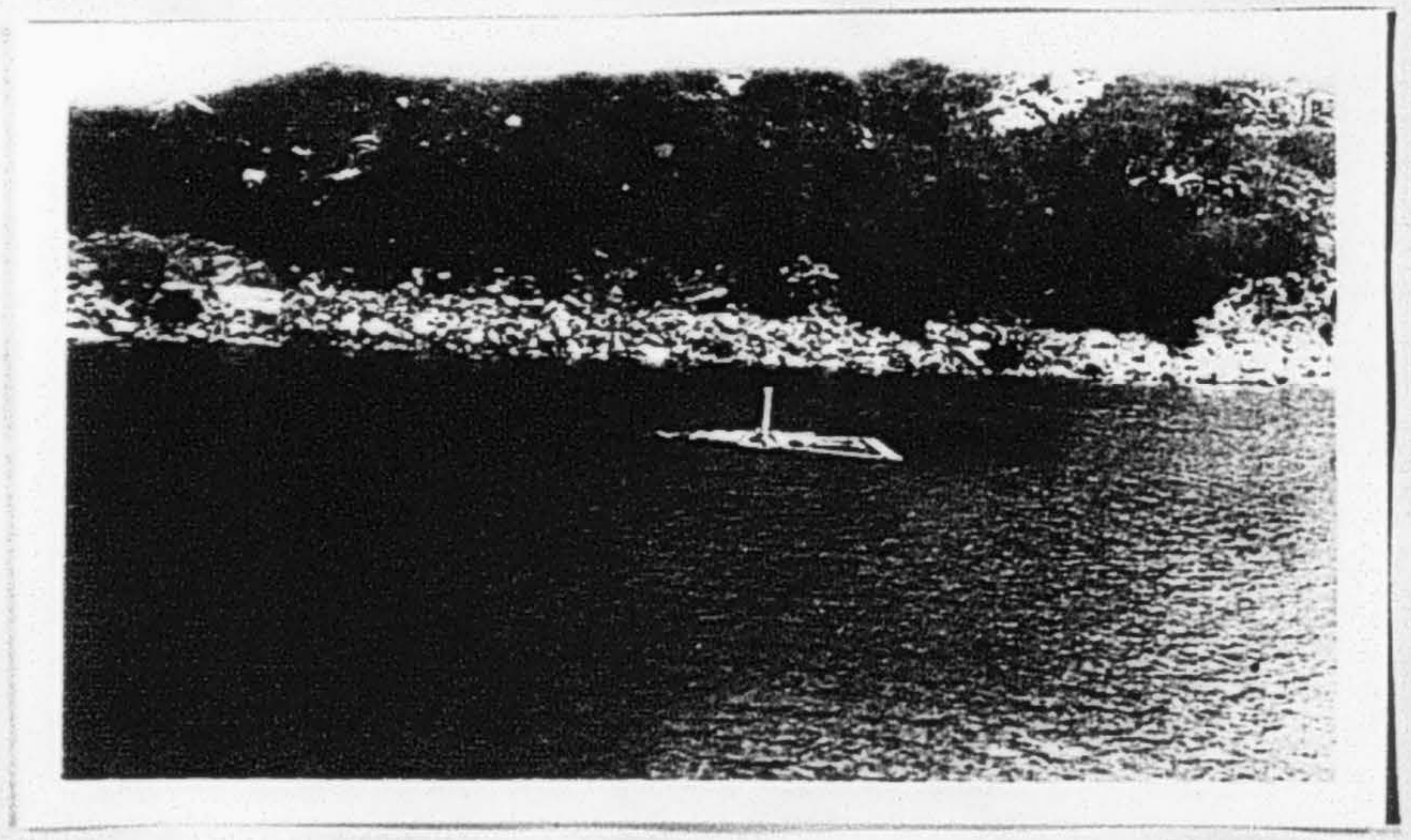
Driving two inch observation well in the El Monte Basin on the San Diego River.



High water in 1922 below El Capitan damsite, looking east.

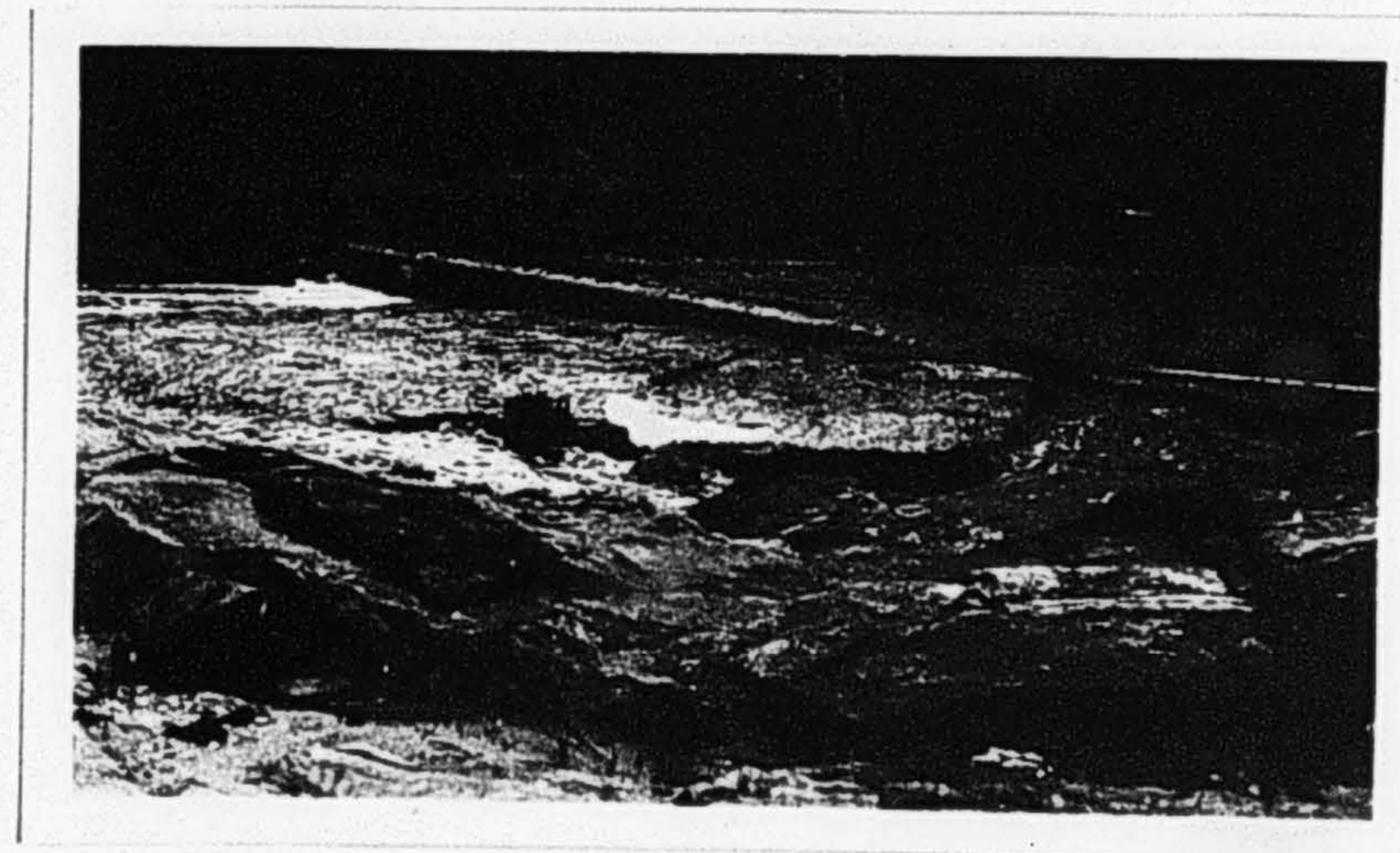


U.S.Weather Bureau rain gage at R.C.Allen residence, Bonita, Cal.



Evaporation pan and protecting raft at Morena Reservoir.

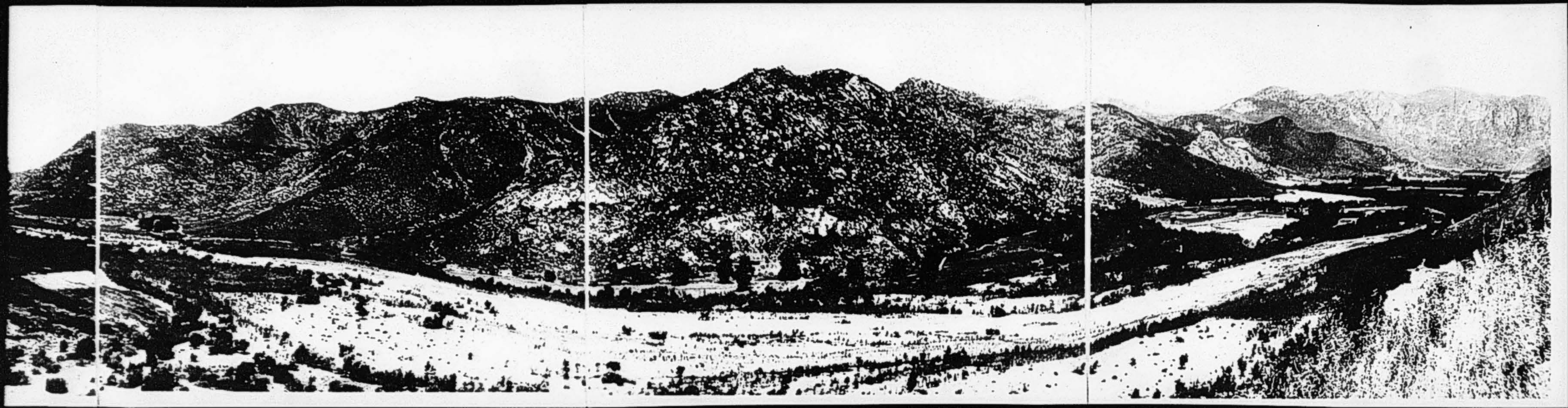
Gaging station with artificial control on San Luis Rey River below Henshaw Dam.

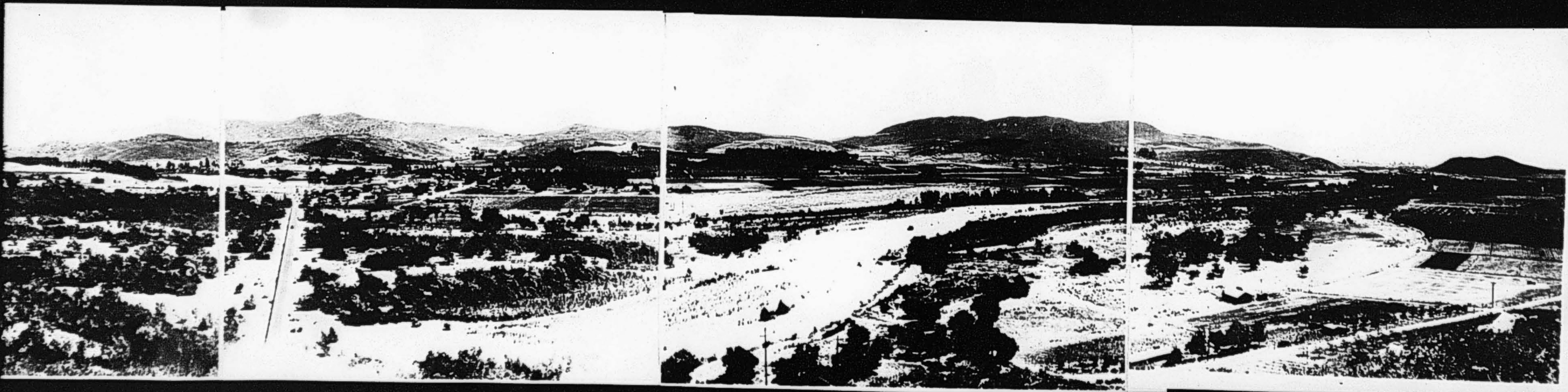


Artificial control at gaging station on Santa Ysabel Creek at Sutherland damsite.

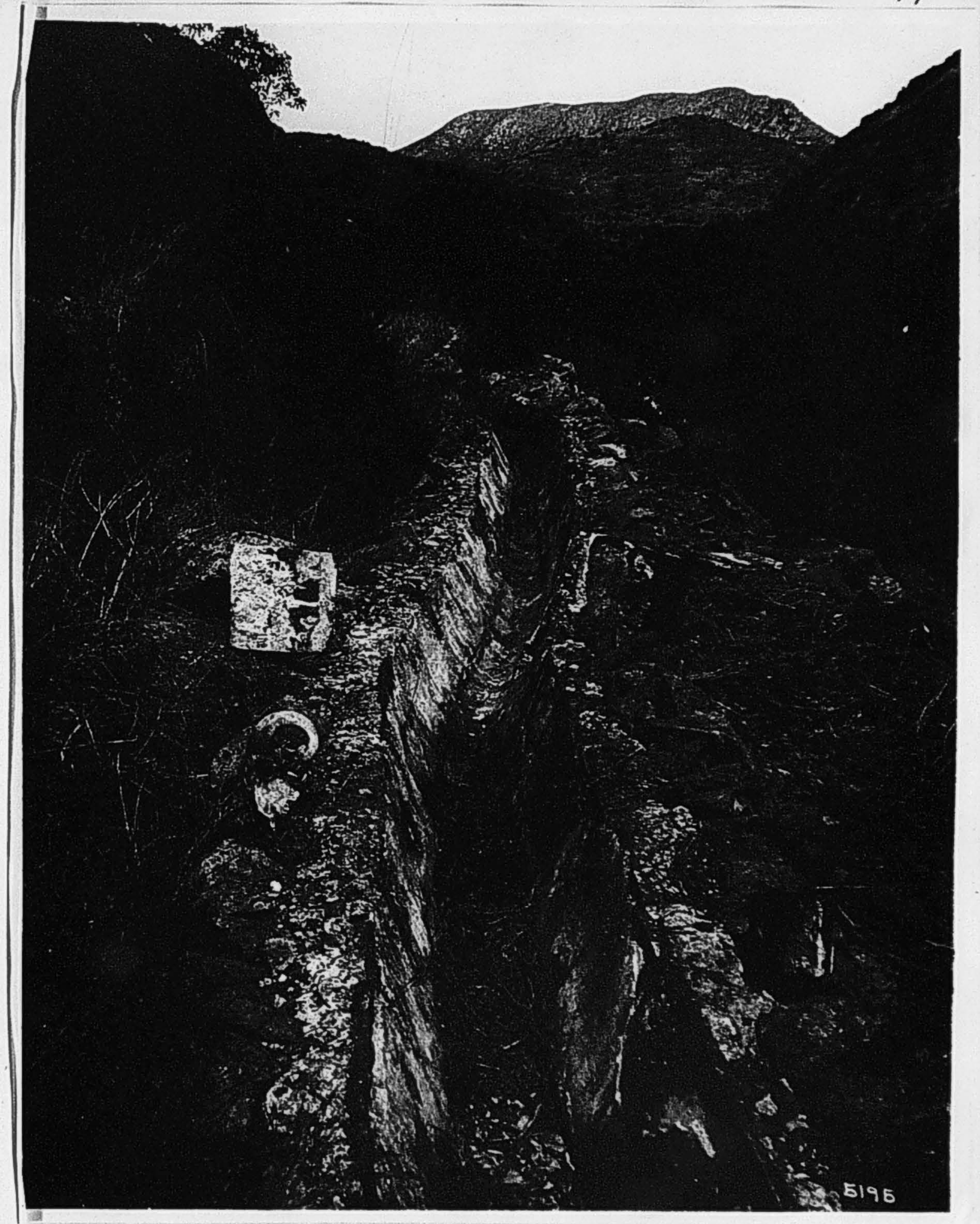
El Monte Basin from San Vicente Creek to El Monte Park.

Lakeside-Santee Basin from San Vicente Creek to Riverview Narrows.

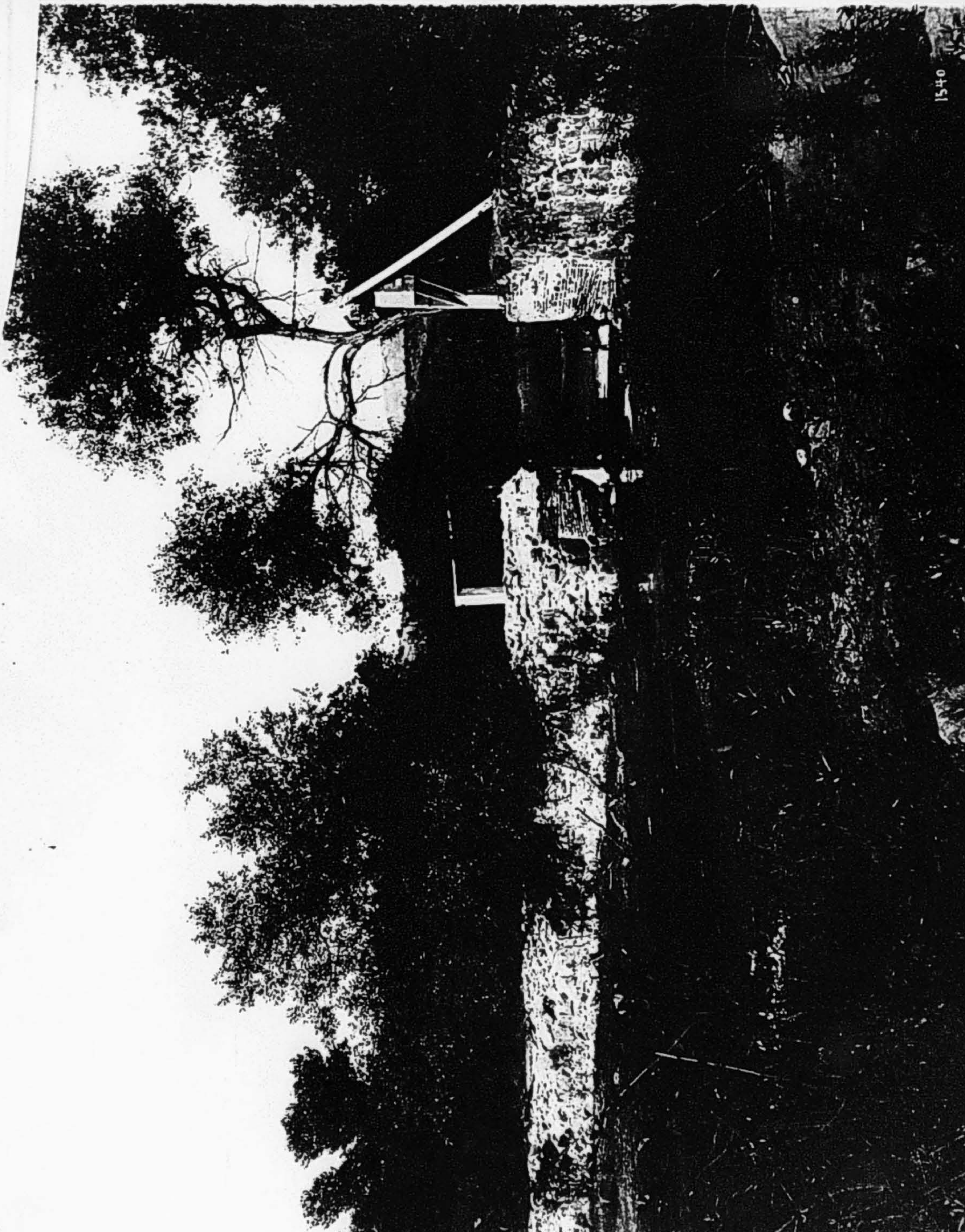




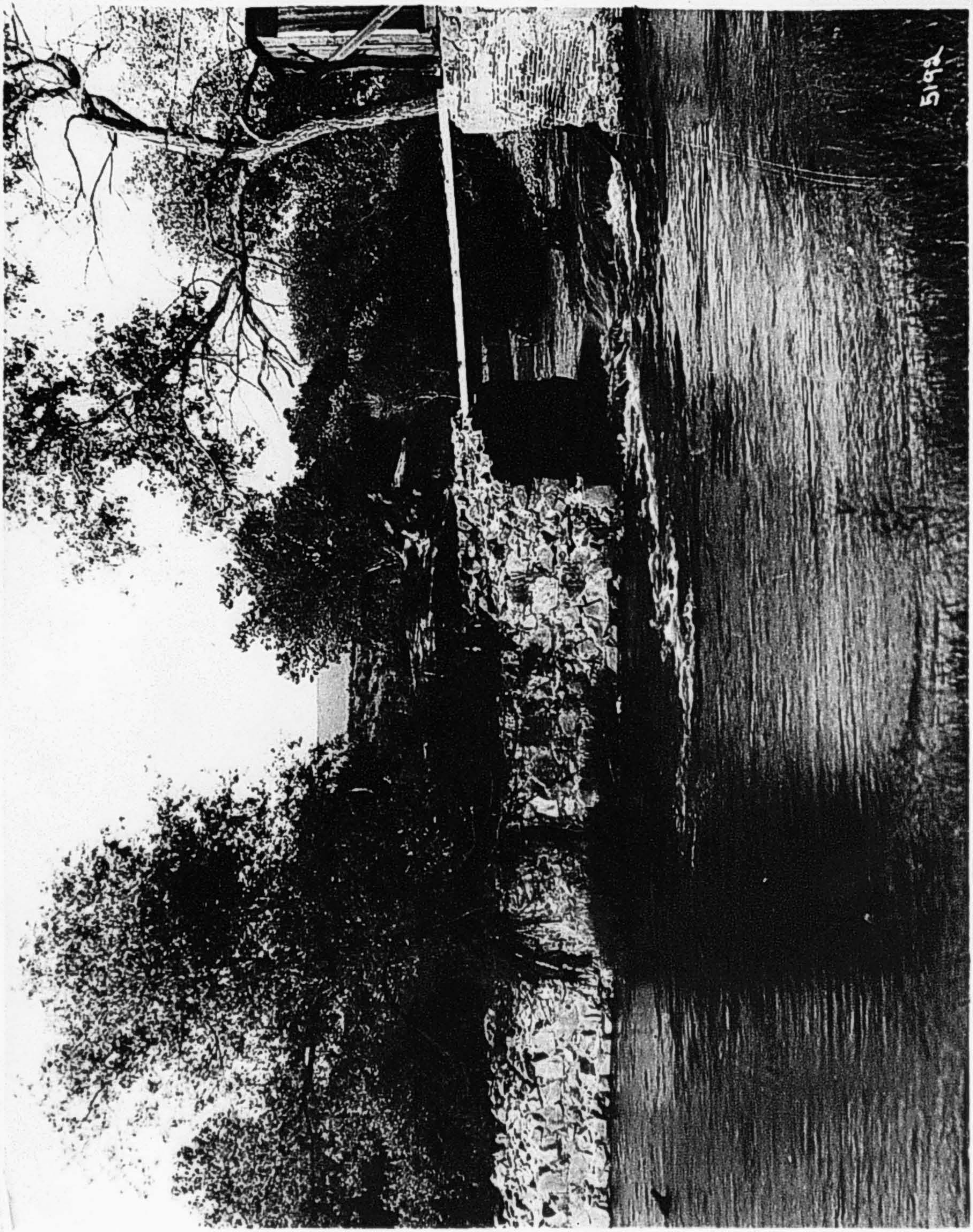
Section of the Old Mission conduit uncovered near Mission Gorge gaging station. Practically intact after 125 years. Also, a view of the right wall of a broken section, showing mortar plaster.



Section of Old Mission conduit practically intact, showing tile sides and bottom.



South end of Old Mission dam showing sluice gate, waterstage recorder shelter and heavy growth of willows, some of which must have been 15 or 20 years old. Picture was taken in 1913 or 1914.



Old Mission dam in about the year 1915, showing shelter for water stage recorder and willow growth, all of which was wiped out in the flood of 1916.