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DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

WATER PROBLEMS

OF

SANTA BARBARA, CALIFORNIA

BY

J. B. LIPPINCOTT

WASHINGTON

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LETTER OF TRANSMITTAL.

Department of the Interior,
United States Geological Survey,
Hydrographic Branch,
Washington, D. C., May 12, 1904.

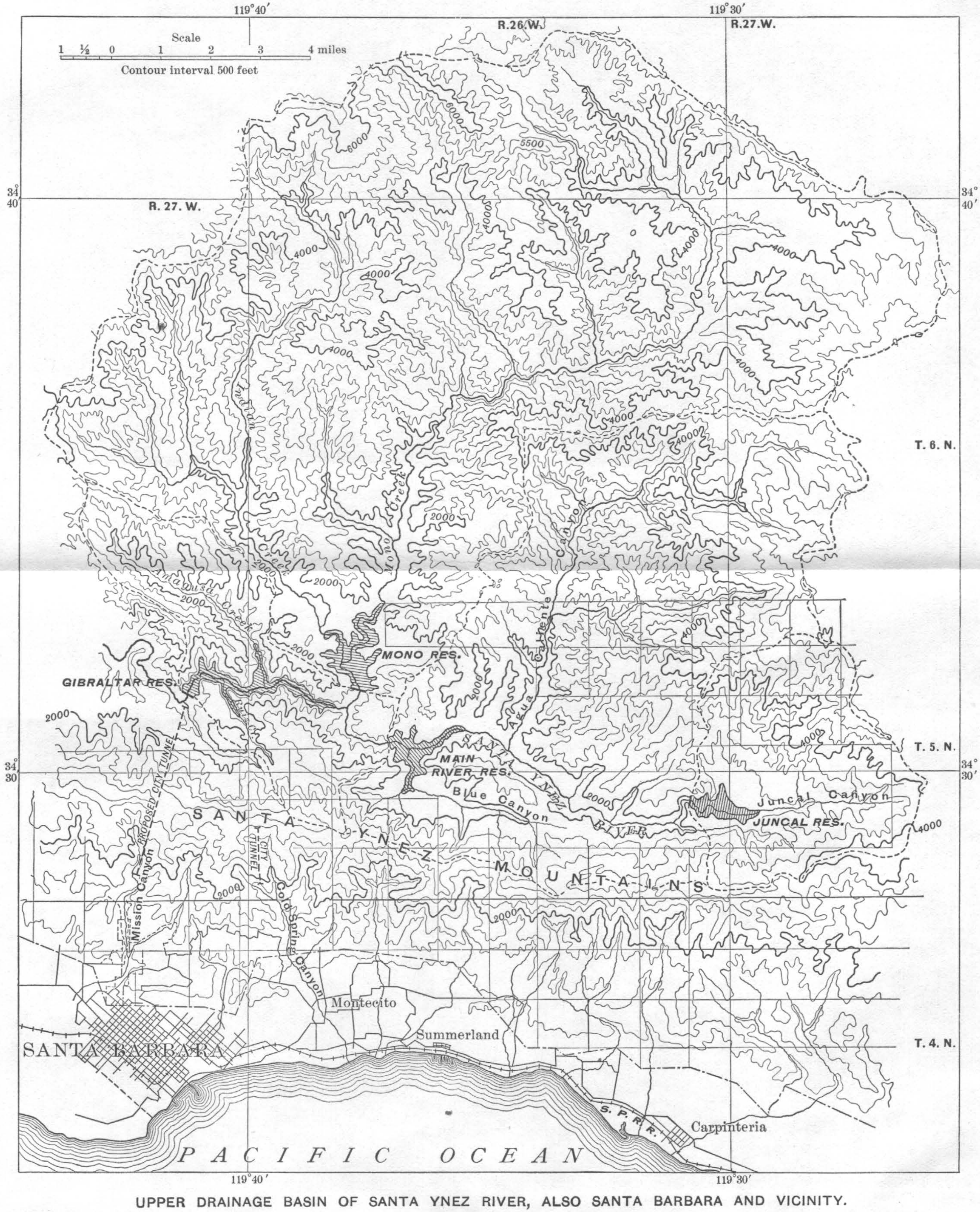
Sir: I have the honor to submit herewith, for publication as a water-supply and irrigation paper, a report on the water problems of Santa Barbara, Cal., transmitted by Mr. J. B. Lippincott.

As the city and suburbs of Santa Barbara form one of the most attractive and productive districts in southern California, a thorough knowledge of the water supply of the region is of the utmost importance. It is thought that the facts brought out in the report will be of much interest.

Very respectfully,

F. H. Newell,
Chief Engineer.

Hon. Charles D. Walcott,
Director United States Geological Survey.



UPPER DRAINAGE BASIN OF SANTA YNEZ RIVER, ALSO SANTA BARBARA AND VICINITY.

WATER PROBLEMS OF SANTA BARBARA, CAL.

By J. B. Lippincott.

INTRODUCTION.

The Santa Barbara coast extending from Goleta to Carpinteria, including the city and suburbs of Santa Barbara, is naturally one of the most attractive and productive districts of southern California. It is, however, deficient in water supply.

Desiring a broad and comprehensive study made of this locality, with a view to a solution of the problems involved, the city and county of Santa Barbara have requested (1) that the topographic work of the Geological Survey be extended so as to cover this district, and (2) that the hydrographic branch of the Survey make an investigation of the water problems involved. These topographic surveys have now been made, and the maps of the Goleta, Santa Barbara, Santa Ynez, and Mount Pinos quadrangles have been published. The Santa Maria quadrangle has been surveyed and the map is now being engraved. This will complete the mapping of the county. These topographic maps are of the very greatest assistance and importance in determining relative elevations, areas and elevations of drainage basins, and possible tunnel locations through the Santa Ynez Range.

In the hydrographic investigations the city of Santa Barbara has cooperated, paying one-half of the expense connected with the maintenance of a gaging station on Santa Ynez River and Mono Creek, on which streams daily observations have been made for silt, volume of flow, and mineral impurities of the water, and also approximately 25 per cent of the expense connected with the preparation of this report. This portion of the work, therefore, is in the nature of a joint investigation by the city of Santa Barbara and the Geological Survey, all of the field work and investigation being done by the Survey and a portion of the expense being paid by the city of Santa Barbara.

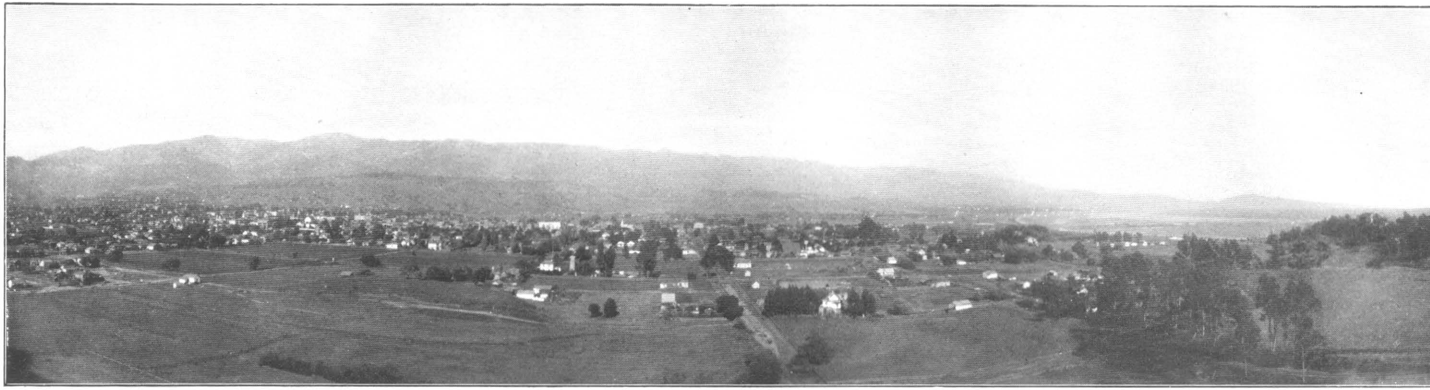
LOCATION AND DRAINAGE OF THE DISTRICT.

The district under investigation extends from Ventura River in Ventura County along the coast as far as Goleta in Santa Barbara County, and more particularly into the high mountainous districts of Ventura and Santa Barbara counties lying on the north side of the Santa Ynez Range and including the drainage basin of Santa Ynez River and its tributaries.

The coastal plain fronting the ocean consists of a series of old marine beaches and undulating foothills facing Santa Barbara Channel. Views of this coastal plain are shown in Pl. II. This district is of great natural beauty, and has become the home not only of agriculturists and horticulturists, but also of many eastern people who have sought it for recreation and health. It is one of the most attractive regions in California. The winds are mild, those from the south being tempered by the Pacific Ocean, and those from the north being barred out by the Santa Ynez Range, which parallels the coast, rising to elevations of from 3,000 to 4,000 feet and presenting a bold and attractive background to the undulating foothill districts. (See Pl. I.)

The streams flowing from the southern slope of this range are precipitous and have short drainage basins of small area. This topography produces a torrential stream condition after rains, followed by a period of extreme low water in time of drought. The range is formed chiefly of shale and sandstone, the strike being parallel to the coast and the dip nearly vertical, inclining somewhat to the south. This geologic formation admits of a number of small but permanent springs in the canyons eroded by the streams, and is also favorable to the development of water by tunnels run at right angles to the line of strike. Beyond the crests of the Santa Ynez Range is the drainage basin of Santa Ynez River. A second range of mountains, consisting of the crest of the Coast Range and culminating in Mount Pinos, the elevation of which is 8,826 feet, rises to the north and trends parallel to the Santa Ynez Mountains. These higher mountains are drained by streams running in a southerly direction and uniting with Santa Ynez River proper, which runs close to the northerly base of the Santa Ynez Mountains, flowing westerly and paralleling the Coast Range. It has a total length of about 70 miles, with flat grades, and offers frequent opportunities for impounding water in storage reservoirs.

The results of the investigations indicate that a solution of the water problem for the coast district lies in impounding the flood waters in the drainage basin of Santa Ynez River and conveying them to Santa Barbara through a long tunnel beneath the Santa Ynez Range.



A

B

VIEWS OF SANTA BARBARA AND VICINITY.

REVIEW OF EARLIER WORK BY OTHERS.

It is here deemed proper to review the work which has been done along this line in the past by other engineers, both for the city of Santa Barbara and for the Santa Barbara Water Company. The first report was made for the city of Santa Barbara on October 19, 1889, by George F. Wright, member American Society of Civil Engineers, and at the time city engineer of Santa Barbara. The second report was presented on July 2, 1896, by Ernest J. S. Purslow, civil engineer for the Santa Barbara Water Company. Both of these gentlemen, who are now deceased, were residents of Santa Barbara, engineers of distinction, men of good standing in the community, and thoroughly acquainted with local conditions. In general their judgment respecting the subject here under consideration is approved by the present writer, both from personal knowledge of the locality and from observations elsewhere. Their opinions particularly with reference to local water supplies on the south side of the range are worthy of acceptance, and it was not deemed necessary or advisable to make further field examinations over this ground which they had previously covered in detail. Because these reports were made a long time ago and are now unfamiliar to many new residents, and are out of print, it is considered advisable to briefly review them.

REPORT OF GEORGE F. WRIGHT, 1889.

NEEDS OF DISTRICT.

Mr. Wright states: "I have endeavored to cover the whole field in my report, trusting in many cases to previous examinations and surveys made by myself, aided by the available maps of that portion of the territory lying south of the summit of the Coast or Santa Ynez Range of mountains." He calls attention to the fact that even at that time the city had never had an ample water supply to meet its demands, a condition which, as all the residents of the district are well aware, has never been materially changed. He states further: "The immediate necessity demands a supply of 2 million gallons per day (equivalent to 200 gallons per capita for 10,000 persons), which will certainly be increased to 3 million gallons, and probably 4 million gallons, per day before many years." This statement was made on the assumption that the city, with an ample water supply, would have a vigorous growth, and a development proportional to that of other towns of southern California as suitably located and having adequate supplies. In marked contrast with this demand, he states that the low-water flow of Mission Creek (a present source of supply) is reported to fall as low as 300,000 gallons daily in midsummer, and that a trial test of the De la Guerra wells showed an average daily output of 600,000 gallons at that time.

STREAMS SOUTH OF COAST RANGE.

A complete investigation was made by Wright of all the adjoining drainage basins, extending from Rincon Canyon on the east to Cañada Refugio on the west, during the summer of 1889. The rainfall at Santa Barbara had been 21.44 inches during the preceding winter, and 21.71 inches the winter before that—unusually good records, as the Santa Barbara mean is only 16.78 inches. Consequently Mr. Wright's figures on stream flow are above what should be accepted as an average condition. His table descriptive of the streams is given below.[a]

TABLE 1.—*Streams east of Santa Barbara and south of Coast Range.*

Name of stream.	Catchment area in square miles.	Distance from city in miles.	Daily flow in miner's inches (1889).[b]	Remarks: Flow in miner's inches.
Rincon, proper	8.8	17	5.8	June 16, 1900: 1.5.
Gobernador	7.8	16	29.0	
Carpinteria, including Sutton	5.3	15	3.9	June 16, 1900: 0.1.
Santa Monica	3.6	11	11.6	
Parida, including Oil	3.3	10	15.5	
Ficay	1.4	8	15.5	
Dinsmore	3.0	6	11.6	July 18, 1902: 3.0.
Cold Spring	3.8	4	11.6	
Mission, including Rattlesnake	5.7	1	23.2	June 14, 1900: 1.0. June 17, 1900: 2.5.
Total daily summer flow			127.7	

[a] During the last year the United States Geological Survey has made a detailed topographic field survey of the mountainous district in the vicinity of Santa Barbara, indicating in contours the area of drainage basins, together with their altitude. These maps are more accurate than any previous ones, and have been used in determining the drainage areas of all the streams described by Wright that could be recognized from his names. In each case the area has been determined above the point where the stream issues from the foothills or mountains. In the case of a few of these streams other measurements are available for later years. These are included and show, particularly for the year 1900, a marked decrease in volume over that measured by Wright. The rainfall in the year 1899-1900 at Santa Barbara was 12.68 inches.

[b] A miner's inch is taken as equal to one-fiftieth of a cubic foot per second, or a flow of 12,925 gallons per day.

TABLE 2.—*Streams west of Santa Barbara and south of Coast Range.*

Stream.	Catchment in square miles.	Length in catchment.	Distance from city in miles.	Daily flow in miner's inches.	Remarks: Flow in miner's inches.
Arroyo Burro		2.5	2.5	11.6	June 17, 1900: 1.5.
Maria Ygnacia	5.7	2.0	6.0	[a] 11.6	
San Jose	6.0	2.5	7.0	13.6	July 30, 1900: 38.1.
San Pedro	2.7	2.0	9.5	3.9	
Arroyo Carnero	3.3	2.0	10.0	3.9	
Annes	4.0	1.0	12.0	3.9	
Annito		1.5	13.0	1.9	
Tecolote	5.2	2.5	14.0	13.6	
Aguila	4.5	2.0	15.0	5.8	
Dos Pueblos	6.7	2.0	17.0	27.2	
Cañada Verde (Las Varas)	2.5	2.0	18.0	3.9	
Cañada Llaces	1.5	2.0	20.0	3.9	
El Capitan	1.5	1.0	22.0	11.6	
Cañada del Corral	1.0	1.0	23.0	7.7	
Cañada Refugio	2.0	2.0	25.0	15.4	
Total				139.5	

[a] Laguna Blanca Water Company.

Wright correctly states that the grades of these local streams on the south side of the mountains are very steep, affording no opportunities for the construction of storage reservoirs. He also states that while it might be possible to divert some of these storm waters by means of large canals into basins in the flat lands to the side, the work would be exceedingly expensive and impracticable.

The conclusion that he reaches with reference to the streams on the south side of the Coast Range is as follows:

I do not deem it practicable to secure an ample supply of water for Santa Barbara south of the Santa Ynez Range of mountains, for the following reasons:

1. The aggregate daily summer flow of the entire watershed from Rincon Creek to and including Refugio Creek is less than 4 million gallons per day.

2. This flow is all claimed by riparian owners, water companies, and individual water claims.

3. Storage-reservoir sites of sufficient capacity and elevation do not exist along the streams, if at all. The construction of numerous small reservoirs would increase the operating expenses and also the first cost of construction.

4. Diverting dams in the streams would be necessary to turn the winter flow, and the conduits leading to the storage reservoirs would necessarily be large and expensive.

5. It is very doubtful if the city of Santa Barbara could establish a claim on the waters of these streams which would enable her to obtain them through legal process. Where it is possible to do so, however, the city can not afford to appropriate water which, if not now needed, soon will be, for the supply of the rapidly increasing population of the Carpinteria and Montecito valleys on the east and the Goleta and Dos Pueblos on the west.

STREAMS NORTH OF COAST RANGE.

Having failed to find an adequate supply of water on the south side of the range, the investigations of Wright were extended to the north side of the range, into the basin of Santa Ynez River. Surveys to determine relative elevations were made, and detailed reports on two reservoir sites, one known as the Juncal, near the head of the Santa Ynez, and the other as the Main River reservoir site, below the mouth of Blue Canyon. A general view of the basin of Santa Ynez River is shown in Pl. III, *B*.

From a study of the rainfall data available at the time of his report Wright concludes that it will be necessary to have a storage reservoir capable of holding water from years of average or excessive rainfall for years of deficient rainfall. He believes that in some winters there will be little, if any, storm water in these streams. From April, 1876, to October, 1877, inclusive, there was a period of drought of nineteen months in which the rainfall was insufficient to much more than supply evaporation. On his basis of 200 gallons per day per capita, for a population of 20,000, requiring 4 million gallons per day, this would call for a storage of 2,280 million gallons, which is equal to 7,000 acre-feet of water, an acre-foot being the volume of water sufficient to cover 1 acre 1 foot deep, or 43,560 cubic feet.

JUNCAL RESERVOIR SITE.

The Juncal reservoir site was determined to have the following capacities with the heights of dam stated:

TABLE 3.—*Capacities of Juncal reservoir with various heights of dam.*

Height of dam in feet.	Capacity in gallons.	Capacity in acre-feet.
200	4,000,000,000	12,276
175	2,352,000,000	7,218
150	1,877,000,000	5,760
125	1,437,000,000	4,410
100	1,050,000,000	3,222
75	705,000,000	2,164
50	350,000,000	1,074

A dam 200 feet high would be 550 feet long on top, and one 100 feet high would be 272 feet long on top. Purslow in his report estimates that a dam at the Juncal 100 feet high, with a diversion conduit to Santa Barbara, would cost $300,000. The area of the drainage basin is given as 23.5 square miles by both Wright and Purslow. From the topographic surveys of the United States

A. MONO CREEK DAM SITE AND GAGING STATION.

B. SANTA YNEZ BASIN ON PROJECTED LOCATION OF OLD CITY TUNNEL.

Geological Survey it is found that they were seriously in error, and that there is but 13.4 square miles of area naturally tributary to this reservoir site. This directly affects the value of the Juncal as a storage reservoir. Wright gives certain figures showing that, in his judgment, the water supply would be always sufficient to meet the demands upon this reservoir. At the time the reports of both Wright and Purslow were written little available data existed indicating the flow that might be expected from drainage basins on the Pacific coast, particularly in southern California. Estimates were therefore based upon observations on eastern streams. Since that

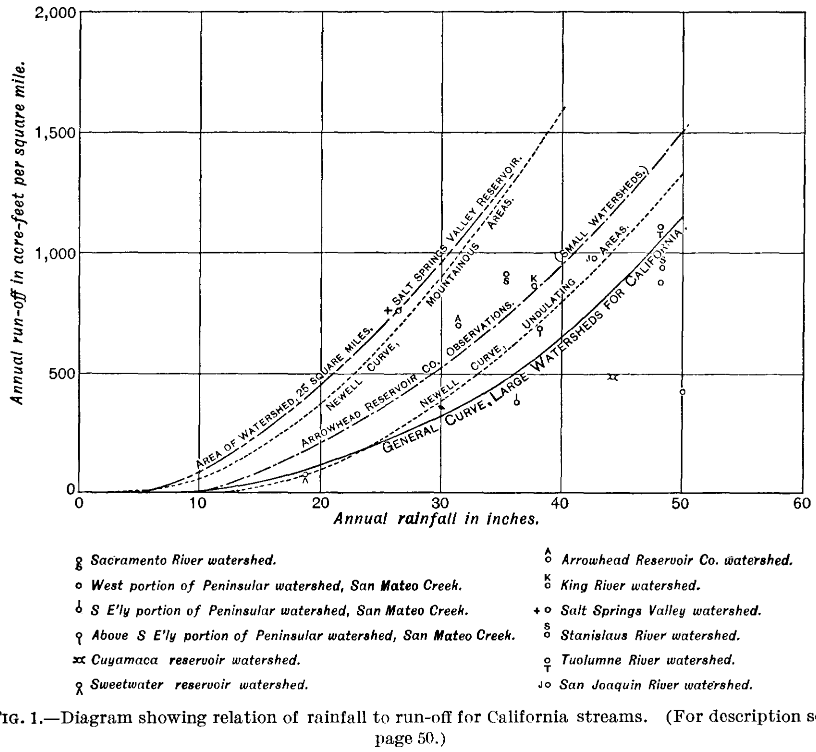


FIG. 1.—Diagram showing relation of rainfall to run-off for California streams. (For description see page 50.)

time, however, the United States Geological Survey has been measuring California streams and determining drainage areas and their rainfall, and there is now better information available on this subject. The whole trend of these late stream measurements has been to show that estimates of run-off for southern California, particularly those based on observations on eastern rivers which were previously considered as comparable, give excessive and unreliable results. While it is impossible to predict accurately what the discharge from any given drainage basin will be, nevertheless, from examinations made of the basin of the Santa Ynez and the application of average conditions observed in localities somewhat similar and of a mountainous character, it is possible to form an approximately correct idea of the true results. Table 12 shows the estimated run-off from the drainage basin of the Juncal and neighboring streams in detail. From an extended comparison of rainfall data it is believed by the writer that the precipitation on average years in the basin of the Santa Ynez may possibly reach 22 inches. But since late records indicate less rainfall, the Santa Barbara mean of 16.78 is used by the author as the basis of his estimates in table 12 (p. 53). Wright considers that it will be over 20 inches throughout the drainage basin, and Purslow that it will be 27 inches. The rainfall in the mountains varies in the same ratio for wet and dry years as the rainfall at Santa Barbara city. The first rains are absorbed by the ground and retained in the soil until evaporated either from the surface or by the growing plants. It takes about 9 inches of rain to meet these demands, and, generally speaking, no material stream flow will result from a winter's rain unless it exceeds this amount, provided all of this precipitation does not occur in hard successive storms, in which event there would be run-off; usually, however, there will be no stream flow unless the winter rain exceeds 9 inches. When these demands of evaporation are met, the succeeding storms furnish more and more of a water supply for the streams, and the per cent of rain so discharged increases in a growing ratio.

From the studies above referred to, assuming a rainfall of 25 inches in this basin, it is concluded that during the year 1897–98, when the rainfall at Santa Barbara amounted to 4.99 inches, there would have been no high-water stream flow in the mountains. In 1898–99 there would have been available at the Juncal reservoir 1,114 acre-feet; in 1899–1900, 1,367 acre-feet. This is a three-year mean of 827 acre-feet, which would yield a supply of but 730,000 gallons per day, evaporation not being deducted. These figures, compared with Wright's estimated necessary supply of 4,422 acre-feet annually to meet future conditions reasonably within sight (20,000 people), show that the Juncal reservoir site and drainage basin would be inadequate to meet the demands of the city of Santa Barbara. The conclusion of Wright or of Purslow that the Juncal alone is a suitable source for a water supply for the city can not be accepted, although it may be used properly as a supplemental reservoir for hold-over purposes, its waters being liberated at such periods as may be necessary to make up for deficiencies in reservoir sites lower on the stream. In conclusion Mr. Wright makes the following statement:

I consider the Santa Ynez River above the mouth of Blue Canyon to be not only an available source of supply, but the only source possible for the future supply of Santa Barbara with an abundance of good potable water, for the following reasons:

1. Not only the sources of the streams but the entire river are uncontaminated by any of the organic wastes pertaining to civilization, and from the rugged nature of the country are likely to remain so. The sandstone gathering-grounds are of the best class for delivering water free from mineral impurities.

2. The elevation and capacity of the storage sites and the extent of the catchment insure an ample supply of water in all seasons.

3. The riparian rights in that portion of the stream sought to be appropriated are merely nominal, as none of the summer flow above Blue Canyon ever appears on the surface as far down as the San Marcos rancho. The only riparian owner is therefore the owner of the Los Prietos y Najalayegua rancho.[a] This right can probably be purchased, or if not, can be condemned by legal process.

4. The expansive capacity of the district for increasing the supply to meet all possible demands is ample and in excess. This feature alone, other things being equal, should decide in favor of this source of supply.

5. Storage reservoir sites are numerous and ample. The fall of the stream being comparatively light, renders it practicable to arrest the entire flow to the extent required by the demand.

6. The expense of constructing a thoroughly efficient and permanent system of works is no greater than would be the cost of works of equal capacity on the coast side, and maintenance will be much less.

I also recommend the construction of the works as a whole. Omitting the storage reservoir is simply gambling on our good luck, viz, that we will not have a dry season this year or next, and so on until we do get a dry year, when it will be too late to save ourselves from great discomfort and possible pecuniary loss.

REPORT OF E. J. S. PURSLOW, 1896.

Mr. Ernest J. S. Purslow, deceased, a civil engineer, living in Santa Barbara at the time and employed by the Santa Barbara Water Company, investigated in 1896 the same questions covered by Wright's report of 1889. As engineer for the water company, he would naturally have a point of view somewhat different from that of the representative of the city.

Purslow states that the present Santa Barbara Water Company, which consolidated the water rights on Mission Canyon and the De la Guerra wells, was incorporated in January, 1889. This was done in order to increase the available water supply then obtained from Mission Creek by a gravity system of diversion, and from tne De la Guerra wells, located in the city limits, by a pumping system.

NEEDS OF DISTRICT.

Purslow says:

The present water supply is so inadequate and incomplete that it is a physical impossibility for the city to increase in size or population, or for the surrounding country to advance in development, until water is procured from a source other than those in the immediate vicinity, which are now all used to their fullest capacity. The scarcity of water is the first impression that visitors receive, and many who have desired to make this their home have abandoned the idea owing to the gravity of this drawback.

[a] On December 22, 1903, this ranch was included in the Santa Barbara Forest Reserve, lien scrip having been issued to the owners for it.

By the general introduction of meters and the most economical type of service taps the supply of 130 gallons should be ample for all purposes; at which rate the immediate demand of the present population would be about 1 million gallons per diem. The total supply at present, during the dry months of a year with average rainfall, is about 600,000 gallons per diem, about half from the Mission streams and half from the De la Guerra wells.

Nothing has retarded the advance of the city so much as the condition of the water supply, and nothing will promote its future prosperity and growth as much as a remedy for this condition. The present demands of the city being upwards of 1 million gallons per diem, a system could not be considered adequate which will not have a capacity to supply at least 1,500,000 gallons per diem as soon as work can be constructed, with means for subsequently increasing the supply with the growth of the city.

The suburbs of Santa Barbara, and the land extending easterly and westerly from the city, are improved only to the extent to which the waters of the small mountain streams have been made available, principally at points adjacent to and riparian on these streams. West of the city, where small quantities of water are obtained, the land is devoted principally to horticulture, and where water is not obtainable it is used as grazing and farming land. East of the city lies the famed district of El Montecito, which is inhabited, to the extent to which the small streams can supply water, by a class of people who for the most part have independent means, many of whom have built substantial and handsome houses and beautified their grounds, and among whom there are enough people of intellectual pursuits and tastes to form a nucleus which makes it especially attractive for that class of people. It is primarily and distinctively a residence district. Consisting of a gentle slope from the foothills toward the channel, broken and diversified by the natural watercourses, which, though bereft of water during the summer months, are lined with natural timber growth, backed and protected on the north by the Santa Ynez Mountains, nearly every spot commanding a comprehensive and magnificent view of the channel and coast line and the distant islands, possessing the most equable climate in the world and everything else which Almighty God could give except plenty of water, it is destined to become one of the garden spots of the world.

Land which has water is sold at from $500 to $1,000 an acre, and although land has very little productive value without water, such dry land is held and readily sold in El Montecito district at from $250 to $500 an acre. In spite of the unprecedented business depression of the past two years, sales of this land have been made during this period of some 40 tracts scattered through this district, aggregating some 670 acres, at an average price of about $330 an acre. There is no other residence district in California where prices for bare, dry, suburban or agricultural land have been so maintained and sales so extensively made during the past two years. El Montecito comprises about 4,500 acres of land susceptible of irrigation, only a small fraction of which is supplied with water for more than domestic purposes. The duty of water here for full-bearing lemon orchards has been found to be one miner's inch to 10 acres of land with the average soil, a miner's inch being equivalent to a continuous flow of 12,960 gallons per diem. Many lemon orchards have been planted during the past two years on tracts of land which have appurtenant to them such small allowances of water that it is feared that the trees will die before reaching full maturity. When orchard trees are young and small a very small quantity of water suffices to moisten the soil immediately surrounding them; but, as they increase in size and their roots extend, it is necessary to use water enough to irrigate the whole orchard surface. The owners of such orchards will be compelled to purchase more water or see their years of labor end in failure. Ornamental grounds, vegetables, oranges, and other fruits require about the same quantity of water as lemons.[a]

[a] The tunnel line from the lower reservoir sites on the Santa Ynez (see p. 41) will command all the lands of El Montecito as well as of the city of Santa Barbara. The elevation of the south portal of the present city tunnel is 1,393 feet above sea level. The new tunnel line proposed through Mission Canyon will be at an elevation of 1,186.46 feet (Geological Survey datum).

POSSIBLE SUPPLY.

Purslow then proceeds to show that the proper and adequate solution of the water problem for Santa Barbara and vicinity consists of the storage of the storm waters of Santa Ynez River and their diversion by means of tunnel lines to the south side of the range. He states that there are three available sites for storage reservoirs on lands owned by the water company on the Santa Ynez—one in Blue Canyon, which he afterwards condemns as an impracticable proposition because of its expense and small drainage area; one on the main river near the confluence of the Blue Canyon with the Santa Ynez, which he names the Main River reservoir site, and which has a large storage capacity; and a third, the Juncal reservoir site, near the headwaters of the stream.

BLUE CANYON SITE.

He states that the Blue Canyon site is located at an elevation of 1,500 feet above sea level, with a drainage area of only about 8 square miles. A contour survey which he made showed that a dam 100 feet high above the bed of the gorge would impound 1,500 million gallons, equivalent to 4,600 acre-feet. He admits that the local drainage naturally tributary is totally inadequate to fill this reservoir. It would require a tunnel 10,550 feet long to connect this reservoir with the south side of the mountains.

MAIN RIVER SITE.

In describing the Main River reservoir site he said: "This is one of the best in California"; certainly a very singular statement for an engineer to make, in view of the fact that the width of the dam site on the bed of the creek is 427 feet. He says the drainage area tributary to the Main River reservoir site is 150 square miles, ranging in elevation from 1,500 to 6,000 feet, with a mean rainfall of 30 inches in the drainage basins and a probable minimum of 7 inches. From the recent official surveys of the United States Geological Survey it has been definitely determined that the drainage area above this reservoir site is 71 square miles. The elevation of the bed of the canyon at the Main River dam site is 1,460 feet above sea level. This reservoir site is of such elevation as to command by gravity the present city tunnel line, which may be extended as the outlet for the Mono reservoir site (see pp. 40–41). The Main River reservoir site is owned by the Santa Barbara Water Company and is of some merit. If a tunnel is carried through the range this reservoir, commanding the present city tunnel in elevation, may ultimately be built, either by the water company or by its successors, thus materially adding to the supply for the district south of the mountains, which demands all the water possible to be obtained from Santa Ynez River.

JUNCAL SITE.

Purslow states that an observer was stationed at the Juncal, recording the rainfall and taking measurements of the flow of the stream during the " past winter," and that these records show that up to the date of writing the flow available for storage was upwards of 800 million gallons (2,455 acre-feet). This quantity includes the flow of Alder Creek basin (2.4 square miles), which he proposed to divert into the Juncal. It can not be definitely stated what space of time he meant to include within this period, but as his report bears date July 21, 1896, it is probable that these measurements extend from the 1st of November, 1895, to say the 1st of July, 1896. The rainfall during that winter was 13.77 inches at Santa Barbara, and his conclusion can not be accepted that this record may be taken as an approximate minimum for streams in the Santa Ynez Mountains, particularly as there was at Santa Barbara in the month of January a precipitation of 6.84 inches, which should, in all probability, have yielded a flood condition in the streams.

Purslow's surveys of the capacity of the Juncal reservoir site practically confirm those by Wright, already stated. The site is one of considerable merit, and possibly the dam should be built ultimately in connection with supplementing the storage capacity of the lower dams. The Gibraltar reservoir site, below the Mono on the trunk stream, however, offers a very much cheaper storage capacity and a much larger available supply. Purslow probably overestimates the underflow at the Main River site.

Purslow proposes using a riveted-steel pressure pipe line to divert the water to Santa Barbara; probably the life of this pipe line would not be more than fifteen years. His detailed estimate of the cost is $300,000 to obtain water from the Juncal. The dam which he proposes is to be 100 feet high, with a storage capacity of 1,023 million gallons. He estimates the minimum season's supply as 400 million gallons, and considers an annual draft of 600 million gallons (equal to 1,845 acre-feet) as the amount that might be obtained from the reservoir with that dam.

It is here estimated that the run-off from the Juncal would have been in minimum years as follows:

Run-off from Juncal reservoir.

	Acre-feet.
1869–70	603
1870–71	335
1897–98	0
1898–99	1,114
1899–1900	1,367

It must be remembered that these estimates are only approximations based upon observations on other streams somewhat similarly situated and are not absolute. However, they are believed to be fair conclusions from the best available data, and, using them, we can not accept the conclusion that 1,845 acre-feet of water could annually be withdrawn from this reservoir site. This, however, does not condemn the site, if it is used in connection with the lower site to supplement the supply in dry years. It is believed that ultimately this reservoir may be constructed for this purpose, but it is not believed that it is wise to base a water supply for the city of Santa Barbara on it alone with its drainage basin of but 13 square miles.

REPORT OF R. B. CANFIELD, 1896.

On July 28, 1896, Mr. R. B. Canfield, president of the Santa Barbara Water Company, made a report supplemental to that of Purslow. Mr. Canfield's conclusions are also of interest because of his intimate and accurate knowledge of the water situation near Santa Barbara, on the south of the Santa Ynez Mountains. It must be remembered that the measurements of Wright to which he refers were made in a year of excessive stream flow.

Canfield says:

Mr. Wright found all the streams east of Santa Barbara, together with Mission Creek—9 streams in all—to be yielding daily 1,650,000 gallons, and the 15 creeks west of Mission Creek, to and including the Refugio, to be yielding daily 1,725,000 gallons, but he justly dismisses the idea of obtaining the needed supply from these sources as impracticable, partly owing to the expense of gathering and conveying the supply from so many points and over so long distances, and partly owing to the fact that all this water is claimed by riparian owners and individual water claimants and water companies organized to supply districts adjacent to some of the streams. It is well known that the demand for this water, especially in the neighborhood of this city, is beyond the capacity of all the streams to supply, and it is obvious that the expense of obtaining water from these sources would be prohibitive.

All the streams (excepting the flow of the Hot Springs) on the south slope of the range east of Mission Creek as far as Romero Canyon, 8 miles distant, were yielding when measured in the summer of 1889 a total daily flow of 500,000 gallons, while the creeks west of Mission Canyon to and including San Jose Creek, 7 miles distant, were yielding a total daily flow of only 475,000 gallons, notwithstanding the comparatively abundant rainfall of preceding seasons. Even though these were the minimum quantities to be obtained in the dry season from these streams (which is far from being the case) and it were possible to bring them all to Santa Barbara for the supply of the city, whether by surface diversion or by means of tunnels in their neighborhood, which would intercept the supplies and drain their channels, it would not be desirable to do so. Santa Barbara, if she could afford the expense necessary for the acquisition of these waters, could not afford the loss she would suffer by the destruction of the prosperity and beauty of her suburbs of Montecito and Goleta. The prosperity of Santa Barbara depends in a large measure upon that of the neighboring rural districts, as does theirs upon that of the city. To the extent to which the city deprives the suburbs of their natural water supply, it injures itself.

During the last spring borings were made under the direction of the city engineer west of the city in the hope of finding considerable underground currents, but without success. The subterranean waters in the eastern part of the ctiy are tapped by the wells of the Santa Barbara Water Company for the supply of its pumping plant; but all efforts to obtain the large additional supply which the city needs from these and other sources have only tended to confirm the soundness of Mr. Wright's conclusion when he said: "I consider Santa Ynez River above the mouth of Blue Canyon to be not only an available source of supply, but the only source possible for the future supply of Santa Barbara with an abundance of good potable water."

Water is now sold in Santa Barbara at the rate of about 16 cents per thousand gallons to the city for street-sprinkling purposes (at the rate of $35,000 per year for 1 second-foot) and to private consumers at from 20 to 25 cents per thousand gallons, which are moderate rates as compared with those realized in some other cities in this State; and it is believed that although the development of the business in the future may justify some reduction of rates, an average rate of 15 cents per thousand gallons at least can be calculated upon. The city requires for its immediate needs at least 1,000,000 gallons of water daily, and its steady growth, soon to be accelerated by the completion of the railroad to San Francisco, will be constantly increasing this demand.

REPORT OF J. LINN MOYER, 1902.

MONO SITE.

On August 5, 1902, Mr. J. Linn Moyer, city engineer of Santa Barbara, made a report based on a reconnaissance through portions of the drainage basin of Santa Ynez River, particularly examining a new reservoir site suggested by Mr. Frank E. Kellogg, which the latter had observed on Mono Creek, the largest tributary of the upper portion of Santa Ynez River. Moyer made a favorable report on this situation, based on this reconnaissance, and made recommendations that further examinations be made. It was his judgment that the reservoir site, which is called the Mono site, was a good one and that the water supply available would be ample to meet the necessities of the city. Pls. III, *A*, and IV, *A*, *B*, show views of the Mono dam and reservoir sites. He recommended as follows:

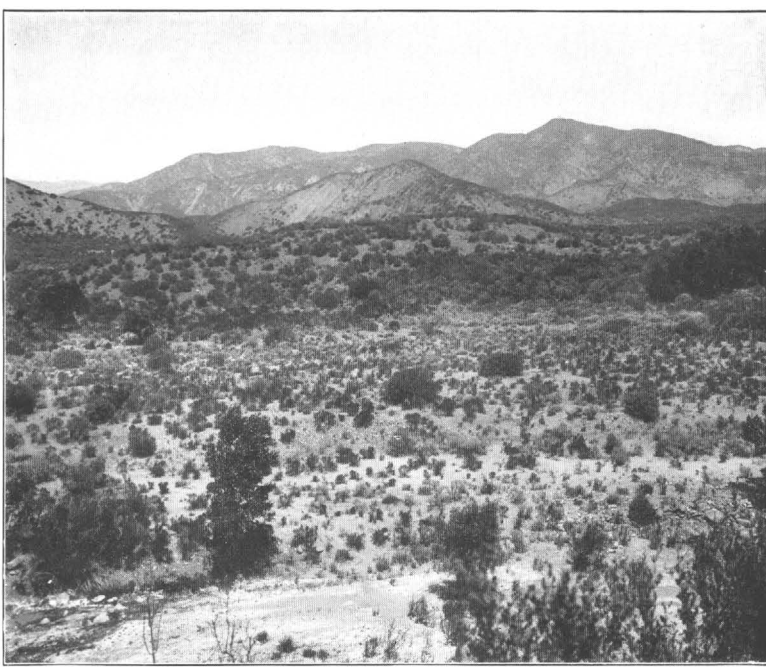
1. That the exact elevation of the dam site be determined in order to ascertain whether or not the water could be conducted to the city tunnel.
2. That borings and excavations be made on the dam site to ascertain the depth of bed rock and the quality of same.
3. That a topographical survey be made of the reservoir basin in order to determine the height necessary to construct the dam, and also to determine the amount and location of land necessary to be purchased.
4. That an option be obtained on the land necessary to be purchased, as will be shown by the topographical survey.
5. That a chemical analysis be made of the waters of Mono Creek.
6. That the grade of the present city tunnel be reduced to the lowest possible rate.

Moyer found that a provision should be made to furnish a continuous supply of 1 million gallons per day in addition to the present flow of the tunnel in order to fully supply the entire present population of the city.

CONCLUSIONS DRAWN FROM FOREGOING REPORTS.

The foregoing reports have been reviewed in extenso because doing so brings these investigations up to date and also because they furnish a proper basis from which to start on the present investigations. It

A. MONO DAM SITE, LEFT ABUTMENT.



B. MONO CREEK RESERVOIR SITE.

View upstream from dam site.

will be seen that all of these distinguished authorities, each one of whom was intimately acquainted with the local situation, agree on the following vital points:

1. That the present supply of water for the city of Santa Barbara is inadequate and that unless it is increased the material development of the town will be seriously impeded.

2. That there is no adequate water supply within a reasonable limit of the city of Santa Barbara on the south side of the range from which the city could be supplied, and even if the water of such small streams as there are could be obtained it would be at a sacrifice of existing development.

3. That it is feasible and desirable to obtain an adequate supply of water from the drainage basin of Santa Ynez River, and that this can be done at a profit.

The writer has, therefore, taken up the consideration of the subject at this point and prepared estimates of cost, etc.

POPULATION AND CONSUMPTION OF WATER.

The population of Santa Barbara, according to the enumeration of the United States Census, is as follows:

Population of Santa Barbara.

1870	2,889
1880	3,460
1890	5,864
1900	6,587
1905 (estimated)	10,000
1910 (estimated)	12,500

The rate of growth of Santa Barbara was most rapid from 1880 to 1890, but it has always shown a substantial increase in population. Projecting it into the future we obtain the populations for 1905 and 1910 as stated above. It is believed by the other engineers, as well as the writer, that the development of the city is largely dependent upon an adequate water supply, not only in the city but upon the adjacent suburban property. If this is once obtained it may be expected that the population will more rapidly increase. Among people looking for future homes, especially in the West, the water question is considered one of prime importance in the selection of a residence. At present (1903) the municipal waterworks has some 709 taps through which water is served, and the Santa Barbara Water Company has about 900, making a total of 1,609 taps, serving a population of about 8,045 persons. The Gates system supplies 50 taps more.

In May, 1902, 301 meters of the municipal waterworks indicated 81 gallons per capita daily consumption. In June, 1902, 329 meters indicated a consumption of 82 gallons per capita. In July, 1902, 369 meters indicated a consumption of 75.5 gallons per capita per day.

It will be seen that 55 per cent of the city's services are metered. It is estimated that 15 gallons per capita per day, not included in the above rate, are used in public buildings and in street sprinkling. It would probably be fair to say, using round numbers, that the present consumption of the city is 100 gallons per capita per day. This is a rather low rate of consumption for a California city, and in all probability the city would use to advantage more water if it were available at reasonable prices. The consumption in Los Angeles before meters were introduced, in the summer of 1901, was 306 gallons per capita per day. After the introduction of several thousand meters it is now 242 gallons per capita per day. The water commissioners of that city in their annual report for 1902 estimate that a reasonable consumption would be 150 gallons per capita per day for metered services. The city of San Jose, in 1890, was using 194 gallons per capita daily. Wright, in his report to the city, estimated on a consumption of 200 gallons, and Purslow considered that 130 gallons should be sufficient.

Considering the evidence in the case, it is believed that it is desirable, for the proper development of the city, improvements of lawns, gardens, etc., that 150 gallons daily, as an average for the year, should be used, and this has been adopted as a proper basis for this report.

In considering the storage of flood waters necessary to meet this situation, it has been estimated that 60 per cent of the water supply would be used in the six summer months, and 40 per cent in the six winter months. The question of evaporation from reservoirs is an important one in estimating on a storage system. It is believed that the annual evaporation from reservoirs in the basin of the Santa Ynez would be approximately 42 inches in depth, 67½ per cent of this occurring in the six summer months, and 32½ per cent in the six winter months. From a study of the monthly rainfall tables of precipitation occurring at Santa Barbara (see table 11) it appears that there would, in all probability, have been no material addition to the waters stored in any reservoirs in this locality from May 1, 1876, to December 1, 1877, a period of nineteen months. Again, between April 1, 1897, and October 1, 1898, or for a period of eighteen months, there would have been no material addition. It will be necessary, therefore, in order to prepare for the worst condition that will probably occur in the future, as judged by a record of thirty-six years' rainfall in the past, to construct reservoirs that will hold a supply of water for a period of nineteen months of continuous withdrawal without replenishment.

With a population of 10,000 persons in 1905, reasonably within sight and necessary to immediately prepare for, at 150 gallons per day, there will be a consumption of 1,500,000 gallons daily. This amount of water withdrawn for a period of nineteen months will require 2,826[a] acre-feet for actual domestic uses. It is also necessary to provide for a loss by evaporation of about 692 acre-feet (for a reservoir of this size for nineteen months), or a total of 3,518 acre-feet for use and evaporation during the worst period of drought that the city will probably ever have to face.

Reducing it to a monthly withdrawal, there will be required for summer use 170 acre-feet, for summer evaporation about 45 acre-feet, and for summer use and evaporation 215 acre-feet.

From surveys that have been made of the reservoirs, described later in this report, it appears that a dam 85 feet high at the Mono site, impounding water to a depth of 75 feet, will give storage capacity for 3,880 acre-feet of water—enough to meet the above needs, even assuming the severe conclusions that no permanent supply can be relied upon from the tunnel, and that the municipality is to furnish all the water for the town. Similarly a dam 100 feet high at the Gibraltar site (see p. 55) would give an equal capacity and have tributary thereto a larger and better water supply.

NEAR-BY SUPPLIES.

The question of local water supply on the south side of the range was extensively discussed under the review of the reports of Wright, Purslow, and Canfield. Generally speaking, the amount now available for the city may be taken in average years as 300,000 gallons daily from Mission Creek, 300,000 gallons from the De la Guerra wells (statement by Purslow), and 350,000 gallons from the city tunnel, making 950,000 gallons to meet an estimated normal present demand of 1,200,000[b] gallons, or a deficit daily of 250,000 gallons.

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[a] One acre-foot is equivalent to 325,851 gallons.
[b] On basis of 150 gallons per day for 8,000 persons.

MISSION CREEK.

The following measurements of Mission Creek taken at various times, as stated, may be of interest in this connection:

TABLE 4.—*Discharge measurements on Mission Creek.*

Date.		Hydrographer.	Discharge in second-feet.[a]	Gallons per day.
1888.				
Jan.	15	A. Poett	0.93	605,594
	24	....do	2.80	18,200,000
Feb.	7	....do	1.37	888,552
Mar.	16	....do	2.23	1,452,000
July	26	....do	.36	233,000
	29	....do	.28	184,747
1889.				
July	13	....do	.43	282,609
	17	....do	.36	232,551
Aug.		G. F. Wright	.34	219,672
	18	A. Poett	.21	137,052
Sept.	1	....do	.32	206,821
1892.				
June	11	....do	.36	232,673
1894.				
June	28	Flourney	.24	155,115
1900.				
May	10	....do	.25	161,600
June	17	L. Moyer	.045	[b] 29,084

[a] One second-foot is equivalent to 50 miner's inches.
[b] Above diversion not on bed rock, 200 feet above dam.

TABLE 5.—*Measurements in Mission Canyon.*

[50 miner's inches=1 cubic foot per second.]

AT NOTCHED WEIR NEAR PORTAL OF PROPOSED NEW CITY MISSION TUNNEL.

Date.		Time.	Hydrographer.	Discharge in inches.
1903.				
Aug.	14	2.30 p. m.	R. L. North and J. Compton	6.367
	15	8.30 a. m.	....do	9.474
	15	9 a. m.	....do	8.817
	15	9.30 a. m.	....do	8.817
	15	10 a. m.	....do	8.689
	15	10.30 a. m.	....do	8.140

TABLE 5.—*Measurements in Mission Canyon*—Continued.

AT NOTCHED WEIR NEAR PORTAL OF PROPOSED NEW CITY MISSION TUNNEL—C't'd.

Date.	Time.	Hydrographer.	Discharge in inches.
1903.			
Aug. 15	11 a. m.	R. L. North and J. Compton	7.823
15	11.30 a. m.	do.	7.832
15	12 m.	do.	7.242
15	12.30 p. m.	do.	6.959
15	1 p. m.	do.	6.363
15	1.30 p. m.	do.	6.109
15	2 p. m.	do.	5.600
15	2.30 p. m.	do.	5.359
15	3. p. m.	do.	5.220
15	3.30 p. m.	do.	4.851
15	4 p. m.	do.	4.851
15	4.30 p. m.	do.	4.851
15	5 p. m.	do.	5.042

AT OLD MISSION DAM.

1903.			
Aug. 22	6.30 p. m.	L. M. Hyde and R. L. North	0.909
23	9.10 a. m.	do.	4.762
24	8.25 a. m.	L. M. Hyde, R. L. North, and G. D. Morrison	8.333
24	6.15 p. m.	do.	6.896
25	7.45 a. m.	L. M. Hyde and R. L. North	10.000
27	7.15 a. m.	R. L. North, R. F. Wyckoff, and G. D. Morrison	10.000

AT NOTCHED WEIR AS ABOVE.

1903.			
Aug. 27	8.30 a. m.	R. L. North and R. F. Wyckoff	9.080
27	9 a. m.	do.	9.080
27	1 p. m.	do.	7.070
27	1.30 p. m.	do.	6.420
27	2 p. m.	do.	5.750
27	2.30 p. m.	do.	5.750
27	3 p. m.	do.	5.410
27	3.30 p. m.	do.	4.950
27	4 p. m.	do.	4.990
27	4.30 p. m.	do.	4.990
27	5 p. m.	do.	4.810

TABLE 5.—*Measurements in Mission Canyon*—Continued.

AT OLD MISSION DAM.

Date.	Time.	Hydrographer.	Discharge in inches.
1903.			
Oct. 3	2.20 p. m.	J. L. Moyer, T. B. Curley, and D. Boyle	5.320

AT NOTCHED WEIR AS ABOVE.

Date.	Time.	Hydrographer.	Discharge in inches.
1903.			
Oct. 19	8 a. m.	L. M. Hyde and C. M. Elliott	7.532
19	8.30 a. m.	do.	7.356
19	9 a. m.	do.	6.742
19	9.30 a. m.	do.	6.314
19	10 a. m.	do.	6.158
19	10.30 a. m.	do.	6.003
19	11 a. m.	do.	6.003
19	11.30 a. m.	do.	5.803
19	12 m.	do.	5.600
19	12.30 p. m.	do.	5.317
19	1 p. m.	do.	5.042
19	1.30 p. m.	do.	4.810
19	2 p. m.	do.	4.591
19	2.30 p. m.	C. M. Elliott	4.591
19	3 p. m.	do.	4.378
19	3.30 p. m.	do.	4.255
19	4 p. m.	do.	4.169
19	4.30 p. m.	do.	4.169
19	5 p. m.	do.	3.970
Nov. 4	8.30 a. m.	G. D. Morrison	8.817
4	9 a. m.	do.	8.753
4	9.30 a. m.	do.	7.708
4	10 a. m.	do.	7.416
4	10.30 a. m.	do.	7.187
4	11 a. m.	do.	6.852
4	11.30 a. m.	do.	6.792
4	12 m.	do.	6.579
4	12.30 p. m.	do.	6.579
4	1 p. m.	do.	6.261
4	1.30 p. m.	do.	6.003
4	2 p. m.	do.	6.003
4	2.30 p. m.	do.	5.853
4	3 p. m.	do.	5.903
4	3.30 p. m.	do.	5.600

TABLE 5.—*Measurements in Mission Canyon*—Continued.

AT NOTCHED WEIR AS ABOVE—Continued.

Date.	Time.	Hydrographer.	Discharge in inches.
1903.			
Nov. 4	4 p. m	G. D. Morrison	5.750
4	4.30 p. m	do	5.600
16	8.30 a. m	R. F. Wyckoff	8.689
16	9 a. m	do	7.945
16	9.30 a. m	do	7.299
16	10 a. m	do	7.242
16	10.30 a. m	do	6.595
16	11 a. m	do	6.792
16	11.30 a. m	do	6.687
16	12 m	do	6.420
16	12.30 p. m	do	6.314
16	1 p. m	do	6.314
16	1.30 p. m	do	5.853
16	2 p. m	do	5.600
16	2.30 p. m	do	5.269
16	3 p. m	do	5.131
16	3.30 p. m	do	4.950
16	4 p. m	do	4.851
16	4.30 p. m	do	4.680
28	8.30 a. m	R. L. North	6.370
28	9 a. m	do	6.690
28	9.30 a. m	do	6.000
28	10 a. m	do	5.900
28	10.30 a. m	do	5.650
28	11 a. m	do	5.650
28	11.30 a. m	do	5.510
28	12 m	do	5.510
28	1 p. m	do	5.040
28	1.30 p. m	do	4.850
28	2 p. m	do	4.720
28	2.30 p. m	do	4.680
28	3 p. m	do	4.680
28	3.30 p. m	do	4.340
28	4 p. m	do	4.300
28	4.30 p. m	do	4.130
28	5 p. m	do	3.970
Dec. 24	10.30 a. m	G. D. Morrison	7.470
24	11 a. m	do	6.560
24	11.30 a. m	do	6.370

TABLE 5.—*Measurements in Mission Canyon*—Continued.

AT NOTCHED WEIR AS ABOVE—Continued.

Date.	Time.	Hydrographer.	Discharge in inches.
1903.			
Dec. 24	12 m.	G. D. Morrison	6.210
24	12.30 p. m.	do	6.160
24	1 p. m.	do	6.160
24	1.30 p. m.	do	5.950
24	2 p. m.	do	5.600
24	2.30 p. m.	do	5.460
24	3 p. m.	do	5.320
24	3.30 p. m.	do	5.080
24	4 p. m.	do	5.040
1904.			
Feb. 29	11.15 a. m.	L. M. Hyde	18.190
Mar. 14	3.30 p. m.	do	16.310

AT OLD MISSION DAM.

1904.			
Apr. 4		L. M. Hyde	16.670

TABLE 6.—*Measurements in Rattlesnake Canyon.*

AT NOTCHED WEIR ABOUT 200 FEET UPSTREAM FROM WHERE WATER IS DIVERTED FOR SANTA BARBARA WATER SUPPLY.

[50 miner's inches=1 cubic foot per second.]

Date.	Time.	Hydrographer.	Discharge in inches.
1903.			
Aug. 17	8.30 a. m.	R. L. North and J. Compton	2.507
17	9 a. m.	do	2.596
17	9.30 a. m.	do	2.507
17	10 a. m.	do	2.216
17	10.30 a. m.	do	2.216
17	11 a. m.	do	2.216
17	11.30 a. m.	do	2.261
17	12 m.	do	2.261
17	12.30 p. m.	do	2.216
17	1 p. m.	do	2.261
17	1.30 p. m.	do	2.216
17	2 p. m.	do	2.216

TABLE 6.—*Measurements in Rattlesnake Canyon*—Continued.

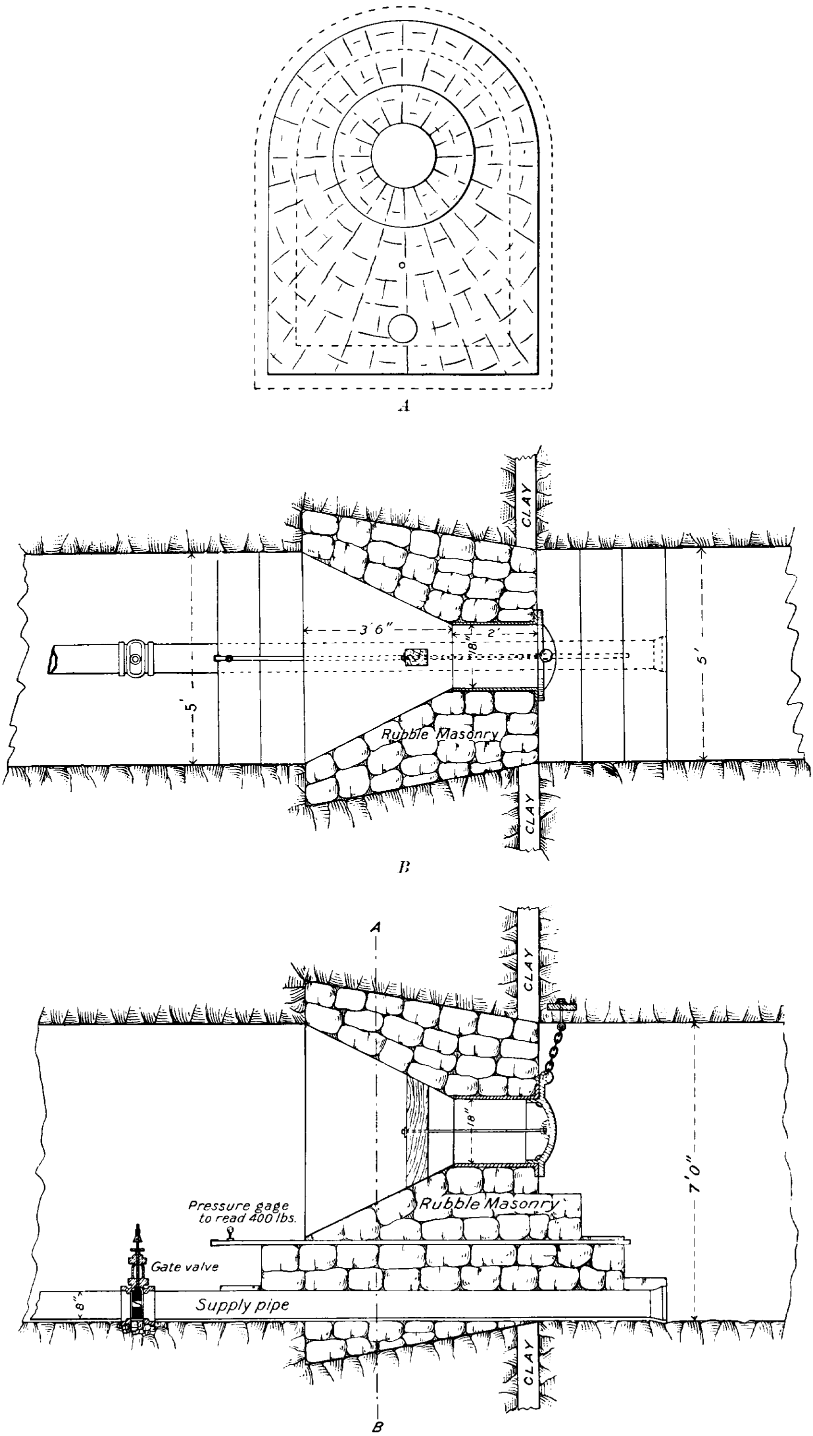
AT NOTCHED WEIR ABOUT 200 FEET UPSTREAM FROM WHERE WATER IS DIVERTED FOR SANTA BARBARA WATER SUPPLY—Continued.

Date.	Time.	Hydrographer.	Discharge in inches.
1903.			
Aug. 17	2.30 p. m.	R. L. North and J. Compton	2.132
17	3 p. m.	do	2.080
17	3.30 p. m.	do	2.080
17	4 p. m.	do	2.080
17	4.30 p. m.	do	2.080
17	5 p. m.	do	2.216
Oct. 3	3.45 p. m.	J. L. Moyer, T. B. Curley, and D. Boyle	2.261
19	8.30 a. m.	R. L. North	1.772
19	9 a. m.	do	1.627
19	9.30 a. m.	do	1.492
19	10 a. m.	do	1.582
19	10.30 a. m.	do	1.471
19	11 a. m.	do	1.582
19	11.30 a. m.	do	1.582
19	12 m.	do	1.302
19	12.30 p. m.	do	1.448
19	1 p. m.	do	1.403
19	1.30 p. m.	do	1.242
19	2 p. m.	do	1.471
19	2.30 p. m.	do	1.302
19	3 p. m.	do	1.262
19	3.30 p. m.	do	1.403
19	4 p. m.	do	1.514
19	4.30 p. m.	do	1.448
19	5 p. m.	do	1.514
Nov. 3	9.30 a. m.	G. D. Morrison	1.871
3	10 a. m.	do	1.847
3	10.30 a. m.	do	1.897
3	11 a. m.	do	1.822
3	11.30 a. m.	do	1.797
3	12 m.	do	1.797
3	12.30 p. m.	do	1.746
3	1 p. m.	do	1.772
3	1.30 p. m.	do	1.772
3	2 p. m.	do	1.651
3	2.30 p. m.	do	1.746
3	3 p. m.	do	1.722
3	3.30 p. m.	do	1.722
3	4 p. m.	do	1.772

TABLE 6.—*Measurements in Rattlesnake Canyon*—Continued.

AT NOTCHED WEIR ABOUT 200 FEET UPSTREAM FROM WHERE WATER IS DIVERTED FOR SANTA BARBARA WATER SUPPLY—Continued.

Date.	Time.	Hydrographer.	Discharge in inches.
1903.			
Nov. 3	4.30 p. m.	G. D. Morrison	1.772
15	9 a. m.	R. F. Wyckoff	2.360
15	9.30 a. m.	do	2.360
15	10 a. m.	do	2.272
15	10.30 a. m.	do	2.160
15	11 a. m.	do	2.160
15	11.30 a. m.	do	2.132
15	12 m.	do	2.132
15	12.30 p. m.	do	2.080
15	1 p. m.	do	2.080
15	1.30 p. m.	do	2.080
15	2 p. m.	do	1.972
15	2.30 p. m.	do	2.051
15	3 p. m.	do	2.080
15	3.30 p. m.	do	2.051
15	4 p. m.	do	2.051
15	4.30 p. m.	do	2.080
28	8.30 a. m.	G. D. Morrison	2.160
28	9 a. m.	do	2.110
28	9.30 a. m.	do	2.030
28	10 a. m.	do	2.050
28	10.30 a. m.	do	2.000
28	11 a. m.	do	1.950
28	11.30 a. m.	do	1.950
28	12 m.	do	1.900
28	12.30 p. m.	do	1.950
28	1 p. m.	do	1.900
28	1.30 p. m.	do	1.850
28	2 p. m.	do	1.820
28	2.30 p. m.	do	1.820
28	3 p. m.	do	1.770
28	3.30 p. m.	do	1.720
28	4 p. m.	do	1.750
Dec. 23	9 a. m.	do	2.510
23	9.30 a. m.	do	2.510
23	10 a. m.	do	2.480
23	10.30 a. m.	do	2.480
23	11 a. m.	do	2.390
23	11.30 a. m.	do	2.360



BULKHEAD AND DISCHARGE PIPES IN OLD CITY TUNNEL, COLD SPRINGS CANYON.

A, End view; *B*, plan; *C*, longitudinal section.

TABLE 6.—*Measurements in Rattlesnake Canyon*—Continued.

AT NOTCHED WEIR ABOUT 200 FEET UPSTREAM FROM WHERE WATER IS DIVERTED FOR SANTA BARBARA WATER SUPPLY—Continued.

Date.	Time.	Hydrographer.	Discharge in inches.
1903.			
Dec. 23	12 m.	G. D. Morrison	2.360
23	12.30 p. m.	do	2.270
23	1 p. m.	do	2.270
23	1.30 p. m.	do	2.330
23	2 p. m.	do	2.360
23	2.30 p. m.	do	2.360
23	3 p. m.	do	2.360
23	3.30 p. m.	do	2.390
23	4 p. m.	do	2.450
1904.			
Apr. 7	1.45 p. m.	L. M. Hyde	12.460

DE LA GUERRA WELLS.

At the De la Guerra pumping station there are seven cased wells from 200 to 700 feet deep. These discharge into a concrete well 25 feet in diameter and 30 feet deep, having a capacity of 110,160 gallons. This well fills during the night and is pumped out during the day. If the wells are considered as discharging as much during the day as they do during the night when the tank is filling, their flow at present is about 220,000 gallons daily and is (in 1903) decreasing. As the pumps run more than twelve hours each day the output is correspondingly greater. There is installed at this station one Prescott pump of 1½ million gallons nominal capacity and one Worthington pump of 1 million gallons capacity daily. The pumps discharge directly into the city mains and work against a pressure head of from 100 to 120 pounds. Mr. Wright states that in August, 1889, a six-day test of these wells indicated a capacity of 600,000 gallons daily. It is stated that these wells afterwards failed and that deeper wells were then sunk, from which the present supply is now obtained.

CITY TUNNEL.

In the month of January, 1896, the city of Santa Barbara started a tunnel for the development of water in sec. 36, T. 5 N., R. 26 W., San Bernardino meridian. The tunnel has been successful in this particular and has been of inestimable service to the city in sustaining it through the period of intense drought of the last few years. The tunnel is 7 feet high and 5 feet wide at the base. The elevation of the portal is approximately 1,400 feet above sea level, and it was driven for the first 4,800 feet of its length on a grade of 1 foot in 100. The purpose in running the tunnel at first was solely to develop water and not with the intention of extending it on through the mountains. It will be noted from the table of discharge that during its construction the discharge was surprisingly constant, irrespective of length. Enough water is thus obtained for a number of consumers, but not enough to supply a large town or city. The amount of water which was extracted from the mountain was sufficient to pay for the cost of the excavation. It is quite possible that in years of ordinary rainfall the unregulated flow of water from the tunnel would have been more constant, but the years of construction were ones of unusual drought. However, from the fact that the water supply has not been materially increased by lengthening the tunnel, and that the flow of the water pays for the cost of the work, it has been a natural and logical sequence that the city should contemplate the extension of this or some other tunnel entirely through the Coast Range into the drainage basin of the Santa Ynez in order to make available the water of this large mountainous area. The tunnel work has been carried on with intelligence, the power from the water coming therefrom being conducted through pressure pipes and used for the running of drills for the excavation work.

COST OF TUNNEL.

As a guide to what the city may expect in the future, the expense of doing this tunnel work is of interest. It will be noted that there has been variation in the cost, owing to local conditions of the labor market, etc. The city has installed the machinery necessary for doing the work, and the contractor has furnished the labor and material necessary for its prosecution at the rate named in the table.

TABLE 7.—*Cost of labor and material in driving city tunnel.*

Distance excavated.	Price per foot.	Distance excavated.	Price per foot.
Feet.		*Feet.*	
0 to 1,000	\$5.50	1,642 to 1,750	....
1,000 to 1,146	7.50	1,750 to 1,786½	\$13.76
1,146 to 1,202	8.73	1,786½ to 2,286	9.30
1,202 to 1,276½	7.58	2,286 to 2,572	10.00
1,276½ to 1,363½	6.89	2,572 to 3,072	10.75
1,363½ to 1,434½	8.25	3,072 to 3,572	10.48
1,434½ to 1,500	9.00	3,572 to 4,072	9.17
1,500 to 1,582	....	4,072 to 5,072	9.00
1,582 to 1,642	9.00		

DISCHARGE OF TUNNEL.

The tunnel is run in a sandstone and shale formation characteristic of the Coast Range, the rock being considerably broken and somewhat stratified. As the work progresses many crevices and cavities in the rock filled with water, probably from rainfall, are found, and as the tunnel cuts the various lines of cleavage these underground reservoirs are tapped. The actual rock is not of a very porous nature and in itself does not yield much water, but it is believed that these cavities will be refilled, at least in part, by subsequent rains and that a material amount of water can be permanently withdrawn from the tunnel. If the city does obtain a supply therefrom permanently there will be just that much more water at its disposal, and there certainly is a market for it all, either in the city or on adjoining agricultural lands.

The water is led from the tunnel to two city reservoirs, each with a capacity of 1,600,000 gallons, situated at an elevation of 350 feet above the city datum plane.

The power now available at the tunnel for driving the drills and blowers is inadequate for its continuation. Generally speaking, it requires from 10 to 12 horsepower to run each air drill, not including the power for the blowers for ventilation.

In order to regulate the flow of water from this tunnel after the last contract was finished, to the 5,000-foot point from the heading, a bulkhead was designed by the author and placed in the tunnel about 800 feet from the portal. During the winter of 1902–3 there was a fair amount of rainfall and the streams were capable during that time of meeting the demands of the city. As soon as the bulkhead could be closed this was done—about July 1, 1903.

Because of the fissured condition of the rock in the tunnel it was not feasible at the point where the bulkhead was first placed to completely close the supply from the heading, as springs occurred below the bulkhead toward the portal, flowing in considerable volume. However, the pressure ran up to 49 pounds to the square inch on July 25, as recorded by the pressure gage placed in the discharge pipe, indicating an accumulated head of water back of the bulkhead of 114 feet. This shows that the tunnel was developed into a storage reservoir. The gate valve in the bulkhead was gradually opened as the season progessed, and the supply maintained a flow of from 24 to 33 miner's inches during the remainder of the summer. On October 17, when the valve was completely opened and the pressure had been reduced to zero, the flow had fallen to 24 miner's inches. This was sufficient to carry the city through the summer successfully.

During the winter of 1903–4 a new bulkhead was placed at a point in the tunnel where a heavy clay seam occurs in the rock. This new bulkhead was more effective than the first one constructed in holding back the water. It is hoped that this will form an impervious barrier against the passage of the ground water, thus enabling the tunnel to accumulate a high head of water.[a]

Table 8a shows the variation in volume discharged from the tunnel, as well as the pressure in pounds per square inch, as the season advances.

TABLE 8.—*Flow of water from city tunnel.*

Date.	Length of tunnel in feet.	Flow in miner's inches.[b]	Flow in gallons per day.
1900.			
May 1	2,952	25.00	323,125
July 26	3,078	19.00	245,575
August 1	3,103	19.00	245,575
October 27	3,267	20.00	258,500
November 4	3,280	25.00	323,125
1901.			
January 9	3,393	38.00	491,150
February 1	3,448	50.00	646,250
February 28	3,561	63.33	818,583
April 1	3,614	55.00	710,875
May 1	3,680	45.00	581,625
June 1	3,740	45.00	581,625
July 1	3,792	[c]35.00	452,375
August 1	3,865	30.00	387,750
1902.			
February 4	4,182	30.00	387,750
March 4	4,256	30.00	387,750
March 31	4,309	33.00	426,525
April 29	4,367	30.00	387,750
June 7	4,509	24.00	310,200
July 25	4,560	25.50	329,588
August 4	4,578	27.75	358,669
September 2	4,647	30.30	391,628
December 1	4,832	30.00	387,750

[a] 24.59 inches of rain fell at Montecito between September 24, 1904, and March 3, 1905, and the pressure on the tunnel bulkhead had increased to 80 pounds per square inch.

[b] 50 miner's inches are equivalent to 1 second-foot, and 1 miner's inch to 12,925 gallons per day.

[c] Estimated.

TABLE 8a.—*Daily mean head over 18-inch weir, and discharge, of Santa Barbara tunnel, 1903.*[a]

Day	January.				February.				March.				April.			
	Mean head over weir.	Discharge.			Mean head over weir.	Discharge.			Mean head over weir.	Discharge.			Mean head over weir.	Discharge.		
		Second-feet.	Miner's inches.	Gallons for 24 hours.		Second-feet.	Miner's inches.	Gallons for 24 hours.		Second-feet.	Miner's inches.	Gallons for 24 hours.		Second-feet.	Miner's inches.	Gallons for 24 hours.
1	0.191	0.405	20.25	261,758	0.210	0.469	23.45	303,122	0.271	0.679	33.95	438.848	0.292	0.756	37.80	488,614
2	.193	.412	20.60	266,282	.214	.482	24.10	311,524	.270	.675	33.75	436,263	.326	.890	44.50	575,220
3	.195	.418	20.90	270,160	.218	.493	24.65	318,633	.270	.675	33.75	436,263	.370	1.068	53.40	690,264
4	.195	.418	20.90	270,160	.217	.489	24.45	316,048	.269	.971	33.55	433,677	.371	1.072	53.60	692,850
5	.195	.418	20.90	270,160	.214	.482	24.10	311,524	.269	.671	33.55	433,677	.369	1.064	53.20	687,679
6	.195	.418	20.90	270,160	.210	.469	23.45	303,122	.268	.668	33.40	431,738	.365	1.046	52.30	676,045
7	.195	.418	20.90	270,160	.214	.482	24.10	311,524	.268	.668	33.40	431,738	.361	1.032	51.60	666,997
8	.195	.418	20.90	270,160	.220	.500	25.00	323,158	.267	.664	33.20	429,153	.357	1.016	50.80	656,656
9	.195	.418	20.90	270,160	.227	.524	26.20	338,669	.267	.664	33.20	429,153	.354	1.003	50.15	648,254
10	.195	.418	20.90	270,160	.235	.553	27.65	357,412	.266	.660	33.00	426,568	.352	.995	49.75	643,083
11	.195	.418	20.90	270,160	.234	.549	27.45	354,827	.266	.660	33.00	426,568	.350	.986	49.30	637,267
12	.200	.435	21.75	281,147	.231	.538	26.90	347,717	.265	.656	32.80	423,983	.346	.969	48.45	626,279
13	.204	.448	22.40	289,549	.228	.528	26.40	341,254	.265	.656	32.80	423,983	.344	.961	48.05	621,109
14	.200	.435	21.75	281,147	.232	.542	27.10	350,303	.264	.653	32.65	422,044	.342	.954	47.70	616,585
15	.200	.435	21.75	281,147	.238	.560	28.00	361,936	.264	.653	32.65	422,044	.340	.947	47.35	612,060
16	.200	.435	21.75	281,147	.246	.589	29.45	380,680	.263	.650	32.50	420,105	.338	.940	47.00	607,536
17	.200	.435	21.75	281,147	.254	.618	30.90	399,423	.263	.650	32.50	420,105	.341	.944	47.20	610,121
18	.200	.435	21.75	281,147	.247	.592	29.60	382,618	.264	.653	32.65	422,044	.350	.986	49.30	637,267
19	.202	.442	22.10	285,671	.240	.567	28.35	366,461	.264	.653	32.65	422,044	.350	.986	49.30	637,267
20	.204	.448	22.40	289,549	.240	.567	28.35	366,461	.266	.660	33.00	426,568	.350	.986	49.30	637,267
21	.205	.452	22.60	292,134	.249	.600	30.00	387,789	.266	.660	33.00	426,568	.350	.986	49.30	637,267
22	.205	.452	22.60	292,134	.256	.626	31.30	404,593	.265	.656	32.80	423,983	.350	.986	49.30	637,267
23	.205	.452	22.60	292,134	.257	.630	31.50	407,178	.265	.656	32.80	423,983	.350	.986	49.30	637,267
24	.205	.452	22.60	292,134	.261	.645	32.25	416,873	.263	.650	32.50	420,105	.350	.986	49.30	637,267
25	.205	.452	22.60	292,134	.259	.637	31.85	411,703	.262	.647	32.35	418,166	.350	.986	49.30	637,267
26	.207	.459	22.95	296,659	.258	.633	31.65	409,117	.262	.647	32.35	418,166	.350	.986	49.30	637,267
27	.210	.469	23.45	303,122	.257	.630	31.50	407,178	.262	.647	32.35	418,166	.349	.982	49.10	634,681
28	.214	.482	24.10	311,524	.265	.656	32.80	423,983	.266	.660	33.00	426,568	.351	.990	49.50	639,852
29	.212	.476	23.80	307,646					.268	.668	33.40	431,738	.350	.986	49.30	637,267
30	.209	.465	23.25	300,536					.269	.671	33.55	433,677	.348	.978	48.90	632,096
31	.207	.459	22.95	296,659					.278	.706	35.30	456,298				
Total				8,787,947				10,114,830				13,253,984				19,035,918
Average	.201	.439	21.93	283,482	.237	.559	27.95	361,244	.266	.662	33.08	427,548	.349	.982	49.09	634,531

[a] By the closing of the bulkhead during the spring of 1904 the water was again impounded in the tunnel and the flow regulated therefrom so as to sustain a fairly constant flow throughout the summer of 1904. Owing to the drought this was the main water supply of the city during that period.

TABLE 8a.—*Daily mean head over 18-inch weir, and discharge, of Santa Barbara tunnel, 1903*—Continued.

Day.	May.				June.				July.				August.			
	Mean head over weir.	Discharge.			Mean head over weir.	Discharge.			Mean head over weir.	Discharge.			Mean head over weir.	Discharge.		
		Second-feet.	Miner's inches.	Gallons for 24 hours.		Second-feet.	Miner's inches.	Gallons for 24 hours.		Second-feet.	Miner's inches.	Gallons for 24 hours.		Second-feet.	Miner's inches.	Gallons for 24 hours.
1	0.354	1.003	50.15	648,254	0.302	0.796	39.80	514,467	0.326	0.890	44.50	575,220	0.307	0.816	40.80	527,393
2	.360	1.029	51.45	665,058	.300	.788	39.40	509,269	.326	.890	44.50	575,220	.318	.857	42.85	553,892
3	.362	1.036	51.80	669,582	.301	.792	39.60	511,881	.326	.890	44.50	575,220	.320	.865	43.25	559,062
4	.362	1.036	51.80	669,582	.302	.796	39.80	514,467	.326	.890	44.50	575,220	.326	.890	44.50	575,220
5	.358	1.021	51.05	659,888	.302	.796	39.80	514,467	.326	.890	44.50	575,220	.329	.902	45.10	582,976
6	.360	1.029	51.45	665,058	.300	.788	39.40	509,269	.300	.788	39.40	509,296	.329	.902	45.10	582,976
7	.363	1.039	51.95	671,521	.300	.788	39.40	509,269	.239	.563	28.15	363,875	.336	.932	46.60	602,366
8	.366	1.050	52.50	678,631	.300	.788	39.40	509,269	.225	.518	25.90	334,791	.333	.919	45.95	593,963
9	.366	1.050	52.50	678,631	.298	.780	39.00	504,126	.220	.500	25.00	323,158	.322	.873	43.65	564,233
10	.360	1.029	51.45	665,058	.292	.756	37.80	488,614	.220	.500	25.00	323,158	.321	.869	43.45	561,648
11	.360	1.029	51.45	665,058	.293	.760	38.00	491,199	.219	.496	24.80	320,572	.328	.898	44.90	580,391
12	.360	1.029	51.45	665,058	.278	.706	35.30	456,298	.219	.496	24.80	320,572	.290	.748	37.40	483,444
13	.358	1.021	51.05	659,888	.306	.812	40.60	524,808	.220	.500	25.00	323,158	.249	.600	30.00	387,789
14	.308	.820	41.00	529,978	.307	.816	40.80	527,393	.220	.500	25.00	323,158	.273	.687	34.35	444,018
15	.223	.510	25.50	329,621	.308	.820	41.00	529,978	.234	.549	27.45	354,827	.275	.694	34.70	448,543
16	.258	.633	31.65	409,117	.310	.828	41.40	535,149	.270	.675	33.75	436,263	.277	.702	35.10	453,713
17	.300	.788	39.40	509,296	.311	.832	41.60	537,734	.292	.756	37.80	488,614	.276	.698	34.90	451,128
18	.301	.792	39.60	511,881	.312	.836	41.80	540,319	.268	.668	33.40	431,738	.275	.694	34.70	448,543
19	.302	.796	39.80	514,467	.313	.840	42.00	542,905	.254	.618	30.90	399,423	.274	.690	34.50	445,957
20	.303	.800	40.00	517,052	.314	.843	42.15	544,844	.258	.633	31.65	409,117	.273	.687	34.35	444,018
21	.304	.804	40.20	519,637	.315	.847	42.35	547,429	.272	.683	34.15	441,433	.270	.675	33.75	436,263
22	.305	.808	40.40	522,223	.316	.850	42.50	549,368	.271	.679	33.95	438,848	.300	.788	39.40	509,296
23	.307	.816	40.80	527,393	.317	.853	42.65	551,307	.267	.664	33.20	429,153	.324	.881	44.05	569,404
24	.308	.820	41.00	529,978	.318	.857	42.85	553,892	.272	.683	34.15	441,433	.254	.618	30.90	399,423
25	.307	.816	40.80	527,393	.319	.861	43.05	556,477	.275	.694	34.70	448,543	.134	.241	12.05	155,762
26	.307	.816	40.80	527,393	.320	.865	43.25	559,062	.274	.690	34.50	445,957	.194	.415	20.75	268,221
27	.306	.812	40.60	524,808	.321	.869	43.45	561,648	.271	.679	33.95	438,848	.277	.702	35.10	453,713
28	.306	.812	40.60	524,808	.322	.873	43.65	564,233	.276	.698	34.90	451,128	.278	.706	35.30	456,298
29	.305	.808	40.40	522,223	.323	.877	43.85	566,818	.264	.653	32.65	422,044	.260	.641	32.05	414,288
30	.303	.800	40.00	517,052	.325	.885	44.25	571,989	.260	.641	32.05	414,288	.258	.633	31.65	409,117
31	.303	.800	40.00	517,052	......	......	......	......	.274	.690	34.50	445,957	.256	.626	31.30	404,593
Total	......	......	......	17,742,639	......	......	......	15,898,056	......	......	......	13,355,452	......	......	......	14,767,561
Average	.324	.886	44.28	572,342	.308	.820	41.00	529,935	.267	.667	33.33	430,821	.285	.737	36.85	476,373

Day.	September.				October.				November.				December.			
	Mean head over weir.	Discharge.			Mean head over weir.	Discharge.			Mean head over weir.	Discharge.			Mean head over weir.	Discharge.		
		Second-feet.	Miner's inches.	Gallons for 24 hours.		Second-feet.	Miner's inches.	Gallons for 24 hours.		Second-feet.	Miner's inches.	Gallons for 24 hours.		Second-feet.	Miner's inches.	Gallons for 24 hours.
1	0.254	0.618	30.90	399,423	0.240	0.567	28.35	366,461	0.228	0.528	26.40	341,254	0.223	0.510	25.50	329,621
2	.252	.612	30.60	395,545	.238	.561	28.05	362,583	.228	.528	26.40	341,254	.222	.507	25.35	327,682
3	.250	.604	30.20	390,374	.260	.641	32.05	414,288	.228	.528	26.40	341,254	.222	.507	25.35	327,682
4	.250	.604	30.20	390,374	.276	.698	34.90	451,128	.228	.528	26.40	341,254	.222	.507	25.35	327,682
5	.248	.596	29.80	385,204	.260	.641	32.05	414,288	.228	.528	26.40	341,254	.222	.507	25.35	327,682
6	.248	.596	29.80	385,204	.250	.604	30.20	390,374	.228	.528	26.40	341,254	.222	.507	25.35	327,682
7	.248	.596	29.80	385,204	.244	.581	29.05	375,509	.228	.528	26.40	341,254	.222	.507	25.35	327,682
8	.248	.596	29.80	385,204	.241	.570	28.50	368,400	.228	.528	26.40	341,254	.222	.507	25.35	327,682
9	.248	.596	29.80	385,204	.240	.567	28.35	366,461	.228	.528	26.40	341,254	.222	.507	25.35	327,682
10	.248	.596	29.80	385,204	.260	.641	32.05	414,288	.227	.524	26.20	338,669	.222	.507	25.35	327,682
11	.248	.596	29.80	385,204	.244	.581	29.05	375,509	.227	.524	26.20	338,669	.222	.507	25.35	327,682
12	.248	.596	29.80	385,204	.241	.570	28.50	368,400	.227	.524	26.20	338,669	.222	.507	25.35	327,682
13	.248	.596	29.80	385,204	.240	.567	28.35	366,461	.227	.524	26.20	338,669	.222	.507	25.35	327,682
14	.247	.592	29.80	382,618	.239	.563	28.15	363,875	.227	.524	26.20	338,669	.222	.507	25.35	327,682
15	.246	.589	29.45	380,680	.238	.560	28.00	361,936	.227	.524	26.20	338,669	.222	.507	25.35	327,682
16	.246	.589	29.45	380,680	.236	.556	27.80	359,351	.227	.524	26.20	338,669	.221	.503	25.15	325,096
17	.245	.585	29.25	378,094	.235	.553	27.65	357,412	.227	.524	26.20	338,669	.221	.503	25.15	325,096
18	.244	.581	29.05	375,509	.235	.553	27.65	357,412	.227	.524	26.20	338,669	.221	.503	25.15	325,096
19	.243	.577	28.85	372,924	.235	.553	27.65	357,412	.227	.524	26.20	338,669	.221	.503	25.15	325,096
20	.242	.574	28.70	370,985	.235	.553	27.65	357,412	.227	.524	26.20	338,669	.220	.500	25.00	323,158
21	.240	.567	28.35	366,461	.235	.553	27.65	357,412	.227	.524	26.20	338,669	.220	.500	25.00	323,158
22	.269	.671	33.55	433,677	.236	.556	27.80	359,351	.227	.524	26.20	338,669	.220	.500	25.00	323,158
23	.262	.647	32.35	418,166	.236	.556	27.80	359,351	.226	.520	26.00	336,084	.220	.500	25.00	323,158
24	.260	.641	32.05	414,288	.236	.556	27.80	359,351	.225	.517	25.85	334,145	.220	.500	25.00	323,158
25	.259	.637	31.85	411,703	.234	.549	27.45	354,827	.225	.517	25.85	334,145	.220	.500	25.00	323,158
26	.221	.503	25.15	325,096	.232	.542	27.10	350,303	.224	.514	25.70	332,206	.220	.500	25.00	323,158
27	.240	.567	28.35	366,461	.232	.542	27.10	350,303	.224	.514	25.70	332,206	.220	.500	25.00	323,158
28	.240	.567	28.35	366,461	.232	.542	27.10	350,303	.224	.514	25.70	332,206	.219	.496	24.80	320,572
29	.240	.567	28.35	366,461	.232	.542	27.10	350,303	.224	.514	25.70	332,206	.219	.496	24.80	320,572
30	.240	.567	28.35	366,461	.232	.542	27.10	350,303	.223	.510	25.50	329,621	.218	.493	24.65	318,633
31	......	......	......	......	.230	.535	26.75	345,779	......	......	......	......	.218	.493	24.65	318,633
Total	......	......	......	11,519,277	......	......	......	11,436,546	......	......	......	10,136,802	......	......	......	10,081,227
Average	.247	.594	29.70	383,976	.241	.571	28.55	368,921	.227	.523	26.15	337,893	.221	.503	25.15	325,201

TOTAL NEAR-BY SUPPLY.

Reviewing these measurements we have a probable summer minimum water supply available for the city from local sources approximately as follows:

Local water supply of Santa Barbara.

	Gals. per day.
Minimum from Mission Creek	100,000
Minimum from De la Guerra wells	300,000
Minimum from city tunnel	300,000
Total	700,000

as against an estimated normal summer demand of 1,200,000[a] gallons per day, or an estimated normal deficit daily of 500,000 gallons.

There is not as much water now being used in the city for beautifying lawns and gardens as would be so applied if a more abundant supply were available. From the above it is evident that the city should take immediate steps toward increasing its water supply.

DISTANT SUPPLIES.

EXTENSION OF CITY TUNNEL.

With a view to the extension of the present city tunnel through the Santa Ynez Range to tap the waters of Santa Ynez River, a system of triangulation was carried across the mountains from Santa Barbara to the Mono reservoir site by Homer Hamlin and W. B. Clapp, of the Geological Survey. The base line of this system was measured on State street, Santa Barbara, between Boulevard and Pedregosa streets, and the most northerly point was the high peaks south of the Mono reservoir site. The base line, which was carefully measured with a 300-foot steel tape under a uniform tension of 25 pounds and corrected for temperature, was 9,753.7 feet long. The angles were measured with a Berger transit No. 1b, circles 6¼ inches in diameter. Eleven principal triangulation stations and 5 secondary stations were occupied, the secondary triangulation being necessary to reach the south portal of the present city tunnel, which is situated in a deep canyon. Angles were repeated three times and measured in six sets of two each. The triangles closed for angles within 0° 0′ 0″ to 0° 0′ 10″. The angle adjustments were made by distributing the difference proportionally as probable error due to weather conditions. The traverse of the outside boundary of the triangulation system closed as follows: N., 45,343.66; S., 45,343.63; E., 28,397.22; W., 28,397.15.

[a] On basis of 150 gallons per day for 8,000 persons.

The north portal of the extended tunnel, as projected, was fixed by a station on the cliff on the south side of Santa Ynez River. The north portal bears N. 26° 38′ 18″ E., and is 18,842.06 feet distant from the south portal of the present city tunnel. This tunnel was 4,895 feet long on January 26, and if an angle is made in it at 5,960 feet it will be necessary to drive 15,006 feet to reach Santa Ynez River and finish the work. By doing so a saving of 1,475 feet will be made; otherwise the tunnel must have a length of 21,376 feet to get through the range. It is probable, however, that a still more favorable location may be found.

From the surveys that have been made during the last season in the drainage basin of Santa Ynez River, the elevation of the south portal of the city tunnel in Cold Spring Canyon was taken at 1,393.06 feet; the rise on grade from the portal to station 48, at the projected north portal, is 49.02 feet. The total length of excavation necessary to complete this tunnel through the range is 15,066 feet. At a grade of 0.1 per cent this will require 15 feet more to be consumed in tunnel grade, making the elevation of the north portal of the tunnel 1,457.18 feet. The elevation of Santa Ynez River bed opposite is 1,425 feet. The necessary grade to be consumed from the north portal of the tunnel to the Mono reservoir site would be about 4 feet, making the elevation of the grade at the Mono reservoir site 1,461.18 feet. The elevation of the bed of the creek at the Mono site is 1,440 feet, so that the conduit grade would be 21.18 feet above the bed of the creek at that point, but the capacity of the lower portion of a reservoir site is always very small, and there would be a loss of but 1 per cent in the capacity of a 100-foot dam at the Mono with the elevations given.

CONSTRUCTION OF NEW TUNNEL.

In the old city tunnel in Cold Spring Canyon several angles occur in the alignment. The grade of the tunnel is also not satisfactory, in that it is too high to reach the bed of the stream at the mouth of the Mono at the elevation of the creek. While the old city tunnel could be used in this regard, it is not considered the best site for a tunnel, in view of subsequent surveys and investigations. Moreover, the old tunnel is delivering a very substantial water supply under existing conditions, particularly since being regulated by the bulkhead described above, and as a new tunnel can be obtained at a satisfactory elevation, which will develop a new water supply and in addition command certain reservoir sites on lower portions of the stream below the mouth of the Mono, it is desirable to adopt the second location. After the first investigations made in the basin of Santa Ynez River, which included the survey of the Mono reservoir site, the Main River reservoir site, and an inspection of sites higher on the stream, a much better site situated on the main stream below the mouth of the Mono was found. This is called the Gibraltar reservoir site and is described more fully below.

The capacity of the Gibraltar reservoir so not quite so great as that of the Mono, but is very satisfactory, while the dam site is very much better, and the tributary drainage area a great deal larger, including not only that of the Mono, but also that of the Santa Ynez above the Mono, and 17 square miles of Main Canyon below. For the season of 1902–3 the measured flow at the Mono dam site was 8,934 acre-feet, at the Santa Ynez above the Mono 9,898 acre-feet, and for the Santa Ynez at the Gibraltar reservoir site 21,202 acre-feet. As the water supply is the most essential feature of the entire enterprise, no hesitation is felt in recommending that the tunnel line which is to be run through the range should be made to command the Gibraltar reservoir site. This would be impossible with the old city tunnel, on account of its high elevation in Cold Spring Canyon. Moreover, the combined cost of the Gibraltar dam and of a tunnel to it from Mission Canyon is less than the combined cost for completing the old city tunnel and building the Mono dam.

For the reasons given above, the triangulation which had been made for the old city tunnel was extended so as to cover the site of a possible new tunnel line from Mission Canyon to the Gibraltar dam site, which would be 19,560 feet long and would run through the same general formation at right angles to the line of the strike of the rock, passing under portions of Mission Creek.

AGREEMENT WITH WATER COMPANY.

An agreement was made with the Santa Barbara Water Company for rights of way for this new tunnel line. This company has for years been acquiring lands along Mission Canyon in order to protect its water supply, which comes mostly therefrom. The company naturally felt that the running of the tunnel beneath Mission Creek might affect its supply of water from the creek and insisted on being secured against such a contingency. In consequence the Santa Barbara water commissioners entered into a contract with the company, by which the city agrees to maintain the supply of the company at 14 inches from July 1 to December 31 and at 22 inches from January 1 to June 30, supplying the water from the tunnel in case it is not flowing naturally in the creek, provided that amount can be supplied from the tunnel alone and irrespective of water subsequently obtained from storage reservoirs. In return the Santa Barbara Water Company gives the city rights of way over all its lands for wagon roads, tunnels, pipe lines, etc., and agrees not to run any tunnels on its lands in the vicinity of the city tunnel. This contract is fully justified by the physical conditions encountered in the water development. Moreover, the water delivered to the water company will be used in any event in the immediate vicinity of Santa Barbara or for the beautifying and improvement of the town.

A section of the proposed new tunnel is shown in figs. 16 and 17 (pp. 91, 92), the timbered section being used only where necessary and the rock section being the prevailing type for the tunnel.

CONTRACT FOR CONSTRUCTION.

The work of driving the tunnel was divided into two parts, a southern portion of the tunnel to be 11,000 feet long and constructed from the south portal, and a northern portion to be 8,560 feet long and constructed from the north portal. Bids were called for and received, and the contracts awarded to F. J. Smith and E. J. Hunt, of Santa Barbara, for the south part, and to Robert Beyrle, of Los Angeles, for the north part. The prices were as follows:

Successful bids for new Santa Barbara tunnel.

	South division.	North division.
Per cubic yard of excavation	$8.00	$9.00
Overhaul per cubic yard per 100 feet (free haul being 500 feet)	.02	.01½
Timbers in place (per M feet, B. M.)	35.00	45.00

The total cost of the southern portion of the tunnel under the contract will be $109,125, and for the northern portion $90,267, a total of $199,392 for the entire tunnel. The estimate of the author, as consulting engineer for the work, was 19,560 feet of tunnel at $10 a foot, $195,600, plus 10 per cent for contingencies, or a total of $215,160. An additional allowance was made of 5 per cent for engineering expenses.

The yardage excavated in the tunnel is to be limited by the quantity shown on the section. After the completion of the work the contractor is required to leave his track in the tunnel for the purpose of hauling cement through it for the construction of the dam on Santa Ynez River, thus avoiding a wagon haul over the high mountains. The contracts were let in February, 1904.

VENTURA RIVER.

From an examination of the topographic maps of the Geological Survey, which have been recently prepared and which are of inestimable value in a general consideration of this subject, it was found that it would be possible by a gravity line to divert the headwaters of Ventura River from a point near the junction of the main and north forks of Matilija Creek by gravity through Casitas Pass to Santa Barbara. A reconnaissance was made of this country, and a number of water measurements were made throughout the length of Ventura River. A month of minimum flow was selected as the proper time at which to make these determinations, as the minimum is the controlling condition in all questions involving water supply. There was a rainfall at Santa Barbara for the seasons of 1901–1902 of 14.06 inches. The stream flow during this season, however, was below normal.

TABLE 9.—*Flow measurements on Ventura River and tributaries.*

1902.	Locality.	Inches.
Sept. 25	At Matilija, above North Fork	99
25	North Fork at mouth	21
	Total, all diverted	120
25	River bed dry from Matilija School to near Coyote Creek	......
25	Below Coyote Creek and below Domestic diversion	14
25	Head Domestic system's lower ditch	185
25	Head Domestic system's upper ditch	62
	Total Ventura River below and near Coyote Creek	261
26	Head of power ditch, below Domestic diversions	75
26	River bed above and near power house	8
	Total	83
26	Domestic ditch above and near reservoir	222

WATER AVAILABLE.

It will be noted that all of the water of Matilija Creek at the point from which a gravity line could be started to Santa Barbara is diverted and now in use, and consequently there was on that date no supply available for Santa Barbara at this point. In addition to this, the intervening topography is rugged and the distance would be very great, rendering it impracticable from a commercial standpoint to obtain a supply from this source.

It will also be noted that there were 75 inches of water diverted into the power ditch of the Ventura waterworks, which runs from a point approximately 4 miles north of Ventura to a point approximately 1½ miles north of this city, and that there were 8 inches of water above the point where this power ditch would discharge into the river, making a total of 83 inches in the lower portion of the river that was not diverted for domestic uses. During the daytime, at the time of the inspection, all this 75 inches of water was being used for irrigation, leaving but 8 inches of water in Ventura River available for surface diversion. Information, however, was given that a portion of the water diverted through the domestic conduits during the daytime is accumulated in a certain domestic reservoir, and that at nighttime, from 11 p. m. until 6 a. m., a discharge of 280 miner's inches from this reservoir ordinarily takes place through the power house for the purpose of developing power and is wasted into the river. This is equivalent to a continuous flow of 82 miner's inches. This water wasted into the sea, taken in connection with the 8 inches flowing in the stream bed above the power house, makes a total of 90 miner's inches of water, which at this time, admitted to be one of drought, might be considered as wasted water and available for sale or disposal by the Ventura Water, Light, and Power Company. In addition to this, it is stated that the 75 inches of water diverted through the power ditch is not permanently sold for irrigation purposes, but is used by irrigators by sufferance on the part of the water company, and that the Ventura Water, Light, and Power Company could sell it to the city of Santa Barbara if it so desired. There thus might be made available from the lower portion of Ventura River a low-water supply of 165 miner's inches (2,145,000 gallons per day), provided all the above assumptions are correct.

The statement was made that there is practically a continuous use of the 30 inches of water from the power ditch during the daytime for irrigation, which might reduce these figures to 135 miner's inches (1,750,000 gallons daily). This is an unusually large amount of water to be available for disposal along this coast, and it was considered to be sufficient to justify a further investigation to determine the cost of its delivery to Santa Barbara.

The elevation at which this water could be obtained is practically 50 feet above sea level, and it would, therefore, have to be pumped to Santa Barbara through a long force main, laid possibly on the railroad right of way, for an aggregate distance of 26.2 miles. There is quite favorable opportunity of obtaining cheap fuel along this line, and a pumping station might be erected at the intake and a sufficient head generated to force the water through the pipe line, delivering it to the city of Santa Barbara at the foot of State street without pressure, in order to avoid the expense of a long pipe line designed to withstand high heads. At this point it would be picked up by a second pumping plant and forced to the high levels of the city. No legal examination of title was made as to the ownership of this water.

COST OF PIPING AND PUMPING.

It may be assumed, therefore, for the sake of estimating, that there is available from the lower Ventura River a supply of water sufficient to furnish 1,500,000 gallons daily, adequate for 10,000 people using 150 gallons per capita each day. This is equal to 2.32 cubic feet per second, or 116 miner's inches of water. This water would have to be purchased from the Ventura Water, Light, and Power Company, from which no figure has as yet been obtained as to the price for which it would be sold. It is believed that the parties owning this water would be willing to contract for its delivery. If $300 per miner's inch were paid for this water, it would cost the city of Santa Barbara $34,800 at Ventura. An 18-inch continuous wooden stave pipe laid from the Ventura River to the foot of State street would be 138,300 feet in length, or 26.2 miles. The friction head to be overcome by water passing through this length of pipe, when carrying 1,500,000 gallons daily, would be 48.4 feet. It is believed that the average friction and hydraulic head on the pipe would be 50 feet. The pipe would be laid either on country roads or possibly along the railroad right of way. At certain projecting and precipitous cliffs the pipe would have to be run through tunnels. The conduit would be what is technically known as a continuous wooden stave pipe with steel bands, a form of construction which is satisfactory. It would be of a more permanent character than riveted pipe, but not of so enduring a nature as cast-iron pipe. Cast-iron pipe, however, because of its present high cost ($45 a ton delivered at Pacific coast terminals), would be entirely out of the question. The water would be delivered without pressure at the foot of State street, in order to avoid excessive cost due to necessarily stronger pipe required in case a high head was put on it to directly connect with the mains of the city for local distribution. From this point it would have to be lifted to domestic reservoirs. The following table is an estimate on the cost of laying such a pipe line:

TABLE 10.—*Estimated cost of Santa Barbara-Ventura pipe line.*

Section.	Length.	Class of excavation.	Cost.	Cost of excavation.	Cost of backfill.	Total cost of trenching.	Cost of pipe.	Total cost.
	Lin. ft.		*Lin. ft.*					
1	7,920	Trench	$0.15274	$1,209.70	$302.42	$1,512.12	$9,504.00	$11,016.12
2	6,864	do	.191	1,311.02	327.75	1,638.77	8,236.80	9,875.57
3	2,640	do	.15274	403.23	100.81	504.04	3,168.00	3,672.04
4	1,584	do	.09546	151.21	37.80	189.01	1,900.80	2,089.81
5	1,320	Tunnel	5.00	6,600.00		6,600.00	1,584.00	8,184.00
6	27,984	Trench	.09546	2,671 35	667.84	3,339.19	33,580.80	36,919.99
7	6,072	Tunnel	5.00	30,360.00		30,360.00	7,286.40	37,646.40
8	7,392	Trench	.09546	705.64	176.41	882.05	8,870.40	9,752.45
9	5,280	Tunnel	5.00	26,400.00		26,400.00	6,336.00	32,736.00
10	9,500	Trench	.17183	1,632.38	408.10	2,040.48	11,400.00	13,440.48
11	61,776	do	.09546	5,897.14	1,474.28	7,371.42	74,131.20	81,502.62
Total	138,332			77,341.67	3,495.41	80,837.08	165,998.40	246,835.48

A portion of the line would be in ground that is quite alkaline. The wooden part of the pipe would not be attacked by the alkali, but the iron rods would be. If we assume a length of life for the pipe of twenty years, and that a sinking fund at 4 per cent interest would necessarily have to be provided to renew it at the end of that time, $8,287.54 would have to be set aside annually to meet the charge. At 4 per cent interest this would capitalize at $207,188, which should properly be added to the first cost of the pipe, giving $454,023 as the real cost of the pipe line to the city. This computation is given in order to compare the real cost of this pipe line with other permanent construction mentioned later.

It would be necessary to install two pumping plants, one at Ventura to force this water through the pipe line against the friction head, and the other to lift the water from the foot of State street to an assumed level of 300 feet to a domestic reservoir. The cost of the first plant would be $9,649, and of the second plant $13,970, or a total of $23,619. If a life of twenty years is assumed for pumping plants also, and provision is made for their renewal by a sinking fund as before, bearing 4 per cent interest, there would have to be set aside each year for this purpose $792.49, which is interest at 4 per cent on $19,802, making a total cost to the city of pumping plants of $43,421.

These pumping plants would be improved and modern triple-expansion condensing steam plants. The first plant would consume 5.5 barrels of crude oil daily, and the second 14.5 barrels of oil daily, or a total ot 20 barrels of oil daily to deliver 1½ million gallons daily. This oil at $1 a barrel, which would be a fair price for a long period of use, would represent a daily charge of $20, and an annual charge of $7,300. Attendance of engineers and assistants would probably amount to $5,000 annually; so the oil and attendance together would be $12,300, which, capitalized at 4 per cent, represents $307,500.

To summarize we now have:

Summary of cost of Santa Barbara-Ventura pipe line.

	First cost.	First cost and maintenance.
1,500,000 gallons of water daily	$34,800	$34,800
Pipe line	246,835	454,023
Two pumping plants	23,619	43,421
Fuel and attendance		307,500
Total	305,254	839,744

This figure of first cost and maintenance would represent the real expense to the city of building and maintaining such a plant perpetually, and on this basis can be properly compared with permanent construction, such as masonry.

This plant would practically be incapable of being increased in capacity without rebuilding the entire system, and no estimates have been included for rights of way.

SANTA YNEZ RIVER.

The county of Santa Barbara, by petition of its board of supervisors, and the city, through its trustees, requested the United States Geological Survey to make topographic surveys and hydrographic investigations in Santa Barbara County to assist in the solution of the difficult water problems which confront this beautiful coast district, often called the American Riviera. As it is the policy of the Geological Survey to carry on its work where the results will be of greatest value, it acceded to this request and has extended its topographic surveys over the greater portion of the county. Pl. I is made up from the results of these surveys. Hydraulic investigations have also been begun, three reservoirs surveyed, several tunnel lines triangulated, and three gaging stations established. It is intended to extend these investigations during the coming season so as to cover the entire drainage basin of Santa Ynez River. To a limited extent the city of Santa Barbara has cooperated financially in the hydraulic work.

Santa Ynez River rises in the mountains of Santa Barbara and Ventura counties, and flows westerly with a flat grade to the Pacific Ocean, having a length of approximately 75 miles. The Santa Ynez Range of mountains, varying in elevation from 3,000 to 4,000 feet, forms the southern boundary of this drainage basin. The northern divide ranges from 4,500 to 5,500 feet, culminating in Mount Pinos, the elevation of which is 8,826 feet. The mean elevation of the basin above the mouth of Mono Creek is 3,500 feet above sea level.

RAINFALL.

The mean rainfall at Santa Barbara is 16.78 inches; at Nordhoff, in Ventura County, at an elevation of 1,200 feet, it is about 18 inches; at Mutau Flat, on the headwaters of Piru Creek, and on the eastern slope of the range, at an elevation of 4,850 feet, it is 19 inches; at Snedden's ranch, on the north fork of the headwaters of the Piru, on the eastern slope of the mountains, at an elevation of 4,900 feet, it is 15 inches; at Cuddy's ranch, at an elevation of 5,000 feet, in Kern County, near the head of Tejon Creek, it is 20 inches, and at Old Fort Tejon, at an elevation of 3,245 feet, it is 18 inches. These records, except those of Santa Barbara, which were begun in 1867, are of rather short duration and fragmentary. The mean rainfall given for each mountain station is determined by finding the ratio of precipitation at Santa

Barbara for the years during which rainfall was observed at the high point in question, and the mean of the 37-year record at Santa Barbara, and applying that ratio to the observed rainfall at the mountain station. There are no known observations of rainfall in the upper portion of the Santa Ynez.

It is well known by the people living along the Pacific coast that the rainfall increases as the slope of the mountain ranges exposed to the sea breezes is ascended. Usually this increase amounts to six-tenths of an inch of rain for each 100 feet rise in elevation, which increase is to be added to the observed precipitation at the base of the range. On the eastern slope of the mountain ranges, on the side away from the ocean, this estimate does not at all hold, there being an actual diminution of rainfall after passing a crest. Consequently it is to be expected that such stations as Mutau Flat and Snedden's ranch, situated easterly from the main crest of the Coast Range, will have less precipitation than occurs on the exposed westerly side of the range. The Santa Ynez Range undoubtedly abstracts a portion of the moisture of the clouds that are passing inland over the drainage basin of Santa Ynez River, but the precipitation must again increase on the westerly sides of the high Coast Range on the northerly and easterly portions of the drainage basin, where the mountains rise from 2,000 to 3,000 feet higher than the summits of the Santa Ynez Mountains.

Mr. Purslow says that the rainfall in the basin of the Santa Ynez above the reservoir sites which he examined is 30 inches, and Mr. Wright states that in his judgment it is over 20 inches. Mr. Marsden Manson, civil engineer of the California Water and Forest Association, prepared a rainfall map, showing precipitation throughout the State, on which he estimates the rainfall in this district as between 20 and 30 inches. Mr. William Hammond Hall, when State engineer of California, also prepared a rainfall map, showing the precipitation for this district to be between 20 and 30 inches. Lieutenant Glassford, of the United States Signal Service, in 1891 officially estimated the rainfall on the headwaters of the Santa Ynez at from 20 to 25 inches.

After a careful examination of the drainage basin, of the vegetation covering it, of available rainfall records, and from a general knowledge of the precipitation throughout this portion of the State, the writer believes that the average rainfall in this basin is about 22 inches. However, in order to be within safe limits in making the estimates of available water supply, the same rainfall is used for computing the run-off of the Santa Ynez basin as has been observed at Santa Barbara.

RUN-OFF.

The question of determining the relation of what is called run-off (or the amount of water the streams discharge) to rainfall is one of considerable difficulty and uncertainty. It is dependent upon the character of the rains, whether gentle showers or violent storms (the latter yielding the greater run-off), and also upon the steepness of the slopes and the size of the watershed. Other things being equal, the small watershed has the higher percentage of run-off. A one or two years' record does not establish a final ratio.

The forest cover of the drainage basin also greatly affects the run-off. If it is a denuded area the floods are more violent and shorter in duration and the summer stream is much lower. If the drainage basin has a proper forest or brush cover the stream is more uniform in flow and carries less silt. The general porosity of the soil and rock also affects the character of the run-off.

A number of efforts have been made to establish this ratio of rainfall to run-off. The diagram presented herewith as fig. 1 (p. 15) shows by curved lines on a horizontal scale the amount of rainfall in inches of depth, and on the vertical scale the total corresponding volume of water discharged in acre-feet, an acre-foot of water being the amount that will cover 1 acre 1 foot deep, or 43,560 cubic feet. The curve which is used in this report is one that has been determined as the result of a large number of measurements in California made by the United States Geological Survey. It will be noted that it indicates less run-off than the others.

The Salt Springs Valley reservoir is in Calaveras County, Cal., in the foothills. The Newell curve for "mountainous areas" is a general determination, by Mr. F. H. Newell, hydrographer of the Geological Survey, for the high mountain areas of the western portions of the United States. The Arrowhead reservoir is in San Bernardino County, Cal. The Newell curve for "undulating areas" is the relation determined by Mr. Newell for hill countries. The general curve for large watersheds for California is the one used in this report as the result of California observations made largely during the drought period through which we have passed. It will be noted that there is no run-off indicated until after the rainfall exceeds 10 inches. All of these curves are much more unfavorable to large run-off than has customarily been accepted for eastern streams.

TABLE 11.—*Record of precipitation at Santa Barbara, Cal.*

[Latitude, 34° 25′; longitude, 119° 40′. Elevation, 100 feet. Authority, War Department and Weather Bureau.]

Year.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Total.
1867-68	0.00	0.00	2.31	12.67	3.97	2.00	1.08	2.44	0.72	0.00	0.00	0.00	25.19
1868-69	.00	.00	1.25	4.26	3.26	2.12	4.22	.46	.20	.00	.00	.00	15.77
1869-70	.00	.30	.65	.57	.25	5.87	.83	.99	.74	.07	.00	.00	10.27
1870-71	.00	1.04	.27	1.41	.86	2.92	.02	2.02	.37	.00	.00	.00	8.91
1871-72	.00	.09	1.83	6.56	2.53	1.81	.18	1.80	.00	.14	.00	.02	14.96
1872-73	.05	.00	.00	4.34	.58	5.48	.05	.00	.00	.00	.00	.00	10.50
1873-74	.00	.00	.27	5.26	4.54	3.17	.78	.28	.14	.00	.00	.00	14.44
1874-75	.00	1.91	1.30	.00	14.84	.18	.38	.10	.00	.00	.00	.00	18.71
1875-76	.00	.00	6.53	.31	7.56	5.67	2.73	.27	.00	.00	.00	.00	23.07
1876-77	.00	.32	.00	.00	2.72	.00	.82	.18	.45	.00	.00	.00	4.49
1877-78	.00	.00	1.32	3.12	7.17	11.73	2.47	3.34	.29	.07	.00	.00	29.51
1878-79	.00	.32	.00	5.16	5.24	.71	.34	1.60	.21	.00	.00	.00	13.58
1879-80	.00	.41	1.62	4.57	1.30	10.86	1.15	5.73	.00	.00	.00	.00	25.64
1880-81	.00	.25	.28	9.73	2.83	.30	1.25	.59	.00	.00	.00	.00	15.23
1881-82	.44	1.47	.33	.95	1.13	2.38	5.74	1.63	.00	.20	.00	.00	14.27
1882-83	.00	.37	.77	.10	2.18	2.92	3.64	.29	2.79	.35	.00	.00	13.41
1883-84	.00	1.32	.00	2.76	6.33	9.68	9.77	2.60	.39	1.62	.00	.00	34.47
1884-85	.00	1.02	.79	6.62	1.23	.07	.35	3.00	.00	.00	.00	.00	13.08
1885-86	.00	.19	9.84	2.47	5.12	1.19	2.03	3.40	.00	.00	.00	.00	24.24
1886-87	.00	.39	.87	.86	.31	8.64	.13	1.43	.33	.03	.00	.00	12.99
1887-88	.38	.31	1.10	4.43	10.15	1.30	3.86	.16	.02	T.	T.	T.	21.71
1888-89	.03	.07	5.62	5.59	.29	1.29	7.31	.49	.76	.13	.00	.00	21.58
1889-90	.00	8.65	3.21	10.64	5.32	2.96	1.10	.31	.18	.00	.00	.00	32.37
1890-91	1.50	.00	.48	3.53	.50	8.82	1.65	1.90	.00	.00	.00	.00	18.38
1891-92	.18	.00	.00	2.26	1.04	2.48	3.36	.34	.62	.00	.00	.00	10.28
1892-93	.00	.42	3.70	7.31	4.52	3.55	7.53	.38	.00	.00	.00	.00	27.41
1893-94	.00	.62	T.	3.50	.65	.50	.22	.35	.86	.00	.15	.00	6.85
1894-95	1.36	.78	.11	4.16	6.25	.67	1.99	.46	.02	.05	T.	.00	15.85
1895-96	.00	.55	.77	.93	6.84	.00	2.37	1.78	.08	.05	.40	.00	13.77
1896-97	.00	.92	3.51	2.92	4.35	3.65	2.73	.02	.00	.00	.00	.00	18.10
1897-98	.00	1.44	.00	.00	.63	1.39	.28	T.	1.25	.00	T.	.00	4.99
1898-99	3.17	.14	.00	.36	4.48	.00	2.78	.64	.00	.78	.00	.00	12.35
1899-1900	.00	2.06	1.97	2.35	2.32	.05	1.58	.42	1.90	.01	.02	T.	12.68
1900-1901	.04	.15	3.99	.02	4.86	3.65	.16	2.07	.34	.10	.06	.09	15.53
1901-2	.36	2.42	1.16	T.	1.36	4.40	2.89	1.40	.07	.00	.00	.00	14.06
1902-3	.00	1.48	4.01	2.24	2.06	1.63	6.12	2.91	.00	.00	.00	.00	20.45
1903-4	T.	T.	.05	T.	.46	4.69	4.40	1.89	.09	.00	.00	.10	11.68
37-year mean													16.78

As has been previously stated, the rainfall for the drainage basin of the Santa Ynez above the Mono, and for Mono Creek, is taken in the computations as 16.78 inches as an average, which is the rainfall observed for thirty-seven years at Santa Barbara.

The drainage area above the various reservoir sites was carefully determined from the topographic surveys of the Geological Survey which have been recently made. The area above the Juncal reservoir site is 13.4 square miles; above the Mono reservoir site, 119 square miles; above the Main River reservoir site, on the Santa Ynez just below the mouth of Blue Canyon, 71 square miles; above the Gibraltar reservoir site on the main river, 207 square miles.

The exposure of the drainage basin of the Santa Ynez proper is more favorable for a large amount of run-off than that of the Mono. The rainfall usually increases as the mountains rise in elevation, but the heaviest precipitation is generally just beyond the crest of the range of hills; consequently we would expect an unusually large precipitation just beyond the summit of the Santa Ynez Range north of Santa Barbara. Moreover, this exposure being a northern one, there is less loss by evaporation from the soil. This rainfall is strikingly indicated by the brush cover on the Santa Ynez Mountains as compared with the cover in the drainage basin of the Mono.

As an illustration, it may be mentioned that during the season of 1902–3 the Mono drainage basin discharged 8,934 acre-feet of water from 119 square miles; the Santa Ynez above the Mono discharged 9,898 acre-feet from 71 square miles, and the basin above the Gibraltar dam site discharged 21,202[a] acre-feet from 207 square miles.

By applying the diagram (fig. 1) showing the relation of rainfall to run-off to the drainage areas of each of the sites, the probable volume of water available at each in each year has been obtained and is given in the last three columns of table 12. It will be noted that there is a very great fluctuation in the volume discharged in various years. For instance, in 1875–76 there were probably 35,190 acre-feet of water discharged through the Gibraltar reservoir site; in the following year there were no flood discharges whatever; while in the year 1877–78 there were probably 66,240 acre-feet. This is a strong argument in favor of building reservoirs of sufficient capacity to hold over from years of abundance to years of deficiency. It would not be possible to catch and retain all the water in all of the years, as there is a limit to the height of dam that should be built to be commercially profitable.

In consulting a table of estimated discharge of stream flow for any given section, it must be borne in mind that the figures are purely hypothetical, exact determination being impossible, for numerous reasons. The character of the run-off is dependent upon the character of each particular rain storm, whether it is a gentle shower or violent downpour. Again, one storm quickly following another will produce a greater stream discharge, because there is less opportunity of absorption of the rain by the ground. The character of the exposure, forest cover, etc., all enter into the considerations, rendering the question one of great intricacy. The table given is based upon general results obtained in southern California and must be considered merely as an estimate made from the most reliable data in hand. In order to obtain intelligent results along these lines, it is exceedingly important for the city of Santa Barbara to maintain gagings on Santa Ynez River continuously, particularly during the construction of the tunnel prior to the building of the dam at Gibraltar.

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[a] Estimated.

TABLE 12.—*Hypothetical run-off for Santa Ynez reservoir sites on basis of observed Santa Barbara rainfall and run-off diagram.*

Year.	Rainfall of Santa Barbara and Santa Ynez.	Run-off per square mile in acre-feet.	Total run-off in acre-feet.			
			Juncal (drainage area, 13 square miles).	Mono (drainage area, 119 square miles).	Main river (drainage area, 71 square miles).	Gibraltar (drainage area, 207 square miles).
1867–68	25.19	210	2,730	24,990	14,910	43,470
1868–69	15.77	60	780	7,140	4,260	12,420
1869–70	10.27	....	....	....	....	....
1870–71	8.91	....	....	....	....	....
1871–72	14.96	50	650	5,950	3,550	10,350
1872–73	10.50	....	....	....	....	....
1873–74	14.44	40	520	4,760	2,840	8,280
1874–75	18.71	105	1,365	12,495	7,455	21,735
1875–76	23.07	170	2,210	20,230	12,070	35,190
1876–77	4.49	....	....	....	....	....
1877–78	29.51	320	4,160	38,080	22,720	66,240
1878–79	13.58	40	520	4,760	2,840	8,280
1879–80	25.64	230	2,990	27,370	16,330	47,610
1880–81	15.25	50	650	5,950	3,550	10,350
1881–82	14.27	40	520	4,760	2,840	8,280
1882–83	13.41	30	390	3,570	2,130	6,210
1883–84	34.47	430	5,590	51,170	30,530	89,010
1884–85	13.08	30	390	3,570	2,130	6,210
1885–86	24.24	190	2,470	22,610	13,490	39,330
1886–87	12.99	30	390	3,570	2,130	6,210
1887–88	21.71	150	1,950	17,850	10,650	31,050
1888–89	21.58	150	1,950	17,850	10,650	31,050
1889–90	32.37	370	4,810	44,030	26,270	76,590
1890–91	18.38	90	1,170	10,710	6,390	18,630
1891–92	10.28	....	....	....	....	....
1892–93	27.41	255	3,315	30,345	18,105	52,785
1893–94	6.85	....	....	....	....	....
1894–95	15.83	60	780	7,140	4,260	12,420
1895–96	13.77	40	520	4,760	2,840	8,280
1896–97	18.10	90	1,170	10,710	6,390	18,630
1897–98	4.99	....	....	....	....	....
1898–99	12.35	20	260	2,380	1,420	4,140
1899–1900	12.68	30	390	3,570	2,130	6,210
1900–1901	15.53	60	780	7,140	4,260	12,420
1901–2	14.06	40	520	4,760	2,840	8,280
1902–3	20.45	120	1,560	[a] 14,280	[b] 8,520	24,840
1903–4	11.68	15	195	1,785	1,065	3,105

[a] Measured flow, 8,934 acre-feet. [b] Measured flow, 9,898 acre-feet.

TABLE 13.—*Measured run-off of Santa Ynez River and Mono Creek for 1902–3.*

Month.	Total run-off in acre-feet.	
	Mono at dam site (drainage area, 119 square miles).	Main river above Mono (drainage area, 71 square miles).
1902.		
July	0	0
August	0	0
September	0	0
October	0	0
November	173	280
December	12	111
1903.		
January	676	1,193
February	389	755
March	1,845	1,230
April	4,820	4,998
May	799	1,045
June	220	286
	8,934	9,898
Estimate for 1902–3	14,280	8,520
Run-off for 1902–3, in acre-feet per square mile	75.1	139.4
1903.		
July	21	68
August	10	31
September	7	18
October	3	9
November	2	[a] 12
December	3	[a] 14
	46	152

[a] Estimated.

Run-off at Gibraltar, in acre-feet, for 1902–3.

[Estimated.]

Mono at dam site	8,934
Santa Ynez above Mono	9,898
17 square miles below Mono, estimated (17 × 139.4)	2,370
Total for Gibraltar	21,202

Total run-off, in acre-feet, of main river at Gibraltar dam site.

[Drainage area, 207 square miles.]

1903.[a]		1904.	
July	0	July	2
August	0	August	0
September	0	September	11,484
October	0	October	535
November	0	November	381
December	17	December	430
1904.		**1905.**	
January (7-31)	45	January	4,538
February	690	February	39,753
March	1,857		
April	1,125		
May	418		
June	42		
Total for season	4,194		

It is suggested that a reservoir should be so constructed as to supply at least 150 gallons per capita daily for a population of 10,000, the use and evaporation in this case amounting to about 2,100 acre-feet yearly. At the Mono reservoir site a dam 85 feet high, holding water to a maximum depth at the dam of 75 feet, would give this continuous supply for nineteen months. At the Gibraltar reservoir site a dam 100 feet high would impound a two years' supply, and a dam 155 feet high would have a capacity of 15,793 acre-feet. These figures as to flow of the streams and capacities of reservoirs indicate the adequacy of a system based upon these physical conditions. The records of stream flow should be continuously maintained to assist in the determination of the requisite height of dam.

QUALITY OF WATER.

The quality of the water in the neighborhood of Santa Barbara has been made the subject of long study by Prof. James A. Dodge, of Santa Barbara. Herewith are given certain analyses made by him of the water of creeks in this vicinity. Although these are not absolutely complete, inasmuch as small quantities of minerals present are not stated, they were made with care. Other complete analyses that were made subsequently show no material difference from the results given. The analysis of the water of the city tunnel as supplied to consumers in Santa Barbara was made at the request of Doctor Cassal, health officer in 1899. The amount of mineral substances in solution in the tunnel water does not materially differ from that shown by the analysis made of Mission Creek waters in 1894. Other analyses made by Professor Dodge at various times, of waters from the wells

[a] Estimated.

in the city, show them to be, generally speaking, very similar to the creek water. Professor Dodge concludes that the ordinary water in use for domestic purposes from the strip of country between Santa Ynez Mountains and the ocean is practically uniform in quality. There are, however, exceptional waters in this vicinity differing decidedly from those above referred to, one of these being the Veronica water, and another the water from the Hot Springs.

ANALYSES OF SAMPLES.

Certain analyses were made of the water from Mono Creek by Prof. Laird J. Stabler, chemist for the University of Southern California and also for the Southern California Medical College, one (No. 5) being of the low summer flow, consisting of merely a few miner's inches seeping through the sands and gravels and naturally containing an abnormally large amount of mineral matter. Another (No. 7) was of the water from the first floods from the drainage basin, which, as is customary after a long drought, carried some of the accumulated salts deposited along the margins of the stream by summer evaporation, and also a large amount of pulverized sediment trampled by stock during the preceding summer and readily picked up and carried away by the first dash of water over the ground. These analyses of the low-water stage at the end of a dry season and the first flood water are the most unfavorable that could be made. The analyses of the later floods, made as the season advanced, give smaller amounts both of silt and of mineral matter, as shown in analyses No. 9 and No. 12.

Analysis No. 1, water of Mission Creek.

[Analyst, James A. Dodge; date of analysis, June, 1894.]

	Grains per U. S. gallon.
Sodium chloride	1.28
Sodium sulphate	6.95
Calcium sulphate	7.45
Calcium carbonate	6.02
Magnesium carbonate	4.21
Potassium carbonate	Trace.
Alumina and iron salts	Trace.
Silica	Trace.
Total	25.91

Reaction of residue left by evaporation in a platinum dish, slightly alkaline.

Analysis No. 2, water of Cold Spring Creek.

[Analyst, James A. Dodge; date of analysis, June, 1894.]

	Grains per U. S. gallon.
Sodium chloride	1.05
Sodium sulphate	5.96
Calcium sulphate	10.63

	Grains per U. S. gallon.
Calcium carbonate	6.25
Magnesium carbonate	6.54
Potassium carbonate	Trace.
Alumina and iron salts	Trace.
Silica	Trace.
Total	30.43

Reaction of residue left by evaporation in a platinum dish, slightly alkaline.

Analysis No. 3, water from the Santa Barbara city water tunnel.

[Analyst, James A. Dodge; analysis made in November, 1899, for Doctor Cassal, health officer.]

	Grains per U. S. gallon.
Sodium chloride	0.537
Sodium sulphate	8.392
Magnesium sulphate	3.118
Magnesium carbonate	1.769
Calcium carbonate	14.097
Iron carbonate	.122
Potassium carbonate	.379
Lithium salts	Trace.
Silica	Trace.
Nitrates	Trace.
Organic carbonaceous matter	Trace.
Total	28.414

Analysis No. 4, water from Santa Ynez River at gaging station one-half mile above mouth of Mono Creek.

[Collected by S. G. Bennett, January 4, 1903; analyst, Laird J. Stabler. Clear water; low stage before winter floods.]

	Grains per gallon.	Parts per 100,000.
Sodium chloride	2.72	4.68
Sodium sulphate	29.82	51.19
Sodium carbonate	16.57	28.41
Total solids	42.91	73.60

Analysis No. 5, water from Mono Creek at gaging station near mouth.

[Collected by S. G. Bennett, January 4, 1903; analyst, Laird J. Stabler. Clear water, low stage.]

	Grains per gallon.	Parts per 100,000.
Sodium chloride	5.94	10.20
Sodium sulphate	58.28	99.94
Sodium carbonate	17.94	30.74
Total mineral matter	81.64	140.00

Analysis No. 6, water from Santa Ynez River above mouth of Mono Creek.

[Collected by W. B. Clapp, November, 1902; analyst, Laird J. Stabler. First flood.]

	Grains per gallon.	Parts per 100,000.
Sodium chloride	2.50	3.5
Sodium sulphate	38.25	65.6
Sodium carbonate	10.13	17.38
Total solids in suspension	1,749.50	2,640.00
Total solids in solution	67.64	116.00

Solid matter deposited in 30 hours, 7.3 per cent by volume; solid matter deposited in 3 days, 7.3 per cent by volume.

Analysis No. 7, water from Mono Creek near dam site.

[Collected by W. B. Clapp, November, 1902; analyst, Laird J. Stabler. First flood.]

	Grains per gallon.	Parts per 100,000.
Sodium chloride	2.3	3.94
Sodium sulphate	33.11	56.80
Sodium carbonate	9.51	16.32
Total solids in suspension	342.80	931.00
Total solids in solution	57.15	98.00

Solid matter deposited in 30 hours, 4 per cent by volume; solid matter deposited in 3 days, 4.1 per cent by volume.

Analysis No. 7, water from Mono Creek.

[Collected January 24, 1903, at low stage; analyst, James A. Dodge.]

	Grains per gallon.
Suspended siliceous matter, separated by filtration	1.46
Sodium chloride	5.49
Sodium carbonate	3.73
Sodium sulphate	13.14
Magnesium sulphate	22.43
Calcium sulphate	10.34
Calcium carbonate	16.99
Aluminum sulphate	1.17
Iron salts	Trace.
Potassium salts	Trace.
Organic matter	Trace.
Total dissolved substances	73.29

The following analyses of waters from Mono Creek and Santa Ynez River were taken from the low stage of the stream subsequent to the first flood, but it is believed that they still contained abnormally high quantities of solids in solution:

Analysis No. 8, water from Santa Ynez River at cable station.

[Collected by H. Rankin, January 29, 1903; analyst, Laird J. Stabler. Low stage.]

	Grains per gallon.	Parts per 100,000.
Chlorides as sodium chloride	2.04	3.5
Carbonates as sodium carbonate	14.45	24.8
Sulphates as sodium sulphate	18.49	31.72
Total solids in solution	34.99	60.00
Total solids in suspension (0.02 per cent)	11.66	20.00

Analysis No. 9, water from Mono Creek at cable station.

[Collected by H. Rankin, January 29, 1903; analyst, L. J. Stabler.]

	Grains per gallon	Parts per 100,000.
Chlorides as sodium chloride	3.67	6.3
Carbonates as sodium carbonate	10.99	18.86
Sulphates as sodium sulphate	37.00	63.44
Total solids in suspension (0.02 per cent)	13.99	24.00
Total solids in solution	56.20	97.2

Analysis No. 10, water from Santa Ynez River at cable station.

[Collected by H. Rankin, January 30, 1903; analyst, L. J. Stabler.]

	Grains per gallon.	Parts per 100,000.
Chlorides as sodium chloride	2.04	3.5
Carbonates as sodium carbonate	16.31	27.98
Sulphates as sodium sulphate	18.64	31.96
Solids in solution	44.51	69.2

Analysis No. 11, water from Mono Creek at cable station.

[Collected by H. Rankin, January 30, 1903; analyst, L. J. Stabler.]

	Grains per gallon.	Parts per 100,000.
Chlorides as sodium chloride	3.67	6.3
Carbonates as sodium carbonate	14.60	25.01
Sulphates as sodium sulphate	44.10	75.64
Solids in solution	65.42	112.0

Analysis No. 12, water from Mono Creek.

[Collected by H. Rankin, January 28, 1903; analyst, James A. Dodge. Flood water.]

	Grains per gallon.
Sodium chloride	0.99
Sodium carbonate	1.05
Sodium sulphate	7.59
Magnesium sulphate	3.52
Calcium sulphate	6.07
Calcium carbonate	7.83
Iron carbonate	.88
Potassium salts	Trace.
Organic matter	Trace.
Total	27.93

This water contained silt, suspended and subsided, consisting mainly of clay, but containing some fragments of vegetable matter, and amounting to 3½ per cent by weight of the total water. This silt subsided with moderate quickness and left the water clear in somewhat less than three days.

Analysis No. 13, water from Mono Creek.

[Collected by H. Rankin, February 26, 1903; discharge, 4.50 second-feet; analyst, L. J. Stabler.]

	Grains per gallon.	Parts per 100,000.
Sodium chloride	4.01	6.87
Sodium carbonate	2.00	3.43
Sodium sulphate	14.85	25.46
Potassium sulphate	1.02	1.72
Calcium sulphate	30.45	52.22
Calcium carbonate	3.82	6.56
Magnesium carbonate	8.42	14.43
Total	64.57	110.69

The mineral matter is rather excessive for domestic purposes. The alkali salts are not beyond the limit for irrigation, but amount present would be large for some soils. The water would form considerable hard scale in boilers. As this is a low-water sample, it shows more mineral salts than flood-water samples.

Analysis No. 14, water from Mono Creek.

[Collected by H. Rankin, February 26, 1903; discharge, 4.5 second-feet; analyst, James A. Dodge.]

	Grains per gallon.
Sodium chloride	3.97
Sodium carbonate	3.91
Sodium sulphate	13.84
Magnesium sulphate	21.55
Calcium sulphate	8.37
Calcium carbonate	22.02
Iron carbonate	Trace.
Aluminum sulphate	0.52
Potassium salts	Trace.
Silica	0.41
Total	74.59
Suspended matter	0.29

Analysis No. 15, from Santa Ynez River at Gibraltar.

[Collected by L. M. Hyde, May 2, 1904; discharge, 16.97 second-feet; analyst, James A. Dodge.]

1. General character of the water.

Clear, colorless, free from odor, of good taste; showing a slight sediment in the bottle, not sufficient for quantitative determination. Reaction slightly alkaline.

2. Organic matter.

A microscopic examination of the very small amount of matter separated by filtering, including the above-mentioned sediment, showed some plant fibers and parts of vegetable organisms; also a few infusoria in a state of activity. These are usually present in river and lake waters.

3. Chemical analysis of the mineral matter in solution.

	Parts per 100,000.	Grains per U. S. gallon.
Calcium carbonate	34.98	20.393
Calcium sulphate	4.03	2.350
Magnesium sulphate	25.78	15.030
Sodium sulphate	12.57	7.328
Sodium chloride	3.64	2.122
Potassium carbonate	1.05	0.612
Lithium salts	Trace.	Trace.
Iron salts	Trace.	Trace.
Nitrates	Trace.	Trace.
Silica	Trace.	Trace.
Total	82.05	47.835

The foregoing substances are to be understood as in the anhydrous state.

	Degrees.
Total hardness	37
Permanent hardness	20
Temporary hardness	17

The total and the permanent hardness were determined by the use of a standardized soap solution. The temporary hardness is found by subtracting the permanent from the total.

The U. S. gallon of 231 cubic inches is the basis of these results, not the imperial gallon, as formerly customary.

This analysis shows that the water is of good quality for domestic use and for irrigation. For table use, like the water of all streams in this vicinity, it would be improved by boiling and settling. This process removes a considerable part of the mineral matter and destroys infusoria and other living organisms. For use in steam boilers it would be advisable to submit this water to a softening treatment before taking it into the boilers.

DISCUSSION OF ANALYSES.

Up to January 28, 1903, this season was not productive of floods, the precipitation having been largely in the form of snow in the higher mountains, and the high water occurring later in the spring. For this reason all of the samples except Nos. 6, 7, and 12 were taken when the stream was at low stage. The water that runs off the surface of the ground in floods will not contain as much mineral matter as that which seeps through the soil into the stream during its low stage. Samples Nos. 12 and 13 show this to be true. It is probable that over 80 per cent of the total annual discharge of the Mono will be in freshets. This being the case, we may expect the water that is stored in reservoirs to be more nearly like the flood-water than the low-water samples analyzed. If the low-water flow tends to deteriorate the whole impounded in the reservoir, it may be carried around the reservoir in a conduit.

The first flood that is flushed over the surface of a drainage basin after a drought will absorb more mineral matter than later floods will find. Thus sample No. 12 shows better water than No. 7. Sample No. 12, from the second flood water of the Mono, shows a water practically the same as that now being used by the city of Santa Barbara from Mission Creek and the city tunnel. The low-water samples contain a high per cent of mineral, but even they are pronounced harmless by Mr. Dodge. The water of the Santa Ynez above the Mono is better than the Mono water. The water stored at the Gibraltar site would be a blended water, grading between the two; and in view of the fact that this is the only source of supply open to the city for an adequate amount of water, it is believed that it should be accepted.

Prof. James A. Dodge, a chemist of marked and recognized ability, residing at Santa Barbara, who made a number of the foregoing analyses, gives the following statement about the quality of this supply:

On the supposition that the proposed reservoir on Mono Creek will be filled with the flood water of the creek, but that the water running in the creek during its low stages will also pass into the reservoir, the water as supplied to this city from that source will in its composition come between the samples analyzed by me and reported on the 16th and 21st of February [No. 12] and the 4th of March [No. 14], and might under certain conditions approximate to the first of these samples.

Considering, therefore, this low-water sample, I call attention to the fact that the principal mineral ingredients—that is, those present in greatest quantity—are the familiar calcium and magnesium salts of our hard waters. A person drinking a quart of this water would take into his stomach from 12 to 13 grains of these salts. He would at the same time take about 5 grains of sodium salts, equally common in our natural waters as used for domestic purposes, together with a very small amount of other harmless mineral substances.

In my opinion, these quantities of all these substances, taken in water, would not be sufficient to produce any deleterious or unpleasant effects upon a person in good health, properly supplied with food. Nor would the habitual use of the water bring about any bad consequences. In the case of some persons in delicate health, or of persons fasting, the same substances in the same quantity contained in the water would probably have the medicinal action of an aperient. This opinion is based on actual experience in the use of such water by myself and by others in the same company.

I will add that this water by being boiled would be caused to deposit a part of the calcium and magnesium salts, in the form of carbonates, and would thereby be improved. Furthermore, aside from the removal of a part of the mineral matter, all water taken from streams and lakes, in view of the possibility of its contamination by disease germs, needs boiling to make it perfectly safe for domestic use. After being boiled and decanted from the precipitated substances, the water, if placed in a suitable receptacle, will keep as long as may be desired and will be quite potable from first to last.

As regards the use of the Mono Creek water for cooking purposes, in my opinion the quantity of mineral substances introduced into the articles cooked with it would not be sufficient to produce any noticeable effects.

For washing this is a hard water. It would, with ordinary soaps, be somewhat more troublesome than the waters now supplied to the people of this city.

In the irrigation of trees, shrubs, and other plants, this water would not produce any injurious effects, unless applied in extraordinary quantity or on soil with little or no drainage.

It must be admitted that these waters are not of high grade for domestic use because of the large quantities of mineral matter in solution, but it is not believed that they will be injurious to health, nor will they be harmful to vegetation. The sulphate of sodium is not harmful, and the sulphate of lime tends to neutralize the carbonates. All stream waters contain more or less mineral matter. Chemically pure water is neither pleasant to drink nor healthful. The question of soils becoming alkaline from irrigation with salty water is largely dependent upon the slope and drainage that the soil itself has. In a hill country water containing unusual quantities of alkali may be used with impunity, while in a flat country a water of much better grade could not be applied in irrigation without producing bad effects. No organic impurities, which are most to be feared, will be found in these waters in dangerous quantities.

It should be stated that the samples Nos. 4 to 11, given Professor Stabler, were not large enough in volume to permit of complete analysis.

Mr. Thomas H. Means,[a] of the Bureau of Soils of the Department of Agriculture, makes the following comment upon the quality of the water as indicated by the foregoing analyses:

I have examined the analyses given in your report to the city water commissioners of Santa Barbara, Cal., with a view to determining whether these waters would be considered favorable for city use or not. I have considered the sources as free from contamination through animals and consequently have confined my attention to the mineral ingredients which the water carries.

As I understand the situation, the water which you propose to carry through the mountains by a tunnel is to be stored in a reservoir on Santa Ynez River and comes in something like equal parts from Santa Ynez River and Mono Creek. The analyses in your report are

[a] Mr. Means has since been appointed engineer of soils of the Reclamation Service.

from samples taken from both streams. The following table is a recapitulation of the analyses, showing only the total solids in 100,000 parts of water:

Comparison of analyses of Santa Ynez and Mono water.

Date.	Stage of Santa Ynez River.	Parts per 100,000.	Date.	Stage of Mono Creek.	Parts per 100,000.
1903.			1903.		
Jan. 4	Low stage before floods.	73.60	Jan. 4	Low stage before floods.	140.00
Nov.[a] —	First flood	116.00	Nov.[a] —	First flood	98.00
Jan. 29	Low stage	60.00	Jan. 29	Low stage	97.20
30	do	69.20	30	do.?	112.00
			28	Flood	48.30
			26	Low water	110.69
			26	do	129.00

[a] 1902.

All of these samples, with one exception, are collected at low stage of the stream, when the amount of soluble matter is usually highest, or at first flood after the dry season, when the accumulations of saline matter from the surface of the soil are swept into the stream. So these analyses probably represent the worst condition of the water. The only flood sample is that from the Mono Creek collected January 28, 1903, and its analysis shows considerably less than half the soluble matter found in the low-stage flow of the stream. I presume if flood samples were collected from the Santa Ynez a similar falling off in amount of soluble matter would be noted. The importance between this difference in low-water and flood stages is very great, especially where the floods can be stored and where it may be possible to divert the low-water flow and carry it around the reservoir.

The waters of Mono Creek seem to carry much more soluble matter than do those of the Santa Ynez. The average of the analyses given under the first four dates in the table shows Mono Creek to carry nearly 49 per cent more soluble matter than does Santa Ynez River. If the same ratio holds during the flood season the mixture of waters in the two streams should carry less than 40 parts per 100,000 parts of water, or a water, as will be shown later, which, according to the most rigid standards in eastern cities and in Europe, would be classed as "good" for domestic use. On the other hand, if the low-water discharge alone is considered the average of a mixture of the two waters would be about 114 parts per 100,000. Later I will show that according to accepted standards this amount of soluble matter is well within the limit of western American sanitary engineers.

The standard most generally accepted in eastern United States and Europe allows 50 parts per 100,000 parts of water. More than that quantity serves to condemn a water or class it as a water only "fair" for domestic use, while waters carrying less than 50 parts are classed generally as good. E. W. Hilgard, of the University of California, places the limit for domestic use at 40 grains per gallon (68.6 parts per 100,000). J. K. Haywood, chief of the water laboratory of the Bureau of Chemistry in the United States Department of Agriculture, in an article on Analysis of Waters and Interpretation of Results, published in the Department of Agriculture Yearbook for 1902, makes the following statement: "Some water analyzers would cast aside all doubt by declaring that waters containing above 686 parts per million (68.6 parts per 100,000) are to be condemned, but such is not the case, as there are many instances, especially in the West, of water containing 1,200 parts per million (120 parts per 100,000) and over being used without apparent evil results."

As a matter of precedent, I might say that there are a number of small western towns using water carrying more than 100 parts soluble matter per 100,000 parts of water, and that the city of Phoenix, Ariz., supplies about 15,000 people with water carrying from 102 to 136 parts, without apparent inconvenience or harmful effect. Numerous domestic supplies for families have been observed by myself carrying from 400 to 500 parts per 100,000, all without evil effect and with no inconvenience except that the waters were unpalatable at first. The inhabitants of some parts of the Southwest have become so used to the saline waters that I have seen pure water salted at table to bring back the familiar taste

I find it very difficult to draw any definite conclusions from the character of the salts in the water, for I am not familiar with the methods employed by the chemists in calculating these analyses. However, it seems that the most important constituents are salts of lime. These serve to make the water hard, will cause considerable losses in soap used, and will give trouble in boiler use by forming scale. I can not say how much of this hardness is "temporary" and how much "permanent." The two analyses, Nos. 13 and 14, are evidently made from duplicate samples by two chemists working independently. One of them, No. 13, would be classed as a hard water with nearly all the hardness permanent, or, in other words, it could not be removed by boiling. On the other hand, when we consider analysis No. 14, nearly one-half of the hardness is temporary, or could be removed by simply boiling and allowing the sediment to settle. If a new set of analyses were made I would suggest they be made by some accepted standard of water analyses and both "temporary" and "permanent" hardness be determined.

Of the other salts present only the sodium sulphate and magnesium sulphate are present in sufficient quantity to warrant consideration. Both these salts are laxative, but only the most delicate constitutions would be affected by the small amounts taken in this water. Newcomers to the locality might notice the effect of the water for a few days, but I am sure no evil effects can possibly come from the constant use of such water.

The small amounts of sodium carbonate would either neutralize the effects of part of the calcium sulphate or would react with some of the magnesium salts to lower the amount of "permanent" hardness. The amount of sodium chloride is so small as to be negligible in considering the value of the water.

In summing up the matter I will say that I think the flood flow of the united Santa Ynez and Mono will prove to be well within the limits set down by the most rigid eastern standards, and that from the available analyses even the low-stage flow will be found to be well within the limits allowable for western cities and much lower in salt contents than many waters which have been in use for a long time without deleterious effects.

If further analyses are made I would suggest that both "temporary" and "permanent" hardness be determined and that some attempt be made to collect flood samples as well as the normal and low stage from both streams.

In respect to the amount of solid matter in the stream, it will be seen that there was less silt in the first flood water from the Mono than from the Santa Ynez; the reverse may be expected under ordinary conditions. Both of these analyses show the percentage of wet silt by volume at the expiration of a short period of settlement. This determination of solid matter by volume gives an exaggerated idea of the way in which the silt might be expected to destroy the storage capacity of the reservoir, for it will compact as it settles in the reservoir and as other silt is deposited upon it. In this manner it will solidify into soil occupying from one-half to one-quarter of the space indicated by its volumetric determination. Later floods have shown less than one-tenth of 1 per cent of silt.

The way to meet the silt problem in the future will be by building the dams higher when their storage capacity is impaired. The elevation of the bed of the creek at the Mono reservoir site is 1,440 feet; the capacity to the 1,530-foot elevation is 6,509 acre-feet. If the water level is raised 10 feet, or to the 1,540-foot elevation, the capacity will be increased 2,254 acre-feet, or 34.6 per cent. If we consider that the reservoir will lose as much as 2 per cent of its capacity annually by silting, or 34 per cent in seventeen years, the original capacity could be restored by raising this dam 10 feet in height at the end of that period of time. In a similar manner the capacity of the Gibraltar reservoir may be increased about 30 per cent by raising the crest 10 feet above the 155-foot elevation.

FOREST COVER.

The true and permanent solution of this silting problem lies in the protection and development of the forest and brush cover of this reserve. A valuable brush cover is shown in Pl. III, *B*. Under existing conditions the Los Prietos Y Najalayegua grant is wedged in between the Pine Mountain and Zaca Lake Forest Reserve and the Santa Ynez Forest Reserve, along the canyon of Santa Ynez River. This private grant is not only pastured to sheep and goats, but is also subject to attacks from fires originating thereon which can not be properly restrained. Sheep have been described as the hoofed locusts of the mountains. Their small feet cut up and pulverize the soil, destroying the plants and roots that might otherwise escape them. They are a menace almost equal to that of fire to every drainage basin in southern California which they enter. Arrangements, if possible, should be made looking toward the condemnation of this property in some way and its addition to the forest reserves above referred to. The board of water commissioners of Santa Barbara very wisely and properly have urged this matter with the Departments at Washington, and the forestry experts who have examined the region have favorably reported upon the action suggested.[a]

With a natural increase of vegetation and protection from the fires which have raged through this district for years past it is believed that the silt danger would be largely mitigated. This is a subject which should be followed up as one of vital importance, and but one solution should be permitted, to wit, the expulsion of the sheep from the drainage basin of the Santa Ynez and the protection of the forest and brush cover from fire. Otherwise the drainage basin is satisfactory. There are practically no human habitations within its borders above the proposed reservoir sites, and probably will be none in the near future, as the country is too mountainous and too inhospi-

[a] In December, 1903, after the above had been written, an Executive order included this grant in the forest reserve, an exchange of holdings having been arranged with the owner, and now the entire reservation, including the whole basin of the upper Santa Ynez, is known as the Santa Barbara Forest Reserve.

table to admit of agricultural pursuits. The greater portion of the basin is now included in forest reserves.

RESERVOIR SITES.

JUNCAL SITE.

Mr. George Wright made surveys of the Juncal reservoir site and determined the following capacities:

TABLE 14.—*Capacities of the Juncal reservoir site for various heights of dam.*

Height of dam in feet.	Million gallons.	Acre-feet.
50	350	1,074
75	705	2,164
100	1,050	3,222
125	1,437	4,410
150	1,877	5,760
175	2,352	7,218
200	4,000	12,276

It will be noted that with a dam 100 feet high the capacity of the Juncal reservoir is 3,222 acre-feet; with a 100-foot dam on the Mono reservoir site the capacity is 8,763 acre-feet. The Mono site, therefore, has 2.72 times the capacity of the Juncal, with the same height of dam. The Gibraltar dam, 100 feet high above stream bed, will hold 6,480 acre-feet. It is believed that the Juncal reservoir site alone will not furnish an adequate water supply to the city, but when used in connection with other reservoir sites having greater drainage areas above them it may be of value. The drainage area above the Juncal is but 13.4 square miles, not 23½ square miles as reported upon previously by other engineers. The length of a dam 200 feet high at the Juncal would be 550 feet on top, and a 100-foot dam would be 272 feet.

Mr. Purslow estimated that the cost of building a 100-foot dam and a riveted-steel pipe line (which latter must be considered as temporary construction) to Santa Barbara would be $282,450. He also states that the run-off from the drainage basin of the Juncal was measured in the winter of 1895–96 and that it amounted to 2,455 acre-feet. On the other hand, it is estimated in this report (see p. 53) that the run-off of the Juncal in 1895–96 was only 520 acre-feet from 13 square miles—a figure, therefore, apparently overconservative. However, there probably was a flood in January, 1896, as the rainfall for that month was 6.84 inches at Santa Barbara and probably 9 inches in the drainage basin of the Juncal. This may have produced a rather abnormal flood condition. As Mr. Purslow gives no details of his work, not even the length of time of his observations, his results can not be accepted as conclusive.

Mr. Wright states that the rock at this dam site, which is quite similar to the formation prevailing throughout this region, weighs 149 pounds per cubic foot. In this estimate this rock has been considered as weighing 150 pounds per cubic foot, as determined at various points along the Coast Range by geologists. Masonry work made therefrom is taken to weigh 143 pounds per cubic foot.

MAIN RIVER SITE.

The Main River reservoir site was investigated by Mr. Purslow. This also was surveyed by W. B. Clapp for the Geological Survey. We find that a dam 65 feet in height would have a storage capacity of 1,311,000 gallons, or 4,023 acre-feet, to the 65-foot flow line. Figs.

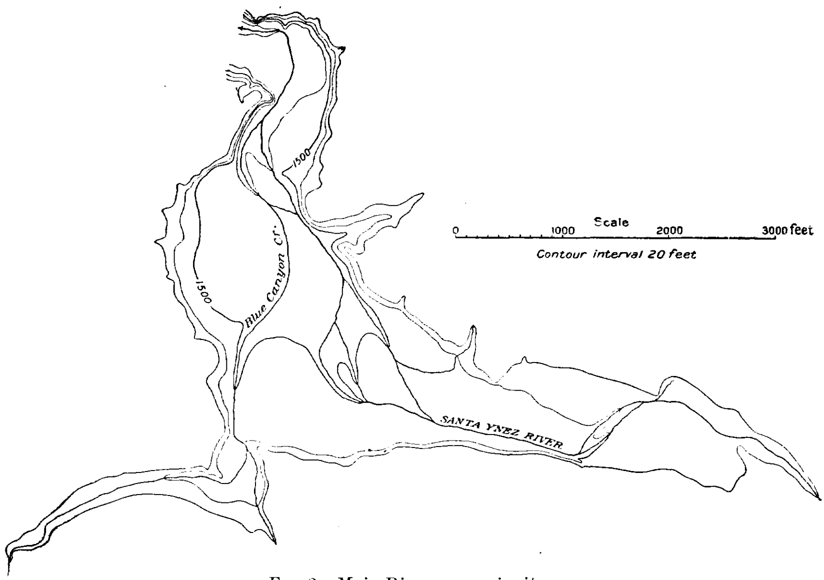


FIG. 2.—Main River reservoir site.

2 and 3 show the reservoir and dam sites. The Mono reservoir site with water held to the 75-foot level would have a capacity of 3,968 acre-feet. The Main River dam, however, would contain very much more masonry and be more expensive than the Gibraltar or the Mono dam. A dam 75 feet high at the Main River site would be 592 feet long on top and 427 feet long on the base. At the Mono dam site a dam 75 feet high would be 277.5 feet long on top and 150 feet long at the bottom. The Gibraltar is still more favorable. With an 85-foot rock-fill dam at the Mono the cost per acre-foot of capacity is $36, while at the Main River site with a 65-foot concrete dam the cost is about $154 per acre-foot of capacity, depending on depth of bed rock.

Mr. Purslow states that it would require a tunnel 15,500 feet long to pass through the Santa Ynez Range to the coast side and that the estimated cost of developing this work would be $557,000. It is believed that a shorter location can be found. The width of canyon covered by débris at the Main River dam site is so great and the depth to bed rock so uncertain that it is impossible to give even an approximate estimate of the cost of this dam. It must be of masonry, as it will have to be an overflow weir. If bed rock is taken as 25 feet below the bed of the creek, it may cost $620,000 for the dam alone.

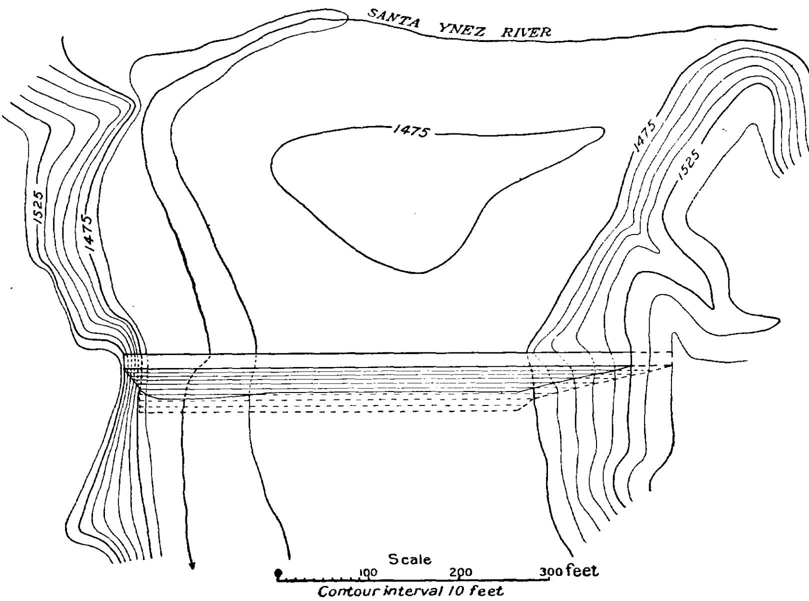


FIG. 3.—Main River dam site.

The effort has not been made in this report to go into the details of these estimates of cost for the Main River and Juncal reservoir sites. The reservoir sites are owned by the Santa Barbara City Water Company. It is believed, however, that if the city of Santa Barbara constructs a tunnel through the Coast Range, in order to lead the water from the lower reservoir sites to the city, the construction by some one of the Juncal or Main River reservoir sites may ultimately follow. This tunnel is a very large element in the cost of the work, and will require by far the greater length of time to construct. It must be so located as to permit the water from all the sites to be led through it by gravity to the coast, and its capacity must be sufficient to accommodate all of the water.

TABLE 15.—*Area and contents of Main River reservoir.*

[Survey by W. B. Clapp.]

Contour.	Acres.	Acre-feet between contours.	Total acre-feet to contour.	Capacity in millions of gallons.
1,460	0.33			
1,470	2.68	15.05	15.05	5
1,480	14.38	85.30	100.35	33
1,490	30.45	224.15	324.50	106
1,500	71.59	510.20	834.70	272
1,510	120.19	958.90	1,793.60	581
1,520	154.69	1,374.40	3,168.00	1,032
1,530	187.66	1,711.75	4,879.75	1,590
1,540	222.06	2,048.60	6,928.35	2,357
		6,928.35		

75-foot flow-line capacity=5,904.05 acre-feet.
Depth of bed rock unknown.

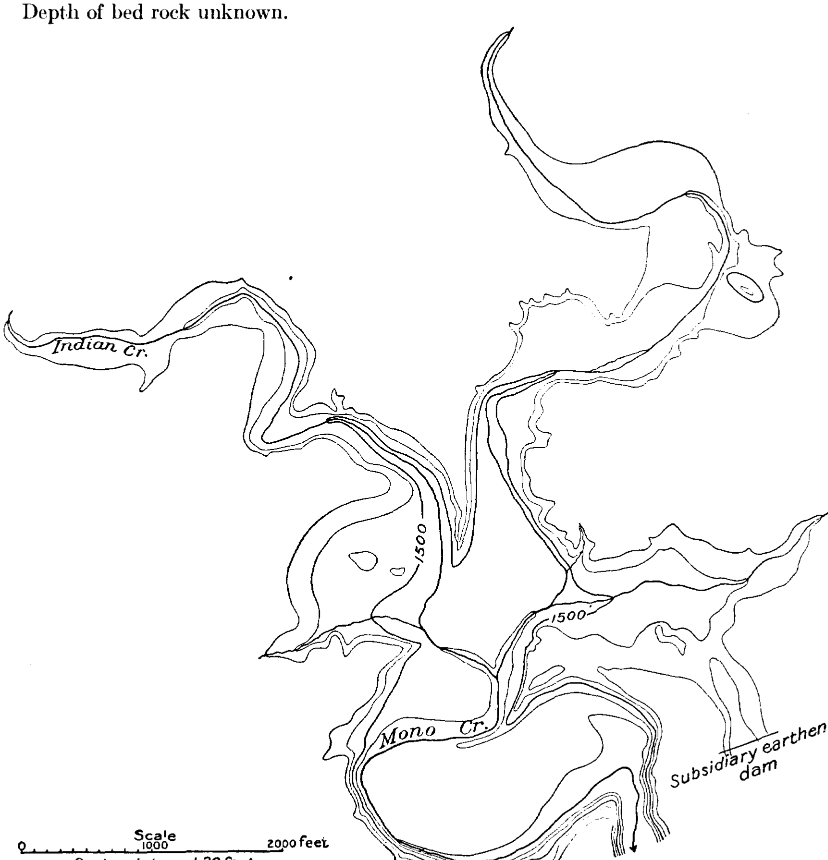


FIG. 4.—Mono reservoir site.

BLUE CANYON SITE.

The Blue Canyon reservoir site is situated in what is known as Blue Canyon, which discharges into the Santa Ynez a short distance above the Main River reservoir site. It is a good reservoir site, but as the drainage basin is only 8 square miles it is not considered feasible to fill it from its tributary natural-water supply. The Blue Cañyon reservoir site is between Santa Ynez River and the crest of Santa Ynez Mountains. The length of tunnel from this reservoir site to the coast side would be 10,500 feet. To fill it from Santa Ynez River, in addition to building this long tunnel, would be too expensive a proposition to justify the construction.

MONO SITE.

A detailed and careful survey was made of the Mono reservoir and dam site by Mr. W. B. Clapp, of the hydrographic branch of the Geological Survey. Fig. 4 shows the results of these surveys, and Pl. IV, *B*, is a view of the site. The following table gives the capacity:

TABLE 16.—*Area and contents of the Mono reservoir site.*

[Survey by W. B. Clapp.]

Contour.	Area in acres.	Capacity in acre-feet between contours.	Total capacity in acre-feet.	Capacity in millions of gallons.
1,440.0	0	....	....	....
1,450.0	1.2			
1,460.0	10.6	....	[a] 94.0	....
		59.0	....	....
1,461.2	....	209.0	00.0	....
1,470.0	31.2	....	174.0	57
1,480.0	49.9	406.0	580.0	189
1,490.0	71.3	606.0	1,186.0	386
1,500.0	98.1	847.0	2,033.0	662
1,510.0	125.4	1,117.5	3,150.5	1,026
1,520.0	164.0	1,447.0	4,597.5	1,498
1,530.0	199.5	1,817.5	6,415.0	2,090
1,540.0	251.4	2,254.5	8,669.5	2,825

[a] Below outlet.

Total capacity in acre-feet 8,763.5
Capacity below outlet 94.0

Capacity, above outlet 8,669.5
Elevation of creek bed 1,440.0
Elevation of outlet 1,461.2
Depth of bed rock unknown.

This reservoir site has tributary to it a drainage area of 119 square miles. The creek passes first through a large flat and then through a narrow gorge. It is an unusually good reservoir site for southern California, but the dam site is poor. If the tunnel which the city is now running is continued at a grade of one-tenth of a foot rise to 100 feet horizontal, the elevation of the north portal of the tunnel on the datum plane that has been used will be 1,457.2 feet.[a] We may assume that a conduit leading from the reservoir site to the portal of the tunnel would descend approximately 4 feet in grade, giving an approximate elevation of the outlet from the reservoir as 1,461.2 feet, or 21.2 above the bed of the stream at the reservoir site. This is not of material consequence, as it is usually the case with reservoir sites that the first 20 or 30 feet above the bed of the stream at the dam site has very limited storage capacity. Thus the total storage capacity to the 100-foot flow line at the Mono reservoir site is 8,763.5 acre-feet and the capacity below the outlet is but 94 acre-feet, so that the net capacity above this outlet with a 100-foot dam would be 8,669.5 acre-feet, or 99 per cent of the total.

DISCHARGE.

Measurements of the flow of the Mono during the winter of 1902–3 were made daily, and the discharge for the season was found to be as follows:

TABLE 17.—*Estimated monthly discharge of Mono Creek at the dam site for season of 1902–3.*

[From daily measurements.]

1902.	Acre-feet.	1903.	Acre-feet.
July	0	January	676
August	0	February	389
September	0	March	1,845
October	0	April	4,820
November	173	May	799
December	12	June	220
		Season	8,934

The mean rainfall at Santa Barbara is 16.78 inches; for the last season it was 20.45 inches. Although the precipitation was in excess of the mean, the rainfall was not delivered in such manner as to produce large stream discharge and in the opinion of local residents the streams were below normal. The five preceding years were all below the mean in precipitation, so that a larger portion of the water than usual was absorbed by the ground. These measure-

[a] For more detailed statement, see p. 40.

ments of the streams should be continued so that the height of dam may be intelligently proportioned to the probable water supply. (See table 12, p. 53, showing estimated volumes of flow annually.)

CONTENTS AND COST OF DAMS.

Two types of dam for the Mono site have been considered. The rock on the sides of the canyon at this dam site is sandstone and shale, the stratification being practically vertical and the strike at right angles to the direction of the stream flow. Pl. IV, *A*, shows the character of this rock at the left abutment, which is the best. It weighs approximately 150 pounds to the cubic foot, and could be quarried in sizes and forms suitable for the work on the dam. The abutments are much better at the Mono dam site than at the Main River dam site, but not so good as at the Gibraltar. Spillway opportunities occur at the right abutment for the accommodation of flood discharges when the reservoir may happen to be full. The dam is considered in each instance to be 10 feet above the elevation of its spillway, so as to prevent the water overtopping the structure. The depth to bed rock is not known. The most serious item in connection with the construction of the dam is probably the transportation of supplies and materials to the site. In case the dam should be a cement, masonry, or concrete structure there would be a large amount of cement, which is a heavy material, to be hauled to the reservoir site. The masonry dam is believed to be the better form of construction, but because of considerations of economy the cost of the rock-fill type of dam has been computed.

These supplies for a rock-fill dam would probably be hauled by teams up Santa Ynez River from the end of the railroad at Ballard, a distance of 40 miles, or possibly through the tunnel when it is completed. The wagon road would be poor for the last 10 miles, but the grades easy. In the original estimate for this dam made for the city of Santa Barbara all material was considered as hauled by wagon to the dam site for both forms of structure. Since then (January 1, 1903) the manufacture of native cements has reduced the price of this constituent materially.

The rock-fill may be the better type for this point because of its greater economy. As the volume of material that would have to be brought in for construction purposes would be relatively small as compared with a masonry dam, it probably would not be advisable to provide for transportation through the tunnel for it, as would be necessary if a masonry dam were built. The estimates are therefore made upon this assumption. Fig. 5 shows a plan for a 110-foot rock-fill dam and fig. 6 a plan for a subsidiary earthen dam.

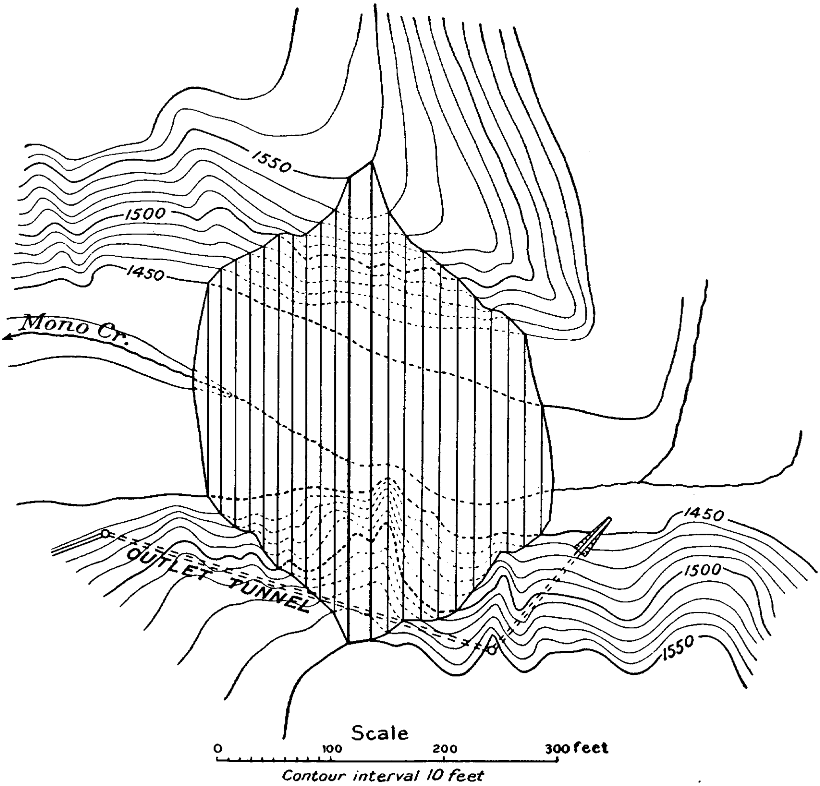


FIG. 5.—Mono dam site, showing 110-foot loose-rock dam.

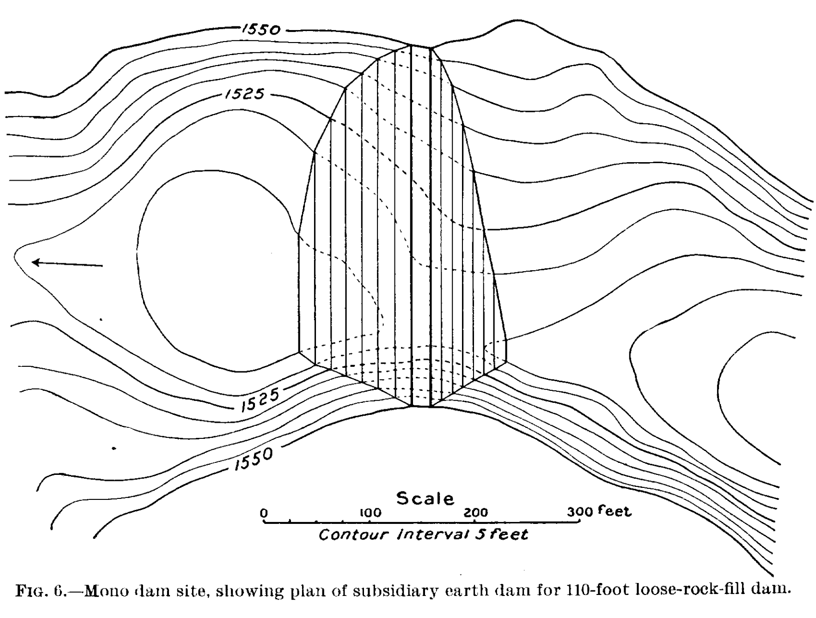


FIG. 6.—Mono dam site, showing plan of subsidiary earth dam for 110-foot loose-rock-fill dam.

All engineers connected with these investigations have declared that it is quite necessary, before preparing an accurate report and estimate on the reservoir sites, to know the position of bed rock at the place where the structure is to rest, and have recommended that these explorations should be carried out in connection with this present investigation. It has been found impossible, however, at this writing, to supply the funds to make this examination, and consequently the estimate must be taken with latitude in this regard.

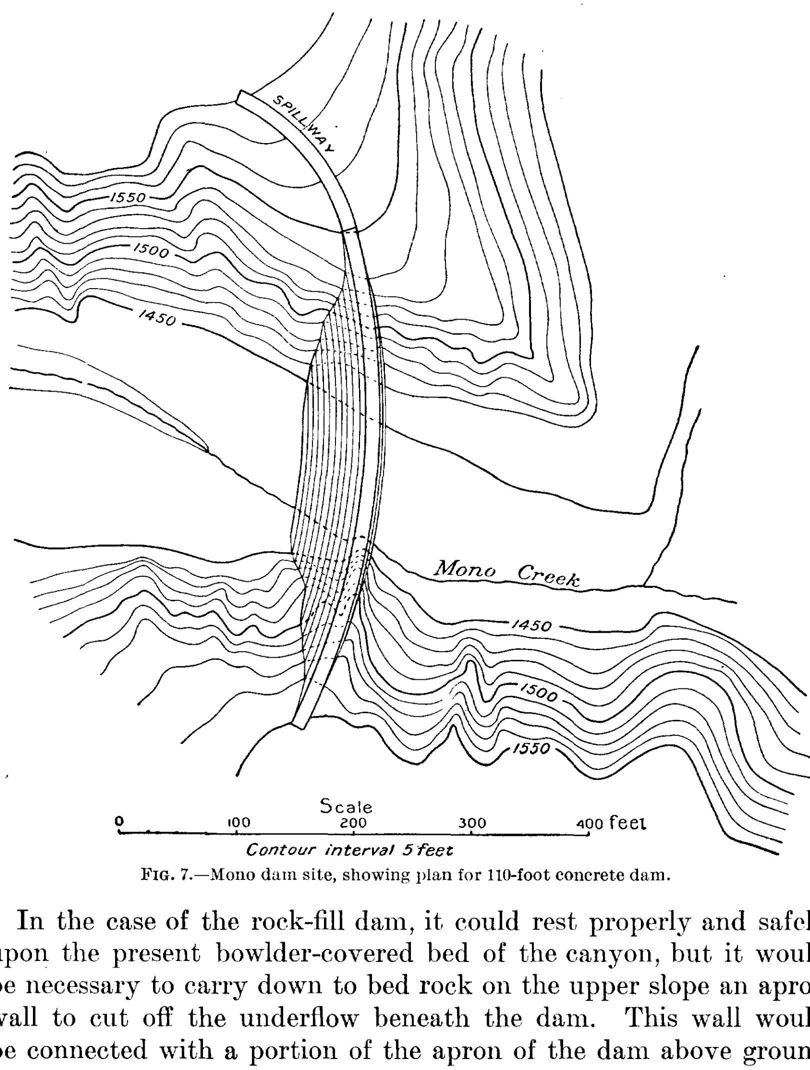


FIG. 7.—Mono dam site, showing plan for 110-foot concrete dam.

In the case of the rock-fill dam, it could rest properly and safely upon the present bowlder-covered bed of the canyon, but it would be necessary to carry down to bed rock on the upper slope an apron wall to cut off the underflow beneath the dam. This wall would be connected with a portion of the apron of the dam above ground in order to make it completely tight. It should be 8 feet thick at its base and 4 feet thick on top at the ground surface, so that for a loose-rock dam there would not be a great quantity of material to be removed from the bed rock, and the amount of cement used would be small

In the case of a concrete or masonry dam, however, the whole structure would have to go down to the bed-rock foundation, which would have to be exposed and thoroughly cleaned. In estimating on the concrete dam it has been assumed that bed rock for the entire width of the canyon is 20 feet beneath the surface of the ground. At a point some 200 or 300 feet below the dam site a ledge of material projecting well out into the canyon, over which the stream flows, has the appearance of being bed rock or ledge matter in place. It is not known, however, whether it extends completely across the stream.

An 85-foot rock-fill dam at the Mono reservoir site would contain 75,480 cubic yards of loose rock, which, it is considered, could be quarried from cliffs that are favorably situated for $1 per cubic yard. Each yard, so thrown into the fill, would make 1¾ yards of fill; consequently a figure of 60 cents per cubic yard has been accepted. A dry-laid wall 2 feet in thickness on the upper face of the dam is provided for, upon which the asphalt-concrete apron will be laid. The upper toe wall is carried down to bed rock in the bed of the stream, 4 feet thick on top, 8 feet at base, and 20 feet high. On the sides of the dam this wall is also estimated upon to seal the asphalt-concrete to the abutments. The asphalted concrete will be put on 1½ feet thick, of broken stone, gravel, sand, and asphalt, the latter being brought from quarries on the lower Santa Ynez. The section of this dam will be 20 feet wide on top, with a very flat slope of 1½ feet horizontal to 1 foot vertical on the upper face and 1¼ feet to 1 foot on the lower face. This flat slope is given to the upper face so that there will be no movement in the asphalt apron. The asphalt also would be rammed into the crevices of the dry-laid wall on which it rests.

The spillway provisions are of vital importance in a rock-fill dam. The maximum flood that was ever measured on Sweetwater River since the dam was constructed there, some fifteen years ago, was 98 cubic feet per second for each square mile of the drainage basin. A flood discharge of Piru Creek was measured at Henderson's ranch on December 18, 1894, of 43 cubic feet per second per square mile of drainage area. On Arroyo Seco, a tributary of the Salinas in Monterey County, on November 21, 1900, a flood of 140 second-feet per square mile was observed. The rainfall, however, in the drainage basin of Arroyo Seco is exceedingly heavy. For the purposes of this report we have assumed a flood of 130 second-feet per square mile of drainage area, or a total flood discharge of 15,470 second-feet, filling the spillway to within 3 feet of the top of the dam. Before the spillway would be filled to the top of the dam the flood would have reached

26,420 cubic feet per second, or 222 second-feet per square mile of drainage basin. The spillway would be 251 feet long and the bottom of it would be 10 feet below the crest of the dam. It would be excavated from the rock at the right abutment of the dam.

A 20-inch pipe has been estimated upon, leading from the Mono reservoir site to the intake of the long tunnel through Santa Ynez Range of mountains. The aggregate cost of reservoir and pipe line to long tunnel is $140,700, or $36 per acre-foot of capacity.

In estimating upon the length of tunnel line through the Coast Range to this reservoir site we have accepted the present tunnel site and assumed that the tunnel is to be completed on an angle line, or in such manner as to avoid the property of all owners other than the city of Santa Barbara. On this basis there would still be 15,006 linear feet of tunnel to run, at an estimated cost of $12 per linear foot.

Estimate for 85-foot rock-fill dam at Mono reservoir site.

[Capacity 3,880 acre-feet.]

DAM.

75,480 cubic yards of loose rock, at 60 cents per yard	$45,288	
2,500 cubic yards of dry-laid wall (upper face), at $1 (extra)	2,500	
Upper toe and side wall to bed rock	16,500	
Asphalt-concrete face 1½ feet thick, 1,861.2 cubic yards, at $8	14,890	
Outlet tunnel, gates, and tower	10,000	
Spillway	20,000	
Clearing reservoir	2,460	
20-inch pipe line to long tunnel 7,000 feet from reservoir, capacity 189 inches	10,710	
Engineering, 5 per cent	6,117	
Contingencies, 10 per cent	12,235	
Total ($36 per acre-foot)		$140,700

TUNNEL.

15,006 linear feet of tunnel through Santa Ynez Range, via angle line, at $12 per foot	$180,072	
Road up Santa Ynez River	5,000	
Engineering, 5 per cent	9,254	
Contingencies, 10 per cent	18,507	
Total		212,833
Grand total		353,533

An estimate is also presented of the cost of building a rock-fill dam at the Mono to an elevation of 110 feet above the bed of the stream, impounding the water to the 100-foot flow line. The conditions would be the same for the construction of this dam as in the case of the 85-foot dam, except that a second small earthen dam would have to be built to close another opening; this is referred to as the subsidiary dam. With the rock-fill type of dam it would be quite feasible to increase the height, raising the dam to such new elevation as might be desired.

Estimate for a 110-foot rock-fill dam at Mono reservoir site.

[Capacity 8,670 acre-feet, 290 miner's inches constant flow.]

142,535 cubic yards of loose rock, at 60 cents per yard	$85,521	
3,733 cubic yards of dry-laid wall, at $1 (extra)	3,733	
Upper toe and side walls	18,099	
Asphalt-concrete face 1½ feet thick, 2,772 cubic yards, at $8	22,176	
Outlet tunnel, gates, and tower	10,000	
Spillway	20,000	
Clearing reservoir, 257 acres, at $15	3,855	
Pipe line to long tunnel, 7,000 linear feet, capacity 366 inches	12,880	
25,745 cubic yards earth in subsidiary dam	7,724	
Engineering, 5 per cent	9,199	
Contingencies, 10 per cent	18,399	
Total ($24.40 per acre-foot)		$211,586
Tunnel through Santa Ynez Mountains, as above		212,833
Grand total		424,419

An estimate is also given for a masonry dam 85 feet high at the Mono reservoir site. This dam would be 12 feet wide on top, with a slope of 2 to 1 on the lower side and 20 to 1 on the upper side. The masonry would be made of hydraulic cement, which would be hauled through the finished tunnel. The outlet, tower, spillway provisions, and clearing reservoir would be the same as in the case of the rock-fill dam. The total cost of a dam of this class, including the 20-inch pipe line to the long tunnel, would be $361,690, or $93 per acre-foot of storage capacity. It thus will be seen that the masonry dam 85 feet high would cost 2.6 times what the loose-rock dam would cost. This is because the latter would be built of material at hand.

Estimate for 85-foot masonry dam at the Mono reservoir site.

[Capacity, 3,880 acre-feet.]

6,612 cubic yards masonry below surface of ground, at $15 (includes excavation)	$99,180	
22,955 cubic yards masonry above ground	172,163	
Total for dam proper		$271,343
Outlet tunnel, gates, and tower		10,000
Spillway		20,000
Clearing reservoir		2,460
7,000 feet of 20-inch conduit, capacity 189 inches		10,710
Engineering, 5 per cent		15,726
Contingencies, 10 per cent		31,451
Total		361,690

Cost per acre-foot of capacity, $93.

QUICKSILVER MINE DAM SITE, RIGHT ABUTMENT.

QUICKSILVER MINE RESERVOIR SITE.

View upstream from dam site.

QUICKSILVER MINE SITE.

A site called the Quicksilver mine reservoir site was discovered about 4 miles below the mouth of the Mono. At this point the river

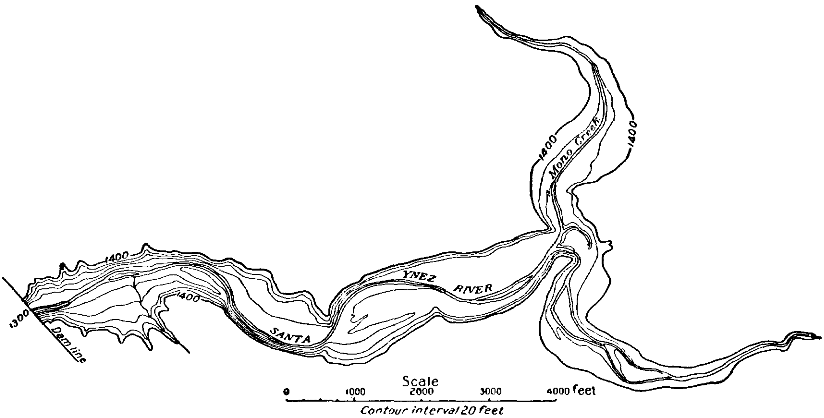


FIG. 8.—Quicksilver mine reservoir site.

passes through a rather narrow canyon of shale rock, shown in Pl. VI. The site itself is shown in Pl. VII. The capacity of this reservoir is

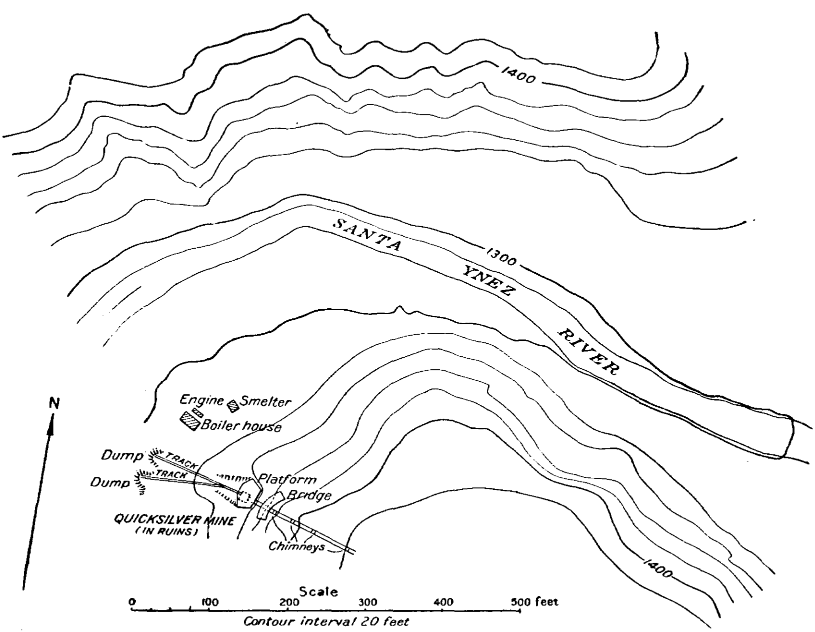


FIG. 9.—Quicksilver mine dam site.

large, but the dam site is not satisfactory because of the absence of suitable building material, and also on account of the character of the abutments. Figs. 8 and 9 show the reservoir and dam sites.

Water impounded to a depth of 100 feet in this reservoir would be flooded back a short distance into the Mono and up the Santa Ynez above the mouth of the Mono. The following is a table of the capacity of this reservoir.

TABLE 18.—*Capacity of Quicksilver mine reservoir site.*

Contour.	Area in acres.	Average area in acres.	Capacity in acre-feet.	
			Between contours.	Total to contours.
1,300	0.57	3.70	37.0	37.0
1,310	6.83	12.05	120.5	157.5
1,320	17.28	26.15	261.5	419.0
1,330	35.01	45.66	456.6	875.6
1,340	56.31	74.02	740.2	1,615.8
1,350	91.73	112.07	1,120.7	2,736.5
1,360	132.42	143.55	1,435.5	4,172.0
1,370	154.69	172.71	1,727.1	5,899.1
1,380	190.74	212.15	2,121.5	8,020.6
1,390	233.56	255.69	2,556.9	10,577.5
1,400	277.82	....	....	....

The Quicksilver mine reservoir site, while of satisfactory capacity, is not considered a feasible proposition because of the character of the dam site.

GIBRALTAR SITE.

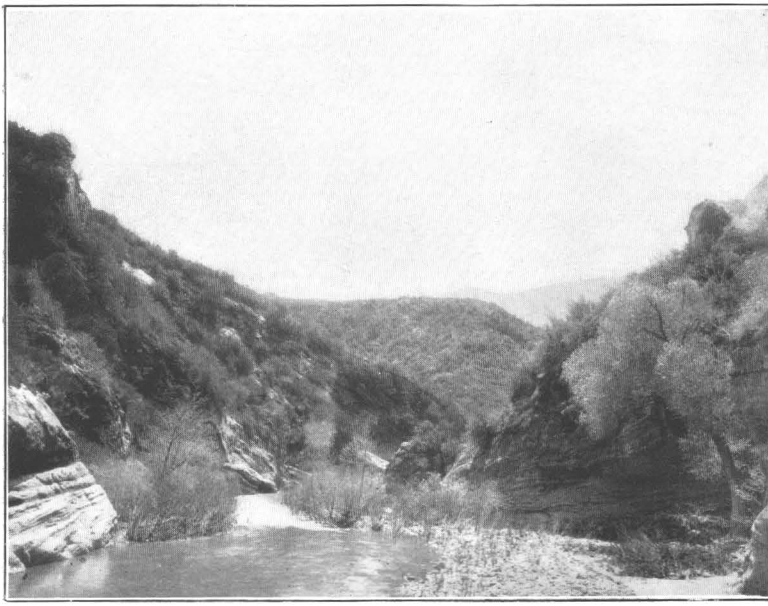
DISCHARGE.

The Gibraltar reservoir site is situated 6 miles below the mouth of Mono Creek on Santa Ynez River. The drainage area tributary to it includes all of the Mono, the main river above the Mono, and 17 square miles additional. The discharge as estimated from the rainfall for the seasons from 1867–68 to 1903–4, inclusive, is shown in table 12 (see p. 53), and as measured[a] for 1902–3 in table 13 (see p. 54). From these it appears that the discharge is from 1.8 to 2.4 times as great as that of the Mono.

CONTENTS AND COST OF DAMS.

The reservoir site, which is shown in fig. 10, lies along a narrow, canyon-like valley with a light grade. The dam site is a rather peculiar and unusual one. An anticlinal fold of sandstone, apparently uplifted through the shales, has been cut by the river in a narrow gorge, as shown in Pl. VIII, *A* and *B*. The crest of this fold is almost level and

[a] Partly estimated.



A. GIBRALTAR DAM SITE, LOWER END OF GORGE.

View upstream.

B. GIBRALTAR DAM SITE, UPPER END OF GORGE AT PROPOSED AXIS OF DAM.

View downstream. Stream turns abruptly to the left. The spillway site is over the crest on the left.

is approximately 150 feet above the bed of the stream, so that a dam built slightly higher than the crest, or, say, 155 feet, will have the advantage of a natural spillway of great length on the side away from the dam and over solid rock. This is the only dam site that has been found in the upper portions of Santa Ynez River where the abutments are of a satisfactory nature and where the building material could be gotten out in such sizes and shapes as may be desirable for the construction of any type of dam.

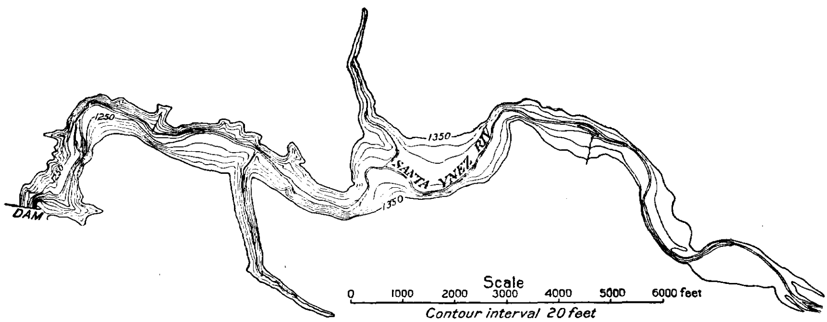


FIG. 10.—Gibraltar reservoir site.

A determination of the specific gravity of this rock has been made by weighing the rock first in air and then in water, which gave a specific gravity of 2.56. Four tests were made, ranging from 2.55 to 2.57. This is equivalent to a weight of 160 pounds per cubic foot. In rubble masonry, one-third of the bulk being mortar and two-thirds solid rock, and the mortar being considered as weighing 103 pounds, the weight would be 140 pounds per cubic foot of masonry in dam.

The ledges are in such a position as to permit a most economical handling of material for masonry construction.

TABLE 18a.—*Capacity of Gibraltar reservoir site.*

[Elevation of surface of stream bed, 1,215 feet.]

Contour.	Area in acres.	Average area in acres.	Capacity in acre-feet.	
			Between contours.	Total to contours.
1,215	0			
1,220	2.12			
1,230	5.74	3.93	39.3	39.3
1,240	13.26	9.50	95.0	134.3
1,250	22.67	17.97	179.7	314.0
1,260	32.37	27.52	275.2	589.2
1,270	50.11	41.24	412.4	1,001.6
1,280	66.24	58.17	581.7	1,583.3
1,290	90.06	78.15	781.5	2,364.8
1,300	119.62	104.84	1,048.4	3,413.2
1,310	152.74	136.18	1,361.8	4,775.0
1,320	188.33	170.53	1,705.3	6,480.3
1,330	227.13	207.73	2,077.3	8,557.6
1,340	271.39	249.26	2,492.6	11,050.2
1,345	296.64	284.01	1,420.0	12,470.2
1,350	332.75	314.70	1,573,5	14 043.7
1,355	367.07	349.91	1,749.6	15,793.3

Table 19 shows the volumes of material for a rock-fill dam situated at the Gibraltar reservoir site, the upper slope to be 1½ to 1, the lower slope 1¼ to 1, the width on top 20 feet, and the height of dam 155 feet, or 10 feet above the level of the spillway. The top of the crest is taken to be at the 1,360-foot contour. Bed-rock conditions are unknown, but for the purpose of this estimate are assumed to be at 1,205 feet. Repeated efforts were made to provide for an exploration of bed rock at this dam site, but owing to financial condi ions and negotiations for the purchase of the property by the city of Santa Barbara it was not possible to arrange for this. The capacity with this dam to the 1,350-foot contour in the reservoir would be 14,044 acre-feet. Fig. 11 shows the plan for a 155-foot rock-fill dam.

In the table 7,444 cubic yards are deducted from the total estimated volume in the dam, as the rock fill will go down only to the 1,210-foot contour, except where the toe walls are located, where they are assumed to go as low as the 1,205-foot contour. The excavation of the spillway is taken at 1,250 cubic yards, which of course would be used in the construction of the dam. The spillway could probably be made much wider, if desired, in excavating the material for the dam. In this estimate it is taken as 350 feet in width.

A dam of this type is considered as having 12,083 cubic yards in asphalt-concrete face and dry-laid wall, this face to be put on as indicated in the drawing and to be covered by the dry-laid wall, to

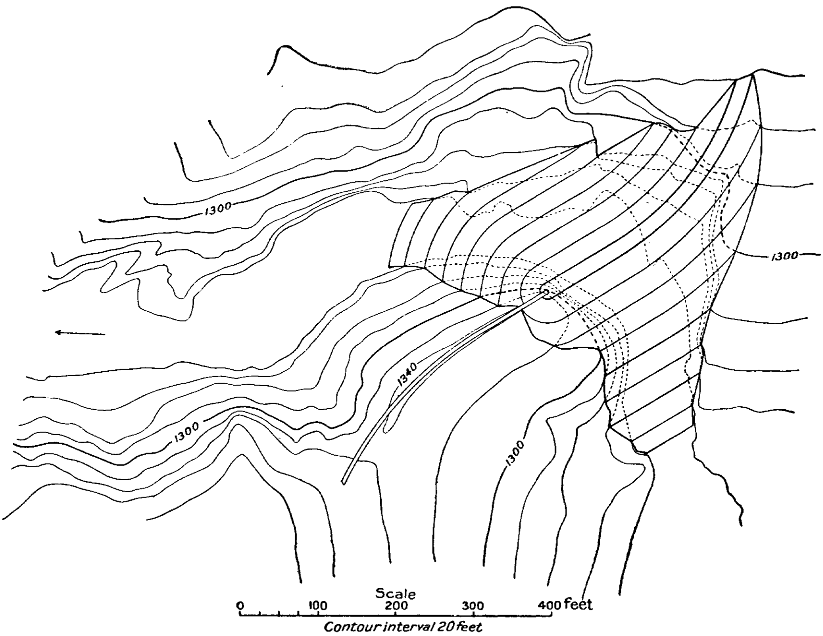


FIG. 11.—Gibraltar dam site, showing plan for 155-foot rock-fill dam.

protect it from the sun, so as to prevent the movement of the asphalt. If this volume is deducted from the total yardage given in the dam, in addition to the deduction mentioned above on account of the rock-fill dam not going down to bed rock for its entire length, the net volume of rock fill will be 233,724 cubic yards.

TABLE 19.—*Volume in rock-fill dam at Gibraltar dam site.*[a]

[Capacity to 1,350-foot contour, 14,044 acre-feet.]

Contour.	Volume between contours in cubic yards.	Contour.	Volume between contours in cubic yards.
[b]1,205	....	1,320	15,231
1,210	7,444	1,330	13,194
1,220	14,713	1,340	10,916
1,230	16,648	1,350	8,148
1,240	19,805	1,360	4,796
1,250	21,536	Total.	253,251
1,260	22,185	Deduct[c]...	7,444
1,270	21,860		
1,280	20,925		245,807
1,290	19,981	Deduct[d]..	12,083
1,300	18,768	Net.......	233,724
1,310	17,101		

[a] Contents of spillway masonry dam=1,250 cubic yards. Spillway dam, 5 feet wide on top; 0.05 to 1 slope on upstream face; 10 feet down, 7 feet thick; 15 feet down, 9 feet thick; 20 feet down, 13 feet thick. Spillway is 350 feet in width; in excavating for dam it may be made wider, the limit in width being the limit of excavations.
[b] Bed rock as estimated, but not determined.
[c] Rock fill goes only to 1,210-foot contour.
[d] Asphalt face and dry-laid wall.

The hand-laid facing on top of the asphalt-concrete is estimated to be 3½ feet thick and the asphalt-concrete 1½ feet, covered with an impervious layer of asphalt two-tenths of a foot thick. The concrete cut-off wall at the upper toe of the dam is estimated as 90 feet long, with a height above assumed bed rock of 5 feet and a thickness on top of 5 feet, downstream vertical, upstream with a slope of 1 to 5 and a thickness at base of 6 feet.

The outlet system would consist of a tower reaching from the 1,220-foot contour to the 1,360-foot contour, a height of 140 feet. The internal diameter of the tower would be 8 feet at top and the thickness of wall 2 feet at top and 6 feet at bottom, the tower standing on a solid concrete base 5 feet thick and 21 feet in diameter. Following is an estimate of the cost:

Estimate of cost of 155-foot rock-fill dam at original site of Gibraltar dam.

Rock fill, 233,724 cubic yards, at 60 cents	$140,234.00
Hand-laid facing, 8,458 cubic yards, at $1.60	13,533.00
Asphalt and concrete facing, 3,625 cubic yards, at $8	29,000.00
Cut-off wall	1,493.00
Overflow weir and subsidiary dam, 1,250 cubic yards, at $9	11,250.00
Clearing reservoir site, 333 acres, at $25	8,325.00

Outlet system:		
Tower, 911 cubic yards, at $9.30	$8,472.00	
Inlet pipes	460.00	
Valve rods	860.00	
Outlet valves	1,000.00	
Outlet tunnel, 1,000 feet, at $5	5,000.00	
Tower house and bridge	500.00	
Total of outlet system		$16,292.00
		220,127.00
Contingencies, 10 per cent		22,012.70
Engineering, 5 per cent		11,006.35
Total		253,146.05

The rock-fill dam can be built only to such height as will permit complete spillway opportunities around the end of the dam. It is, however, feasible to build a masonry dam that will not be the full height, permitting the water to waste over the top of the dam during different stages of its construction. For instance, the dam could be built to a height of 50 or 100 feet, and construction stopped until the demands or desires of the city should call for its completion; the final structure could then be built to its ultimate height of approximately 155 feet. When the dam was completed to its full height the overflow and waste water could then be directed through the spillways.

If such a dam should be built of cyclopean rubble masonry on a gravity section and also on a curve, the top would stand at the 1,560-foot contour. The estimate given below is based on bed rock being at a depth of 5 feet beneath the present stream bed, but it is not known what the depth actually is, and the final estimates might be greatly modified by these conditions. A determination of this point is essential before beginning the construction of the dam and before the final estimate on its cost can be made.

Three estimates have been prepared on the assumption that the dam will not be built to its full height from the start. These are for dams 95 feet high, with a capacity of 3,413 acre-feet, equivalent to a continuous flow of 4.715 second-feet, or 236 miner's inches per annum; 125 feet high, with a capacity of 8,558 acre-feet, equivalent to a continuous flow of 11.82 second-feet, or 591 miner's inches per annum; and 155 feet high, with a capacity of 15,793 acre-feet, equivalent to a continuous flow of 21.81 second-feet, or 1,090 miner's inches per annum.

These estimates of discharge are on the assumption that the reservoir would be filled by the stream every year. This, however, can not be done, for in some winters there will be little more addition to the reservoir than enough to make up for evaporation. If it is assumed that the 155-foot dam is built, and that its capacity is

15,793 acre-feet, and that this will have to furnish the supply of water for nineteen months, the yield will be 831 acre-feet monthly; with the reservoir half full the monthly loss by evaporation would average about 66 acre-feet, leaving 765 acre-feet monthly for distribution during the dry period, or a continuous flow of 13 second-feet, equivalent to 650 miner's inches, or 8,400,000 gallons daily. Putting it another way, the flow will be approximately 900 miner's inches in the summer time and 400 miner's inches in the winter time. Fig. 12 shows a plan of a 155-foot masonry dam.

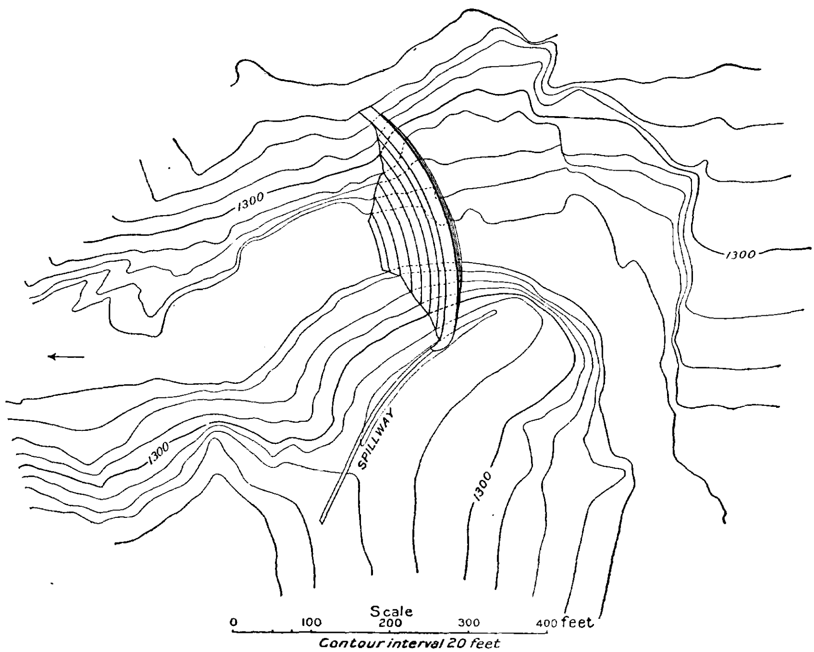


FIG. 12.—Gibraltar dam site, showing plan for 155-foot masonry dam.

With the lower size dam the surplus water is considered as wasted over the top of the dam, and the dam is made safe on the gravity section with 10 feet of water passing over its crest; in addition it is to be a curved dam. These same conditions will obtain with a dam 125 feet high. The 155-foot masonry dam is designed to let the surplus water pass through a spillway, the water standing within 5 feet of the top of the dam, and the capacity being 15,793 acre-feet. This is a greater capacity than that for the 155-foot rock-fill dam, because with the rock-fill dam greater safety in spillway capacity would be required, and this type would have to be built at least 10 feet above the level of the spillway. Figs. 13, 14, and 15 give sections of the dams considered. In the estimates masonry weighing 140 pounds per cubic foot is used.

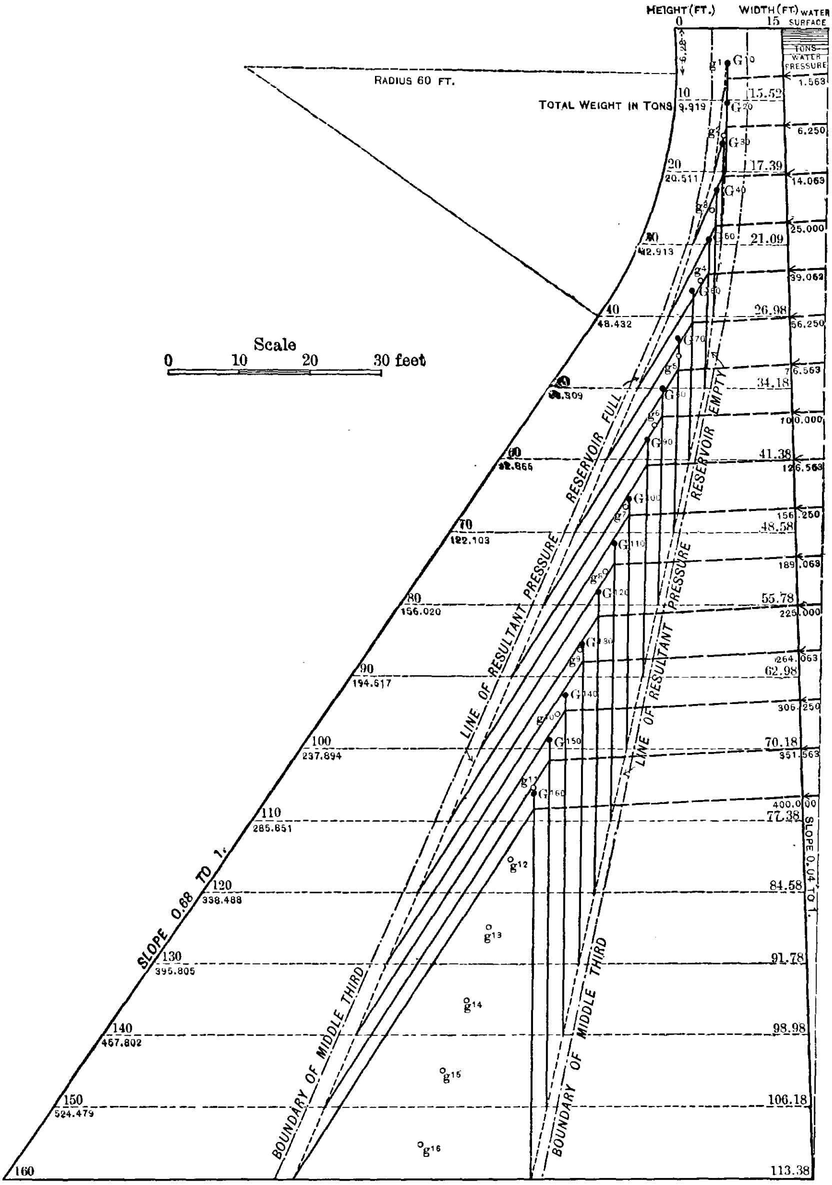


FIG. 13.—Section of masonry dam for Gibraltar reservoir based on concrete weighing 130 pounds per cubic foot.

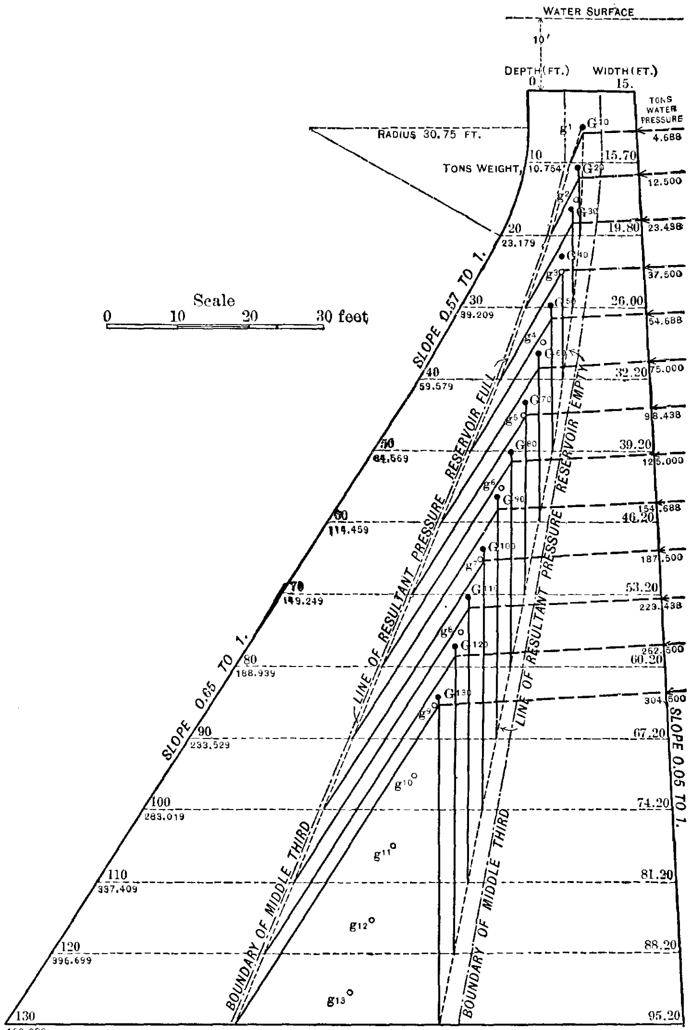


FIG. 14.—Section of masonry overflow weir dam based on masonry weighing 140 pounds per cubic foot.

The following is an estimate on three types of dams:

Estimate of cost of 95-foot masonry overflow dam located at lower site of Gibraltar dam.

[Capacity 3,413 acre-feet.]

Masonry, 15,331 cubic yards, at $7	$107,317.00
Excavation to bed rock, 1,280 cubic yards, at $2.50	3,200.00
Clearing reservoir, 120 acres, at $25	3,000.00
Outlet system, tower, gates, tunnel, etc	9,971.00
	123,488.00
Contingencies, 10 per cent	12,348.80
Engineering, 5 per cent	6,174.40
Total	142,011.20

Cost per acre-foot of capacity, $41.61.

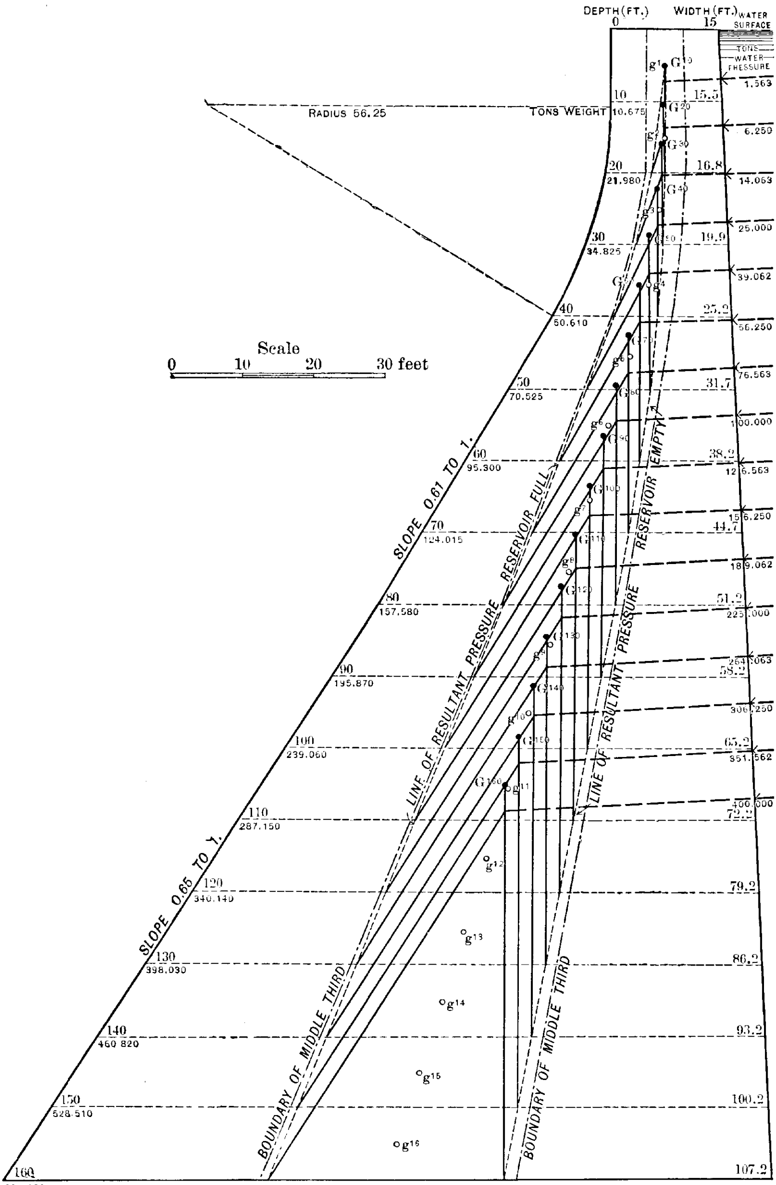


FIG. 15.—Section of masonry dam based on masonry weighing 140 pounds per cubic foot.

Estimate of cost of 125-foot masonry overflow dam located at lower site of Gibraltar dam.

[Capacity 8,558 acre-feet.]

Masonry, 27,971 cubic yards, at $7	$195,797.00
Excavation to bed rock, 1,579 cubic yards, at $2.50	3,948.00
Clearing reservoir, 227 acres, at $25	5,675.00
Outlet system, tunnel, gates, tower, etc	13,000.00
	218,420.00

Contingencies, 10 per cent	$21,842.00
Engineering, 5 per cent	10,921.00
Total	251,183.00

Cost per acre-foot of capacity, $29.35.

Estimate of cost of 155-foot masonry dam located at lower site of Gibraltar dam.

Masonry in dam, 42,250 cubic yards; masonry in spillway, 833 cubic yards; masonry in protection wall, 56 cubic yards; total masonry, 43,139 cubic yards, at $7	$301,973.00
Excavation to bed rock, 1,731 cubic yards, at $2.50	4,328.00
Clearing reservoir, 350 acres, at $25	8,750.00
Outlet system, tower, gates, tunnel, etc	16,292.00
	331,343.00
Contingencies, 10 per cent	33,134.30
Engineering, 5 per cent	16,567.15
Total	381,044.45

The flood discharge from these drainage basins is considered in the discussions of the spillway for the Mono reservoir site. Taking a maximum flood discharge of 130 cubic feet per second per square mile from the entire 207 square miles that are tributary to the Gibraltar reservoir site, the spillway of 600 feet in length would be running full and the water passing 3½ feet deep over the top of the masonry dam. This would be a most extraordinary flood, and it is believed that the dam, with the gravity section that it has, in addition to its arched shape, would stand this.

In the case of the 125-foot dam such a flood would pass over the crest of the dam 9½ feet deep, and the dam is designed to withstand with safety an overflow of 10 feet on a gravity section without the aid of its curved shape.

For the 95-foot dam under similar conditions the depth of water would be 11 feet.

TUNNELS TO GIBRALTAR SITE.

Because of its elevation and location it will not be possible to use the old city tunnel in Cold Spring Canyon in reaching the Gibraltar reservoir site. The elevation of the surface of the water at the Gibraltar, with a dam 155 feet high, is 1,360 feet above sea level, and the estimated elevation of the northern end of the old Cold Spring Canyon tunnel at its northern portal would be 1,457 feet. The location also is not suitable for the Gibraltar site. Because of these facts, a new tunnel location was sought as an outlet for the Gibraltar reservoir site. The triangulation was extended so as to cover the distance intervening between Mission Canyon and the Gibraltar dam site, and it was found that a tunnel from Mission Canyon to the Gibraltar would be 19,560 feet in length, and from Rattlesnake Canyon to the

Gibraltar it would be 20,763 feet in length. The length necessary to complete the old tunnel from Cold Spring Canyon through to Santa Ynez is 14,901 feet. It must be remembered, however, that the old tunnel has very irregular grades, that the cross section of it is not uniform, and that the alignment is irregular. In addition to that, the present heading is 5,000 feet from the portal, so that the total length of the Cold Spring Canyon tunnel, if completed, would be 19,901 feet. Because of these irregularities in the old tunnel and the dis-

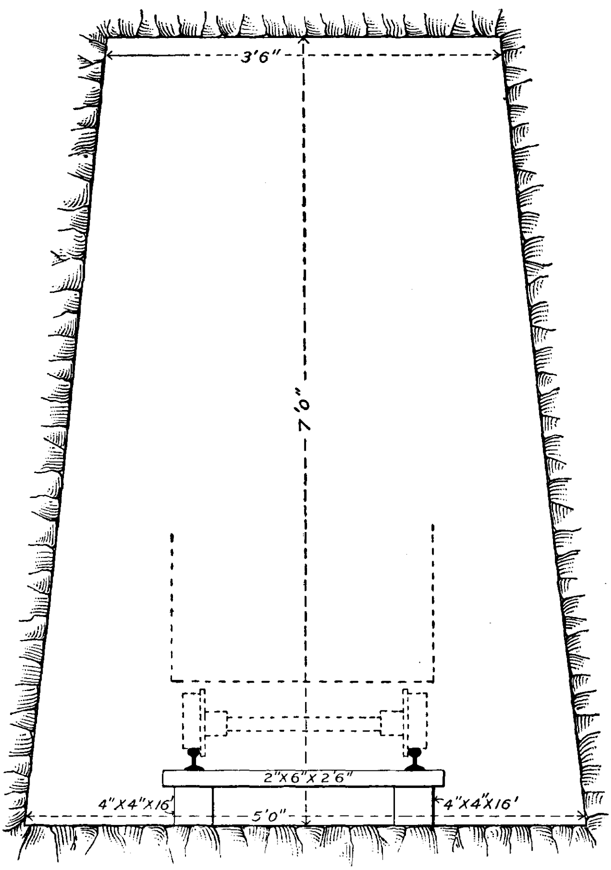


FIG. 16.—Section of new Santa Barbara tunnel in solid rock.

tance in from the heading, it has been estimated that the cost to complete it would be at the rate of $12 a foot; the total cost of completing it, building roads, engineering, etc., having been previously estimated at $212,833 (see p. 77).

The following is an estimate of the cost of building the Mission or the Rattlesnake tunnel.[a]

[a] Since writing the above, contracts have been entered into for the construction of the Mission Canyon tunnel line at a figure slightly below this estimate (see p. 43). Figs. 16 and 17 show sections of this tunnel.

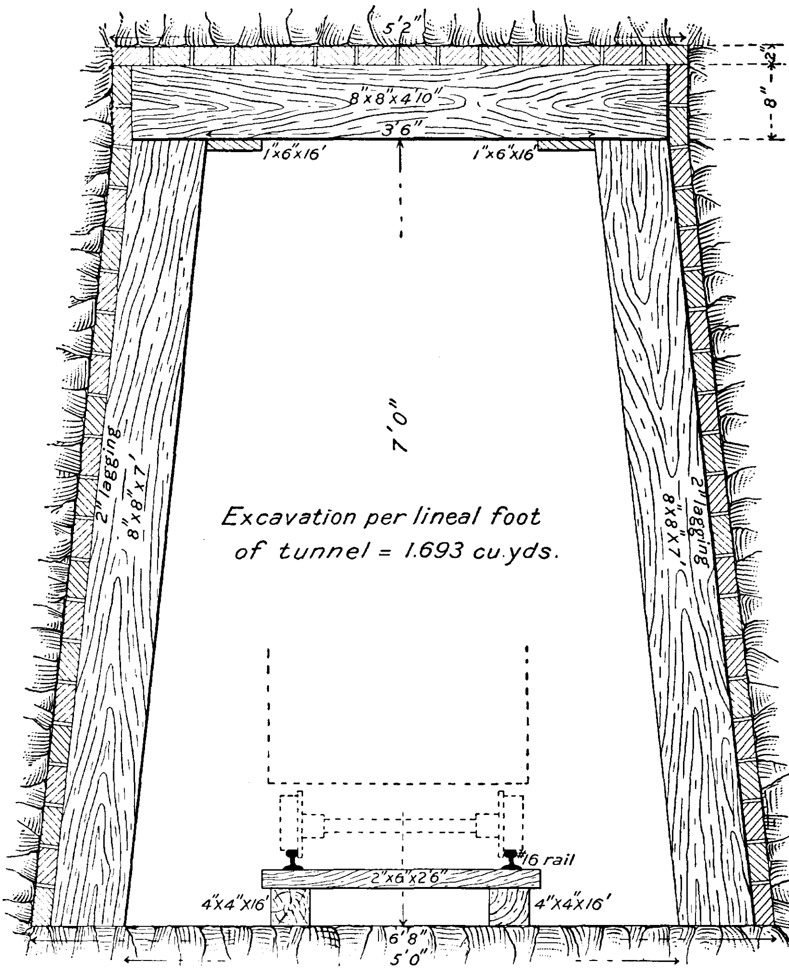


FIG. 17.—Section of new Santa Barbara tunnel in loose rock.

Estimate of cost of building Mission Canyon tunnel.

[Length based on triangulation by L. M. Hyde.]

19,560 linear feet, at $10 per linear foot	$195,600
Road up Santa Ynez River	2,500
Road up Mission Canyon	2,500
Engineering, 5 per cent	10,030
Contingencies, 10 per cent	20,060
Total estimated cost	230,690

Estimate of cost of building Rattlesnake Canyon tunnel.

[Length based on triangulation by L. M. Hyde.]

20,763 linear feet, at $10 per linear foot	$207,630
Road up Santa Ynez River	2,500

Road up Rattlesnake Canyon	$3,500
Engineering, 5 per cent	10,682
Contingencies, 10 per cent	21,363
Total estimated cost	245,675

COMPARISON OF GIBRALTAR AND MONO SITES.

In order to compare the costs of the combined tunnel and reservoir for the Gibraltar site and for the Mono site, the following table is given:

TABLE 20.—*Comparative estimates of dams and tunnel lines at Gibraltar and Mono.*

GIBRALTAR.	
95-foot masonry overflow dam (3,413 acre-feet, at $41.61)	$142,012
19,560 feet of tunnel (Mission line)	230,690
Total	372,702
125-foot masonry overflow dam (8,558 acre-feet, at $29.35)	251,183
19,560 feet of tunnel (Mission line)	230,690
Total	481,873
155-foot masonry dam (15,793 acre-feet, at $24.13)	381,044
19,560 feet of tunnel (Mission line)	230,690
Total	611,734
155-foot rock-fill dam (15,793 acre-feet, at $16.02)	253,146
19,560 feet of tunnel (Mission line)	230,690
Total	483,836
MONO.	
85-foot rock-fill dam (3,880 acre-feet, at $36)	140,700
15,006 feet of tunnel	212,833
Total	353,533
110-foot rock-fill dam (8,670 acre-feet, at $24.40)	211,586
15,006 feet of tunnel	212,833
Total	424,419
85-foot masonry dam (3,880 acre-feet, at $93.22)	361,690
15,006 feet of tunnel	212,833
Total	574,520

The masonry dam is the better form of construction for a storage reservoir. In addition the abutments at the Gibraltar reservoir site are much more secure and satisfactory than at the Mono site. The water supply is more than twice as great at the Gibraltar as at the Mono and its quality is better.

Making the comparison for masonry dams, it will be seen that the cost for the 155-foot masonry dam at the Gibraltar site would be

$24.13 per acre-foot of water impounded, while for the 85-foot masonry dam at the Mono site it would be $93.22 per acre-foot.

With a 125-foot masonry dam at the Gibraltar, the capacity of the reservoir would be 8,558 acre-feet, and the total estimated cost of the dam and tunnel would be $481,873.

A 110-foot rock-fill dam at the Mono would have a capacity of 8,676 acre-feet, and with the completion of the Cold Spring tunnel would cost $424,419, which is less than the cost of the Gibraltar 125-foot dam. The Gibraltar dam, however, would undoubtedly be safer, have fully twice the water supply available for dry years, and would furnish better water. These things considered, there can be no doubt whatever that it is advisable to construct the Gibraltar dam with the Mission Canyon tunnel, rather than the Mono site with the completion of the Cold Spring Canyon tunnel.

The real governing factor in the entire situation is the quantity and quality of the water, and on this basis there can not be any doubt that the Gibraltar site is far the better. During the winter of 1902–3 the total discharge of Mono Creek at the Mono reservoir site was 8,934 acre-feet, while at the Gibraltar it was 21,202 acre-feet, or 2.4 times as much. In addition the situation is such at the Gibraltar site that the masonry dam can be gradually built higher as the demand of the city for a greater water supply grows, while there are distinct limitations to the construction of a higher dam at the Mono site.

FINANCIAL STATEMENT.

The financial results to be expected from the expenditure of the money necessary to build the work above referred to are not extensively considered, because it is not so much a question of whether these works can be constructed at a commercial profit as it is a question of how much it will cost to get an adequate water supply for the locality. It goes without saying that if the coast district is to continue to grow it must have water, and the only question is whether this can be obtained at reasonable cost.

The output from this system should be 1½ million gallons daily for 10,000 people. On page 25 it is shown that in order to meet the worst-known drought of nineteen months and deliver 150 gallons daily for 10,000 persons, plus the evaporation, a storage capacity of 3,518 acre-feet is required. This is on the assumption that all of the water must come from the reservoir and none can be obtained from the tunnels or streams on the south side of the range, a condition which the writer believes never will exist, but which he assumes for safety. At the Gibraltar site a dam 95 feet high will practically accomplish this at a cost for dam and tunnel of $372,702. Assuming an interest rate of 4½ per cent on this cost, we shall have an annual fixed charge of $16,772. The works will all be permanent. Construction and maintenance charges should be very low, say $4,000 per annum. Operation should not be over $2,000. This gives a total annual charge of $22,772 for 547 million gallons, or a maximum of 4.1 cents per 1,000 gallons delivered at the intake of the domestic system. As the dam is increased in height the cost per unit of storage and the proportional charge for the tunnel will rapidly decrease with the resulting increased supply. With a dam 155 feet high on the above basis the cost per thousand gallons would be 1.1 cents. The long tunnel will undoubtedly also itself contribute a material supply to the city. Mr. Canfield, the president of the Santa Barbara Water Company, states as follows:

Water is now sold in Santa Barbara at the rate of about 16 cents per thousand gallons to the city for street-sprinkling purposes (at the rate of $35,000 per year for 1 second-foot), and to private consumers at from 20 cents to 25 cents per thousand gallons, which are moderate rates as compared with those realized in some other cities in this State, and it is believed that although the development of the business in the future may justify some reduction of rates, an average rate of 15 cents per thousand gallons at least can be calculated upon.

This is certainly a very reasonable charge for water in southern California. The lowest meter rate known in the State (that of the city of Los Angeles) is 9 cents per 1,000 gallons delivered to the consumer. Of course, there must be an intermediate charge for distribution system and administration which comes after the water is delivered to the mains.

Both Mr. Wright and Mr. Purslow considered the construction of these storage reservoirs as a profitable investment from a commercial standpoint. If the water was delivered free at sea level to the city, it would cost two-thirds as much for fuel alone (say 2.7 cents), with triple-expansion engines, to pump it to the city reservoir as it would to obtain it from this contemplated system of storage reservoirs. If interest, depreciation, and services are considered it would cost more to pump it.

There would undoubtedly also be a very considerable element of profit that might be derived from the water power available from the supply, since the elevation of the southern portal of the tunnel is approximately 1,200 feet and the elevation of the domestic reservoirs only 350 feet.

The result of the construction of the long tunnel probably will be the construction of the dam to the maximum height commensurate with the water supply of Santa Ynez River by the city, or by other parties who might make arrangements with the city for carrying water through this long tunnel. This should be a condition that the city would encourage.[a] The water not required by the

[a] Since writing the above the city has entered into a contract with the Santa Barbara Water Company to permit of such a use of the city tunnel by the company.

municipality would be used in developing and irrigating the beautiful coast plain near Montecito or in other adjoining localities. The improvement of this region would, of course, add to the prosperity of the county and city of Santa Barbara.

In this report estimates on right of way have not been included.

CONCLUSIONS.

In conclusion it may be stated—

(1) That the only extensive addition that can be made to the water supply of the Santa Barbara coastal plain is by the construction of a tunnel from Santa Ynez River to the coast side of the mountains and the building of an impounding reservoir for the holding of the winter flood waters of Santa Ynez River.

(2) That by far the most desirable point on Santa Ynez River for this construction is the Gibraltar reservoir site.

(3) That the water can be delivered at a reasonable cost for both irrigation and domestic use to Santa Barbara and vicinity from this site, and the construction is believed to be entirely justified and commercially feasible.

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Reference.

U. S. Dept. of the Interior.

see also

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