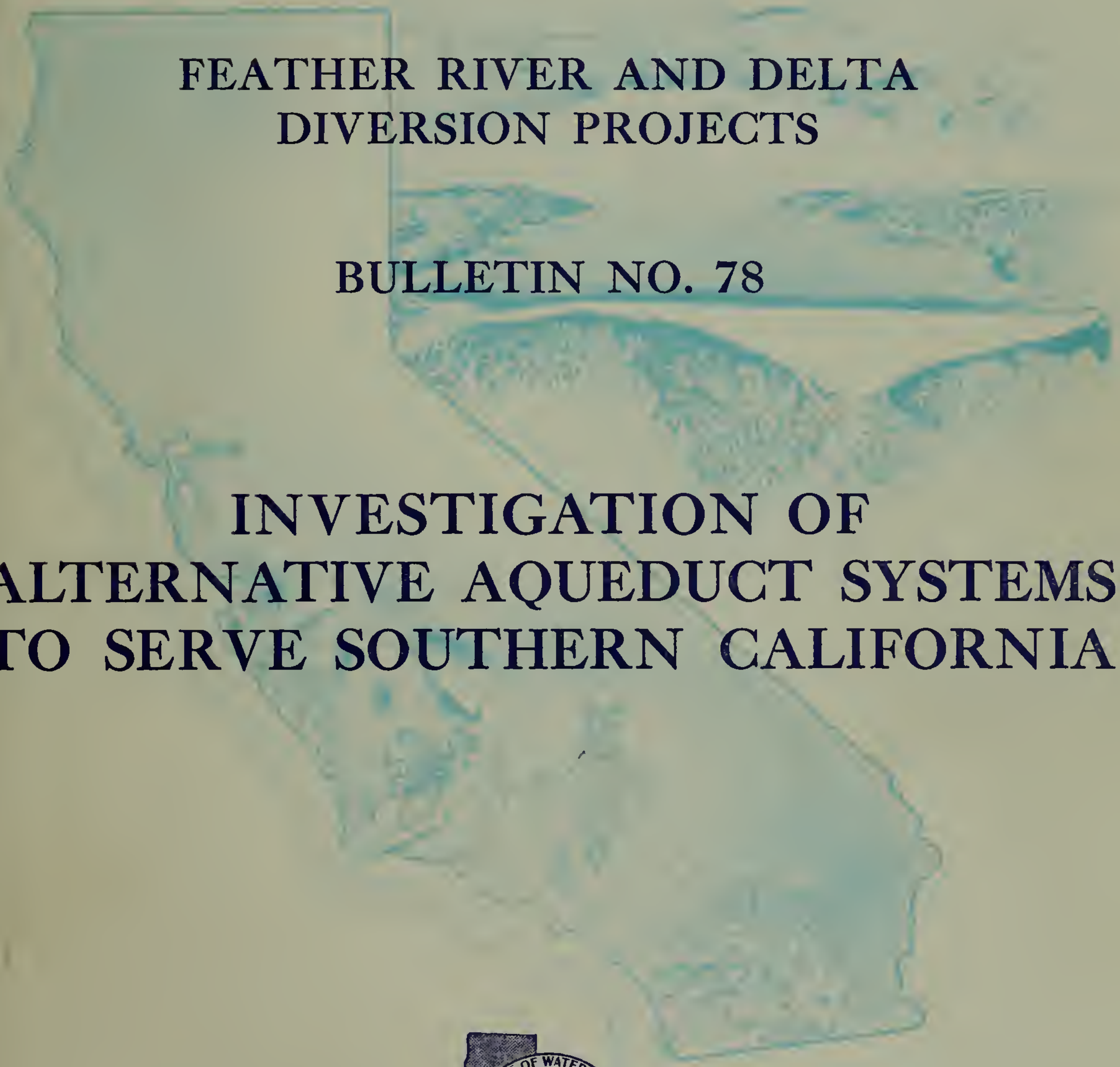
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES



FEATHER RIVER AND DELTA DIVERSION PROJECTS

BULLETIN NO. 78

INVESTIGATION OF ALTERNATIVE AQUEDUCT SYSTEMS TO SERVE SOUTHERN CALIFORNIA

EDMUND G. BROWN
Governor

HARVEY O. BANKS
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DECEMBER 1959

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ADDRESS REPLY TO
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STATE OF CALIFORNIA
Department of Water Resources
SACRAMENTO

December 1, 1959

Honorable Edmund G. Brown, Governor
Members of the Legislature of the
State of California

Gentlemen:

I have the honor to transmit herewith Bulletin No. 78, "Report on Investigation of Alternative Aqueduct Systems to Serve Southern California", preparation of which was initiated through funds provided by Item 419.5 of the Budget Act of 1956, and continued under subsequent appropriations.

This bulletin presents the results of comprehensive analyses of the future water needs of that portion of Kern County in the San Joaquin Valley; the coastal portions of Los Angeles, San Bernardino, Riverside, and San Diego Counties; the counties of San Luis Obispo, Santa Barbara, Ventura, and Orange; and the Antelope Valley-Mojave River and Whitewater-Coachella areas. Based on those projected water needs, extensive and detailed studies were conducted to determine that aqueduct system serving the entire area which would produce the greatest net economic benefit and which would deliver water to the ultimate consumer, considering the total area, at minimum over-all cost.

The latest projections of future population and economic growth in these areas, as reported in this bulletin, indicate that the recent phenomenal growth therein will continue. It is estimated that about 5.5 million acre-feet of supplemental water would have to be imported from northern California by the year 2020 to sustain this growth, and that initial water deliveries would have to be made by 1965 in the San Joaquin Valley portion of these areas, and by 1971 to most of the remainder.

It is concluded that the one system that would meet these demands for water most economically, would comprise an aqueduct from the Delta along the west side of the San Joaquin Valley to Avenal Gap, branching there into a coastal aqueduct leading to Santa Maria Valley, and an inland aqueduct from Avenal Gap south through Kern County and across the Tehachapi Mountains, with a west branch terminating at the north edge of San Fernando Valley and an east branch extending along the south edge of the Antelope Valley through the San Bernardino Mountains and terminating at Perris Reservoir site in Riverside County. This system would also provide the best combination, from the standpoint of mineral quality, of imported northern California water with the other sources of water, both local and imported, available to southern California.

This aqueduct system has been determined to be the optimum, or most favorable, under several alternative schemes of operation as regards power for pumping and the utilization of recovered energy. Final decision as to the operational scheme to be employed which would provide the most economic and financially advantageous combination of power for pumping and the utilization, or disposition, of the energy to be recovered by power drops in the Tehachapi and San Bernardino Mountains and on the Coastal Aqueduct near the City of San Luis Obispo, would ~~will~~ be made after further study which will include consideration of the feasibility of addition of pumped storage hydroelectric power generation.

Bulletin 78 is not intended to be a complete feasibility report. It is directed principally to the single objective of determining the optimum aqueduct system to serve the long-range water needs of the areas to be served thereby.

The aqueduct facilities which will be constructed with the financing to be provided under the Burns-Porter Act (the Water Development Bond Issue Act), will comprise the first stages of development with sufficient capacity to supply the needed supplemental water until 1990. If water demands develop as now anticipated, additional capacity would have to be added at that time.

Because of the long period of time which necessarily will be required for the construction of this aqueduct system, the final design thereof and the acquisition of the necessary lands, easements and rights-of-way must be carried forward

Honorable Edmund G. Brown, Governor
Members of the Legislature of the
State of California - 3 December 1, 1959

as speedily as possible. Actual construction work must be started as soon as possible if we are to be able to deliver supplemental water within the various service areas in time to keep pace with their expanding needs.

Very truly yours,

Harvey O. Banks

HARVEY O. BANKS
Director

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PREFACE

Subsequent to the release of the preliminary edition of Bulletin No. 78 entitled "Preliminary Summary Report on Investigation of Alternative Aqueduct Systems to Serve Southern California," February 1959, comments thereon were received from local water service agencies and other interested parties. The text of this final edition of Bulletin No. 78 has been edited and revised to reflect certain of these comments.

Senate Bill No. 1281, passed by the 1959 California Legislature and approved by the Governor, amends Section 11260 of the Water Code relating to the Feather River and Delta Diversion Projects in accordance with the findings of the foregoing preliminary edition of Bulletin No. 78, subject to such further modifications as the Department of Water Resources may adopt.

During the same legislative session, Senate Bill No. 1106, entitled the "California Water Resources Development Bond Act" was passed by both houses and subsequently was signed by Governor Edmund G. Brown. This bill provides, among other items, for issuance of one billion seven hundred and fifty million dollars in general obligation bonds "to assist in the construction of a State Water Resources Development System," including the San Joaquin Valley-Southern California Aqueduct System. Provision is made for ratification of the bill by the electorate in the general election of November 1960. In conformance with the findings of the preliminary edition of Bulletin No. 78, the bill provides for construction of initial stages of aqueduct facilities to ". . . termini in the vicinity of Newhall, Los Angeles County and Perris, Riverside County, and having a capacity of not less than 2,500 second-feet at all points north of the northerly boundary of the County of Los Angeles in the Tehachapi Mountains in the vicinity of Quail Lake," and also for construction of an aqueduct extending to Santa Maria River.

ACKNOWLEDGMENTS

Valuable assistance and data used in the investigation were contributed by agencies of the Federal Government and of the State of California, by cities, counties, public districts, and by private companies and individuals. This cooperation is gratefully acknowledged.

Special mention is made of the helpful cooperation of the following:

Agricultural Extension Service, University of California
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Bureau of the Census, United States Department of Commerce
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California Department of Employment
California Department of Finance
California Department of Industrial Relations
California Division of Highways, Department of Public Works
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Elliott Company
Federal Power Commission
Forest Service, United States Department of Agriculture
General Electric Company
Hercules Powder Company
International Business Machines
Joy Manufacturing Company
Kaiser Steel Corporation
Kern County Land Company
Los Angeles County Flood Control District
Los Angeles County Regional Planning Commission
Moran Engineering Company
Newhall Land and Farming Company
Portland Cement Association
Richfield Oil Company
San Bernardino County Flood Control District
San Diego County Water Authority
Security-First National Bank
Southern California Research Council
Sunkist Growers, Incorporated
Tejon Ranch Company
The Metropolitan Water District of Southern California
Tidewater Oil Company
Union Oil Company of California
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POWER ADVISORY COMMITTEE

In May, 1958, there was formed, by mutual agreement, a committee composed of officials of the three major utilities serving power to the areas in which project pumping and power recovery facilities would be located. This committee, formed for the purpose of coordinating the efforts of the individual companies in advising the Department on problems related to the various possibilities for utility participation in the operation of the Project, has provided valuable guidance on these important questions. Members of the Power Advisory Committee are listed as follows:

Name	*Title and Affiliation*
Wallace L. Chadwick	Vice President, Southern California Edison Company
Walter Dreyer	Vice President and General Manager, Pacific Gas and Electric Company
William S. Peterson	General Manager and Chief Engineer, Los Angeles Department of Water and Power

ENGINEERING ADVISORY COMMITTEE

The Department of Water Resources requested the water service agencies and entities interested in water supply problems in the southern portion of the State to appoint a committee of prominent engineers to work with and advise the Department on its alternative route studies. This Department gratefully acknowledges the assistance and advice generously contributed by the committee during the course of this investigation. Members of this Engineering Advisory Committee are listed as follows:

Name	*Title*	*Sponsoring Agency*
Louis J. Alexander	Vice President and Chief Engineer, Southern California Water Company	Board of Directors, West Basin and Central Basin Municipal Water Districts
Paul Bailey	Engineer	Orange County Water District
Paul Beerman	Director of Public Works, City of San Diego	City Council, City of San Diego
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Robert H. Born	Chief Engineer, San Luis Obispo County Flood Control and Water Conservation District	Board of Supervisors, San Luis Obispo County
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Albert A. Webb	Consulting Engineer	Board of Directors, Western Municipal Water District of Riverside County

REPORT TO

DIRECTOR—DEPARTMENT OF WATER RESOURCES
STATE OF CALIFORNIA

BY

BOARD OF CONSULTANTS

ON

ALTERNATIVE AQUEDUCT SYSTEMS TO SERVE SOUTHERN CALIFORNIA

September 1959

MAJORITY REPORT

INTRODUCTION

Mr. Harvey O. Banks, Director, California Department of Water Resources, by letter of January 10, 1958, invited and authorized this Board to assist and review the studies by his Department directed toward the selection of the best route or combination of routes for the conduction of Northern California water from the Kings-Kern County line to Southern California. The studies by the Department pursuant to this objective have been both ramifying and complex, involving broad and detailed matters of engineering, geology, economics, and finance. The Department's conclusions derived from these studies are set forth in the Department's Bulletin No. 78.

Mr. Banks subsequently, by letter of June 22, 1959, requested the Board to confine its final report to:

a. Determination of probable future water requirements.
b. Determination of probable time when water from Northern California will be required.
c. Designation of areas to be served by the aqueduct system to Southern California.
d. Selection of the most favorable aqueduct system.

Item d, above, "Selection of the most favorable aqueduct system," is, of course, the final objective of this phase of the Department's investigation. Items a, b, and c, above, although very complicated and important in themselves, must be considered primarily as basic antecedents to the problem of selection of the most favorable aqueduct system.

This Board has been in existence approximately 19 months, and during that period its efforts and activities have been of various kinds. We have had numerous meetings, both private and with executives and staff members of the Department; we have inspected in the field various aqueduct routes and sites of the principal structures and have made reconnaissance observations by airplane over large portions of the areas of study; individual members of the Board have joined the staff in detailed field observations of critical portions of the routes to see at first hand and to help the staff assess the problems imposed by the physical setting of the various lines and sites, and also have maintained close contact with individuals of the staff, giving their personal attention to specific matters of economics, geology, design, construction and cost estimation; we have met in public sessions with a large number of individuals and public entities having interest in and knowledge about the water problems of Southern California; we met in a similar way with representatives of the utilities which might supply power for pumping over the various topographic divides, and might purchase any power recovered on the downslope sides of those divides; we have reviewed progress reports on various phases of the Department's studies and the preliminary drafts of Bulletin No. 78; and we have directed, from time to time, communications of comment, discussion, and recommendation to the Director of the Department.

By specific assignment, we limited our deliberations to the consideration of aqueduct routes and systems south of the Kings-Kern County line, which would serve southern San Joaquin Valley, Antelope Plain, the San Luis Obispo, Santa Barbara and Ventura areas, the Antelope Valley-Mojave and Whitewater-Coachella areas in the desert, the Southern California Coastal Plain, and Coastal San Diego County. We have not considered any of the engineering or other problems involved in the collection and transportation of water north of the Kings-Kern County line.

SELECTION OF THE MOST FAVORABLE AQUEDUCT SYSTEM

The basic conclusions of Bulletin No. 78 are, first, that no individual route will serve adequately the various parts of Southern California which now need or will soon need additional water, and, second, that a combination of routes, designated in Bulletin No. 78 as System B, will be the most effective and favorable combination for the conveyance of water to the various areas of water-need. We concur in these basic conclusions.

It will perhaps be self-evident, but we wish to emphasize that the studies underlying Bulletin No. 78, although intricate and voluminous, are sufficient only for the accomplishment of this limited objective: the selection of the most favorable aqueduct system for the conduction of water to areas of need in Southern California. Having ascertained the most favorable system, the Department must now subject it to intensive additional studies of various kinds—engineering, geological, economic, and financial—so that the outlines of the Aqueduct System, now broadly drawn, may be sharpened and defined. The following topics of this report bear upon the various phases of Bulletin 78 which have led to the selection of the most favorable aqueduct system, and some of the further studies which will be required before any attempt is made at final, detailed design. We believe that these additional studies will improve the scheme and enhance the advantages of System B over alternative systems; but it must be anticipated that future studies will lead to material and significant changes within the framework of the recommended system as now defined.

GROWTH OF POPULATION AND WATER DEMAND

The impending need for more water than is available from existing sources is a matter of common knowledge. Population in Southern California continues to increase, industry to expand, and irrigated agricultural land, although confronting a curtailment in many parts of Southern California because of urban encroachments, is in other parts expanding rapidly and will expand very significantly in the future if enough water is made available at reasonable cost. Analysis of the probable pattern of future water demand in the various parts of Southern California, and for the various main purposes—domestic, industrial, and agricultural—has been a basic first step in the Department's investigations.

Chapter II of Bulletin 78 summarizes the comprehensive study that the Department has made of these matters. In this study, the Department has divided the Southern California area into seven major service areas, and has projected, decade by decade to the Year 2020, the expectable growth in population, future water-needs, and the required importations of water for various kinds of use.

The projections have been made by methods that are standard for this type of analysis, and those methods have been applied carefully and thoughtfully. In our opinion, the projections portray the trends of growth and water demand as realistically as is possible in the face of uncertainties inherent in the prognostication of future events. Naturally, the projections are most reliable for the next two or three decades, and become more speculative as they are applied to the more remote future.

These projections will startle all but close students of population trends in the Southern California service areas and the dynamic potential for future growth. For instance, it is estimated that the present population of about 8,700,000 will increase to about 19,900,000 in 1990 and to over 28,000,000 in the Year 2020. The Southern California coastal plain is expected to have the highest population increase; but the projections indicate a surprising population growth elsewhere. Table 1, attached, summarizes the anticipated growth of population in the seven major service areas.

The Department concludes that the water needs accompanying those estimated growths in population will follow this pattern: imported water from the north will be required prior to 1970; these requirements may

TABLE 1
PRESENT AND PROJECTED POPULATION IN THE SEVEN MAJOR SERVICE AREAS OF SOUTHERN CALIFORNIA

Quantities in Thousands

Service Area	Year							
	1958	1960	1970	1980	1990	2000	2010	2020
Kern County	241.4	249	325	395	503	685	922	1,184
San Luis Obispo	66.5	70	92	130	205	340	520	700
Santa Barbara	123.5	148	207	283	385	520	695	915
Ventura County	175.3	182	288	425	635	1,000	1,350	1,700
Antelope-Mojave	142.0	157	330	726	1,188	1,619	1,951	2,222
Whitewater-Coachella	54.0	60	99	159	249	367	488	575
Southern California Coastal Plain and Coastal San Diego County	7,856	8,476	11,690	14,623	16,620	18,387	19,826	21,030
Total	8,658.7	9,342	13,031	16,741	19,785	22,918	25,752	28,326

Data from Table 4 of Bulletin 78.

TABLE 2
HISTORICAL AND PROJECTED ECONOMIC DEMAND FOR IMPORTED WATER IN THE SOUTHERN CALIFORNIA AREA

Quantities in Acre-Feet per Annum

Service Area	Year							
	1950	1960	1970	1980	1990	2000	2010	2020
Kern County	0	0	146,000	823,000	1,409,000	1,606,000	1,700,000	1,785,000
San Luis Obispo	0	0	0	5,000	19,000	28,000	37,000	55,000
Santa Barbara	0	0	15,000	58,000	93,000	121,000	154,000	196,000
Ventura County	0	0	10,000	41,000	55,000	115,000	168,000	236,000
Antelope-Mojave	0	0	15,000	80,000	142,000	175,000	195,000	208,000
Whitewater-Coachella	0	0	0	0	35,000	55,000	90,000	100,000
Southern California Coastal Plain and Coastal San Diego County								
Gross Demand	165,600	612,000	1,240,000	2,014,000	2,663,000	3,309,000	3,786,000	4,105,000
Claimed Colorado River Rights	1,150,000	1,150,000	1,150,000	1,150,000	1,150,000	1,150,000	1,150,000	1,150,000
Net additional demand	0	0	90,000	864,000	1,513,000	2,159,000	2,636,000	2,955,000
Total required from Sacramento-San Joaquin Delta	0	0	276,000	1,871,000	3,266,000	4,259,000	4,980,000	5,535,000

Data from Table 12 of Bulletin 78.

reach 3,266,000 acre-feet by 1990, and 5,535,000 acre-feet by 2020. Table 2 summarizes the anticipated water demands in the various service areas at intervals up to 2020.

In deriving these over-all figures, it has been necessary, of course, for the Department to anticipate the changing economies of the different areas. The Department concludes that the areas of irrigated crops in the coastal part of Los Angeles County will decrease from 58,000 acres in 1957, to none in 1990. In Coastal San Bernardino and Orange Counties, the Department concludes, the irrigated area will decrease from 179,000 acres in 1957 to 42,000 acres in 1990, and to none in 2020. In Coastal Riverside County, it is estimated that irrigated areas will decrease rather uniformly from 76,000 acres in 1957 to 46,000 in 2020. On the other hand, increases are anticipated in San Diego County and Southwest Riverside County from 61,000 acres in 1957, to 178,000 in 2020. The Department estimates that Kern County will experience a large increase in irrigated area if water becomes available at reasonable cost, and San Luis Obispo and Santa Barbara Counties are estimated to have smaller but substantial growths in agriculture after the importation of Northern California water; but in Ventura County a decrease in irrigated acreage is anticipated as municipalities and industries encroach upon land now irrigated. In the desert (Antelope-Mojave and the Whitewater-Coachella areas), the cost of imported water from Northern California will, in the opinion of the Department, prohibit any significant expansion of irrigated agriculture beyond that which may be possible by some future development of the meager local supplies of water. Therefore no provision has been made by the Department for furnishing any imported water from Northern California for irrigation use in these desert areas. We believe that this is a logical assumption and that it should be used as the basis for final designs.

In developing the probable future land use and water requirements, the Department has taken into account the present available water supplies and has determined the approximate time at which water from the Sacramento-San Joaquin Delta would be made available under each of the three Aqueduct Systems to guarantee the continued and future growth of the various service areas. A summary of the probable delivery dates is given in Table 3.

TABLE 3
ESTIMATED DATE OF FIRST WATER DELIVERY

1	2	3	4
	Date of First Proposed Water Delivery		
Service Area	Aqueduct System A	Aqueduct System B	Aqueduct System C
Kern County (San Joaquin Valley)			
Upper Antelope Plain	1971	1971	1971
Avenal Gap to Pumping Plant In-III	1965	1965	1965
Pumping Plant In-III to Pumping Plant In-IV	1966	1966	1966
Pumping Plant In-IV to Pumping Plant In-VI	1967	1967	1967
San Luis Obispo			
Upper Salinas Valley	1971	1971	1971
San Luis Obispo-Arroyo Grande	1991	1991	1991
Nipomo Mesa	1972	1972	1971
Santa Barbara			
Santa Maria Valley	1971	1971	1971
Santa Ynez Valley	1971	1971	1971
South Coastal Area	1971	1971	1971
Ventura County			
Ventura River Area	1991	1991	1991
Santa Clara-Calleguas Area	1971	1971	1971
Antelope-Mojave			
Kern County	1972	1971	1975
Los Angeles County	1972	1971	1975
San Bernardino County	1982	1982	1982
Whitewater-Coachella	1982	1982	1982
Southern California Coastal Plain and Coastal San Diego County	1971[1]	1971[2]	1971[3]

Column 1 from Tables 15-17 and 20, Bulletin 78.
Column 2 from Table 15—Bulletin 78.
Column 3 from Table 17—Bulletin 78.
Column 4 from Table 20—Bulletin 78.

[1] Water delivered to upper Santa Ana Valley and Perris Reservoir and San Diego Aqueduct in 1990. Earlier delivery would increase cost of water due to earlier construction expenditures.

[2, 3] Water delivered to upper Santa Ana Valley, Perris Reservoir and San Diego Aqueduct in 1982.

While agreeing generally with the reasonableness of these projections, as to the areas to be supplied with water imported from Northern California, and their probable future lines of development, water demands and dates of first water deliveries, we wish to emphasize three specific points of uncertainty. First, the projections of irrigated areas and the resulting water demands are based on certain assumed costs of imported water. Naturally, any significant changes in actual cost of water may decrease or increase the anticipated water demands. Second, it has been assumed by the Department that the amount of water required for municipal and industrial use will not be appreciably affected by the cost of imported water. However, water imported from Northern California undoubtedly will cost substantially more than the waters now available; and the increase in cost could retard the present trend in per capita consumption, and thus lead to importation of amounts different than anticipated at any given time. Third, some imponderables surround the supply of water to Southern California from Colorado River. Storage works on Upper Colorado River, now under construction or contemplated, and related developments of irrigation projects, could reduce the flow at Lee Ferry to at least that specified by the Colorado River Compact—and possibly to some lesser amount, since hydrologic records complete to this time indicate that the average annual run-off of the river has been less than was anticipated when the compact was made. If the average annual run-off continues in the future to be less than originally anticipated, the amount of water available for diversion into the Colorado River Aqueduct conceivably could be less than the claimed rights of the Metropolitan Water District. Moreover, the availability of Colorado River water could be decreased by an adverse decision in the Arizona-California litigation, now in progress, relative to the allocation of Colorado River water between the two states.

Regardless of the specific accuracy of these projections, they support beyond argument this basic conclusion: Southern California will need large quantities of water in excess of the present supply, this need beginning in the rather near future and increasing thereafter. The Department should therefore maintain a continuous study of actual trends and developments so that the projections can be progressively modified in the light of real occurrences.

QUALITY OF WATER

Southern California, as represented by the seven service areas listed in Table 2, now obtains its water from a variety of sources: Southern California Coastal Plain and Coastal San Diego County are served by Owens River and Colorado River Aqueducts, by extensive groundwater basins in some parts and by local supplies of surface water; Southern San Joaquin Valley in the Kern County service area, is inadequately served by groundwater; the desert areas are served by groundwater; and the San Luis Obispo-Santa Maria-Santa Barbara areas are served partly by groundwater, but mainly by surface water.

These various waters differ widely in quality. Owens River water has a low mineral content, the Colorado River has a rather high mineral content (between 700 and 800 parts per million); the various local sources, surface and subsurface, are different in quality among themselves, but generally lie between these two extremes.

Testimony was recently introduced in the litigation between Arizona and California to the effect that upstream developments upon the Colorado River would cause a deterioration of water quality downstream, probably increasing the total dissolved solids to 1,100 or 1,200 parts per million. The United States Public Health Service has established 500 parts per million as the desirable limit of total dissolved solids for a drinking water, but considers 1,000 parts per million as permissible. It cannot be predicated just when this anticipated deterioration in quality of Colorado River water will occur, but it must be considered in connection with the routing and timing of deliveries of Northern California water.

At the behest of the Department, the Stanford Research Institute has studied and reported upon the "Effects of Difference in Water Quality—Upper Santa Ana and Coastal San Diego County." That report concludes that the continued use of Colorado River water in these areas will raise the mineral content of certain groundwater basins by about 1980 to 1,000 parts per million total dissolved solids. This conclusion is based on the assumption that the mineral content of Colorado River water being delivered to the Colorado River Aqueduct will continue to be about as it is today. Any deterioration in the quality of Colorado River water would, of course, increase the content of dissolved solids in the water of these underground basins at rates faster than predicted.

Another facet of the problem involves the quality of the water that would reach the several areas from the Sacramento-San Joaquin River Delta. Bulletin 78 concludes that water reaching the upper Santa Ana Valley and Coastal San Diego County from this source would have a mineral content of about 200 parts per million after full development and utilization of upstream storage and construction of delta improvement works for salinity control. This conclusion may be on the optimistic side, but in any case would be invalid if the improvements upstream in San Joaquin Valley and in the Delta were not provided. The actual conditions in the Delta should be examined periodically with regard to water quality so that progressive planning may keep step with actual conditions.

Speaking generally, water from the Delta will meet all requirements for irrigation without further treatment. However, most of this water delivered south of Tehachapi Mountains will be required for urban or industrial use. It will have to be treated for the removal of bacteria, tastes, odors, color, and turbidity. Bulletin 78 recognizes this necessity and includes in its estimates of capital and annual costs proper amounts which will be incurred for filtration and chlorination by the local agencies distributing the water beyond the main aqueduct.

ALTERNATIVE AQUEDUCT SYSTEMS

The Department has studied means of conveying Northern California water to Southern California for almost a decade. The studies have considered many routes which would lead by various directions into the Southern California service areas. These many routes can be grouped generally into three categories:

1. Routes that would head westerly from Avenal Gap and then southerly through San Luis Obispo and Santa Barbara Counties to San Fernando Valley.
2. Routes to southern San Joaquin Valley and across Tehachapi Mountains and then to the Southern California Coastal Plain via San Fernando Valley.
3. Routes which, after traversing the southern end of the San Joaquin Valley, would cross Tehachapi Mountains and extend easterly through the desert areas, and thence by tunnel into the Southern California Coastal Plain.

It became evident from these studies that no one route could serve all of the Southern California areas of need, and that some combination of routes would be required. The Department, in Bulletin 78, designates these combinations of routes as ''systems.'' Of the various combination of routes (systems) that were considered, three systems finally emerged as those deserving detailed analysis and comparison. The Department has designated these as Systems A, B, and C. Each aqueduct system is a conception of works to be constructed by and at the expense of the State, or some over-all agency to make water available to the seven main service areas. The Department properly assumes that the additional works required to deliver water to and within the service areas would be provided by and at the expense of the local agencies in the various service areas.

This ''system'' concept follows naturally from the fact that supplemental water will be required:

1. In San Luis Obispo and Santa Barbara Counties.
2. In southern San Joaquin Valley.
3. In Ventura County, Los Angeles County, and Orange County.
4. In San Bernardino, Riverside, and coastal San Diego Counties, where a basic need exists and where, also, a supply of water of low mineral content will be needed to maintain a proper salt balance in the surface and subsurface supplies.
5. In the desert areas—the Antelope-Mojave and Whitewater-Coachella regions.

Obviously, no one route can supply all of these widely separated areas.

The Department's Aqueduct System A is primarily a coastal route with a branch to serve southern San Joaquin Valley and the high desert areas. The main aqueduct would lead westward from Avenal Gap and thence southward through the upper Antelope Plain, San Luis Obispo County, Santa Barbara County, Ventura County, and finally through Conejo Reservoir to terminal storage in San Fernando Valley at Bell Canyon Reservoir.

A smaller inland aqueduct from Avenal Gap would lead to Buena Vista Lake and thence to the service areas in south San Joaquin Valley, and continuing southward through a series of pumping plants, into the desert to a terminus at Little Rock Creek to serve the Antelope-Mojave and Whitewater-Coachella areas.

The Department's Aqueduct System B is primarily an inland route, the major aqueduct extending from Avenal Gap along southern San Joaquin Valley and across Tehachapi Mountains, traversing those mountains by a series of pumping plants, penstocks and tunnels to Cottonwood Creek. Enroute, this aqueduct would serve south San Joaquin Valley areas. At Cottonwood Creek the inland aqueduct would divide into the western and eastern branches.

The Western Branch would continue from Cottonwood Creek in tunnels, siphons, power drops, reservoirs, and canals through Castaic Reservoir and on to the Balboa Terminus in San Fernando Valley.

The Eastern Branch would extend from Cottonwood Creek through a power drop, canals, and pumping plants, traversing the desert area to Cedar Springs Reservoir, on the headwaters of Mojave River. In this section water would be diverted to the Antelope-Mojave and Whitewater-Coachella areas. From Cedar Springs Reservoir, the branch would tunnel through San Bernardino Mountains and continue through power drops, afterbays, and siphons to terminal storage in proposed Perris Reservoir.

A Coastal Branch would divert from the main aqueduct at Avenal Gap and proceed by pumping and power-recovery plants, canals, tunnels and siphons to a terminus in Santa Maria Valley in Santa Barbara County, servicing enroute upper Antelope Plain and San Luis Obispo County.

The Department's Aqueduct System C may be considered as Coastal and Inland in equal degree. One aqueduct would extend from Avenal Gap via Buena Vista Lake across Tehachapi Mountains, passing into the desert area and following the same general alignment as the Eastern Branch of the Inland Aqueduct System B, terminating at Perris Reservoir. A second aqueduct would extend westerly and southerly from Avenal Gap through San Luis Obispo, Santa Barbara, and Ventura Counties, following the same general alignment as the Coastal Aqueduct of System A, and terminating at Bell Canyon Reservoir in San Fernando Valley.

Each of the three systems, as described in Bulletin 78, requires a different combination of open canals, pipelines, siphons, tunnels, pumping plants to lift the water across the topographic divides, and power plants to recover power on the downstream side of these divides. Moreover, the sizes and capacities of the various elements of each system differ also, and different facilities are required for the distribution of the water by local entities to each service area, from the aqueducts to the points of consumption.

It is our opinion that the three Aqueduct Systems, as selected by the Department for detailed study, have been well chosen and that they represent a logical and practical basis for the determination of the most favorable aqueduct system for conveying imported water from the Sacramento-San Joaquin Delta to furnish a supplemental water supply for the Southern California area.

CONVEYANCE AND DISTRIBUTION OF IMPORTED WATER TO SERVICE AREAS

It is the concept of the Department that after the aqueducts have been built, passing through some of the service areas and terminating at points that are strategic for the distribution of water to others, the local agencies will assume the engineering and financial responsibility for building the systems necessary to convey the water into the various areas of use and to the individual users. But even though the State or equivalent over-all agency would have no responsibility for these distribution systems, they nevertheless represent an element of cost that must be considered in the comparison of alternative aqueduct systems. The manner of local conveyance and distribution within the individual service areas would differ significantly for the three alternative aqueduct systems, and the costs would differ also. We, as a Board, concur in this concept.

Speaking generally, the Department has outlined and estimated costs of conveyance and distribution works within the various service areas to points selected common to all three aqueduct systems for serving the consumers, but has not studied the costs that would be involved in getting the water from those common points to the consumers themselves. There are a few exceptions to this generalization in areas of future irrigation in which there now exist no distribution facilities whatever—in these instances the Department's studies have been carried all the way to the farmers' headgates.

These studies of conveyance and distribution have required a detailed consideration of sizes and capacities, taking into account seasonal demands, the needs for local storage for regulation or protection against outage, the pumping requirements and the possibility of power recovery, the treatment of water by filtration and chlorination where required, the applicability in some instances of groundwater replenishment and storage underground, the sequences and timing of the construction, and other like matters of similar engineering intricacy.

The cost of these conveyance and distribution facilities, as estimated by the Department, are listed on Table 4, and may be summarized as follows:

	Est. Capital Costs in 1000 Dollars			*Cost of Distribution Facilities as a Per Cent of the Main Aqueduct Cost*
Aqueduct System	*Main Aqueducts*	*Distribution Facilities*	*Total*	
A	2,361.0	1,220.0	3,581.0	51.7
B	1,807.0	745.0	2,552.0	41.2
C	2,162.0	703.0	2,865.0	32.5

It should again be pointed out that it has been assumed by the Department, and properly so, that these costs are to be assumed by the local agencies. They are of major importance, involving in Aqueduct System B, 41% of the cost of the main aqueducts. Further, although they represent the cost of such works to common points in the service areas, there will still remain very large additional expenditures on the part of the local agencies to permit delivery of water to the customers.

The cost of distribution facilities to convey and deliver aqueduct water to the customers will be an item of major importance in determining the cost of bringing Delta water to the users in the various service areas. A great deal of additional study will therefore be required to determine the total cost of water delivered to the customers.

PUMPING AND POWER RECOVERY

A very crucial element in designing any route or system is the scheme adopted for pumping over the various topographic divides and for recovery and utilization of the power that may be generated on the downstream sides of those divides, since the utilization and disposal of the energy thus consumed and generated will affect vitally the economics of the whole plan. Bulletin 78 lists and briefly describes the following schemes for pumping and power recovery:

1. Purchase of off-peak electric power and sale of the power that may be generated.
2. Purchase of off-peak electric power and the feedbacks of generated power into the pumping system.
3. Pumping by direct steam and steam-electric drive and sale of the power that may be recovered.
4. Pumping by direct steam and steam-electric drive and feedback of the power which is generated into the pumping system.
5. Pumping by steam-electric drive; feedback of the power which is generated into the pumping system.
6. Pumped storage (a system involving pumping into high-level reservoirs during periods of off-peak power demand, the release of water to the aqueduct as required, and the retention of the remainder for later return through the penstock for generation of power during periods of peak demand).

Undoubtedly, different schemes of pumping and power recovery will prove to be most favorable for different parts of the adopted system.

The Department has considered it to be unnecessary that all of these schemes be analyzed fully to attain the limited objective of Bulletin 78: the selection of the most favorable aqueduct system. For purposes of financial comparison, the Department, in Bulletin 78, elected to appraise aqueduct Systems A, B and C, assuming that pumping and power recovery would be by: (a) off-peak electric and feedback (No. 2 above), or (b) steam and steam-electric drive and feedback (No. 4 above); and a comparison of capital and annual costs for these two schemes is made in Bulletin 78—with the qualification that the off-peak electric and feedback scheme was considered to be infeasible for Aqueduct System A.

By this comparison, the Department concludes that the "steam" or "steam-electric drive" with power feedback would be cheaper both in capital cost and annual costs than the "off-peak electric drive with power feedback." Accordingly, all further financial and economic analyses set forth in Bulletin 78 are based on the use of the "steam" or "steam-electric" drive with power feedback for pumping and power recovery.

We agree with the Department that comparisons made on this basis are legitimate and can lead to proper conclusions as to the most favorable aqueduct system. However, we wish to express strongly our opinion that in the future, prior to final design, complete studies and comparisons must be made of all reasonable schemes of pumping and power recovery.

It is again appropriate to state, in anticipation of a later topic of this report, that the Department favors Aqueduct System B, and that we concur. Aqueduct System B clearly seems to be the most favorable system for the conduction of water from northern to southern California. It is our belief that future studies of pumping and power recovery schemes will enhance the advantages of Aqueduct System B over the alternative systems, and improve the economic advantage of that system beyond that indicated in Bulletin 78. We recommend particularly that a conclusive study be made of the possibilities of pumping with low-valued utility off-peak power and generating higher valued peaking power for disposal, and extending this concept to the possible utilization of pumped-storage (Item 6). Parts of System B appear to be particularly adapted to this concept and if later studies prove this to be so, the problems of financing and repayment may well be significantly easier than indicated in Bulletin 78.

We have arrived at the following general convictions regarding pumping and power recovery:

1. That the project can be and should be financially self-supporting, with the costs of construction, operation, and maintenance defrayed by the various service areas which are to be the recipients of the imported water; and that credit for energy disposed of or used, from power recovery plants, should be applied to the capital and operating costs of the pumping plants which contribute falling water to the recovery plants.
2. That to accomplish 1, above, full advantage must be taken of the existing and well integrated facilities of the power utilities operating within the different areas under consideration; and in this connection, we urge that the Power Committee, formed in 1958, and composed of representatives of the power utilities and the Department, continue actively its meetings and discussions.
3. That any schemes selected for pumping and power recovery should be aligned with proven engineering practices, since the quantities of water and the heights of pump-lift, when taken in combination, are without precedent, and since the consequences of erratic or undependable operation would be so serious to the economy that will be built around this project. The project must operate consistently and dependably. We are frankly dubious of the practicability of any plan to pump by direct steam-drive. There is no precedent for this kind of pumping in the quantities and to the heights here contemplated.

Since any system will require large amounts of energy for pumping and will recover lesser amounts, the net drain upon the State's and the Nation's reserves of energy must be considered. However, this consideration has little bearing upon the choice of aqueduct system, since the estimated net expenditures of energy by the different systems differ very little. Those systems requiring lesser expenditures of energy for pumping, recover less power; and the systems requiring greater expenditures of energy, recover more. By way of example, we extract from Table 23 of Bulletin 78 the following comparisons between Aqueduct System A (predominantly Coastal), Aqueduct System B (predominantly Inland), and Aqueduct C (equally Coastal and Inland):

ESTIMATED ANNUAL POWER CONSUMPTION AND GENERATION

	Aqueduct System A	*Aqueduct System B*	*Aqueduct System C*
Pumping plant consumption for year 2000 in million KWH	6,291	10,703	9,040
Power plants generation for year 2000 in million KWH	1,082	3,779	2,588
Net consumption in million KWH	5,209	6,924	6,452
Average annual fuel consumption, 1965-2020 (in millions of barrels of oil per year)	8.03	9.35	8.67

Aqueduct System A requires the least energy but recovers the least. System B requires the most energy but recovers the most. System C is intermediate between A and B. The differences in fuel consumption are not great. Such comparisons will be different for each scheme of pumping and power recovery; but it seems probable that System B will benefit more than the other systems from further study and refinement.

TABLE 4

SUMMARY OF COST COMPARISON FOR AQUEDUCT SYSTEMS A, B AND C MAIN AQUEDUCT-DELTA TO SYSTEM TERMINALS PLUS LOCAL DISTRIBUTION FACILITIES

Quantities in Million Dollars

	Aqueduct System								
	A			B			C		
Basis of comparison	Main aqueduct	Distribution facilities	Total	Main aqueduct	Distribution facilities	Total	Main aqueduct	Distribution facilities	Total
Total capital costs	2,361.0	1,220.0	3,581.0	1,807.0	745.0	2,552.0	2,162.0	703.0	2,865.0
Present worth of capital costs	1,589.0	699.0	2,288.0	1,225.6	515.0	1,740.6	1,498.9	492.0	1,990.9
Present worth of operating costs	861.9	564.4	1,426.3	940.6	456.0	1,396.6	955.0	453.2	1,408.2
Present worth of capital costs plus present worth of operating costs	2,450.9	1,263.4	3,714.3	2,166.2	971.0	3,137.2	2,453.9	945.2	3,399.1
Average unit cost of water per acre-foot over repayment period	$33[1]	----	$50[2]	$29[1]	----	$42[2]	$33[1]	----	$45[2]

Data from Tables 31, 35, 36, 37 and 38 of Bulletin 78.

[1] Average cost at main aqueduct over repayment period.

[2] Average cost delivered to service areas over repayment period.

FINANCIAL AND ECONOMIC ANALYSIS

The economic comparisons which the Department has made of the several aqueduct systems are sufficient for selection of an aqueduct system. These comparisons are summarized below in terms of ratios, derived from actual dollar values as set forth in Table 4.

SUMMARY OF ECONOMIC COMPARISON OF ALTERNATIVE AQUEDUCT SYSTEMS

(Comparisons are expressed in ratios with System B shown as unity in each instance)

	Aqueduct System A	*Aqueduct System B*	*Aqueduct System C*
1. Capital cost of main aqueduct south of the Delta (to be built by the State or over-all agency)	1.31	1.00	1.20
2. Capital cost of local conveyance and distribution facilities (to be built by local interests)	1.64	1.00	0.94
3. Capital cost of main aqueduct south of the Delta and local conveyance and distribution facilities	1.40	1.00	1.12
4. Average unit cost of water delivered to service areas	1.19	1.00	1.07
5. Total direct benefits	1.00	1.00	1.00

Inasmuch as these comparisons indicate that the total direct benefits are essentially equal for the three systems, Aqueduct System B is shown by relative total capital and unit costs to be economically superior to System C and possesses a substantially greater advantage over System A. The estimates of costs and benefits made by the Department were based on various assumptions which are considered generally to be valid for present purposes. However, when a full study has been made of pumping and power recovery schemes, it is likely, as we have mentioned earlier, that System B will appear in an even more favorable light. We hold this opinion because System B appears to offer a substantially greater opportunity to capitalize on the economic advantages of using low-valued off-peak commercial power for pumping and the generation of high-valued peaking power by the power recovery facilities.

The Department has made certain assumptions relative to the recovery of all costs of building and operating the main aqueduct system. These assumptions are that:

1. The capital investment of each stage of construction will be repaid with interest at 3½ per cent per annum within a period of 50 years.
2. The interest due on the investment during the period of construction and prior to delivery of water will be capitalized.
3. The repayment of the capital investment will commence on the date of first water deliveries.
4. Costs of the Aqueduct Systems were allocated to the service areas by the "Proportionate Use of Facilities Method."
5. Pumping plant costs were allocated to the service areas in the same proportion that the peak capacity requirements bore to the summation of peak requirements of all service areas.
6. Costs of power recovery plants were added directly to the cost of pumping plants which they would serve and were allocated to the service areas in the same manner as for the pumping plants.
7. Credit for energy from the power recovery plants was applied to the capital and operating costs of the pumping plants which contribute falling water to the recovery plants.

The Department has assumed that the aqueduct system will be built in stages and the foregoing assumptions were applied to each stage. We believe them to be in accordance with good practice and that their use is logical and reasonable, although it should be recognized that the interest rate is somewhat low under present market conditions.

The Department, in Bulletin 78, has developed what is termed an "average cost of water," over the 50 year repayment period, for the entire service area and points out that this is not the price at which it is assumed water will be sold, and we wish to reiterate and emphasize this point. The actual "cost of water" represents the money that must be obtained each year from some source to amortize the debt and cover operation and maintenance costs in each year for the basic aqueduct system.

In considering such amortization, the Department contemplates that each service area will begin annual payments to cover the "cost of water" to the area when water is first delivered. These annual payments will be, from the first year of repayment, sufficient to pay costs allocated to the area for (1) all maintenance and operation; (2) all interest on capital; and (3) part of the capital cost. Item (3) above may be somewhat less in the early years than in later years, but will be geared to return all the capital cost allocations over a period of 50 years, less the period of construction prior to water delivery. We anticipate that the use of water in each service area will start from some minimum quantity the first year of delivery and increase to the full estimated consumption only after several years. It is unlikely that recovery of costs during these early years can come entirely from charges for water delivered.

For this reason, if the project is to be self-liquidating and if it is to amortize its own costs, some repayment arrangement will be required that will provide funds from each service area to meet the annual payments above described, every repayment year equal to the annual "cost of water" for the whole service area. Amounts which are not provided from water sales can be obtained as taxes in service areas, in some such manner as has been employed by the Metropolitan Water District to provide funds for the Colorado River Aqueduct and its appurtenant facilities; or some other comparable and equally effective mechanism may be devised.

DESCRIPTION OF AQUEDUCT SYSTEM B

As background for discussions which follow, we must re-describe the recommended system—Aqueduct System B—in more detail. It would bring water southward from the latitude of Avenal Gap in the following ways:

A principal aqueduct, designated the Inland Aqueduct, would pass generally southward via a reservoir at the site of Buena Vista Lake, across Wheeler Ridge and Pastoria Creek, serving enroute the areas of water-need in south San Joaquin Valley, and continuing to Tehachapi Mountains. Four pumping plants would be required enroute to lift the water to an elevation of approximately 3,415 feet, at which elevation a tunnel would traverse the mountains. Emerging from the tunnel near Cottonwood Creek, on the south side of Tehachapi Mountains, the aqueduct would divide. A Western Branch would continue via Castaic Reservoir to a Balboa terminus in San Fernando Valley. This branch includes two power drops on the south side of the mountains between Cottonwood Creek and Castaic Reservoir. This branch, then, would serve Ventura County, Los Angeles County, and adjacent portions of the Southern California Coastal Plain.

At Cottonwood Creek the Eastern Branch of the Inland Aqueduct would drop some 500 feet and proceed generally south and east to a point near Pearblossom, and then be pumped again some 500 feet to permit gravity flow to Cedar Springs Reservoir on the headwaters of Mojave River. Beyond Cedar Springs Reservoir, a four-mile tunnel would conduct the water through San Bernardino Mountains to two power drops in Devil Canyon, a short distance north of San Bernardino. From there, the aqueduct would continue across the upper Santa Ana Valley to Perris Reservoir, which would be the major terminus of this Eastern Branch. From Perris Reservoir, water could be supplied to the San Diego Aqueduct, the Metropolitan Water District Aqueduct, and to service areas to the west. Laterals could be constructed between Devil Canyon and Perris Reservoir to serve other areas to the east and west. This branch, then, would deliver water to the Antelope-Mojave area, the Whitewater-Coachella area, portions of Southern California Coastal Plain, and Coastal San Diego County.

A coastal branch would diverge from the main aqueduct at Los Perillas Reservoir, a small forebay near Avenal Gap. From Los Perillas Reservoir at about elevation 325, the water would be pumped in three lifts to about elevation 1,190 and then carried largely in canal to the east portal of a tunnel beneath Polonio Pass, with diversions enroute to supply upper Antelope Plain in San Joaquin Valley. Westward from Polonio Pass, the aqueduct would extend to another tunnel beneath Cuesta Pass near San Luis Obispo. Just south of Cuesta Pass, the aqueduct would drop approximately 500 feet to San Luis Obispo power plant, and continue to its terminus at Santa Maria River about 405 feet above sea level. This branch, then, would serve upper Antelope Plain, San Luis Obispo County, and Santa Barbara County.

Each prong of this system involves a complex assortment of canals, pipe-conduits, tunnels, siphons, reservoirs, pumping plants, and power plants. It is unnecessary to restate the details of specific features and combinations of features which make up the recommended system. In our opinion, the general routes, the proposed structures and their locations and the sizes and capacities which the Department has brought together in framing their recommended system are reasonable and workable and entirely satisfactory for the accomplishment of the Department's present objective: the determination of the best aqueduct system for the conduction of water to the areas of need in Southern California.

However, we wish to emphasize that many changes in detail will result from the further studies which are now required to perfect the selected system sufficiently for final design and construction. In particular, modifications will result inevitably from a complete investigation of all different schemes of pumping and power recovery, since each scheme will have, within the framework of the selected system, its own best combination of locations, types, and sizes of the various component elements. The greatest changes will result if a pumped-storage scheme of pumping and power recovery proves to be advantageous.

Apart from the detailed changes which may be made, a few larger elements of Aqueduct System B perhaps can be improved by further study. Bulletin 78 proposes a lateral diversion from near Hesperia to serve the Whitewater-Coachella area. At first glance, it appears that this area could be served more economically from the Colorado River Aqueduct of the Metropolitan Water District, through some exchange agreement with the District. If such an arrangement could be effected, the Whitewater-Coachella Lateral would be decreased in length, the flow would be increased through the aqueduct to Cedar Springs Reservoir, Devil Canyon power plants and Perris Reservoir.

About 20 miles east of Cottonwood Creek, the same Eastern Branch of the proposed aqueduct passes quite close to Fairmont Reservoir on Los Angeles' Owens River aqueduct system. This reservoir serves as regulating storage to permit peaking of power plant operation below that point on the Owens River aqueduct. We understand that the aqueduct has a capacity of about 1,000 cfs between Fairmont Reservoir and Dry Canyon, but that the average aqueduct flow is only about 500 cfs. Conceivably, an agreement with the City of Los Angeles would permit the use of this reservoir facility for delivering some water to San Fernando Valley—with advantage to all parties concerned.

On the coastal prong of the recommended system, the aqueduct, as mentioned earlier, terminates in Santa Maria Valley. That part of Santa Barbara County southerly and westerly of Santa Maria Valley is proposed to be served by a lateral constructed and operated by local agencies. It may be that further study will indicate the possibility and desirability of continuing the main aqueduct to Cachuma Reservoir on Santa Ynez River, so that this reservoir could serve as terminal storage. This change would require an agreement with the Bureau of Reclamation. Such a plan would provide badly needed storage for diversion to adjacent service areas and would permit feeding some water backwards into the aqueduct if an outage should occur to the north.

We single out these three instances of possible modification of the recommended system simply as examples of improvements in the system which may result from further study, and to re-emphasize that the investigations and analyses reported in Bulletin 78 are not, and were not meant to be, final or conclusive in all detail. We believe that conservative assumptions have been applied to these and similar areas of incomplete study and that the recommended system can only be improved by future studies. We do not mean to imply that the studies to date have been careless or superficial; indeed, they have been entirely adequate for present purposes. But the problem at hand is one of enormous complexity and we wish merely to make the point that much remains to be done before the project is finally designed and built.

GEOLOGICAL CONDITIONS AND CONSTRUCTION PROBLEMS

Any conceivable system to conduct water from northern to southern California will present very formidable problems of design and construction because of difficult conditions of geology and terrain. The entire area of interest south of Avenal Gap is seismically active. At several points, major faults of known or suspected activity must be crossed and many other faults, both major and minor, from which earthquakes could emanate, lie close by. The Department and this Board have consulted Doctors Perry Byerly and Hugo Benioff, both eminent seismologists, about the seismic potentialities of the area. Any system will pass through areas of unstable ground where landslides have occurred in the past and will occur in the future. The coastal areas are particularly vulnerable in this regard. Routes in south San Joaquin Valley will traverse areas of ground-subsidence. This subsidence is of two kinds: subsidence resulting from the withdrawal of underground water for irrigation, and subsidence which in some areas results from the application of water to the parched soils of this arid region. In many instances, the individual structures—dam sites, pumping plants, power plants, conduits, and canals—will require special design because of inferior foundations. All tunnels will traverse difficult ground.

Such difficult natural conditions have beset engineering construction in these parts of California since the earliest occupation of the area, and they have not prevented the successful consummation of major engineering undertakings. The magnitudes of some features of this project greatly exceed the magnitudes of like works that have been successfully constructed in these areas in the past, but the hazards confronted by these larger works now proposed can be surmounted by the exercise of the same principles and methods by which similar difficulties, in this area and elsewhere, have been successfully surmounted.

The Department has recognized the difficult natural conditions which confront the construction of any aqueduct route or system to Southern California, and accordingly has studied the geology ably and with great care, and has appraised very realistically the engineering problems imposed by the different geologic and topographic conditions in the different areas. The preliminary designs outlined in Bulletin 78 have been adapted very appropriately to the natural conditions. It is proposed to cross the major active faults on the surface rather than underground in tunnels, even though this requires pumping to higher elevations than would otherwise be necessary. In particular, the elevation of the Tehachapi Mountains tunnels permit crossing the Garlock and San Andreas faults on the surface. San Andreas fault would again be crossed at the surface after leaving the tunnel through San Bernardino Mountains. On the Coastal Route, also, San Andreas fault would be crossed on the surface, beyond the western portal of Polonio Pass tunnel.

The choice between open canal, pipe-conduit or tunnel throughout the system has been appropriate to the geology and topography of the different parts of the system. Special problems, such as the areas of ground-subsidence in south San Joaquin Valley, have been and are still the subject of special research, and we believe that the solutions to such special problems as suggested in Bulletin 78 are practical and realistic. Bulletin 78 has recognized the problems inherent in the design of structures such as dams, powerhouses, and pumping plants which will rest on foundations ranging from mediocre to poor in quality.

In short, the area under consideration is not conducive to easy and routine design and construction. It presents many problems and difficulties arising from the geology and topography. But the Department has recognized and studied each of these problems and proposes methods for surmounting them which, in our opinion, are entirely practicable.

OPERATING PROBLEMS

The long aqueduct lines, numerous pumping lifts, power plants, power supplies, and storage facilities which must be combined for system operation will present major operating problems. These problems will be accentuated by the fact that all three routes making up System B will encounter difficult natural conditions, as mentioned previously.

With terminal storage at Cedar Springs, Perris, Castaic, Bell Canyon, and Conejo Reservoirs, any shut-down of the aqueduct will not immediately affect the supply of water to the service areas downstream. However, a serious break in the aqueduct north of Avenal Gap would disrupt service both to the Inland and Coastal lines. Bulletin 78 contemplates the construction of reservoirs for emergency storage by the local entities comprising the individual service areas—not by the State or some over-all agency constructing the aqueduct system. Such construction will be necessary in Kern County, San Luis Obispo County, Santa Barbara County, and in the Antelope-Mojave and Whitewater-Coachella areas. Breaks in the Coastal or Inland aqueducts, south of Avenal Gap and upstream from the terminal reservoirs would, of course, cause serious problems, but smaller areas would be affected.

Special consideration must be given to the problems arising from shut-downs, caused by physical breaks in the conduit, power outages, normal operating disturbances, or other emergencies or catastrophes. To provide for such contingencies, there should be sufficient storage and wasteway capacity at strategic points along all three routes to handle the flow until the aqueduct can be shut down or its flow drastically reduced at some upstream point of control. We recommend that careful study be made of these operating problems before final designs are undertaken.

ESTIMATES OF COST

Individual members of the Board have worked closely with the Department in the development of cost estimates. In our opinion, proper consideration has been given to availability of construction materials, the special procedures of design and construction necessary to surmount local problems, and trends of costs determined from analysis of recent bids on somewhat similar work.

We believe that the unit costs adopted for the various features of the aqueduct system are in general agreement with 1958 prices, and that the resulting total costs are reasonable. Adequate provision has been made for contingencies, engineering and overhead. Of course, if prices continue to increase as they have in the past, the estimates must be revised from time to time.

We wish to point out again the distinction that is made in Bulletin 78 between the capital and operating costs of the various branches of the system itself, and the separate costs which would be incurred by the local entities responsible for the distribution of the water from various points along the system into the various service areas. Distribution facilities have been assumed to be constructed and operated by appropriate local agencies who would distribute the water as required to meet local demands. The costs of such distribution facilities are cited only for comparison of total costs for the three main aqueduct systems which were studied, and are not assumed to be a charge against the State or other over-all agency constructing and operating the main aqueduct.

STAGING OF CONSTRUCTION

In a project of this magnitude with construction continuing over several decades to meet the progressive demands for water, and with expenditures of hundreds of millions of dollars each decade, it would be highly desirable to so plan the works that they may be built in successive units or stages, thus reducing capital expenditures in the earlier years of the project, and securing some income from early water use for application toward the costs of later construction. The Department has concluded that only a limited amount of staging is practicable and beneficial. This conclusion is based in part upon the concept that it would be impracticable to enlarge either canals or tunnels at some later time because they must be maintained in continuous operation. Accordingly, the Department's estimates for these features are based upon initial construction of these features to the capacity estimated to be required in Year 2020. Similarly, all dams and reservoirs are assumed by the Department to be built initially to the 2020 capacity. This procedure was based on the premise that adequate funds could be made available. The Department, however, has assumed stage-construction for pipe-siphons and for pumping and power plants and penstocks. The Department argues plausibly in this connection in Bulletin 78 and it may well be that it is correct in its conclusions. Nevertheless, we have certain misgivings and believe that the whole problem of staging of construction requires further study.

While duplicate tunnels and canals of smaller size would certainly cost more than single structures of larger size, the initial capital cost and interest charges would be much less if smaller ones were constructed initially. We wish to re-emphasize a point made earlier, that the projections of growth of population and water demand, although as good as can be made, contain elements of speculation, and may prove to be erroneous for periods in the more distant future; and the ultimate capacities now thought to be required 30 to 60 years hence may be too high or too low. Developments now unforeseen may occur in the fields of construction, pumping and power generation before the turn of the next century. We question the wisdom of building at the outset in accordance with present anticipations of the total demands and the technologies of the remote future.

CONCLUSIONS

1. We agree with the Department's selection of Aqueduct System B as the most favorable, subject, however, to modifications after further detailed investigations. Aqueduct System B provides: (1) An Inland Aqueduct south of Avenal Gap to the southern end of the San Joaquin Valley, thence across the Tehachapi Mountains with a Western Branch on to a terminus in the San Fernando Valley, (2) an Eastern Branch Aqueduct leaving the main aqueduct at Cottonwood Creek in the Tehachapi Mountains and going eastward to a point north of San Bernardino where it turns south to penetrate the San Bernardino Mountains and terminate in upper Santa Ana Valley at Perris Reservoir, and (3) a Coastal Aqueduct westward from Avenal Gap to San Luis Obispo and Santa Barbara Counties with south terminus at Santa Maria River.

2. Aqueduct System B has the following principal advantages over any of the others:
   a. Least capital cost to the State or other over-all agency.
   b. Least capital cost of combined main aqueducts and local conveyance and distribution facilities.
   c. Least average cost of water over the repayment period as delivered to service areas.
   d. Best distribution of water south of the Tehachapi Mountains to meet water demands and problems of water quality.
   e. Most favorable for power recovery program.

3. Aqueduct System B requires higher pumping lifts for large quantities of water than alternative systems. But, any system must include large pumping installations, and Aqueduct System B would require only about 16 per cent more fuel oil or its equivalent than would be required by a coastal aqueduct, which would have the lowest consumption. Furthermore, large financial benefits may be realized by incorporation of the most appropriate power-recovery methods.

4. The estimates for future water needs are large, but reasonable. However, the estimates for the near future are much more reliable than those for the more remote future, and all planning should maintain flexibility to conform to trends as they may actually develop.

5. We concur in the assumption that no plans should be made by the Department for furnishing a supplemental irrigation supply to the Antelope-Mojave and Whitewater-Coachella service areas. The cost of water will be too high for such use. Supplemental supply for these areas should be confined to future municipal and industrial demands.

6. We believe that all reasonable methods of pumping and power recovery should be thoroughly investigated. No other elements of the contemplated works present such unprecedented problems of construction or operation, or offer such opportunities for savings in capital and operating costs. We believe that the best solution will be the one taking maximum advantage of the integrated facilities of the public utilities in the area, using, insofar as possible, lower-valued utility generated off-peak power for pumping, and generating higher-valued peaking power for sale. A possible alternative method would be to deliver power from project plants into the utility systems and withdraw energy from such systems to serve the projects' pumping plants. We doubt the reliability of the direct steam driven pumping schemes outlined in Bulletin 78, and believe that for the unprecedented volumes of water and heights involved, this scheme will prove to be inadequate.

7. The topographical and geological conditions to be met by any route or combination of routes are formidable; but the Department has recognized these difficulties and proposes sound methods to meet them.

8. We believe that the estimates of construction costs presented in Bulletin 78 are realistic for the present time.

9. In a project of this size and importance, staging and timing is important. Prognostications of events in the distant future are uncertain because of possible changes in economic trends and technologic advantages now unforeseen. For these reasons, initial construction to the capacities now estimated for the distant future involve unpredictable uncertainties—the works built to meet these anticipations could be smaller or larger than ultimately necessary. We recommend further serious study of staging and timing of aqueduct construction.

10. We believe that the entire project can and should be self-supporting with the costs of construction and operation defrayed by the various service areas which are to be the recipients of the imported water; that credit for energy sold or used, from power recovery plants, should be applied to the capital and operating costs of the pumping plants which contribute falling water to the recovery plants; and that complete financial analyses should be made at an early date to determine the probable total cost of water in the several service areas, with particular attention to such costs during the early years of operation.

BOARD OF CONSULTANTS

s/A. H. AYERS
A. H. Ayers

s/ROGER RHOADES
Roger Rhoades

s/JOHN S. LONGWELL
John S. Longwell

s/DAVID WEEKS
David Weeks

s/CARL R. RANKIN
Carl R. Rankin

s/RALPH A. TUDOR
Ralph A. Tudor, Chairman

MINORITY REPORT

FEATHER RIVER—SOUTHERN CALIFORNIA AQUEDUCT

Report by
ADOLPH J. ACKERMAN
Consulting Engineer

December 31, 1959

HYDRO-ELECTRIC
DEVELOPMENTS

PLANNING
FINANCING
DESIGN
CONSTRUCTION

ADOLPH J. ACKERMAN
CONSULTING ENGINEER
1250 SHERMAN AVENUE
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MEMBER

AMER. INST. OF
CONSULTING
ENGINEERS
A. S. C. E.
A. S. M. E.
A. I. E. E.

January 7, 1960

LETTER OF TRANSMITTAL

Director
Department of Water Resources
State of California
Sacramento, California

Dear Sir:

I am submitting herewith my report on an engineering review of the "Alternative Feather River Project Aqueduct Route Studies."

Insofar as the present status of available studies has permitted, I have attempted to respond to the terms of reference which were given to the Board of Consulting Engineers on January 10, 1958.

In order to meet my professional obligations on matters which are within the area of my specialization, I have found it necessary to file a special report. The submission of such a report has had the approval of the Chairman of the Board.

It has been a privilege to serve the State of California in this matter.

Sincerely yours,

A.J.Ackerman

Adolph J. Ackerman
Member
Board of Consulting Engineers
Alternative Aqueduct Routes

cc: Chairman and
Members of the
Board

AJA:wja

The Board of Consulting Engineers on Alternative Routes
Feather River–Southern California Aqueduct
Department of Water Resources, State of California

December 31, 1959

COMMENTS ON THE FINAL REPORT OF THE BOARD

By ADOLPH J. ACKERMAN
Consulting Engineer and Member of the Board

The Final Report of the Board of Consulting Engineers on Alternative Aqueduct Routes was submitted to me for my signature. After a careful examination of the Report, and a review of all available references, I have signed the Report with the notation: "I regret that I cannot join in this report, since the problems of financial feasibility, which are within the area of my professional specialization, have not been adequately examined. I am therefore submitting a separate report."

I cannot subscribe to all of the statements in the Final Report for the following reasons:

1. The Report refers to the original letter of instructions from the Director of Water Resources, dated January 10, 1958. This letter not only outlined the unrestricted conditions under which the Members of the Board accepted appointment, but it also provided a guide for developing all essential facts during the period of investigation. The Report also refers to a letter subsequently received by the Board on June 22, 1959, which "requested the Board to confine its final report" to four specific questions; the Report has been written to respond to this request. However, I consider myself bound by the original instructions to the Board, and by the recommendations of a previous Board of Consulting Engineers (report of May 8, 1957), that "no specific project be authorized for construction prior to detailed investigation of its engineering feasibility, economic justification and financial feasibility." In my opinion, this demands a conclusive analysis of basic problems such as the estimated cost of a project of limited size, determination of the best operating procedures, probable price of water to the consumer, financing problems and their influence on the State's credit position (or on greater tax levies), repayment of invested capital, and similar issues. Such a program of analysis would lead to the drawing of basically different conclusions from those contained in the Final Report.

2. Much valuable technical work has been carried out in the past three years on topographical and geological mapping, studies of hazards due to earthquakes, problems in design, construction and tunneling, and studies of growth in demand for water. Notwithstanding the importance of these features in the planning of a project, they are nevertheless, in my opinion, only a means to an end of formulating a sound program of financing. In other words, the overriding question is: "Is the project, as conceived, of the type that the money can be successfully raised by voluntary investment from the savings and accumulated resources of the thrifty, or will it be forcibly extracted from the pockets of the taxpayers?" The feasibility of voluntary investment has not been demonstrated, and the available evidence only points to the latter source of money.

3. The basic issue is not "water," but "financial soundness" of the project as now conceived. The citizens are expected to decide by their vote on the financing of this project; for this purpose they should receive the essential facts from an impartial source, so that they can determine to what extent they are willing to commit themselves to the requisite tax obligations which may be required to maintain the integrity of the State's credit. The proposed project would call for the largest financial commitments ever undertaken by a State for a single project; its magnitude cannot be visualized by the voters who will be expected to express their approval or disapproval. This has placed all the more obligation on the Board of Consulting Engineers in helping to develop a competent and independent interpretation, particularly from the standpoint of "financial feasibility," (within the conventional definition). At this stage no adequate demonstration is available to show the "financial feasibility" of the project as now proposed. The adoption of a project under these circumstances would contribute to damaging the State's credit position for many years to come. In my opinion any inference, that the current proposal has been developed to a stage where the public can repose its full confidence in it, is wholly unwarranted.

In summary, I do not question the sincerity or good intentions of the engineers who have planned the Feather River-Southern California Aqueduct project. I do, however, *seriously* question the soundness of their proposals.

Both the stature of the engineering profession as well as the public confidence in the profession are under severe test. It may well be said that never before in engineering history have such great responsibilities been entrusted to a Board of Consulting Engineers. With respect to the planning of public works, a Board of professional engineers has the primary obligation of safeguarding the public interest. The public has developed a great trust and faith in the integrity of the engineering profession and this serves as a powerful challenge to merit such confidence in the future. This demands not only the impartial and competent exercise of professional skills and self-imposed disciplines, but it also demands, at times, a declaration of unpalatable truths.

In support of my position I have prepared the more detailed report which is presented in the following pages.

REPORT

By ADOLPH J. ACKERMAN

Member, Board of Consulting Engineers
Alternative Routes, Feather River—Southern California Aqueduct

December 31, 1959

In discharging my professional obligations, as I see them, on one of the greatest engineering problems ever to confront an independent consulting engineer, I feel obliged to avail myself of the privilege granted to me by my distinguished colleagues on this Board by recording my opinions and conclusions in greater detail. I consider this my obligation in serving the public interest.

Status of the Board of Consulting Engineers

When this Board was first appointed in January, 1958, there was general recognition that its members had been selected with exceptional prudence; the specialized qualifications of each member implied that all facets of the unprecedented problems in this project would receive adequate study, and that the collective judgments and conclusions which would evolve from the Board's deliberations would represent the highest level of performance within the capabilities of the engineering profession. Certainly, the public officials and the people of the State of California, as well as all the investors throughout the country who place their savings in California's undertakings, have a right to expect such professional performance. Furthermore, public assurances have been given that such professional services are an intrinsic part of the basic planning at the current stage of this project.

The comprehensive nature of the Board's assignment and responsibilities are indicated in the terms of reference which the Director addressed to the Board on January 10, 1958, and which are reproduced in the later pages. These terms of reference not only enumerate 13 specific elements of the problem, which should receive the Board's consideration, but also ''any others you deem significant.'' This statement has placed on the Board a major responsibility of determining how the resources of the engineering profession may be applied to best serve the interests of the people of the State of California during this critical stage of ''molding'' the total ''conception'' of a new project.

During the frequent meetings and field trips of the Board Members, there was evidence of a high degree of mutual confidence as well as unanimity of judgment on the basic criteria which should be considered in developing the optimum plan for a water delivery system.

It was generally assumed that during the current planning stage of this project, in which the Board participated, all of the essential alternative studies would be made and that, through a process of direct comparison, the best solution would emerge so it could be acceptably understood by all concerned; at the same time, the less promising concepts could be eliminated through the evidence of conclusive analysis. There was ample reason to expect that, with competent engineering planning procedures, such studies could be made within the available time.

The Board has examined a great mass of engineering data and reports. Notwithstanding the fact that the Board had indicated the need for certain additional studies which it considered essential before valid conclusions and recommendations could be reached, the requisite planning studies and financial analyses, unfortunately, were not placed at its disposal for adequate study before its services were terminated. As a consequence, the Board did not have the opportunity to present its independent views in time to serve as a reference during the period of legislative debate on this project. Furthermore, by allowing the Board's status to expire on June 30th, 1959 (State funds not being available beyond that date for continued services), the Board has not been in a position to write the kind of concise and conclusive independent engineering report which is traditionally expected, and which responsible officials and the general public could study before voting on this project.

Specialized Responsibilities

Within the scope of the unrestricted professional services which are commonly implied by the appointment of an independent Board of Consulting Engineers, two important issues have developed in areas which I regard as my field of professional specialization. These relate to the technical and economic problems in the field of pumping and power recovery, and to the broader problems of financing and managing the project. More specifically, in addition to some of the technical factors which have been examined, I regard the following related factors as significant in developing a soundly engineered concept for consideration by the interested citizen. These are:

a. Financial feasibility.

b. Relationship to other financing programs; total financing capacity.

c. Administrative responsibility for building and operating the project.

d. Relationships with existing agencies in the field of water supply and power.

In view of the lack of essential planning information within the area of my specialized responsibilities, I was confronted with the choice either of giving my consent and participation to a Board Report on which serious limitations have been imposed, or of recording, to the best of my ability and in greater detail, my professional judgment and opinions, based on my two and one-half years of participation in the planning of this project.

After due consideration I have chosen to exercise the privilege of presenting this report. The summary which follows is supported by a more detailed exposition in the later pages.

Summary

1. The typical citizen is seldom conscious of the tremendous resources of skill and discipline which results in the delivery of safe drinking water to his home at low cost. He has become mentally conditioned throughout his lifetime to give little or no heed to the problems of operating a water supply system, or to the problems of financing and building a major extension of additional water supply to meet the needs of a growing population. He simply places his faith and trust in the engineering profession and in the skills and disciplines which the professional engineer has vowed to apply to the best of his ability in safeguarding the public welfare. The very fact that the individual citizen has this implicit faith and confidence in the integrity of the engineering profession, serves as a powerful challenge to every engineer to merit such faith and confidence in the future.

2. The Feather River-Southern California Aqueduct as proposed would be a project of unprecedented magnitude. The planning of such a project within economic and financially sound principles is a tremendous responsibility; the significance of the combination of a new public organization and the unprecedented responsibilities with which it is confronted, must be kept in mind. A seasoned organization with a high record of performance, if given an assignment of competently planning a project only one-tenth in magnitude of the one here under consideration, would find itself hard pressed to fulfill its responsibilities in a commendable manner. Therefore, an adequate allowance of time for the planning period is a prerequisite. A hasty and inadequate performance at the planning stage would lead to confusion, waste of money and a serious loss of time at a later stage.

3. Under our system of government the citizens will be called upon to exercise their privilege and franchise of deciding whether or not the project should be authorized. The foremost questions in each one's mind are, of course: "What will this cost me?" and "What will be the price of the water?" The development of the desired answers with the supporting evidence must, of necessity, be complete and understandable in all respects, not only to the local citizen, but also to the many citizens throughout the country who might be willing to invest their savings in the State of California and in the proposed project.

4. As part of the basic planning of a major project it is essential to indicate the structure of a suitable organization or agency, which would be expected to administer such vast responsibilities. Competent administrative capacity of a high order would be required, free from political pressures, and special qualifications would be a prerequisite particularly in the areas of financial responsibility as it applies to the investor, to the consumer, to the taxpayer, and to the State's credit position.

5. In the course of developing the technical factors for this project during the past two years, the hydraulic capacity of the aqueduct, in terms of annual quantity of water delivered to Southern California, was increased somehow, and without satisfactory explanation, from 1,800,000 acre-feet to 3,499,000 acre-feet; the capacity of the aqueduct south of the Delta was raised to 8,000,000 acre-feet. All planning of project facilities was stepped up to meet hypothetical conditions assumed to prevail in the year 2020, based on estimates that Southern California's population of 8,850,000 in 1958 would increase to 28,600,000 by the year 2020.

6. Instead of determining the most economical and financially feasible "first stage" which would meet the demands for water in the foreseeable future, with provisions for expansion as and when justified by future circumstances, the concept of "global" or "total planning" of a project to meet demands in the year 2020

has been introduced. I do not consider it feasible to make a sound appraisal of a project concept based on conditions which are presumed to materialize more than a half century from now.

7. On August 4, 1958 the Board outlined its specifications of what it considered a suitable Final Report. The Board also made an evaluation of progress in the planning of the project and questioned the feasibility of completing the necessary investigations before July 1, 1959. However, on February 26, 1959 the Department published a preliminary summary known as "Bulletin 78" which the Board had declined to approve. This report subsequently served as a basis for legislation enacted in June 1959, and it has thus become a document of historical importance.

8. Engineering studies were directed to three alternative project concepts, designated as "System A," "System B" and "System C." All three systems have the common generalized objective of "bringing water from the north to the south" and of meeting all demands for water in Southern California to the year 2020. However, as described in the State's "Bulletin 78," these concepts do not include analyses of the optimum scheme of operation, and bear no relationship to a clearly defined facility as might be visualized in a railroad "system."

9. References to the Board of Consulting Engineers have been published with the implication that it has endorsed the work on "Bulletin 78." For example, one of the Department's Annual Reports states: "the best engineering talent available from outside the State's service was brought in to work with the Department engineers through a seven-man Board of Consultants."

10. Although the Board pointed out in its letter of August 4, 1958 that the pumping and power recovery studies, as outlined, must be completed before any rational decision can be made as to the most feasible route, the Department has chosen to designate "System B" as the "selected system" without having met the Board's request for studies which it considered essential.

11. Although an estimated figure of $1,807,000,000 has been indicated for the portion of the project (south of the Delta) designated "selected system B," little recognition has been given to the probability of cost increases during the coming decades, which in terms of current trends could readily increase the estimated cost of the project by 100% or more.

12. The total public expenditures (which by implication are authorized if the currently proposed bond issue of 1.75 billion dollars is approved) are likely to be several times greater, since this does not cover the total program involved in delivering 8,000,000 acre-feet per year to the service areas south of the Delta.

13. Financing of the project has been proposed by issuing general obligation bonds, with "the full faith and credit of the State of California pledged for the punctual payment of both principal and interest thereof." An examination of this proposal calls for a review of recent reports by Legislative Committees which contain such warnings as: "The existing rate of increase in the State's general obligation bond indebtedness is presently reaching problem proportions even without any bonds for water projects," and "It thus can be seen that the financial position of the State is not encouraging," and "In recapitulation, California in the 1959-60 Fiscal Year finds itself on the brink of one of its most serious fiscal crises." (For detailed references see later pages.)

14. As a means of holding the indicated cost of water at the terminal points to palatable levels, low interest rates have been assumed, and the estimated earnings have been spread out over a total payout period of 105 years. "Cost Recovery Schedules" were submitted to the Board at its meeting in Sacramento on April 24, 1959. It has been assumed that, to whatever extent 50-year bond issues reach their redemption date, without funds for such redemption being available, new bonds would be issued automatically until the payout for the entire project has been reached. This overlooks the fact that 50 years from now the State's commitments for additional public facilities cannot be visualized as to type, magnitude or capital requirements. It also ignores the harmful effect of such a policy on the marketability of all bonds for this project.

15. The estimated revenues are based on low water charges which make it impossible to absorb all the capital charges in less than 100 years. According to the "Cost Recovery Schedules," large operating deficits are shown to accrue as long as 75 years after initiation of construction. Such deficits are indicated as being met by the questionable solution of raising additional capital, apparently by issuing more bonds. A major economic setback could result in incurring even greater deficits than have been assumed.

16. As a result of these financing procedures, the debt status for the project near the end of the contemplated construction period in the year 2009 is shown to be $2.73 billion. This corresponds to 50 per cent more than the estimated $1.81 billion cost of constructing the aqueduct facilities south of the Delta. Furthermore, additional bonds would be issued, according to the tabulations, after completion of the construction program, in order to meet further operating deficits and to provide for the redemption of the earlier bond issues as they mature. As a result, the "cumulative capital requirements" reach a figure of $4.23 billion. The graphical charts in appendix A indicate how the estimates of bonded indebtedness, due to the water program as proposed, would build up on top of the State's current indebtedness, depending upon the future policy of budget balanc-

ing with respect to all other State activities. By 1990 the State debt would stand somewhere beween six and sixteen billion dollars.

17. The Department's payout tables show capital requirements for the Aqueduct Project South of the Delta increasing until the year 2040. If this is the final year in which it is proposed to issue 50 year bonds, these would mature in the year 2090, or 130 years after the start of construction of the project. With such continuous and overlapping bond commitments, the concept of committing water rights to correspond to the life of the bond issues would entail a commitment of such rights for a period of 130 years.

18. By employing prices of water and revenue estimates based on present day concepts of the value of water to the citizen and, by relating these revenue estimates to project expenditures to be made in the distant future, subject to inflationary influences, it becomes quite impossible to apply competent judgment on which to forecast the repayment possibilities on bond issues. The forecast of progressive growth in consumption of water (and in resulting revenues) have been based on the assumption that there will be no disturbing influences on the growth and general economy of the State during the 100-year period of payout. Such an assumption is outside of the range of competent judgment, and wholly unsupportable.

19. A proper correlation of financial studies would need to take account of the significant recommendation made in an Engineering Report to the State in 1955, which points out that the Oroville Reservoir Project can be deferred for a considerable period, and that a more economical pumping and power scheme (than the one given priority in Bulletin 78) can be developed through cooperation with the existing power systems.

20. For pumping the water over the Tehachapi Mountains, the Department has chosen to give preference to an unprecedented scheme which would call for the building of special steam plants. In contrast, the water could be delivered to Southern California at less cost, and at a great saving in capital investment, if the electric utilities were permitted to cooperate by supplying the pumping power, and by distributing the power recovered at the power plants. This would also assure a higher degree of dependability of the power supply, particularly in emergencies.

21. No clear demonstration has been presented that a commitment on the part of the public for a bond issue of $1,750,000,000 is needed. First of all, substantial opportunities exist for financing a major portion of the project by means of revenue bonds; it would be in keeping with sound financial planning to establish this on a realistic basis before contemplating the idea of burdening the taxpayer with a major obligation. Eventually it may become necessary to issue State obligation bonds on the order of $300,000,000 for certain elements of a well-defined first stage of the project, *provided* that the full potentialities of earnings and revenues have been identified, and *provided* that the requisite administrative structure has been established and is functioning within sound financial disciplines.

22. A serious defect in engineering analysis of the financing problems is implied in the sequence of published pronouncements regarding the size of the proposed bond issue, as reported in several numbers of a national engineering magazine. In January 1959 the proposed bond issue was announced as $658,000,000. Three months later the bond issue was reported to be $960,000,000, and in May a proposal for a bond issue of $1,750,000,000 was reported. The inference of such a range of estimates is that the financial planning for the project has been developed without regard to the recognized professional disciplines.

23. No conventional demonstration has been made of the financial feasibility or justification for the project, and no clearly engineered concept has been presented which may be considered as valid and in the public interest. Any inference at this stage that the project has had the benefit of a complete engineering study and represents the best product of the engineering profession in which the public can repose its full confidence is, in my opinion, wholly unwarranted.

24. The execution of a ''global (or total) plan of development'' under the procedures evidenced to date would result in such a concentration of responsibilities and authority as to violate the most elementary principles of sound engineering, as well as of good government and of public service.

25. At this stage the overriding problem is to guard against the possibility of public officials and taxpayers, by a simple vote, adopting unlimited commitments for themselves and for future generations, without the opportunity of examining the alternatives. Any implication that they should relinquish important rights and place them irrevocably into the hands of even the best talent which the engineering profession could offer, would not only be a reflection on the good sense of the general public, but would also constitute an exploitation of professional obligations.

DETAILED REVIEW

Water for Southern California

The past several years represent an important period in the study of water supplies in California. Based on a long record of earlier studies and inventory of water resources, several fundamental facts have been established:

(1) A shortage of water is developing in Southern California which, at the present rate of growth in consumption, is likely to reach a critical stage by 1970-75 when the remainder of the currently available water resources in that region will have been fully developed.

(2) The resources of fresh water which fall on the northern region of the State, and which are largely being wasted by drainage into the Pacific Ocean, offer an opportunity for diverting surplus waters to Southern California to meet local demands for the foreseeable future.

(3) In view of the statewide nature of the problem, the 1957 Legislature has established a Department of Water Resources to examine the engineering and economic problems involved in conducting water from the north to the south, and to determine how such a development could be carried out to best serve the public interest.

(4) "Water rights matters as they apply to the Department's responsibilities are, of course, the major concern of the Water Rights staff members. Acting under legislative directives (Section 10500, Water Code), the Department of Water Resources, in order to insure the orderly development of the State's water resources, has reserved approximately 90 per cent of the present surplus waters on the major streams of the State for use in furtherance of general or coordinated plans for development of the State's water resources." (First Annual Report, Dept. of W.R. 1956-57.)

This is a major assignment and a tremendous responsibility; the significance of this combination of a new public organization and the unprecedented responsibilities with which it is confronted must be kept in mind. A seasoned organization with a high record of performance, if given an assignment of competently planning a project only one-tenth in magnitude of the one here under consideration, would find itself hard pressed to fulfill its responsibilities in a commendable manner.

Appointment of Board of Consulting Engineers

These facts, undoubtedly, influenced the Director of the Department of Water Resources during the latter months of 1957 to appoint an independent Board of Consulting Engineers. This appointment was of historical importance in several respects:

1. The Director indicated his determination to draw on the full resources of the engineering profession in developing the basic plans for the Feather River-Southern California Aqueduct along sound and economical lines.
2. The Board was assured of the requisite freedom and independence in the exercise of its responsibilities.
3. The Board accepted exceptionally great responsibilities in examining the merits of a project of unprecedented magnitude, and in committing its professional obligations of serving the public interest. In view of the confidence generally accorded to the engineering profession, this demanded that the Board discharge its obligations within the highest standards of the profession.

Terms of Reference

On January 10, 1958 the Director of Water Resources addressed the following terms of reference to the Board:

"Under legislative directive this Department is making a comprehensive investigation to determine the best system to deliver waters of the Feather River Project throughout that portion of California lying south of Latitude 35° 45′.

"We request that the Board of Consultants review these studies from time to time, and all other pertinent data and that you report to the Director, Department of Water Resources, your opinion as to which aqueduct system would be in the best interests of the State of California and of the potential users of that water in the southern portion of this State.

"Within the limits of available funds, you are free to devote whatever time you find necessary. The staff of this Department will assist you in every way possible in your review of their studies. If at any time further studies are found necessary or desirable, please so advise me so that arrangements may be made. At your first meeting, we will advise you as to the funds that are available for the services of your Board.

"Your review and report should include consideration of the following elements of the problem and any others you deem significant:

"1. Costs of construction of each alternative system or variant.

"2. Time required for construction of each alternative system or variant.

"3. Special hazards that could affect construction costs or times for construction.

"4. Special hazards that could affect future operation of each system or variant.

"5. Power and energy requirements and feasibility of recovery of power and energy.

"6. Unit costs of transportation and delivery of water to each sub-area in excess of the cost of development and transportation of that water southerly to Latitude 35° 45′.

"7. Prices that users of water for municipal and industrial purposes could be expected to pay for water delivered to each sub-area.

"8. Prices that users of water for irrigation use could be expected to pay for water delivered to each sub-area.

"9. Growth in demand for supplemental water for domestic and industrial purposes and the sub-areas in which such demands will develop.

"10. Growth in demand for supplemental water for irrigation use and the sub-areas in which such demands will develop.

"11. Regulatory storage required for economical operation and the time and place where such storage should be provided.

"12. Integration of supplies of water of the Feather River Project with the supplies available from local sources, from the Colorado River and from other sources, for each sub-area, with particular reference to the quality of the water available from these sources and through the Feather River Aqueduct System and to operation of ground water basins.

"13. Proper points of delivery of Feather River Project water to the water supply systems of the local contracting agencies.

"It is respectfully requested that your Board furnish me within ninety days subsequent to the first meeting of the Board, your comments and advice on the studies which the staff of this Department have made to date and the current and projected work programs."

Board Activities

Following its appointment, members of the Board devoted themselves to an examination of the voluminous reports which have been developed during the past years, and to a review of current studies which were being carried out by the various engineering divisions of the Department of Water Resources.

The Board held a total of nine formal meetings and forwarded its observations to the Director of Water Resources in the form of some eighteen formal communications from the Chairman or Vice Chairman, together with various letters from individual Board members dealing with matters concerning their specialized areas of interest.

A significant step was taken by the Board when it held public hearings in Los Angeles on May 12 and 13, 1958. At these meetings official representatives from the three power agencies, from the Metropolitan Water District, and from other interested agencies submitted their preliminary views for the Board's consideration.

In its formal communication of August 4, 1958, the Board informed the Director:

"The Board is of the definite opinion that it is unlikely that it will be possible to complete the necessary investigations and prepare a final report to permit the selection of the most feasible route prior to July 1, 1959. At the same time, the Board understands the obligation of the Department to present a report to the legislature at its session during the early part of 1959. It is therefore, recommended that an Interim Report be submitted to the legislature giving a summary of progress to date and advising that the final report will be made available later in the year. This procedure would permit the completion of the pumping power and pumped storage studies as outlined and which, in our opinion, must be completed before any rational decision can be made as to the most feasible route."

In this letter, the Board also stated that:

"The Final Report submitted by the Department should, in the Board's opinion, represent the best the engineering profession can provide. It should be thorough, complete and defensible in all respects. The physical facilities as proposed and operating procedures should be sound from the standpoint of standards as applied by the many large water utilities in the State. The pumping and power features should be thoroughly coordinated with the power facilities and the resulting financial analyses should reflect probable power costs and power sales at the various aqueduct facilities. In other words, when the Final Report is released, it should embody a complete practical plan of development from sources to the service areas. The facilities should be designed to supply both irrigation and municipal water to the designated service areas in accordance with the best practices and in complete coordination with the water and power utilities."

Preliminary Departmental Report

On February 12 and 13, 1959 the Board met in Los Angeles for the purpose of reviewing a first draft of a proposed report which had been designated as "Bulletin No. 78, Preliminary Summary Report on Investigation of Alternative Aqueduct Systems to Serve Southern California".

The meeting of the Board had been called as part of the preparations for official publication of "Bulletin 78" at a public hearing on February 26 of the following week. However, advance copies of the proposed Bulletin were not available for examination during the Board meetings, and the Board adjourned without taking formal actions. Nevertheless the public hearing was held on February 26, and subsequently the Director informed the Board that "the California Water Commission by formal resolution had approved the overall concept of 'Aqueduct System "B"' (as presented in "Bulletin 78") for transport and delivery of water from Northern California to Southern California."

Shortly after this public hearing the project became the subject of active legislative consideration. On June 17, 1959 the Legislature passed a bill formalizing the project, and a proposal is to be submitted to the State electorate in November, 1960, in the form of a referendum on a bond issue of 1.75 billion dollars with which to finance the construction of a part of the project. These events, in effect, have given "Bulletin 78" the status of a document of historical importance.

Revised Terms of Reference

The Department continued with the preparation of various studies correspinding to the Board's terms of reference, and as had been requested from time to time by the Board. These studies were particularly concerned with analyses of financial feasibility of the project. However, in April the Director requested that the Board's final report be limited to the following four facets of the problem:

(a) Determination of probable future water requirements.
(b) Determination of probable time when water from Northern California will be required.
(c) Designation of areas to be served by the aqueduct to Southern California.
(d) Selection of the most favorable aqueduct system.

This request was confirmed in the Director's letter of June 19, 1959 addressed to the members of the Board.

Although I recognize the need for dealing with the realities of currently available information and of accomplished facts, I feel obliged, nevertheless, to consider myself bound by the original terms of reference. I have, therefore, sought to discharge my responsibilities as I regard them in relationship to the public interest, and in terms of a perspective from which I cannot depart.

Board Responsibilities

The Board of Consulting Engineers, in several respects, has been confronted with responsibilities of unprecedented importance. On behalf of the engineering profession the Board has had a duty similar to the obligation which the Supreme Court of the United States has in the judicial or legal area. Originally the Board was presented with the opportunity of developing a masterful report, based on an impartial analysis of all relevant factors, and of interpreting and translating a highly involved technical proposal of unprecedented magnitude into understandable language for the responsible citizen. Certainly this project is of such importance that nothing less than the best should have come forth. However, instead of this, the time limit for the Board's services was reached before it was in a position to present a conclusive report.

Planning Concept at Issue

The basic issue is this: (1) Shall a project concept be developed in which the first stage is clearly defined but of limited scope, capable of supplying the amount of water needed in the foreseeable future, financed within the limits of current abilities and means, and capable of earning realistic revenues for repayment, and with the possibilities of expansion, as may be determined by some future decision of the citizens? Or (2), shall a concept be adopted of a "global" or "total project" of unprecedented size, which is aimed at some arbitrarily chosen objective more than a half century in the future, with the attendant inability to forecast ultimate costs, prices of water, growth of demand, repayment schedules, economic stability or depressions, and similar imponderables?

Notwithstanding the fact that the first concept represents the conventional and feasible approach, the currently adopted project is based on the second concept. Such an open-ended program of public works would tax the imagination of even the most competent planning engineers, if they tried to define the broad spectrum of responsibilities which are implied in its execution. At this stage the overriding problem is to guard against the possibility of public officials and taxpayers, by a simple vote, adopting unlimited commitments for themselves and for future generations, without the opportunity of examining the alternatives. Any implication that they should relinquish important rights and place them irrevocably into the hands of even the best talent which the engineering profession could offer, would not only be a reflection on the good sense of the general public, but would also constitute an exploitation of professional obligations.

Any inference, at this stage, that the project has had the benefit of a complete engineering study and represents the best product of the engineering profession, in which the public can repose its full confidence is, in my opinion, wholly unwarranted. The execution of a "global" or "total plan of development" under the procedures evidenced to date would result in such a concentration of responsibilities and authority as to violate the most elementary principles of sound engineering, as well as of good government and of public service.

Financial Feasibility

A demonstration of "financial feasibility" of a project requires the determination of the most economical project concept in terms of a self-contained first stage, in terms of the estimated first cost, in terms of the estimated operating costs of the project, and in terms of the resulting revenues which may reasonably be expected. Such investigations are a fundamental part of the basic planning for a new project; failure to develop them would constitute a failure in professional responsibilities.

The expression "financial feasibility", when correctly applied, is one of major importance; in simple terms it means that the project will pay for itself under conventional policies of operation, and that the bonds to finance the project are saleable. However, in modern times considerable effort is being made to give this expression new definitions and interpretations which tend to undermine the entire process of project planning and financing. The financial feasibility of a sound project is readily defined, provided all of the essential factors have been presented in a fair manner. In examining an engineering report, it should be possible for any person of reasonable competence in the field of finance to satisfy himself regarding the validity of the claims of financial feasibility. In view of the considerable abuse which is practiced in the use of the term "financial feasibility", it is important to recognize that other definitions of this expression deserve examination; some may be unsupportable or deliberately misleading.

The demonstration of financial feasibility of a project, as presented in a sound engineering report, is essentially the same information which eventually appears in a prospectus at the time the bonds are offered for sale. Potential investors have developed considerable confidence in honestly prepared prospectuses and it is, of course, of greatest importance that the financial picture for this California project be presented within the limits of such accepted practice. This should have been defined in the present case for a practical first stage of development, and there is no reason for mystery or guesswork.

A study of the expected revenues from this project calls for estimating the price of water delivered to each of the various sub-areas in Southern California, as suggested in the original terms of reference. This, of necessity, requires consideration of the cost of bringing the water from Northern California to Avenal Gap, together with the cost of delivering the water southward from Avenal Gap and pumping it by the most economical means over the Tehachapi Mountains to a suitable terminal reservoir and into a primary distribution system.

The opinion has been advanced that it is not feasible to estimate the earning capabilities of a project without having contractual commitments from the prospective consumers. This, however, is not a valid claim. By developing dependable market studies, the experienced engineer is capable of making fair appraisals and estimates (for a reasonable period ahead) of all elements of a project, including revenues from water supply and from electric power.

The Department submitted a series of "Cost Recovery Schedules", one for each of the eleven service areas south of the San Francisco Delta, to the Board at its meeting in Sacramento on April 24, 1959. These schedules, or tabulations, were stated to represent "payout tables" for the project.

The purposes of these financial analyses, as stated in the Department's official report on Page VII-1 of "Bulletin No. 78", were to ascertain "(a) the financial feasibility, apart from considerations as to sources of capital investment funds, of constructing each system, (b) the portion of the total capital investment in each system attributal to delivering water to each service area, and (c) the unit cost of water delivered to various points on the systems." It should be noted that the analyses cover a period of 103 to 105 years.

For each service area, the estimated "equivalent annual cost" per acre foot of water is shown on the bottom of the corresponding tabulation. These figures (in round numbers) for all eleven service areas are also tabulated in Table 24, page VII-7 and on Page VIII-13 of "Bulletin 78".

Unfortunately, the studies of estimated costs and revenues and other elements of the financial picture, which were presented to the Board up to the time of its final meeting, were not adequate to allow sound conclusions to be reached in compliance with the original terms of reference.

The Benefit-Cost Ratio

For certain types of proposed projects attempts have been made in recent years to demonstrate their justification by means of computations which purport to show that the expected *benefits* from the project exceed the estimated *cost* of the project. Such computations are referred to as "*benefit-cost* analyses", and are claimed to indicate the so-called "economic feasibility" of a project; they are generally being introduced on projects for which it is difficult, or impossible, to demonstrate "financial feasibility" by means of conventional "*revenue-cost* analyses".

The hazard in using evaluations of benefits, instead of revenues, for justifying a proposed project, lies in the arbitrary way in which "benefits" can be evaluated and manipulated. This is a departure from the economic principles which are generally employed, and tends to weaken the protection of the public interest which is traditionally afforded by sound engineering planning. A means for exploiting the planning procedures is thus opened.

One of the principal conclusions (No. 10) stated in "Bulletin 78" is:

"This system, designated Aqueduct System 'B' in this report, is feasible of construction and operation from an engineering standpoint; is economically justified, having a ratio of primary benefits produced to costs of 2.38; and is financially feasible from the standpoint of recovery of the incurred costs, from water revenues."

Unfortunately, no demonstration of "financial feasibility" in the traditional engineering manner has been presented. Furthermore, the "benefit-cost ratio" has little significance and no direct relationship to the conventional concept of "financial feasibility."

Financing Policy

Estimates of the revenues required to liquidate the bonded indebtedness were carried forward for a period of over 100 years, without regard to the conventional concept of "financial feasibility" based on staged development and a fifty-year limit for debt repayment. Instead, it was assumed that bond issues which were limited to a fifty-year life, but which had not been fully amortized, would be reissued at maturity for an additional period of up to fifty years, without regard to the financial market or the credit position of the State at that time. Furthermore, any operating deficits encountered during the 100-year period were assumed to be met by issuing more bonds. By inference also, any limited water rights would be committed for a similar period of over 100 years.

The interest rate was assumed at 3½%, which cannot be considered a realistic basis. Although a low interest rate, below the prevailing market, helps to keep down the indicated price for delivered water, it also gives a misleadingly favorable picture of the "financial feasibility" of the project. This is equally true of the approach of considering only the "global" project, with water rates set so low that the resulting revenues would require the period for completing the bond repayments to be stretched out to more than 100 years.

A serious defect in engineering analysis of the financing problems is implied in the sequence of published pronouncements regarding the size of the proposed bond issue, as reported in several numbers of a national engineering magazine. In January 1959 the proposed bond issue was announced as $658,000,000. Three months later the bond issue was reported to be $960,000,000, and in May a proposal for a bond issue of $1,750,000,000 was reported. The inference of such a range of estimates is that the financial planning for the project has been developed without regard to the recognized professional disciplines.

"Bulletin 78" indicates that instead of dealing with a limited project calling for the delivery of 3,880,000 acre-feet of water in the ultimate plan, it is actually proposed to build a project capable of delivering 8,000,000 acre-feet; this would involve expenditures which are likely to exceed 6 billion dollars.

The question of financing such a tremendous project calls for examination of the State's other general financing requirements, its bonding capacity in the coming years, the hazards to the State's credit position, and the problems of the various local agencies which are expected to finance distribution facilities and other structures to implement the main water delivery system.

The State's Financial Position

Various Legislative reports provide valuable references for examining the financial position of the State. These have an important bearing on the problem of financing the Aqueduct Project by means of General Obligation Bonds. In the Twelfth Partial Report by the Joint Committee on Water Problems of March 24, 1959 the Committee reports on pages 12, 13 and 22:

(Page 12) "The present rate of bond sales will *double* the State's bonded indebtedness within approximately four years and thus bring it up among the top ranking states in bonded indebtedness per capita. The existing rate of increase in the State's general obligation bond indebtedness is presently reaching problem proportions even without any bonds for water projects."

(Page 13) "It thus can be seen that the financial position of the State is not encouraging. Funds for water resources development are being sought at a time when the State has a serious general fund deficiency which does not finance its existing programs. At the same time the State is already placing general obligation bonds on the market at a rate which requires careful management not to depress the market. As the latest program to be added by the State, water resources development stands in an unfavorable position with respect to funds."

(Page 22) "Great care in the authorization and timing of bond issues for water resources development, or for other purposes, will be required to preserve the State's credit position and avoid excessive interest costs. In fact, careful management will be required to permit any water project construction program to be financed".

The "Report of the Joint Legislative Tax Committee" published by the Senate of the State of California in May 1959 stated in its "Conclusions" (Page 40):

"In recapitulation, California in the 1959-60 Fiscal Year finds itself on the brink of one of its most serious fiscal crises. Governmental functions are being carried out only at the cost of an ever widening gap between revenues and expenditures. Available reserves are either dwindling or have been committed so as to leave no hope from this quarter for substantial budgetary aid beyond June, 1959. This dark financial outlook results primarily from the unparalleled population growth taken in conjunction with the necessity to match federal aid programs and the pressing need for a water program."

"Presently earmarked funds and continuing appropriations leave less than one-third of state expenditures under the direct budgetary control of the Legislature. This situation derogates the traditional and historic role of the Legislature to determine the application of the citizens' tax moneys to the problems of State. As the control of the budget function is removed from the people's elected representatives, the people are left without voice in the expenditures of their public moneys. The net effect is that when unanticipated financial demands arise, the Lgislature, restricted by earmarked funds and the semifixed demands upon the available General Fund, has little alternative, on a short term basis, but to meet the emergency by expropriating reserves or increasing taxes. Reserves are now near complete depletion and only the latter course will be available in the future."

Pumping and Power Recovery

The idea of conveying the water over the Tehachapi Mountains, to an elevation of some 3,500 ft. above sea-level, and down on the southern slope, is a valid concept, provided the most economical system of pumping and power recovery is employed. The aqueduct section known as the "Tehachapi Crossing" will represent the largest investment along the route of the aqueduct, and the choice of pumping and generating equipment for this section, with related operating procedures, requires particularly careful engineering study.

At the outset, five alternative schemes of pumping and power recovery were suggested for study. Some, obviously, had more merit than others, but it is quite feasible, for those skilled in the art, to make the requisite technical and financial analyses of the various alternatives within the available time, and to develop acceptable demonstrations of the relative merits of such alternatives, as well as of the one scheme which is superior to the others. Such an analytical process has the advantage of letting the evidence speak for itself and thereby removing any implications of personal or partisan bias.

Although my professional experiences and background in this specialized field have given me a level of judgment on which the outcome of such comparative studies could be predicted with reasonable accuracy, I consider it presumptuous to suggest that my judgment be accepted solely on faith and confidence. I preferred to rely on the outcome of the Board's specifications for carrying out such studies. If these specifications had been respected, I am confident that it would have resulted in producing conclusive evidence, to the satisfaction of all concerned, regarding the best means for conveying the water over the mountain range.

Furthermore, it should be noted that, in an Engineering Report made for the State in 1955, this problem was examined with considerable care. The most obvious technical solution, namely, a pumping scheme utilizing off-peak electrical energy from the utility systems, combined with on-peak generation of energy in the power recovery plants on the south side of the mountains, and return of the resulting energy to the utility systems, was shown to offer several important advantages: Firstly, the net cost of the energy required for conveying the water across the mountain range can be reduced substantially below the cost involved in other alternatives; and secondly, this, in turn, contributes to a lower cost for the delivered water. Although some increase in the size and cost of the water passageways is required in the ultimate stage for such intermittent operation, together with other provisions to assure maximum dependability of operation for such an interchange of electrical energy, subsequent studies during the past two years have demonstrated the feasibility of incorporating such provisions without losing the advantages previously mentioned. In the course of these studies the managements of the utility systems have displayed a highly cooperative attitude in seeking a solution which will best serve the public interest.

It is difficult to understand why a scheme, with the fundamental advantages and economies as forecast in the Engineering Report of 1955, has been displaced by a new proposal which involves a questionable concept of pumping, without acceptable precedent, together with the idea of the State building its own steam boiler plants.

A plan for taking advantage of the tremendous resources of power supply from the California utility systems would contribute not only to a reduction in the cost of water delivery, but also to a reduction in capital costs by eliminating the construction of special steam facilities. Furthermore, a supply of power from the existing utility systems has considerably greater dependability, since a great diversity of power sources would be available, along with the organizational resources, with which to meet any emergency. To whatever extent such a cooperative system of operation contributes to the reduction in the cost of delivery of water, and to greater reliability of service, the utility systems should be given the opportunity to participate in the program. However, contrary to this, the economic potentialities in this respect have not been given full consideration in ''Bulletin 78''.

An adequate solution of the ''Tehachapi Crossing'' problem, in terms of the best technical and operating features for pumping and power recovery, and in terms of optimum economics and financial feasibility, was called for by the Board in its letter of August 4, 1958. These studies were considered by the Board as a prerequisite ''before any rational decisions can be made as to the most feasible route''.

Administrative Responsibilities

A very important factor in developing a new project concept is the organizational plan for managing the financing and construction of the project as well as its ultimate operation. This has a direct bearing on the ultimate cost of delivered water to the service areas. A number of large public agencies in various parts of the United States provide a pattern of competent administration and operation of similar projects. Through a long-standing record of good performance and service, substantially free of political controls, such agencies have demonstrated their capabilities and sense of responsibility to the public as well as to the investors.

Although this question of a most suitable type of administrative agency received limited consideration for the present project, it appears to be of such basic importance that its further examination should be given highest priority.

APPENDIX "A." FORECAST OF BONDED INDEBTEDNESS

(Due to California Water Plan) State of California

In order to illustrate the impact which the currently proposed Water Plan would have on the State's financial position, the relevant data have been assembled and are presented graphically in Charts No. 1 to 4. (It should be noted that Charts No. 3 and 4 are hypothetical studies, without regard to the probability of future modifications in financing policies. Their purpose is to show the implications of current proposals for financing the Water Plan.)

Chart 1. *Annual Tax Collections and Borrowings*

The lower line shows ''Annual Tax Collections'' from 1945 to 1959, corresponding to data presented in the California Budgets of 1957-58 and 1958-59. Annual tax collections have increased from less than 0.5 to more than 2.0 billion dollars in the past 14 years. However, since 1946 tax collections have been insufficient to meet annual obligations. The general obligation bonds which have been issued each year to obtain the additional funds required to meet financial commitments are shown by the shaded area, while the upper line shows the annual financial commitments.

Before 1945 a policy of balancing budgets by means of tax collections had been in effect; in fact, the total bonded debt was reduced by 40 per cent between 1940 and 1945. Beginning in 1946, this trend was reversed, with general obligation bonds being sold each year in increasing amounts. At present, the rate of borrowing through the sale of general obligation bonds is $310,000,000 per year.

According to a U. S. Department of Commerce Bulletin of March 31, 1959, the State of California borrowed more money in 1958 than did any other State in the Union, namely, $337 million. In round figures this amounted to more than twice the borrowing of the next-highest state, New York; four and one-half times that of each of the next three highest states, Pennsylvania, Illinois, and Texas; and nearly twelve times that of the state of Michigan.

Chart 2. Trends of Bonded Indebtedness, Population and Per Capita Bonded Indebtedness

The growth in debt due to borrowing by issuing general obligation bonds is shown by the line AB, ''Cumulative Bonded Indebtedness''. From 1945 to 1959, the debt has increased, in round figures, from $100 million to $1,700 million, or to 17 times the 1945 figure. By comparison, the relative rate of growth in California's population, which is generally considered as spectacular, is shown by the lower dotted line. From 1945 to 1959 the population has increased from 8.5 million to 15.3 million, or to 1.8 times the 1945 figure.

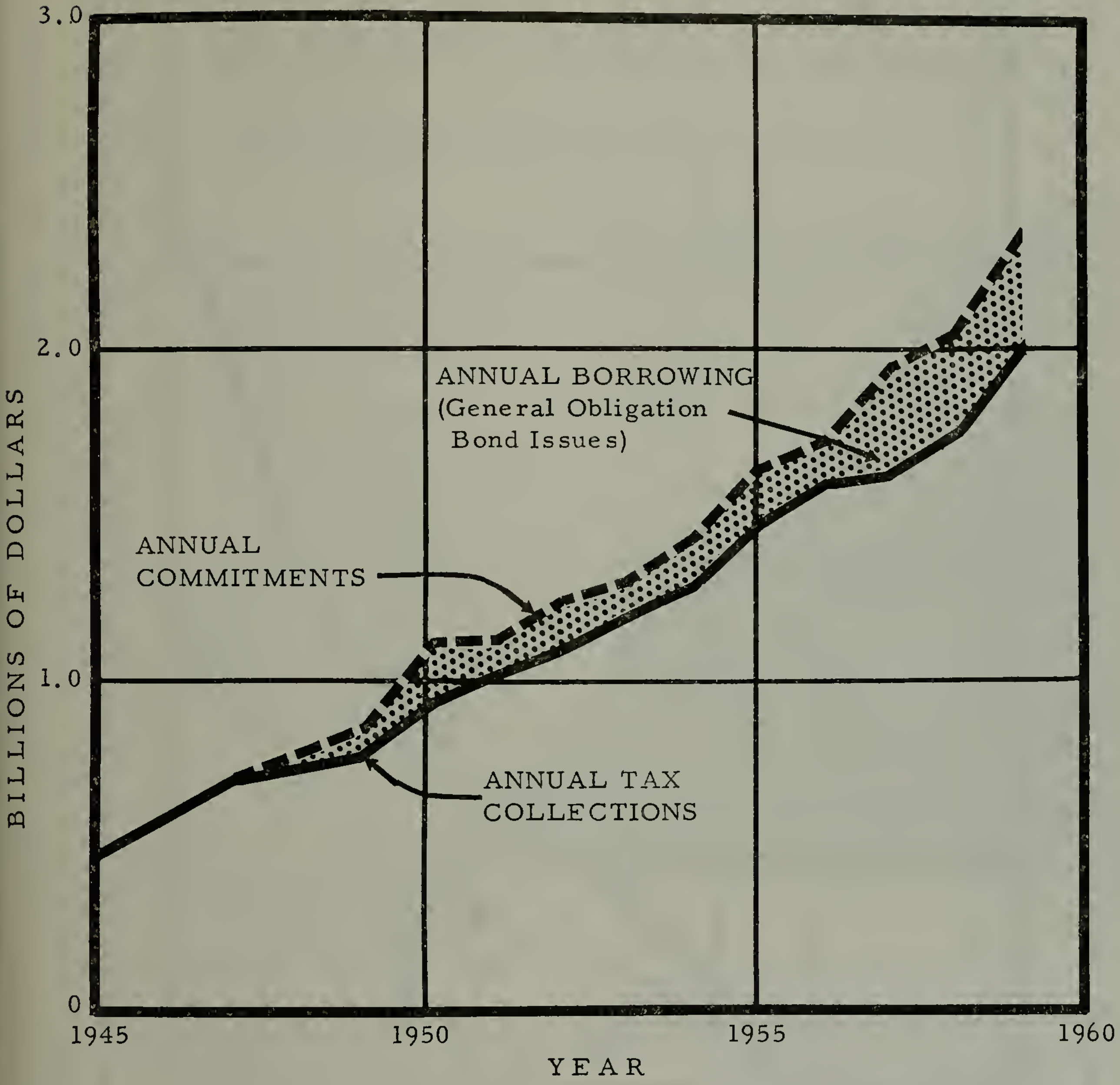


CHART 1

ANNUAL TAX COLLECTIONS
and
BORROWING

Dec. 31, 1959

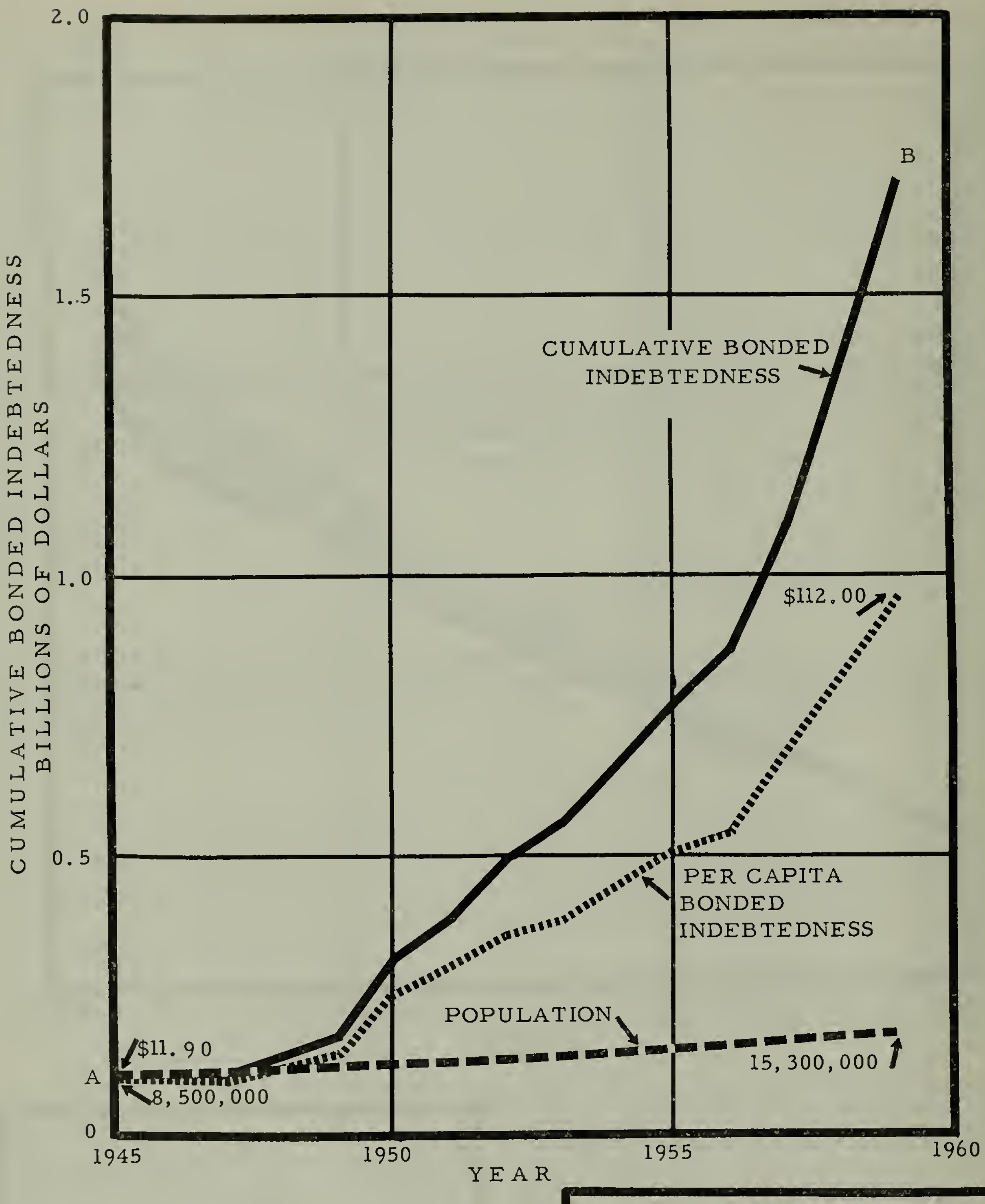
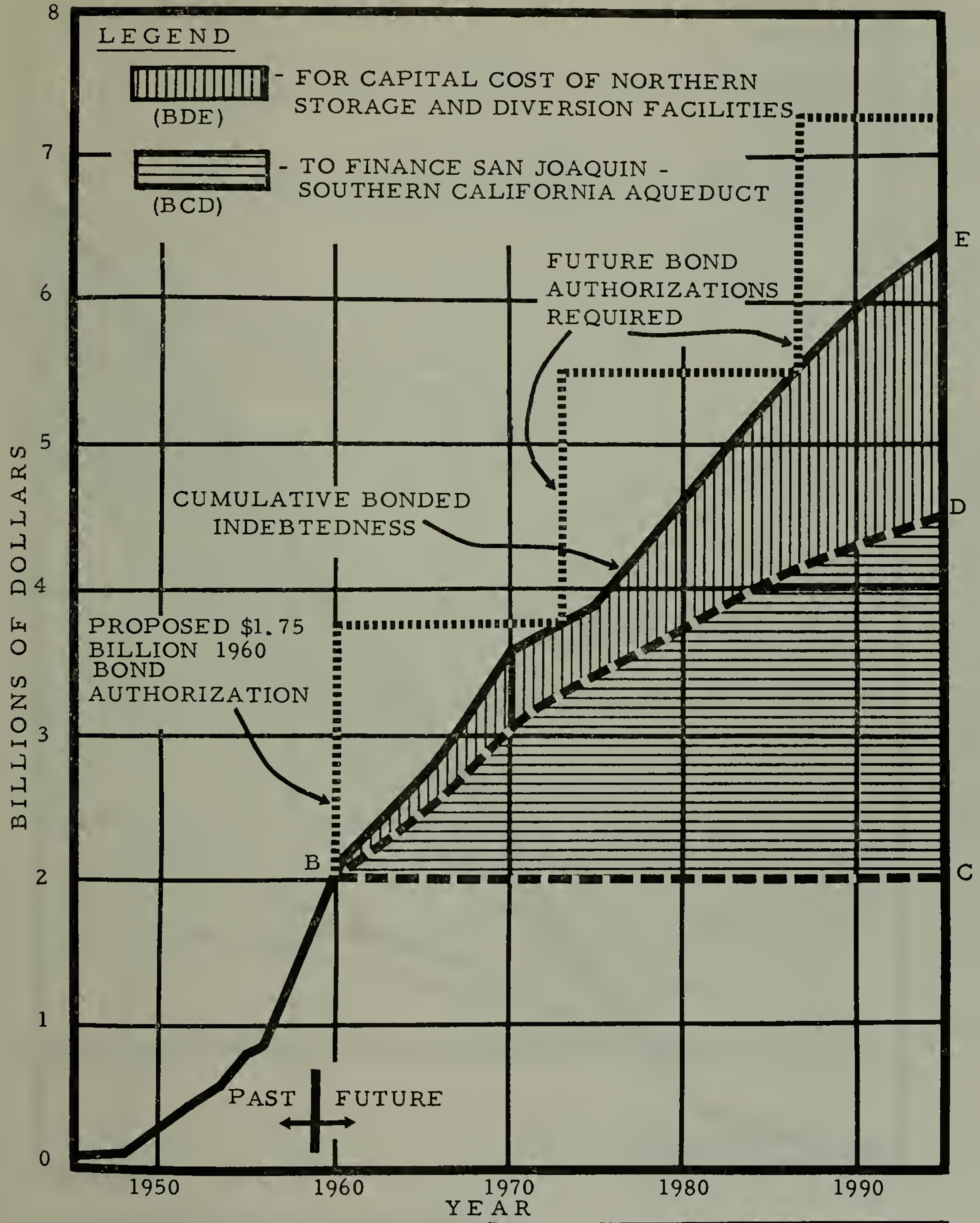
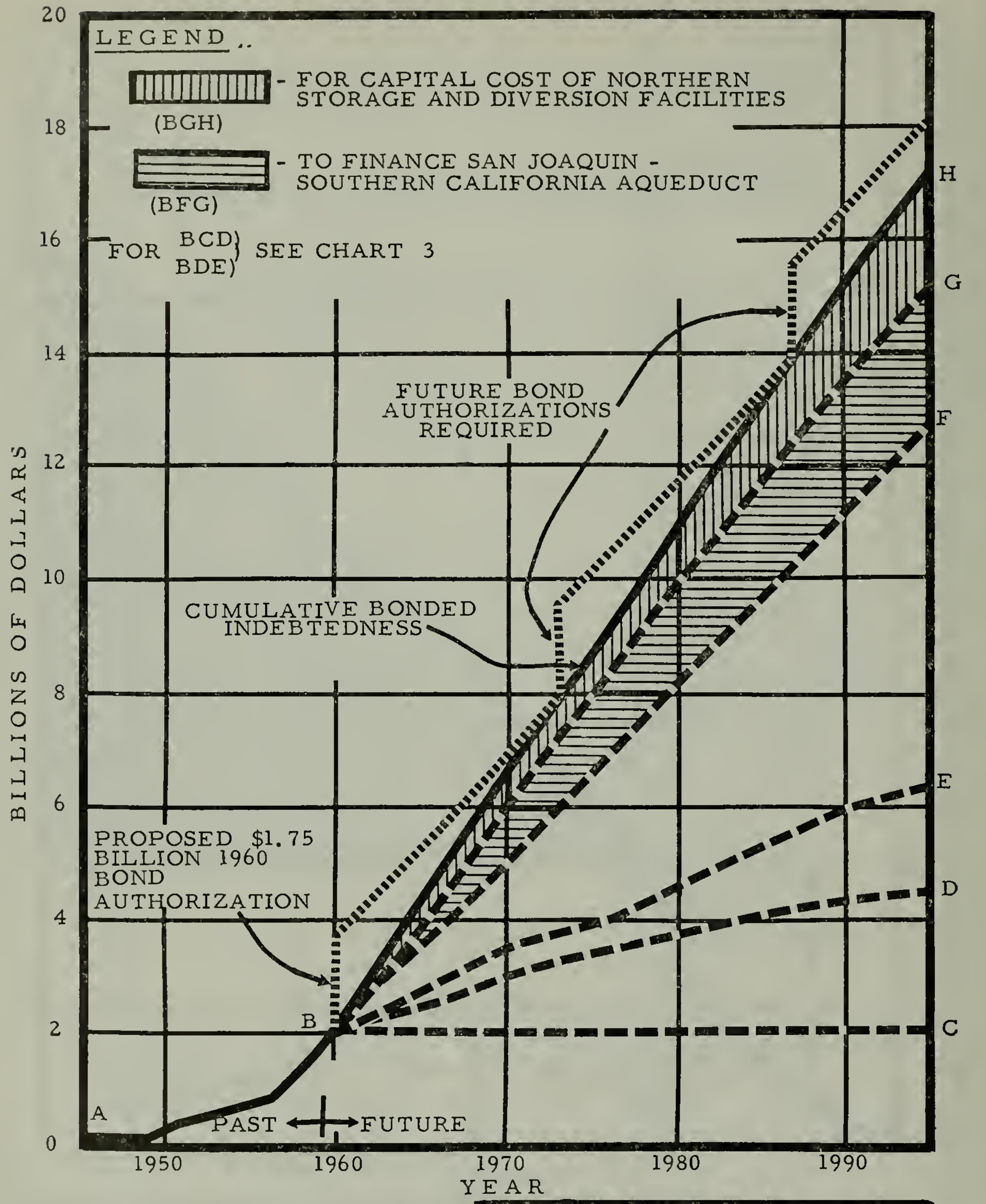


CHART 2
TRENDS IN POPULATION,
BONDED INDEBTEDNESS
and
PER CAPITA BONDED DEBT
Dec. 31, 1959



NOTE: Assuming tax revenues increased after 1960 to meet all State Obligations except for water plan. (See line BC)

CHART 3
FORECAST OF CUMULATIVE BONDED INDEBTEDNESS FOR STATE WATER PLAN
Dec. 31, 1959



NOTE:

Assuming new bonds issued after 1960 in current annual amounts to supplement tax revenues for meeting all State obligations apart from Water Plan. (See line BF)

CHART 4
FORECAST OF CUMULATIVE BONDED INDEBTEDNESS
for
STATE WATER PLAN
Dec. 31, 1959

In other words, since 1945, the bonded debt has increased at a considerably greater rate than the population. This is illustrated by the middle line, "Per Capita Bonded Indebtedness" which shows that by 1959 the per capita debt had increased to a point 9.4 times the 1945 figure.

In this connection Mr. Robert Harkness, Chief of the State's Budget Division, Department of Finance, stated on January 29, 1958: "The present rate of bond issues will double the State's bonded indebtedness within approximately four years and thus bring it up among the top ranking states in bonded indebtedness per capita." He also pointed out that: "The existing rate of increase in the State's general obligation bond indebtedness is presently reaching problem proportions even without any bonds for water projects."

The statement by the Los Angeles Panel of Financiers on November 13, 1957 is also significant: "- - - The big supply of State of California general obligation bonds with large and frequent offerings has pushed up the interest rate. This has also increased interest costs on bonds of California cities and districts. Some investors have their portfolios pretty full of State of California bonds, and they are loath to buy more except at liberal interest rates. Investors generally like diversity in their bond portfolios. A large supply of bonds does affect the market and the interest rate." (See Subcommittee Report on Policies for Water Projects, Joint Committee on Water Problems. March 24, 1958. Page 13.)

Chart 3. Forecast of Cumulative Bonded Indebtedness for State Water Plan
(See note on page 46)

(Based on assumption that tax collections would be increased after 1960 to meet all State obligations except for the Water Plan)

Chart 3 shows a forecast of total bonded indebtedness which would be incurred under the assumption that after 1960 no issues of general obligation bonds would be required except for the financing of the proposed Water Plan. This would require an increase in annual taxes of about $310,000,000.

The line AB from Chart 2 is reproduced in the lower left of Chart 3 to show bonded indebtedness since 1945. The bonded debt is expected to reach $2.02 billion in 1960. The line BC represents the assumption of no increase in debt after 1960 for financing of State programs other than the Water Plan.

New issues of general obligation bonds which would be required to finance the San Joaquin-Southern California Aqueduct south of the Delta are represented by the line BD. These bond issues would cover capital costs of construction "plus operating deficits." (Note: Data for this part of the Water Plan were taken from eleven "Cost Recovery Schedules" or financing analyses of Aqueduct System "B", which were presented to the Board of Consulting Engineers in Sacramento on April 24, 1959. Assumed costs per acre-foot of delivered water as used in these tables, are reproduced to the nearest dollar on pages VII-7 and VIII-13 of "Bulletin 78"; these unit costs of water apparently served as the basis for the Department's estimates of future water demands and deliveries. Thus, on page VIII-14 it is stated "Since water deliveries from the aqueduct system were adjusted to the rates of economic demand for water that will occur at the foregoing costs, and since full recovery of invested capital with interest was achieved from water revenues over the postulated period of 50 years for each stage of aqueduct construction, the aqueduct system from this standpoint is considered financially feasible.")

Still more bond issues, represented by the increase in debt between curves BD and BE, would be required to finance construction of the Northern storage and diversion facilities which are required to augment the supply of water for the aqueduct. (Data for this part of the Water Plan were obtained from the brochure, "Water—Today and Tomorrow" published by the Department of Water Resources in 1959.)

These various bond issues would increase the bonded indebtedness, in round figures, from $2 billion in 1960 to $6 billion in 1990. It is to be noted that during the next 30 years three water bond issues, of $1.75 billion each, would be required to finance the water program as proposed in the references cited above.

Chart 4. Forecast of Cumulative Bonded Indebtedness for State Water Plan
(See note on page 46)

(Based on assumption that new bonds would be issued after 1960 in current annual amounts to supplement tax collections for meeting various State obligations in addition to the Water Plan)

In the lower portion of Chart 4 (to a compressed scale) the curves AB, BC, BD, and BE which were presented in Chart 3 are reproduced for comparative purposes. In the upper portion of Chart 4, the effect of continuing the current policy of borrowing is projected into the future.

In this case, it is assumed that issuance of general obligation bonds at the present rate of $310 million per year would be required in the future for State obligations other than the Water Plan. This would result in a total debt amounting to $11.3 billion in 1990, as indicated by the line BF. Above this would be superimposed the borrowing necessary to finance the Water Plan as described for Chart 3, which would bring the total bonded indebtedness to the amounts indicated by the line BH. The combined result would be to increase the State's bonded indebtedness, in round figures, from $2 billion in 1960 to over $15 billion in 1990.

STATEMENT IN REPLY TO MINORITY REPORT

The minority report prepared by Adolph J. Ackerman, member of the Board of Consultants, was received by the Department of Water Resources on January 8, 1960. A review of Mr. Ackerman's report indicates that it contains several mis-statements as related to the final edition of Bulletin 78, to present statutes and to the bond issue bill (the Burns-Porter Act, Chapter 1762, Statutes of 1959), notably:

1. The letter of January 10, 1958, from the Director of Water Resources to the Board, quoted in full in Mr. Ackerman's report, sets forth the purpose, scope and areal coverage of the Board's activities. The letter of June 19, 1959, from the Director to the Board, also quoted by Mr. Ackerman, was in response to the Board's request for clarification on several points. Six members of the Board considered the June 19, 1959, letter as the clarification which had been requested by the Board, not as a change of instructions. It will be noted that at no time was the Board of Consultants asked, *nor did the Board itself ask,* to give consideration to the feasibility of any of the facilities to be located north of Avenal Gap (approximately 35°, 45′ north). These facilities include Oroville Dam, Reservoir and Power Plants; the Upper Feather River Basin Features; the Delta Water Project; the North Bay Aqueduct; the South Bay Aqueduct; San Luis Dam and Reservoir; the Delta to San Luis Canal; the San Luis Canal; the Pacheco Pass Tunnel Aqueduct; and the San Joaquin Valley Drainage System. These features are all encompassed within the State Water Facilities to be financed under the Burns-Porter Act, but are not within the purview of Bulletin 78.

2. As indicated by Conclusion No. 16 of Bulletin 78,

> "Pending further study none of the operational schemes evaluated or referred to in the Bulletin should be considered adopted features of the San Joaquin Valley–Southern California Aqueduct System",

the Department of Water Resources is fully aware of the need for additional studies to determine the most feasible method of pumping and power recovery, contrary to Mr. Ackerman's statement. Attention is also invited to the statements appearing on pages 53 and 54 of Bulletin 78 relating to this general subject. Six members of the Board of Consultants considered that the work accomplished by the Department of Water Resources, supported by special consultants for review of pumping plant design, was sufficient to select the most feasible *route* for the San Joaquin–Southern California Aqueduct System.

3. Conclusion No. 11 in Bulletin 78 states:

> "This optimum aqueduct system is adaptable to stage construction over a 55-year period consistent with the buildup of economic demand for water therefrom."

Mr. Ackerman has failed to acknowledge this conclusion in stating that:

> "Instead of determining the most economical and financially feasible 'first stage' which would meet the demands for water in the foreseeable future, with provisions for expansion as and when justified by future circumstances, the concept of 'global' or 'total planning' of a project to meet demands in the year 2020 has been introduced."

4. The cost recovery schedules, referred to by Mr. Ackerman as having been submitted to the Board on April 24, 1959, were preliminary in nature and, responsive to the recommendation of the Board, are not included in Bulletin 78. Financial analyses of aqueduct systems A, B, and C, as presented herein in Tables 28, 29, and 30, respectively, do not propose the large operating deficits as implied by Mr. Ackerman.

5. Statements made by Mr. Ackerman relating to (1) the cost of all aqueduct and regulatory works south of the Delta, (2) the facilities to be provided by the proposed $1.75 billion bond issue, and (3) the ability of the State of California to assume an additional bonded indebtedness of $1.75 billion are not within the scope of the studies reported in Bulletin 78, nor are they within the scope of study for which the Board of Consultants was retained. Analyses of such factors require data and information beyond that presented in Bulletin 78 and *beyond that requested by the Board or any member thereof.*

6. Mr. Ackerman's analyses presented in Appendix A "Forecast of Bonded Indebtedness" of his report appear to be based upon information which he did not obtain nor request from this Department and which is completely at variance with the terms of the Burns-Porter Act, the California Water Fund Act, the Davis-Grunsky Act, the present requirements for repayment as set forth in the Water Code, and with the policies adopted by the State for financing and repayment of the State Water Facilities.

Harvey O. Banks

HARVEY O. BANKS
Director

REPORTS OF CONSULTANTS FOR REVIEW OF PUMPING PLANT DESIGN

June 25, 1959

Mr. Harvey O. Banks, Director
California Department of Water Resources
Post Office Box 388
Sacramento 2, California

Dear Mr. Banks:

In accordance with a request made by you in July, 1958, the undersigned consultants, Dr. A. G. Christie and Professor A. Hollander, jointly and in cooperation with the engineering staff of the Department, have studied the possible application of steam turbines for driving pumps for the Feather River and Delta Diversion Projects. Special attention was given to the study of turbine drive at Pumping Plant In-VI, because the combination of large capacity requirement and very high operating head at this plant gave promise of an installation possessing both simplicity of design and good operating economy.

Comments on the merits of steam-drive for Pumping Plant In-VI were submitted in individual letters, Dr. Christie's letter of October 9, 1958, concentrating on discussion of the steam turbine application and Professor Hollander's letter of October 1, 1958, concentrating on the pump application. Opinions as to the practicability and expected reliability of the application were expressed in these letters, and subsequently confirmed by design studies and development of a suitable pump layout by the Byron Jackson Company, as follows:

(1) Single-stage centrifugal pumps for the required combination of very large capacity and high head have not been built heretofore, and it will therefore be necessary to conduct developmental work and extensive model tests to optimize hydraulic and mechanical features. Such model tests would be required regardless of the prime mover employed, whether it be a steam turbine or an electric motor.

(2) Pumps of design, operating head, and characteristics similar to those required for the steam-drive application have been produced in sizes greater than 5000 Horsepower and are in service today. Test data taken from these pumps have been used to predict, by the application of well-established principles, the performance of a pump of the required characteristics. There is no doubt as to the engineering feasibility of such a pump.

(3) Steam turbines are well suited as prime movers for pumps and may be expected to show a high degree of reliability in such service.

(4) Steam turbine equipment for the operating conditions contemplated would represent no radical departure from previous constructions.

(5) Auxiliary equipment associated with the pump and the steam turbine would be of conventional design.

In summary, it is stated that the major components, as well as the auxiliary equipment, for a steam-drive installation at Pumping Plant In-VI are considered quite practicable of design and construction. The opinion is confidently expressed that the contemplated combination of these components would give an entirely satisfactory operating installation.

Very truly yours,

/S/ A. G. Christie
Consultant on Steam Turbine Applications

/S/ A. Hollander
Consultant on Pumping Equipment Applications

Byron Jackson, Division of Borg-Warner Corporation
P.O. Box 2017, Terminal Annex, Los Angeles 54, California, U.S.A.

July 2, 1959

Mr. Harvey O. Banks, Director
California Department of Water Resources
P. O. Box 388
Sacramento 2, California

Subject: Feather River Project
Station VI Pumping Equipment
State Agreement #250189
Byron Jackson Order # L-338953-A

Gentlemen:

Under the terms of subject order Byron Jackson was directed to assist in the selection of pumps suited for the proposed direct steam-drive pumping application at Pumping Plant VI of the Feather River Project acqueduct; (sic) make alternative designs and estimate costs and weights of pumps; and prepare layout drawings of the pumping equipment and appurtenances thereto.

Under date of February 6, 1957 a preliminary letter was forwarded, reporting on a number of discussions held with representatives of your office, and stating that a completely successful design could be produced for the outlined conditions. This statement was predicated upon the accomplishment of an exhaustive model investigation of the many and varied problems involved.

Design studies have been carried out to assist in pump selection, preliminary design and layout, preliminary cost and weight estimates, and station layout.

After some preliminary work in which tentative designs were suggested for both the high head pumps and their vertical suction boosters, models were selected from among our many pump designs. It was then possible, by factoring, to make hydraulic layouts, select impellers, and predict hydraulic performance.

Weights, pattern costs, casting, fabricating, and machining costs have since been calculated or estimated. This information will be forwarded to you within a week.

Performance curves PC 25098 and PC 25099 showing anticipated performance of the suction boosters and the high head pumps are enclosed. The single suction specific speeds (in GPM units) of the vertical booster of 1925 rpm, and the high head pump of 1805 rpm are optimum. Efficiencies shown on enclosed curves are the minimum expected for models.

Outline drawings showing the High Head Pump dimensions (Dwg. 2E 1585), and the Suction Booster and High Head Pump (Dwg. 2F 866) are also enclosed.

In our study of this problem, an effort has been made to recommend the combination of pumps best suited to this particular installation. This requires a medium-head vertical booster pump at relatively slow speed to produce the NPSH required by the high head turbine-driven unit.

A unique casing design has been suggested for the high head unit to permit the use of reasonable sections, simple bolting, and fully confined, circular gaskets, while at the same time permitting high test pressures without danger of leakage or rupture.

As pointed out in our letter of February 6, 1959, and reiterated above, the scope of this problem is such that it should be studied in great detail by the use of homologous models. In addition to head, capacity, and power, numerous details should be thoroughly investigated on the model level.

It is emphasized that extensive model work is required for all pumping projects of any considerable size, especially where previous work can not be applied directly. This would be true regardless of the type of driver used.

We again offer our cooperation and facilities as may be required to produce models and perform required tests.

Very truly yours,

Byron Jackson Division
Borg-Warner Corporation

/S/ Carl Blom
Vice President and Manager of Engineering

Los Angeles, California
March 27, 1959

Mr. Harvey O. Banks, Director
Department of Water Resources
P. O. Box 388
Sacramento 2, California

Dear Mr. Banks:

As members of your Engineering Advisory Committee on the Feather River Project Alternative Aqueduct Route Studies, we have been pleased to periodically review the progress made by your engineers and economists on these studies. We have regarded this opportunity to serve as a distinct privilege. Our participation has been as individual engineers familiar with the water field and acquainted with the various local areas of interest. The personnel of your staff have been most cooperative in working with and considering the expressed objectives of the Committee.

The Committee has found the engineering principles and criteria used by the staff to be sound. The frequent meetings with your staff have developed our understanding of the bases of the report so it is with great confidence that we endorse Bulletin No. 78, "Preliminary Summary Report on Investigation of Alternative Aqueduct Systems to Serve Southern California", February, 1959. This Committee agrees with findings of the report that Aqueduct System B is the most economical means of serving water to areas south of Avenal Gap.

We thank you for the privilege of serving on your Committee.

Very truly yours,

Louis J Alexander
Louis J. Alexander, Chief Engineer
S. C. Water Company, Los Angeles

Paul Bailey
Paul Bailey, Consulting Engineer
Orange County Water District

R. H. Born
Robert H. Born, County Hydraulic
Engineer, San Luis Obispo County

Paul Beermann
Paul Beermann, Dir. of Public
Works, City of San Diego

Doyle F. Boen
Doyle F. Boen, Gen. Mgr. and Chf.
Engineer, Eastern Mun. Water Dist.

E. F. Dibble
E. Fitzgerald Dibble, Consulting
Engineer, San Bernardino Municipal
Water District

G. L. Henderson
George L. Henderson,
Consulting Engineer, Bakersfield,
Kern County

Julian Hinds
Julian Hinds, Consulting Engineer
United Water Conservation District
Santa Paula

Richard S. Holmgren
Richard S. Holmgren, General
Manager and Chief Engineer, San Diego
County Water Authority

Henry Karrer.
Henry Karrer, Consulting Engineer
Kings River Water Conservation Dist.

Norman H. Caldwell
Norman H. Caldwell, County Director
of Public Works, Santa Barbara County

Wm S. Peterson
William S. Peterson, Gen. Mgr. and
Chief Engineer, Department of Water
and Power, City of Los Angeles

Brennan S. Thomas
Brennan S. Thomas, Gen. Mgr. and
Chief Engineer, Long Beach

Albert A. Webb
Albert A. Webb, Consulting Engineer,
Western Municipal Water District
of Riverside County

BULLETIN NO. 78

FEATHER RIVER AND DELTA DIVERSION PROJECTS

INVESTIGATION OF ALTERNATIVE AQUEDUCT SYSTEMS

TO SERVE SOUTHERN CALIFORNIA

CHAPTER I

INTRODUCTION

Since the original authorization by the Legislature in 1951 of the Feather River and Delta Diversion Projects as the initial units of The California Water Plan, a question has prevailed with respect to the route, or routes, by which water from the projects should be delivered to the vast and and ever-growing metropolitan areas of southern California. Basically, this question is centered around the selection of one of two general aqueduct locations, either an inland alignment with a relatively high pumping lift required to cross the mountains at the southern end of San Joaquin Valley, or a lower level coastal alignment extending from the San Joaquin Valley near the Kings-Kern County line through San Luis Obispo, Santa Barbara, and Ventura Counties, and into Los Angeles County.

Other related matters affecting southern California, over which questions have been raised, include: the time when additional imported water will be needed and how rapidly this water will be utilized once it has been introduced; the ability of project beneficiaries to pay for surplus northern California water; water service to the various portions of southern California with construction of one or another of the routes; the availability and cost of energy for pumping; the possibility of recovering a portion of the energy consumed in pumping; and the feasibility of bringing water from the Delta to southern California from financial and economic standpoints. Further, the extensive and dynamic growth experienced in southern California since 1951, in itself, has dictated a re-evaluation of the Feather River and Delta Diversion Projects as they relate to this area.

Commencing in fiscal year 1956-57, the Department of Water Resources, under legislative authorization and appropriations, undertook a detailed investigation of alternative aqueduct routes to southern California to supplement and extend prior work on this problem. The investigation was designed to provide answers to the foregoing questions, and, from engineering and economic analyses, to determine the proper location and capacity of aqueduct facilities to serve surplus northern California water to southern California.

AUTHORIZATION FOR INVESTIGATION

Statutory authorization of the Feather River and Sacramento-San Joaquin Delta Diversion Projects is contained in Division 6, Article 9.5 of the California Water Code, which is quoted as follows:

> "11260. The units set forth in publication of the State Water Resources Board entitled 'Report on Feasibility of Feather River Project and Sacramento-San Joaquin Delta Diversion Projects Proposed as Features of the California Water Plan,' dated May, 1951, as modified in the publication of the Division of Water Resources entitled 'Program for Financing and Constructing the Feather River Project as the Initial Unit of the California Water Plan,' dated February, 1955, and including the upstream features set forth in Chapter VI of the 1955 report, except the features on the south fork of the Feather River, *subject to such further modifications thereof as the department may adopt*, and such units or portions thereof may be constructed by the department and maintained and operated by it to such extent and for such period as the department may determine, as units of the Central Valley Project separate and apart from any or all other units thereof." (Emphasis supplied.)

This investigation was authorized and funds provided therefor by the California State Legislature in Item 419.5 of the Budget Act of 1956, which is quoted in part as follows:

> "419.5—For surveys, explorations, investigations, preparation of construction plans and specifications; surveys of, negotiations for, and acquisitions of, rights of way, easements, and property, including other expenses in connection therewith, for the Feather River Project, as authorized by Section 11260 of the Water Code and as modified by the report of the Division of Water Resources of February, 1955, entitled 'Program for Financing and Constructing the Feather River Project,' and as may be modified subsequently, Water Project Authority___ 9,350,000
> provided, that this appropriation shall remain available for expenditure until June 30, 1960; provided further, that, notwithstanding any other provisions of law, the appropriation made by this item may be expended to reimburse the Division of Water Resources Revolving Fund for expenditures incurred prior to July 1, 1956, which may be properly chargeable to this item; provided further, that $3,550,000 of this item shall be used only for engineering and exploration work, and for acquisition of reservoir sites for the Alameda-Contra Costa-Santa Clara-San Benito branch aqueduct in Alameda, Contra Costa, Santa Clara and San Benito Counties; provided further, that $500,000 of this item shall be used only for studies of alternative coastal aqueduct routes; provided further, that $200,000 of this item shall be used only for studies of alternative aqueduct routes to San Diego County; provided further, that $200,000 of this item shall be used only for location studies, surveys, engineering and exploration work for an aqueduct to service areas within west and south San Joaquin Valley, including Kern County . . ."

The Governor's budget, as submitted, which was the basis for the afore-mentioned Budget Act, had requested an amount of $197,900 from the foregoing $9,350,000 appropriation for exploratory and investigational work on alternative routes for the San Joaquin Valley-Southern California Aqueduct through the Tehachapi Mountains (Inland Route).

Additional funds for continuation of the investigation were provided by the Legislatures of 1957 and 1958.

Item 417 of the Budget Act of 1957 is quoted as follows:

> "417—For studies, investigations, geologic exploration including other necessary expenses to determine the best and most economical aqueduct routes for the delivery of water to the lower San Joaquin Valley and Southern California, Department of Water Resources, payable from the Investment Fund ....$673,000"

Item 425 of the Budget Act of 1958, which is quoted in part as follows, appropriated a total of $3,723,672.

> "425—For surveys, explorations, investigations, preparation of construction plans and specifications; surveys and negotiations for rights-of-way, easements and property, including other expenses in connection therewith, for the Feather River Project, as authorized by Section 11260 of the Water Code . . ."

Of the above amount, $760,000 was budgeted for the completion of the aqueduct studies.

In connection with the original appropriation in 1956, the Legislature approved Senate Concurrent Resolution No. 19 pertaining to studies of aqueduct routes to San Diego County, which is quoted as follows:

> "WHEREAS, The Division of Water Resources of the Department of Public Works has under consideration and study the selection of alternate aqueduct routes to San Diego County in connection with studies being made of the Feather River Project; now, therefore, be it
>
> "*Resolved by the Senate of the State of California, the Assembly thereof concurring,* That the Division of Water Resources is requested in connection with its study to consider possible routes for such an aqueduct through San Bernardino County and Riverside County and to report thereon to the Legislature at its 1957 Regular Session; and be it further
>
> "*Resolved,* that the Secretary of the Senate send a copy of this resolution to the Division of Water Resources and to the Director of Public Works."

The funds provided for the investigation of alternative aqueduct routes to southern California are summarized in the following tabulation:

Budget Act of 1956	
Alternative Aqueduct Routes to San Diego County	$200,000
Alternative Coastal Aqueduct Routes	500,000
Engineering and exploration for an aqueduct to service areas in San Joaquin Valley	200,000
Engineering and exploration for aqueduct routes through Tehachapi Mountains	197,900
Subtotal	$1,097,900
Budget Act of 1957	
Studies and investigations to determine most economical aqueduct routes for delivery of water to San Joaquin Valley and southern California	$673,000
Budget Act of 1958	
For completion of studies and investigations and preparation of the final report on most economical aqueduct route or routes for delivery of water to San Joaquin Valley and southern California	$760,000
Total	$2,530,900

RELATED INVESTIGATIONS AND REPORTS

The investigation of alternative routes for the San Joaquin Valley-Southern California Aqueduct is intimately related to and in effect a continuance of certain prior investigational work of the former Division of Water Resources and other State agencies on water problems and water resource developments in the State. Reports and data available from these investigations were utilized in the preparation of this report. Use was also made of pertinent material and data contained in reports of other agencies.

The California Water Plan

The unprecedented development of California, with attendant increases in demands for water during World War II and the years immediately following, served to stimulate public concern over the State's water supply problems. The California State Legislature, in recognition of the growing statewide water problems, by Chapter 1541, Statutes of 1947, directed the State Water Resources Board to conduct an investigation of the water resources of California, designated the "State-wide Water Resources Investigation". Funds were provided in the 1947-48 budget for commencement of the investigation and additional funds were provided through 1955 by subsequent Legislatures.

The "State-wide Water Resources Investigation" was conducted under direction of the State Water Resources Board by the Division of Water Resources until July 5, 1956, and subsequently by the Department of Water Resources. Three bulletins were published pursuant to this investigation. Bulletin No. 1, "Water Resources of California", was published in 1951, and contains a compilation of data on precipitation, unimpaired stream runoff, flood flows and frequencies, and quality of water throughout the State. Bulletin No. 2, "Water Utilization and Requirements of California", June, 1955, presents determinations of the present use of water throughout the State for all consumptive purposes and presents forecasts of probable ultimate water requirements based in general on the capabilities of the land to support further development. The third and concluding phase of the Statewide Water Resources Investigation was reported on in Bulletin No. 3, "Report on The California Water Plan", published in May, 1957. This bulletin presents preliminary plans for the full practicable development of the water resources of the State to meet the ultimate water needs therein insofar as possible. The bulletin describes plans for local water resource development together with those works needed for the major transfers of water from the surplus areas of the north to the water deficient areas of the south, designated the California Aqueduct System. Bulletin No. 3 does not contain construction proposals, but serves as a broad framework within which specific projects will be integrated as growing needs for water dictate.

The Feather River and Delta Diversion Projects

The Feather River and Delta Diversion Projects, initial major units to be developed in accordance with The California Water Plan, were developed by the Division of Water Resources in 1951, in consideration of the impending need for additional water in the central and southern portions of the State, and also in recognition of the critical need for flood control on the Feather River.

Report of 1951. The projects were originally formulated by the Division of Water Resources for the State Water Resources Board in "Report on Feasibility of the Feather River Project and Sacramento-San Joaquin Delta Diversion Projects Proposed as Features of The California Water Plan", May, 1951. Major units of the projects included a multipurpose dam and reservoir on the Feather River near Oroville, a power plant at the dam, an afterbay dam and power plant, a Delta cross channel, an electric power transmission system, a conduit to transport water from the Sacramento-San Joaquin Delta to Alameda and Santa Clara Counties, and a conduit to transport water from the Delta to the San Joaquin Valley and to southern California. A steam plant for generation of electrical energy for project purposes was contemplated for construction near Oceano in San Luis Obispo County. The aqueduct to southern California was contemplated as an inland or "high line" route extending from the San Joaquin Valley in a tunnel through the Tehachapi Mountains at about elevation 3,300 feet. The proposed aqueduct location then followed along the southerly side of the Antelope Valley, thence through another tunnel into the South Coastal Area near the City of San Bernardino. From this point, the location extended to the south in a series of tunnels and siphons to a terminus in San Diego County near the Mexican border, at elevation 2,854 feet.

The Feather River and Delta Diversion Projects were authorized by the Legislature by Chapter 1441, Statutes of 1951. This act also authorized and directed the Department of Public Works to conduct the necessary investigations, surveys and studies, and preparation of plans and specifications for the construction of the works authorized by the act and to submit the same to the Water Project Authority for its approval.

Report of 1955. Further studies of the Feather River and Delta Diversion Projects were carried on by the Division of Water Resources until 1955, at which time a report entitled "Program for Financing and Constructing the Feather River Project as the Initial Unit of The California Water Plan", February, 1955, was submitted to the Legislature. It was concluded in this report that the projects were engineeringly and financially feasible, and it was recommended that the Legislature appropriate funds to initiate their construction. This report recommended modifications of the original plan including the addition of the San Luis Reservoir on the west side of the San Joaquin Valley.

The report of February, 1955, also included analyses of alternative aqueduct routes to southern California including the afore-mentioned "High line" route and modifications thereof consisting of power drops to points of terminus near Castaic and San Bernardino, a long tunnel route at elevation 1,870 feet from the San Joaquin Valley to the South Coastal Area, and a coastal route commencing in the vicinity of Devils Den in the San Joaquin Valley and extending along the coastward side of the Coast Range through San Luis Obispo, Santa Barbara, and Ventura Counties, to a terminal reservoir near Castaic in Los Angeles County. The cost and accomplishments of these various routes were presented in the report without recommendations.

Bechtel Report. The 1955 Legislature appropriated $250,000 to its Joint Interim Committee on Water Problems for an independent study of the project. This committee employed Bechtel Corporation to perform the study. The results of the Bechtel Corporation's independent review were reported to the Committee in "Report on Engineering, Economic and Financial Aspects of the Feather River Project", December 31, 1955.

The Bechtel report found the project to be engineeringly and financially feasible and recommended among other things, further studies of the ". . . High Line route via Castaic Creek power development and terminating in San Fernando Valley."

Bulletin No. 61. In recognition of the critical water supply situation in San Diego County, the Legislature approved the afore-mentioned Senate Concurrent Resolution No. 19 in 1956, and appropriated $200,000 for study of aqueduct routes to San Diego County. The Department of Water Resources, under an accelerated program, completed an investigation and in the spring of 1957 published Bulletin No. 61, entitled "Feather River Project Investigation of Alternative Aqueduct Routes to San Diego County". This report recommended the immediate construction of an aqueduct originating at the westerly portal of San Jacinto Tunnel on the Colorado River Aqueduct of The Metropolitan Water District of Southern California and extending south a distance of about 104 miles through southwestern Riverside and coastal San Diego Counties. This aqueduct initially would deliver Colorado River water, but subsequently, at such time as water from northern California were available in the area, could be utilized for its delivery. Subsequent to the publication of this report, The Metropolitan Water District of Southern California and the San Diego County Water Authority have proceeded with the financing and have initiated construction of this aqueduct substantially in conformance with the recommendations contained in Bulletin No. 61.

Other Related Investigations and Reports

In addition to the afore-mentioned reports on comprehensive water resource investigations conducted by the Department of Water Resources and its predecessor agency, the Division of Water Resources of the Department of Public Works, information and data contained in numerous other prior reports of the Division of Water Resources and in reports of other agencies and individuals were of material value in the conduct of this investigation. Principal reports of this nature which were so utilized are as follows:

Division of Water Resources

"South Coastal Basin Investigation. Overdraft on Ground Water Basins". Bulletin No. 53. 1947.
"Santa Margarita River Investigation". Bulletin No. 57. June, 1956.

State Water Resources Board

"Santa Ana River Investigation". Bulletin No. 15. June, 1955.
"Ventura County Investigation". Bulletin No. 12. April, 1956.
"Los Angeles County Land and Water Use Survey, 1955". Bulletin No. 24. June, 1956.
"San Luis Obispo County Investigation". Bulletin No. 18. May, 1958.

Department of Water Resources

"Report on Proposed Semitropic Water Storage District, Kern County". June, 1958.
"Orange County Land and Water Use Survey". Bulletin No. 70. January, 1959.

U. S. Department of the Interior, Bureau of Reclamation

Calleguas Project, California, Report on Feasibility of Water Supply Development, May, 1958.
Report on Victor Project, April, 1952.
Santa Ynez River Basin, California, November, 1955.
Santa Maria Project, California, September, 1955.

Other Agencies

Miscellaneous Publications of the following Federal Agencies:
  Department of Commerce.
  Department of Agriculture.
  Department of Labor.
  Department of Health, Education, and Welfare.
  Department of the Interior.
  National Industrial Conference Board.
Miscellaneous Publications of the following State Agencies:
  Department of Finance.
  Department of Employment.
  Department of Industrial Relations.
Miscellaneous Publications of local southern California agencies as follows:
  County Farm Advisers.
  Annual Reports of Water Agencies.
  City and County Planning Commissions.
  Chambers of Commerce and Boards of Trade.

OBJECTIVES AND SCOPE OF INVESTIGATION AND REPORT

In compliance with the legislation authorizing study of alternative routes for the San Joaquin Valley-Southern California Aqueduct System and appropriations provided therefor, the investigation was directed toward the selection of the proper location and capacity of aqueduct facilities to serve surplus northern California water to the portion of the State generally south of the Kings-Kern County line. Selection of the location of aqueduct facilities between the Delta and the Kings-Kern County line was beyond the scope of this investigation. However, the capacities of these facilities will be affected by the economic demand for water south of the Kings-Kern County line.

Objectives

Specific objectives of the investigation, which are in conformance with the foregoing, are summarized as follows:

1. Determination of probable future requirements for supplemental water from Northern California in the Southern California area and the rates of growth in economic demand for such water for various purposes after it has been introduced into the several areas under consideration.
2. Determination of the probable times when water from Northern California will be required in the several areas.
3. Designation of the areas to be served by an aqueduct system to the Southern California area.
4. Selection of the most favorable, or optimum, aqueduct system to serve those areas. In accordance with the authorizing legislation, this entailed:
    A. Study of alternative coastal and inland aqueduct routes for delivery of water south of the Transverse Ranges.
    B. Study of aqueduct routes for service of water in the southern San Joaquin Valley.
    C. Study of aqueduct routes to and through San Bernardino and Riverside Counties for water service there and to San Diego County.

The several possible alternative pumping and power recovery schemes applicable to delivery of water over the alternative routes considered were evaluated to the extent necessary to ascertain the influence of operational scheme on the selection of aqueduct locations and capacities. Appropriate financial and economic analyses were made in order to compare the costs and accomplishments of the several alternative aqueduct systems to serve the Southern California area and thus enable the selection of the optimum system which should be constructed.

Basic Assumptions. Basic assumptions employed in carrying out the foregoing objectives were as follows:

1. Surplus Northern California water will represent a supplemental and not a substitutional water supply for the Southern California area.
2. A continuing supply of water, adequate in quality and quantity, will be made available to satisfy forecast economic demands for surplus Northern California water.

3. The State's financial responsibility will extend only to the primary aqueduct system and will not include the costs of secondary conveyance and distribution facilities within the various service areas.
4. The aqueduct system selected for construction should provide a maximum degree of water service throughout the Southern California area at an over-all minimum cost to the ultimate consumer.
5. Such an aqueduct system and each unit thereof should be financially feasible from the standpoint of recovery of the investment and other costs involved and be economically justified.

Aqueduct System Concept. In the Division of Water Resources report, "Program for Financing and Constructing the Feather River Project as the Initial Unit of The California Water Plan", dated February, 1955, consideration was given to a maximum water delivery in the southern part of the State of 840,000 acre-feet per year to Kern County and about 1,800,000 acre-feet per year for the "area south of the Tehachapi Mountains". Deliveries of water to San Luis Obispo County, northern Santa Barbara County, and in significant quantity, to the Whitewater-Coachella area portion of the Colorado Desert Area were not contemplated. The recent studies made in connection with this investigation reveal there is also a need for surplus northern California water to sustain the future economic growth of these latter areas.

It is apparent that neither a "coastal" route nor an "inland" route, separately, could provide water service to all parts of the water deficient southern California area. In view of this and in conformance with the objectives of the investigation, there was evolved an investigational concept embracing not only the selection of a route for delivery of water to the area south of the Tehachapi Mountains but also the selection of an "aqueduct system", which would include facilities needed to supply surplus northern California water to all portions of the southern California area where an economic demand therefor will exist.

Closely related to the aqueduct system concept is the problem of providing continuing water service in the most economical manner to sustain forecast long-term growth in the southern California area. As shown in Chapter II, it is estimated that the amounts of water contemplated for delivery to the southern California area in the 1955 report will be fully utilized by about 1990, and that a substantial additional amount of water will be required thereafter. The economic desirability of including capacities, in the initial construction of certain conveyance facilities, sized in accordance with forecast water demands rather than on the basis of the supply from the Delta that would be made available from the Feather River and Delta Diversion Projects as shown in the 1955 Report, is presented herein. This is of particular importance in considered canals and tunnels, which, in most instances, are not economically adapted to staged construction.

Scope

The unprecedented problems inherent in developing the proper aqueduct system to serve southern California, from numerous alternatives, required intensive study in a wide variety of technical fields including engineering, geology, demography, and economics.

The investigation required contact with hundreds of agencies and individuals to obtain local and statewide opinions on the need for water, ability to pay for water, local water problems, prognostications of economic development, and other related matters. Field and office investigations were conducted over an area extending from the Kings-Kern County line to the Mexican border and from the coast across the mountains into the desert area. Several thousand miles of aqueduct alignment were subjected to at least reconnaissance examination. Drilling operations were conducted at critical tunnel locations and dam sites and other structures. Field mapping was secured over a substantial area where existing map coverage was insufficient for planning purposes.

Numerous estimates of cost were prepared for various types of aqueducts such as canal sections, pipe lines, tunnels, cut and cover sections, and flumes. The unusual problems associated with transporting large quantities of water over unprecedented distances covering widely varying topographic and geologic conditions required consideration of new designs and development of many original analytical techniques.

The results of this investigation are summarized in this report under the following chapter headings:

Chapter I. Introduction.
Chapter II. Economic Demand for Imported Water.
Chapter III. Water Quality Considerations.
Chapter IV. Alternative Aqueduct Systems.
Chapter V. Pumping and Power Recovery.
Chapter VI. Conveyance and Distribution of Imported Water within Service Areas.
Chapter VII. Financial and Economic Analyses.
Chapter VIII. The Optimum Aqueduct System.
Chapter IX. Conclusions.

Detailed supporting information and data covering specific phases of the investigation are presented in the following separate appendixes:

Appendix	*Title*
A	Long Range Economic Potential of the Antelope-Mojave River Basin, January, 1959.
B	Effects of Differences in Water Quality, Upper Santa Ana Valley and Coastal San Diego County, January, 1959.

C Procedure for Estimating Costs of Tunnel Construction, September, 1959.

*D Economic Demand for Imported Water, ______________.

*E Financial and Economic Analyses, ______________________.

*F Conveyance and Distribution of Imported Water Within Service Areas, _______________.

G Designs and Cost Estimates, _________________.
(Office report in two volumes.)

CONDUCT OF INVESTIGATION

This investigation was initiated and carried out by the Southern California District Office of the Department of Water Resources. Although work was rapidly prosecuted on all phases of the investigation, initial consideration was given to studies in San San Diego County leading to the preparation of the afore-mentioned Bulletin No. 61.

The over-all investigation required both field and office forces numbering at the maximum approximately 100 persons, including engineers, geologists and research personnel. In addition to work by Department personnel, a substantial amount of contract work was undertaken by outside firms. Much of the mapping was accomplished by contract as was a substantial portion of the diamond drilling at tunnel and dam sites.

Two important phases of the investigation were studied under contract for the Department of Water Resources by outside firms.

In 1957, the Department of Water Resources contracted with the firm of Booz, Allen & Hamilton, Management Consultants, to make an economic survey of the Antelope Valley-Mojave River area. The purpose of this study was to develop basic data needed to ascertain the probable economic demand for water in this area. The results of this firm's investigation are published separately as Appendix A.

In the spring of 1958, in recognition of the concern over continued use of Colorado River water in the Upper Santa Ana Valley and coastal San Diego County from a water quality standpoint, the Department of Water Resources entered into a contract with the Stanford Research Institute to investigate and determine the economic benefit, if any, of utilizing northern California water in the foregoing areas in lieu of Colorado River water. Results of this investigation by the Stanford Research Institute are published separately as Appendix B.

The cooperation and advice of numerous manufacturing and industrial firms were received in developing estimated costs of facilities. Of particular importance was the valuable assistance obtained from the steel and concrete pipe industry and the manufacturers of pumps, turbines, and appurtenant equipment.

Public and private electrical utilities were of great assistance to the Department, both through individual contacts during the period of the investigation and through the formation of a committee to work with Department personnel. The work of this committee provided guidance on the important problems of pumping and power recovery, and it is anticipated that the activities of the committee will continue during the final design phase.

Valuable advice was received from several of the major oil companies on the probable future availability and price of fuel oil as a source of energy for pumping.

Throughout the investigation, liaison was maintained with responsible local agencies through 10 meetings with an Engineering Advisory Committee composed of officials and representatives of water agencies throughout the southern California area. The Department, throughout the course of this investigation, periodically reported on its progress to this committee and advised them of the techniques and procedures utilized in the investigation. Valuable advice and comments were received from the committee on the many facets of the investigation.

Assistance and advice on specialized problems encountered during the investigation were obtained from consultants employed by the Department. These men, eminent in their respective fields, performed valuable service on the investigation.

In addition to the foregoing, a service agreement was entered into with the Byron Jackson Division of the Borg-Warner Corporation to assist on the selection and design of certain pumping machinery.

RELATED NORTHERN WATER SUPPLY FACILITIES

Although this investigation and report deal specifically with selection of facilities to serve surplus northern California water to the southerly portion of the State, generally south of the Kings-Kern County line, it is obvious that the facilities so selected and the criteria for their selection will influence design of project facilities to the north.

The capacity of diversion facilities at the Delta and of the aqueduct from this point south to the Kings-Kern County line must reflect required aqueduct capacity to the south. Similarly, the location and the elevation of the aqueduct at the Kings-Kern County line reflect the requirements of water service to the north, topography and other physical conditions between the Delta and this point, and the proposed San Luis Reservoir.

Water supplies for the aqueduct system will be obtained from presently surplus water reaching and wasting from the Delta augmented by regulated releases from the authorized Feather River Project. In the future, additional storage projects will be required in northern California to meet the increasing demands

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* To be published in latter part of 1959.

in the watersheds of origin and on the San Joaquin Valley-Southern California Aqueduct System and the other Delta diversion projects.

Water would be diverted from the Delta and conveyed southward to San Luis Reservoir, which would provide off-stream storage necessary for the capture and regulation of winter and spring flood flows passing through the Delta. Under current plans, San Luis Reservoir and the aqueduct from this point south to the vicinity of Kettleman City would be a joint venture with the Federal Government's proposed San Luis Project.

The economic and financial analyses of aqueduct systems presented herein necessarily include appropriate costs of the aqueduct and regulatory storage facilities between the Delta and the Kings-Kern County line, as well as the cost of water in the Delta with construction of the Feather River Project.

AREA OF INVESTIGATION

The area of investigation, termed in the broad sense herein as the "southern California area", includes the water deficient southerly portion of the State, and represents the potential service area for surplus northern California water generally south of Avenal Gap near the Kings-Kern County line, as shown on Plate 1, "Location of Investigational Area". It is at this northerly limit of the investigational area that a coastal aqueduct to deliver northern California water to the area south of the Transverse Ranges would originate.

The investigational area embraces a large portion of Kern County in the San Joaquin Valley; the coastal counties of San Luis Obispo, Santa Barbara, Ventura, Los Angeles, and Orange; the coastal segments of San Bernardino, Riverside, and San Diego Counties; and portions of the desert area included within the Counties of Los Angeles, Kern, San Bernardino, and Riverside.

The area comprises about 30,000 square miles and has a present population of about 8.7 million, which is in excess of one-half of that of the entire State. The assessed valuation of the area is now over 14 billion dollars or about 58 per cent of that of the State. Included in the area are the rapidly growing metropolitan centers of Los Angeles and San Diego, the rich agricultural valley lands of westerly and southerly Kern County, and the highly productive agricultural lands found in the many coastal valleys from San Luis Obispo County to the Mexican border. Growth in economic development is also being experienced in the desert, both in the Antelope-Mojave area and in the Whitewater-Coachella area of the Colorado Desert region.

The construction of the extensive Vandenberg Air Force Base, in northern Santa Barbara County, has stimulated a substantial population growth. This influence is expected to continue in the future and will substantially affect the rate of growth in demand for water in the county.

With the exception of the north coastal portion of San Luis Obispo County, the entire area has insufficient local water resources, either presently developed or potentially developable, to satisfy forecast water demands. Realization of the economic potential of the area will require large scale importations of water from outside sources. At the present time, the economy of a substantial portion of the area is being sustained by ground water overdraft estimated to be in excess of one million acre-feet annually.

Most of the southern California coastal plain and coastal San Diego County is within The Metropolitan Water District of Southern California, and does or could receive Colorado River water as a supplemental supply. In addition, the City of Los Angeles imports water from the Owens-Mono basins through the Los Angeles Aqueduct.

In many portions of coastal southern California, irrigated agricultural acreage has been declining in recent years largely as a result of urban area expansion. The population growth in the coastal plain area has been spectacular and no early cessation of this growth is foreseen.

That portion of Kern County in the San Joaquin Valley has, since World War II, shown a significant increase in irrigated acreage, which is continuing in those areas where water is available. Additional substantial acreages in this area would be developed to irrigated agriculture if supplemental water were available. Kern County also has exhibited a rapid growth in population, particularly in the Bakersfield area.

For analytical purposes the investigational area was subdivided into "service areas". These service areas were somewhat arbitrarily chosen but generally reflect differences in cost of delivering surplus northern California water thereto. It is to be emphasized that the boundaries thereof were taken for analytical purposes only and that the areas are not to be construed as representing proposed entities for contracting of surplus northern California water.

The areas so selected are shown on Plate 2, "Water Service Areas and Organized Water Agencies in Southern California Area", and are listed as follows:

Service Area

Kern County
  Upper Antelope Plain
  Avenal Gap to Pumping Plant In-III
  Pumping Plant In-III to Pumping Plant In-IV
  Pumping Plant In-IV to Pumping Plant In-VI
San Luis Obispo
Santa Barbara
Ventura County
Antelope-Mojave

Whitewater-Coachella
Southern California Coastal Plain and Coastal
San Diego County

The San Luis Obispo and Santa Barbara Service Area boundaries differ from the county boundaries by the inclusion within the Santa Barbara Service Area of all of the Santa Maria Valley Water Conservation District, which District contains about 13,000 acres of San Luis Obispo County.

Although the Bakersfield metropolitan area in the Kern County Service Area is physically included within the "Avenal Gap to Pumping Plant In-III" subunit, it is treated in all respects in this bulletin as though it were in the subunit "Pumping Plant In-III to Pumping Plant In-IV", because of the necessity from an economic standpoint of lifting water therefor through Pumping Plant In-III.

CHAPTER II

ECONOMIC DEMAND FOR IMPORTED WATER

Achievement of the objectives of the investigation required determination of when and where surplus northern California water will be needed and the rate of growth in demand therefor once it has been introduced. Results of these water demand estimates are essential for design purposes as well as for testing the financial feasibility and economic justification of the aqueduct system and for estimating the sequence and timing of construction of its component units.

Estimates of growth in economic demand were made for the two primary purposes for which northern California water would be utilized, namely, urban, including industrial use, and irrigated agriculture. Estimates for both of these purposes were prepared for the period from the present until year 2020. In this manner, development trends and probable water demands were estimated for a period sufficiently far into the future that proper aqueduct sizing will be assured and a basis provided for financial and economic analyses of aqueduct facilities.

Projections of growth and attendant economic demand for water may be generally categorized into "long-term" and "near-future" estimates. It is obvious that projections made for the next twenty to twenty-five years may be expected to have a greater degree of reliability than those for sixty years hence. Nevertheless, sound planning dictates that aqueduct facilities considered for near future service be constructed in a manner that is not in conflict with, but rather in furtherance of, probable long-term needs.

BASIC PLANNING ASSUMPTIONS

In estimating the nature and magnitude of future development, the element of conjecture can be minimized substantially by recognition and careful evaluation of historical trends and presently established policies and patterns. In developing the estimates of economic demand for water, these trends, policies, and patterns were separately analyzed for the area as a whole and for each subdivision thereof. Assumptions were made with respect to future conditions which are believed to be reasonable and conservative. It is therefore considered that the predicted future conditions in the southern California area, as developed in this investigation, have a high probability of occurrence. However, it is anticipated that periodic reevaluations will be made of estimates presented herein utilizing the experience and knowledge of the future. This will be of particular importance with respect to staging of aqueduct facilities.

The principal underlying assumptions employed in developing the estimates were:

1. *Surplus northern California water will be a supplemental and not a substitutional water supply.* It was assumed that preference would be given to the utilization of local surface and ground water supplies over northern California water insofar as the continued use and further conservation of these supplies, where feasible, indicated economic and/or financial advantage. However, it cannot be arbitrarily assumed that predicted overdrafts, at the time northern California water would be available in various areas, would be immediately overcome by use of this imported water. Rather, individual consideration was given to each area with respect to local attitudes, policies of governing political entities, and the costs of continuing the overexploitation of ground water and hazards attendant thereon. Full recognition was given to conditions extant in those areas where ground water extractions have now been limited by local voluntary action or by court decree.

2. *A water supply adequate in quantity and quality will be available to meet forecast economic demands.* While this assumption is inherent in the preparation of any estimate of water demand, with selection of either one or the other of the basic alternative aqueduct routes under consideration, i.e., coastal or inland route, some portions of the investigational area could not feasibly receive water service or such service would be substantially delayed or more costly. Thus, it is obvious that the magnitude, timing, and rate of growth in demand for northern California water is to a certain extent a function of aqueduct system selection. However, since it was a primary purpose of the over-all investigation to determine the relative costs and accomplishments of the alternative systems and select one from the alternatives, no presumption as to which system would be constructed could be made for these particular studies. As a result, the basic estimates of growth in economic demand for water in each component service area reflect the assumption of availability of water from preliminary analyses of that alternative aqueduct system which would provide water thereto at the least cost. Postulated delivery schedules and design capacities of units of the systems so derived were then adjusted, where necessary, to the demand which it was estimated would develop with the timing of construction and cost of water delivered by each system.

3. *Initial deliveries of surplus northern California water physically could be made to the San Joaquin*

Valley in 1965 and south of the Tehachapi Mountains and to the coastal counties in 1970. The physical availability of surplus northern California water to areas of need in the southern California area and the timing of delivery thereof is dependent on aqueduct system selection, construction capability, and upon the reconciliation of many matters beyond the scope of this report, the outcome of which cannot be forecast at this time. Further, a construction timetable once established may be varied by unforeseen difficulties or circumstances. The foregoing assumptions as to time of availability of water were based upon an accelerated construction timetable for the aqueduct facilities which could not be exceeded in any significant degree without loss in efficiency and increase in cost. It should be recognized that all parts of the coastal counties and all lands south of the Tehachapi Mountains could not possibly be served with northern California water by 1970, nor would all such areas have an economic demand for this water at that time.

4. *The full cost of water at the main aqueduct involved in delivering water to each service area, including full recovery of capital cost with interest, is the proper basis for estimating economic demands for supplemental water for purposes of aqueduct system selection and preliminary design.* The term "growth in economic demand for water" connotes a relationship between demand and price of water. At the present time the pricing schedule for water to be delivered under the San Joaquin Valley-Southern California Aqueduct System has not been nor can it be now established. It is not the purpose of this investigation to establish a pricing schedule but rather to estimate the future demand for water by areas on a reasonable basis. The assumption employed is believed to result in conservative estimates, particularly with respect to the development of and demand for water by irrigated agriculture. In a subsequent section of this chapter there are presented the results of estimates of variation in projected irrigated agricultural development with price.

The preliminary costs employed in preparing the basic estimates of growth in demand for imported water are as follows:

Service area	*Cost, at main aqueduct, in dollars per acre-foot*
Kern County	
Upper Antelope Plain	16
Avenal Gap to Pumping Plant In-III	10
Pumping Plant In-III to Pumping Plant In-IV	16
Pumping Plant In-IV to Pumping Plant In-VI	24
San Luis Obispo	26
Santa Barbara	27
Ventura County	49
Antelope-Mojave	38
Whitewater-Coachella	52
Southern California Coastal Plain and Coastal San Diego County	43

The method of determining the foregoing costs is presented in Chapter VII. In addition to these costs, the estimated costs of distributing water within service areas were reflected in the demand projections.

Individual consideration was given to the present service area of The Metropolitan Water District of Southern California with recognition of present pricing policies of the District under the assumption that these policies would prevail in the future. A direct charge to the user of $30 per acre-foot was assumed in projecting development in the District area. It was assumed that the District would recover the difference between this charge and the cost of water in the main aqueduct, under its present procedure of taxation, or otherwise. This value represents an estimated average charge that might be assessed in the future for both Colorado River water and northern California water. In the District area, these two sources of supplemental water must be considered together.

5. *The full claimed right of The Metropolitan Water District of Southern California to Colorado River water will be available to its present member agencies.* This claimed right amounts to 1,212,000 acre-feet annually. Estimated losses in delivery leave a net amount available for water service of about 1,150,000 acre-feet annually. Under this assumption, this supply of water was considered available for use only by the present District agencies and no annexations of additional agencies were postulated. It is recognized that such annexations may occur, and, if this were to happen, it would serve to advance the date of full utilization of the Colorado River water supply in the District area.

SOURCES OF WATER SUPPLY FOR SOUTHERN CALIFORNIA

It is well recognized that most of the southern California area has existing or future requirements for water far in excess of presently available water supplies. The eventual need for importation of substantial quantities of surplus northern California water to the southern California area was set forth in State Water Resources Board Bulletin No. 3, "Report on The California Water Plan".

In developing plans for the importation of supplemental water from northern California, consideration must be given to the availability of other possible sources of water to supply the forecast water needs of the area since these might influence the timing and rate of growth in economic demand for northern California water.

Local Water Resources

With few exceptions, local water resources are now fully developed and, in fact, the existing economy in many portions of the area is subsisting on ground water overdraft. This annual overdraft is estimated to be about 300,000 acre-feet in the South Coastal Area, approximately 100,000 acre-feet in the Antelope-Mojave area, and about 540,000 acre-feet in westerly and southerly Kern County.

There is an increasing public awareness of these dwindling water reserves. Continuing and progressive lowering of ground water levels with increased pumping costs, intrusion of sea water in coastal areas, and exhaustion of water supplies in certain other areas have stimulated an ever increasing use of imported water where available. South of the Tehachapi Mountains, this has been reflected in continued annexations to The Metropolitan Water District of Southern California. Restrictions on use of local ground water supplies have been put into effect by both voluntary action and court decree in several areas, which have also resulted in increased use of imported water and annexations to the District.

In San Luis Obispo County and, to a lesser extent, in Santa Barbara, Ventura and San Diego Counties, there are additional local water resources economically feasible of conservation. However, as is shown in this chapter, satisfaction of the estimated future economic demand for water in these counties will require importation of substantial amounts of water from outside sources.

Estimated annual safe yields of water from considered maximum probable development of local sources are presented in Table 2 by service areas.

Importation From Existing Sources

Large water importation projects have been constructed in the past and are now delivering water to various portions of the southern California area. The Friant-Kern Canal of the Federal Central Valley Project supplies substantial quantities of water to the north central portion of Kern County. However, water service from this canal is not provided to, nor is contemplated for, the westerly and southerly portion of the County.

The Los Angeles Aqueduct, which has been in operation for many years, brings water from the Owens-Mono basins to the City of Los Angeles. The aqueduct is capable of delivering an average of about 320,000 acre-feet per year and has been operated for the past several years at essentially full capacity.

The Coachella Valley County Water District has been distributing Colorado River water to its service area in Improvement District No. 1. Additional quantities of imported water which would be needed in portions of the Whitewater-Coachella area outside of this service area, primarily for urban growth, must be supplied from other sources.

Colorado River water is also served to a substantial portion of the South Coastal Area through facilities of The Metropolitan Water District of Southern California. As stated, the claimed rights of the District in and to water of the Colorado River amount to 1,212,000 acre-feet per annum. In 1950-51, the District sold 167,000 acre-feet of water to its member agencies. In 1957-58, sales of Colorado River water by the District had increased to about 540,000 acre-feet, which represents an average annual increase of about 53,000 acre-feet. The rights of California agencies in and to the waters of the Colorado River are now in litigation instituted by Arizona.

Other Possible Water Sources

Several other sources of water supply were considered as either possible alternatives to importation of water from northern California or with respect to the effects of these sources on the rate of growth in demand for northern California water.

Reclamation of Water from Sewage. At the present time there are over 600,000 acre-feet of sewage being discharged to the ocean annually from the metropolitan areas of southern California. Over the past several years, the Department of Water Resources has made studies of the feasibility of reclaiming water for beneficial use from this source. These studies have indicated that about 40 per cent of the total volume of sewage currently being discharged to the ocean could feasibly be reclaimed, at costs ranging from $13 to $40 per acre-foot, depending on the location of the reclamation plant, use of the product, and other pertinent factors. The quantity that might be reclaimed is limited by the excess mineral content of the sewage from some of the contributing areas and by the possible markets or uses for such reclaimed water. The mineral quality of much of the sewage tends to continually deteriorate with increasing industrial development unless steps are taken to segregate industrial wastes and dispose of them separately.

Reclaimed water cannot be used directly for general water supply purposes. Potential markets or uses for reclaimed water would, therefore, be limited to certain industrial purposes, recharge of ground water aquifers, repulsion of sea water intrusion, and minor agricultural and recreational purposes. Separate distribution systems would be necessary, adding to the expense. Sewage from most of the inland area is already being effectively reclaimed through use for irrigation or disposal to ground water.

The recharging of ground water basins by spreading or injection offers the best possibility for use of reclaimed water. On a large scale, the amount of water that could be put to general use in this manner would be limited by infiltration rates of these lands, transmissibility of the aquifiers, pumping patterns, and availability of sufficient ground water storage. Care must be exercised in utilizing ground water storage so as not to interfere with the storage capacity needed for conservation of local runoff. It is also important that there be no continuous recycling of reclaimed water. In order to avoid increases in mineral concentration, to levels which would render the water unfit for use, and the creation of adverse salt balance conditions in the underground basins, the recharge would necessarily be limited to the coastal plain where only one re-use would occur.

The expanding use of detergents is causing increasingly severe problems in the treatment of sewage. It is very costly to remove detergents sufficiently to prevent foaming in the effluent.

It should be noted that the total quantity of sewage discharged to the ocean is not all "wasted" since it serves a necessary beneficial purpose in disposing of unusable saline and toxic waste products from urban development.

It was concluded that with the establishment of a definite market and the demonstration that the reclaimed water is competitive in cost to other sources of water available at the time such reclamation is contemplated, this source of water supply might satisfy a small increment of the total water demand of a portion of the coastal segment of southern California. This increment of supply might also be important in the event there is a delay in the introduction of northern California water to the area. However, this reclaimed water, because of its limited magnitude and because of the problems inherent in its reclamation and utilization, cannot be considered as a substitute for importation of water from northern California.

Desalinization of Drainage Waters from Imperial Valley. An investigation was made of the possibility of reducing the salt content in waters entering the Salton Sea through the New and Alamo Rivers from Imperial Valley and transporting this water to the South Coastal Area. At the present time, the membrane demineralization process appears to be the least expensive method for reducing the mineral content of this water from 2,000 parts per million to roughly 500 parts per million. It should be noted that the mineral content of this water has increased in the last few years. The cost of desalinization of the 1.2 million acre-feet of water annually available from this source would be about $140 per acre-foot. Amortization of the capital investment plus annual operation and maintenance charges for the facilities to transport the water from the edge of Salton Sea to Perris Reservoir in Riverside County would be approximately $45 per acre-foot, resulting in a total estimated unit cost in the order of $185 per acre-foot.

In addition to the direct costs involved, consideration must be given to possible adverse effects that might result to recreational areas now developing around the Salton Sea. Without inflow to the Sea from the New and Alamo Rivers, evaporation over a period of years would practically eliminate this body of water. Investments amounting to several millions of dollars have been made along the shores of Salton Sea and, with the demand for recreational areas in southern California, additional expenditures are to be expected in this area.

Conversion of Sea Water. A source of water for municipal and industrial uses which has received widespread publicity during recent years is the ocean. The desalinization of ocean water has been studied by the Department of Water Resources and by the Stanford Research Institute under contract with the Department as well as by University of California, the Office of Saline Water, United States Department of the Interior, and other research groups. Study has been made of all known methods of accomplishing this conversion.

Conversion on the scale which must be considered as an alternative supply to water from northern California has never been undertaken. The best estimates that can be made at this time of accomplishing such conversion and reducing the mineral content of sea water to a usable quality range from $160 per acre-foot to over $600 per acre-foot, depending on the method. These estimates postulate further technological advances in order to reduce the cost to the low value. In addition, substantial costs would be incurred in pumping and conveyance of this supply from sea level to points of use inland. Water from this source, on the basis of the best information available at this time, is not competitive in cost to other sources of additional water supply for southern California, nor is there any reason to expect that it will become competitive in cost in the foreseeable future.

Summary. In view of the foregoing, it was concluded that an alternative source of water supply that meets the criterion of practicability, and is of comparable magnitude and economically competitive with water imported from northern California, is not available to the southern California area, and that in the foreseeable future the expected economic growth of this area is dependent upon this importation. However, as is related in Chapter VII, the estimated costs of water from these sources do aid in establishing the value or benefit in supplying northern California water to the southern California area.

INVENTORY OF LAND AND WATER RESOURCES

The maximum limit to which irrigated agricultural or urban areas can develop is basically dependent upon the nature and areal extent of lands available for these uses. Further, the near future growth or change of these land uses is greatly influenced by the existing type and areal extent of land utilization. Accordingly, lands within the southern California area were evaluated with respect to their adaptability for various water using developments after determinations had been made of the present level of such development. Summarized in Table 1 are the results of this evaluation by service areas.

TABLE 1

PRESENT WATER SERVICE AREA AND IRRIGABLE OR HABITABLE LANDS

(Values in acres)

Area	Irrigated lands[a]	Urban, suburban and military lands[a]	Total present water service area	Total irrigable and/or habitable area[b]
San Luis Obispo Service Area[c]	22,500	[d]5,600	28,200	464,900
Santa Barbara Service Area[e]	78,700	[d]12,800	[d]91,500	368,400
Totals	101,200	[d]18,400	[d]119,700	833,300
Coastal Los Angeles County[f]	91,700	457,900	549,600	808,700
Orange County[e]	101,800	69,200	171,000	332,600
Coastal Riverside County[g]	98,900	29,500	128,400	483,000
Coastal San Bernardino County[e]	85,800	53,600	139,400	274,700
Coastal San Diego County[h]	79,500	[d]70,800	[d]150,300	713,600
Totals, Southern California Coastal Plain and Coastal San Diego County Service Area	457,700	681,000	1,138,700	2,612,600
Ventura County[e]	123,200	26,100	149,300	211,300
Kern County Service Area[b]	357,800	26,300	384,100	1,162,100
Antelope-Mojave Service Area[e]	103,100	[d]12,400	[d]115,500	[i]----
Whitewater-Coachella Service Area[b]	65,100	10,600	75,700	[i]----

[a] Gross areas containing inclusions of non-water-using lands.
[b] Includes presently developed water-using areas.
[c] The data for this area were obtained from Department of Water Resources Bulletin No. 18, and represent the net areas of land use as of 1953.
[d] Does not include large military reservations in these areas.
[e] 1957 field survey.
[f] Summation of 1957 field survey in Upper Santa Clara River Valley and 1955 field survey in coastal plain.
[g] Summation of 1957 field survey in Upper Santa Ana Basin and 1958 field survey in Santa Margarita River watershed.
[h] 1958 field survey.
[i] Not determined. Availability of land not considered to be a limiting factor to development in these areas.

As previously stated, estimates were also made of the dependability and magnitude of local water supplies either presently developed or feasible of development. In the case of possible future development, consideration was given to the probable cost of these supplies as compared to the estimated costs of imported water, local attitudes toward financing of works, water rights, and other items influencing local water supply development. The estimated safe annual yield of present and projected local water supply development by decades for the period from 1960 to 2020 is set forth in Table 2. Values for coastal Los Angeles County include the supply from the Owens-Mono basins sources through the Los Angeles Aqueduct estimated at 320,000 acre-feet per annum.

URBAN DEVELOPMENT

Of particular importance in planning delivery of additional water to the southern California area is the probable location and rate of growth of future urban development. Estimates of this growth were based on projections of population and studies of probable future economic conditions in this area.

TABLE 2

ESTIMATED SAFE YIELD OF LOCAL WATER SUPPLY DEVELOPMENT

(In thousands of acre-feet per annum)

Area	1960	1970	1980	1990	2000	2010	2020
San Luis Obispo Service Area[a]	88	94	128	147	174	187	189
Santa Barbara Service Area[a]	175	181	181	181	181	181	181
Totals	263	275	309	328	355	368	370
Coastal Los Angeles County[b]	743	743	743	743	743	743	743
Orange County	154	154	154	154	154	154	154
Coastal Riverside County	135	135	135	135	135	135	135
Coastal San Bernardino County	135	135	135	135	135	135	135
Coastal San Diego County	111	111	111	111	111	111	111
Totals, Southern California Coastal Plain and Coastal San Diego County Service Area	1,278	1,278	1,278	1,278	1,278	1,278	1,278
Metropolitan Water District's Present Service Area[c]	1,029	1,029	1,029	1,029	1,029	1,029	1,029
Ventura County	149	179	205	205	205	205	205
Kern County Service Area	400	520	520	520	520	520	520
Antelope-Mojave Service Area	130	130	130	130	130	130	130
Whitewater-Coachella Service Area[d]	--	--	--	--	--	--	--

[a] Does not include Cuyama Valley or Carrizo Plain areas.
[b] Includes supply available from Los Angeles Aqueduct at 320,000 acre-feet per year.
[c] These values also included in those areas containing this district.
[d] Data not available.

The nature and extent of future economic and population growth, and the related development and uses of land, water, and other natural resources in California will be affected both by future levels and patterns of the national population and economy, and by the economic and geographic resources, conditions, and potentialities for growth within the State itself. Accordingly, the scope of these studies included the national as well as the state level in order that the best possible picture of conditions influencing the size and distribution of California's future population might be obtained.

Population Projections

Population forecasts were made for the period from the present until year 2020. The following summarizes the principal general assumptions employed in the study:

(1) There will be no devastating war, deep and prolonged economic depression, or widespread disaster occurring in the nation or California.
(2) There will be a continued long-term growth of the economy of the same general trend experienced between 1910 and 1958, which may in-

clude recessions such as those experienced during the last ten years.

"High", "median", and "low" projections of the population of the United States, California, and the southern California area were made on the basis of three sets of detailed assumptions regarding future conditions. The latest available population data for all areas were obtained from authoritative sources. Projections of future population for the United States and California were then computed through application of fertility, mortality, and net migration rates to the present age and sex distribution of the population. These estimates were prepared for each five-year interval in the future with increases and decreases calculated by application of the anticipated rates of change. The elements of change were derived from detailed studies of the probable range of future fertility and mortality rates and net migration for the particular area concerned. The latest projections of the United States Bureau of the Census and other agencies making projections of population were considered in these studies. The net migration rates used were based on a study of census regions of the entire United States.

The State's population was distributed among the geographical regions of the State by analyzing, for each region, historical growth trends, patterns of economic development, relative advantages for urban growth, net areas of vacant habitable lands, and expected changes in urban population densities. In developing the regional populations, use was made of prior studies of regional land and water resources by the Department of Water Resources, and studies of economic potentials developed for various regions by the Department and other agencies.

From analysis of the results of the projections of high, median, and low populations for the nation, California, and the southern California region, and the basic assumptions employed in connection therewith, it was concluded that the median projections were most probable of attainment. The median projections were, therefore, adopted for use in water requirement forecasts.

TABLE 3

ESTIMATED PRESENT AND FUTURE POPULATION OF THE UNITED STATES, CALIFORNIA, AND THE SOUTHERN CALIFORNIA REGION

Year[a]	United States	California	Southern California region[b]
1958	173,435,000	14,612,000	8,705,500
1960	180,400,000	15,830,000	9,380,000
1970	210,000,000	21,700,000	13,100,000
1980	247,000,000	28,200,000	16,838,000
1990	288,000,000	35,000,000	19,920,000
2000	330,000,000	42,000,000	23,080,000
2010	375,000,000	49,000,000	25,955,000
2020	420,000,000	56,000,000	28,550,000

[a] As of July 1.

[b] Southern California region comprises the nine southern California counties of San Luis Obispo, Santa Barbara, Ventura, Kern, Los Angeles, Orange, San Bernardino, Riverside, and San Diego.

Set forth in Table 3 are the estimated present populations of the United States, California, and the southern California region, and the median projections therefor by decades to year 2020.

The foregoing projections correlate closely with the latest projections of the Bureau of the Census and other demographic authorities.

The estimated future population of each of the nine southern California counties and selected subdivisions thereof are presented in Table 4 and are shown graphically by Figure 1, entitled "Historical and Projected Median Population in California and Selected Southern California Areas". These forecasts were made in a manner similar to that described for the southern California region. In distributing the regional population to certain subdivisions thereof, use was made also of a method known as the "concentric theory of growth". This method correlates the relationships between population density, time, and distance from the center of large metropolitan areas.

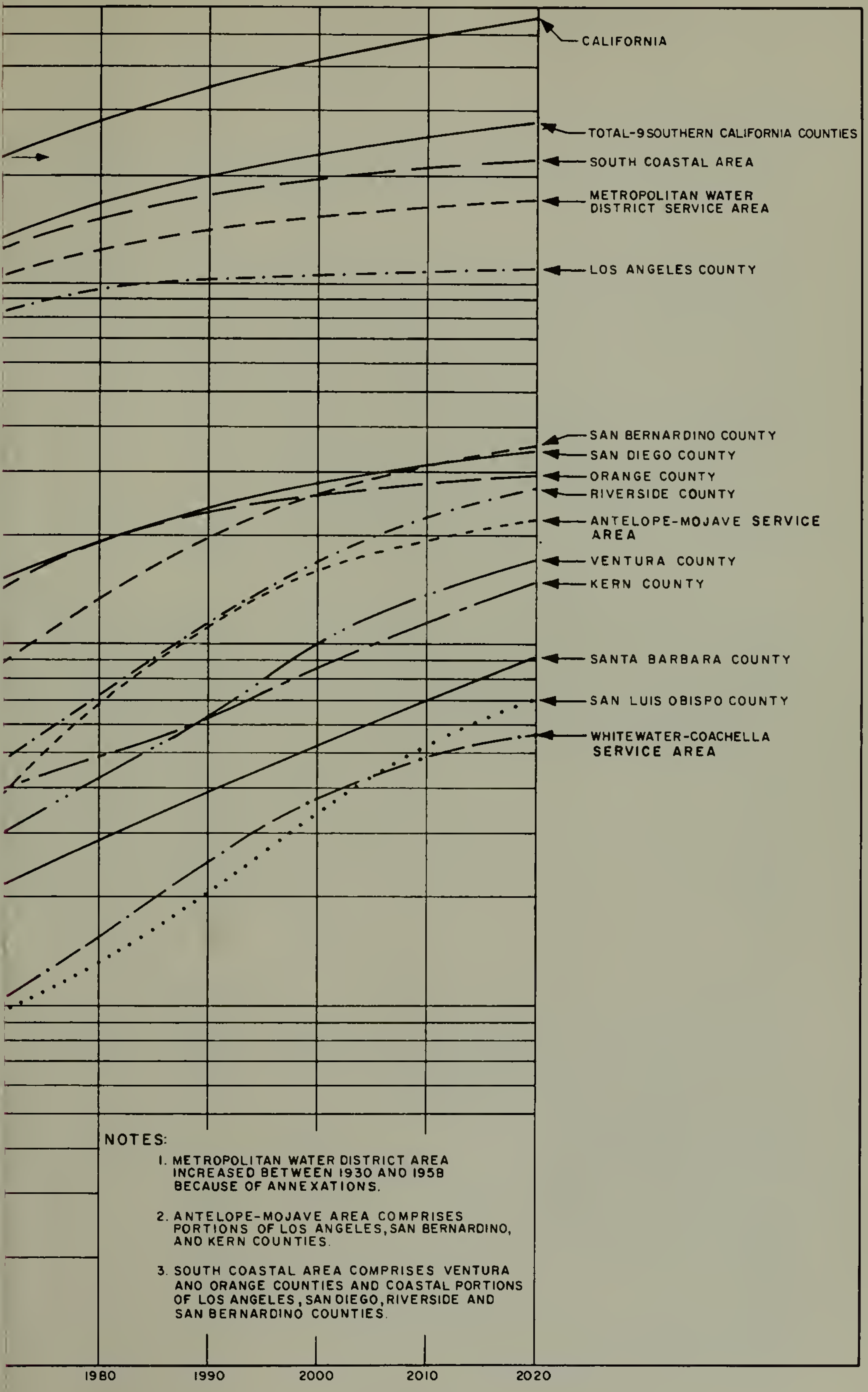
For the Antelope-Mojave Service Area, the data and conclusions contained in Appendix A, "Long Range Economic Potential of the Antelope Valley-Mojave River Basin, January, 1959", prepared under contract with the Department by the firm of Booz, Allen and Hamilton, were given special consideration. The projected population for the Antelope-Mojave Service Area shown in Table 4 is in close agreement with the projection in Appendix A through year 1990. Thereafter, the difference between the two projections increases, with the Appendix A projection being substantially greater by year 2020. The basic cause of this difference appears to lie in the projected relationships between this area and the other regions of the State. The projections reported herein are based upon studies encompassing all regions of the State and the future economic interrelationships thereof, which were beyond the scope of the investigation reported in Appendix A.

In any event, both projections show that California's continuing population expansion will force the creation, in 60 years or less, of a large metropolis in the Antelope-Mojave desert, which would exceed the present populations of all but eight of the leading metropolitan areas in the nation.

It was estimated that other outlying areas in the southern California region will likewise experience great percentage gains in population throughout the study period as the present urban centers become saturated. Los Angeles County is expected to maintain its lead in population, however, and also will exhibit a numerical gain therein greater than the total population forecast for any other county in the State.

During the ensuing 20 years, it is considered that there will be a high probability for projected median

FIGURE 1



NOTES:

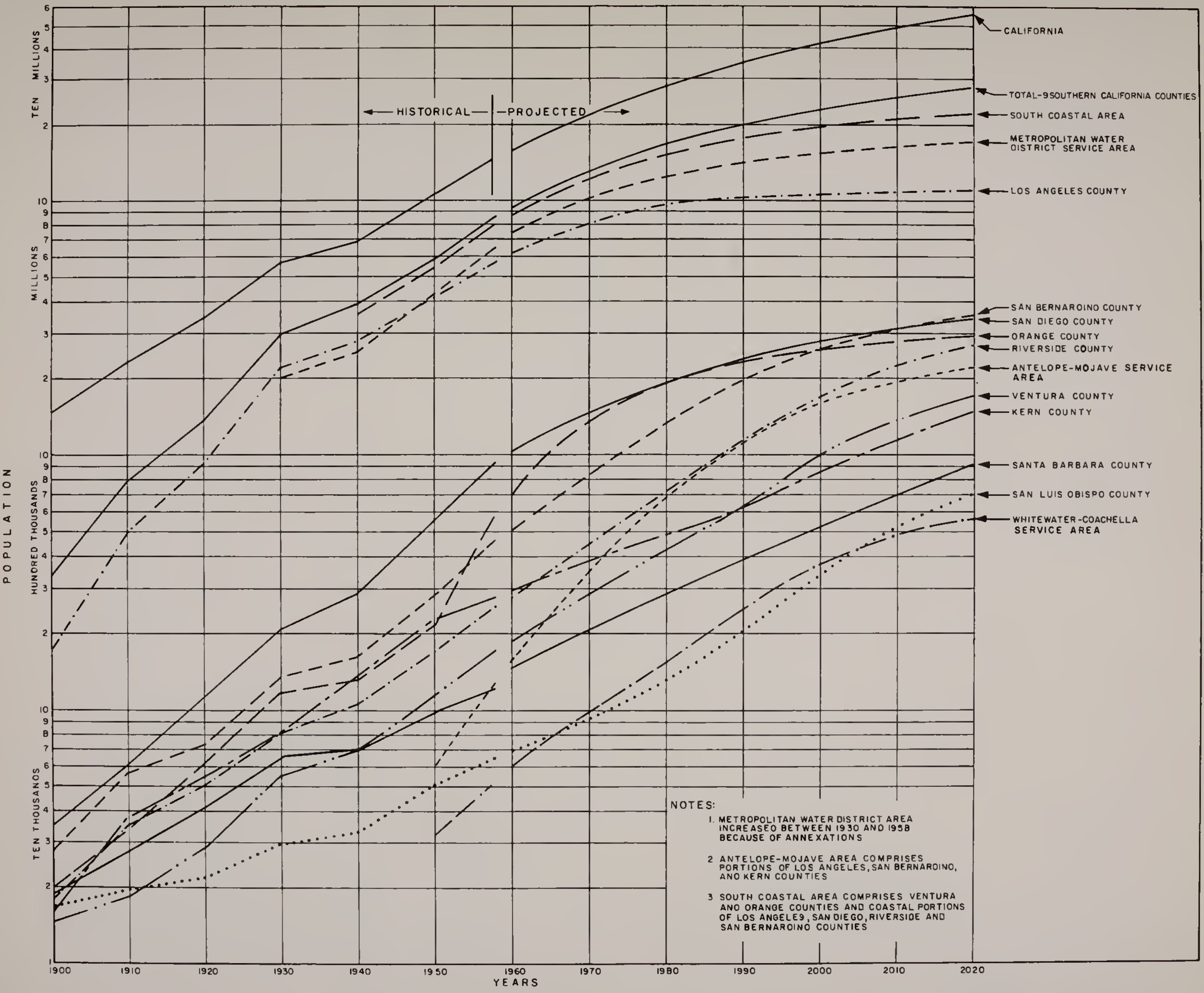
1. METROPOLITAN WATER DISTRICT AREA INCREASED BETWEEN 1930 AND 1958 BECAUSE OF ANNEXATIONS.

2. ANTELOPE-MOJAVE AREA COMPRISES PORTIONS OF LOS ANGELES, SAN BERNARDINO, AND KERN COUNTIES.

3. SOUTH COASTAL AREA COMPRISES VENTURA AND ORANGE COUNTIES AND COASTAL PORTIONS OF LOS ANGELES, SAN DIEGO, RIVERSIDE AND SAN BERNARDINO COUNTIES.

IFORNIA AND SELECTED SOUTHERN CALIFORNIA AREAS

FIGURE 1



NOTES:

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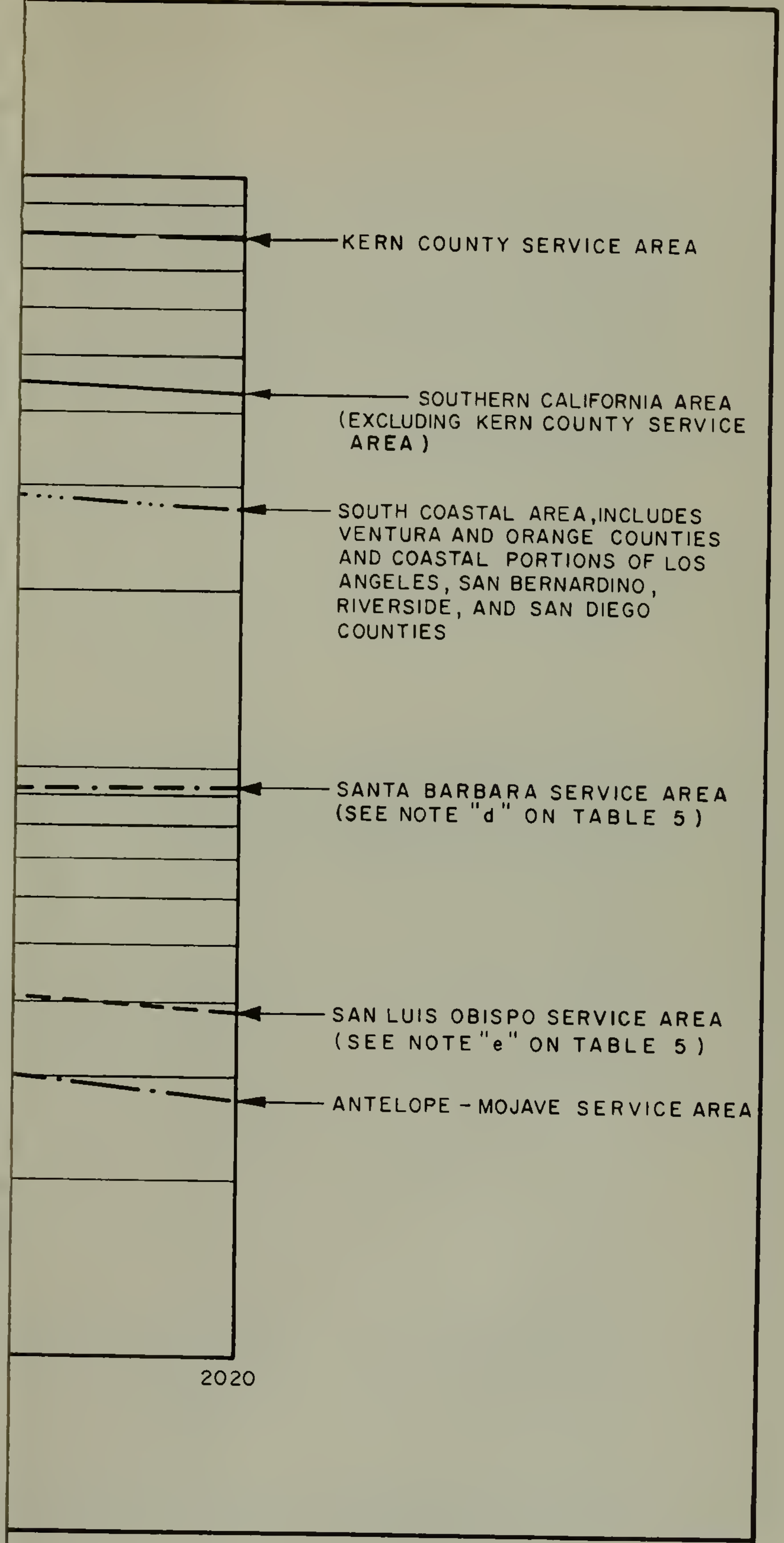
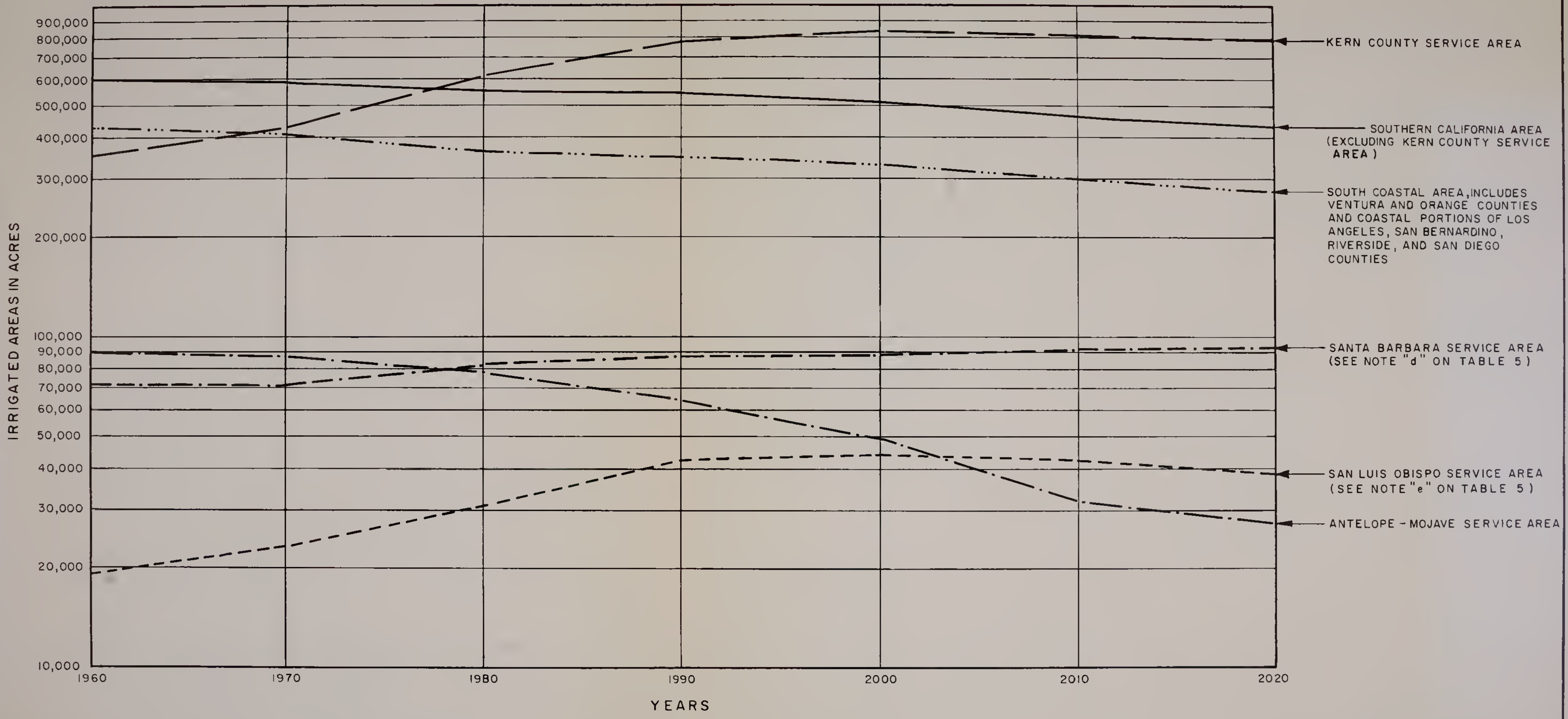
HISTORICAL AND PROJECTED MEDIAN POPULATION IN CALIFORNIA AND SELECTED SOUTHERN CALIFORNIA AREAS

DEPARTMENT OF WATER RESOURCES 1959

FIGURE 2



NIA AREA



PROJECTED AREAS OF IRRIGATED CROPS IN THE SOUTHERN CALIFORNIA AREA

DEPARTMENT OF WATER RESOURCES 1959

TABLE 4

PRESENT AND PROJECTED POPULATION IN THE SOUTHERN CALIFORNIA AREA[a]

(Values in thousands)

Area	1958	1960	1970	1980	1990	2000	2010	2020
San Diego County	943.4	1,020	1,455	1,900	2,350	2,800	3,150	3,455
Coastal San Diego County	941.5	1,018	1,452	1,895	2,341	2,784	3,110	3,396
Southwestern Riverside County[b]	2.0	2.3	2.9	3.7	4.5	6.3	7.6	8.5
Present Metropolitan Water District Service Area[b]	875.3	960	1,369	1,789	2,201	2,585	2,837	3,055
Riverside County	258.2	279	443	710	1,120	1,680	2,260	2,700
Coastal Riverside County[b]	184.6	200	322	525	840	1,275	1,730	2,080
Present Metropolitan Water District Service Area	161.9	180	281	482	770	1,159	1,550	1,840
San Bernardino County	470.5	513	830	1,310	1,975	2,610	3,150	3,550
Coastal San Bernardino County	402.3	449	695	1,029	1,482	1,894	2,270	2,580
Present Metropolitan Water District Service Area	121.6	144	208	306	531	754	958	1,128
Los Angeles County	5,792	6,185	8,078	9,700	10,310	10,660	10,880	11,100
Coastal Los Angeles County	5,731	6,115	7,898	9,270	9,632	9,808	9,908	10,015
Present Metropolitan Water District Service Area	5,087	5,460	7,014	8,098	8,326	8,474	8,551	8,630
Orange County	596.8	692	1,320	1,900	2,320	2,620	2,800	2,950
Present Metropolitan Water District Service Area	591.5	675	1,298	1,857	2,243	2,475	2,621	2,747
Totals—Present Metropolitan Water District Service Area	6,837	7,419	10,170	12,532	14,070	15,447	16,517	17,400
Totals—Southern California Coastal Plain and Coastal San Diego County	7,856	8,476	11,690	14,623	16,620	18,387	19,826	21,030
Ventura County	175.3	182	288	425	635	1,000	1,350	1,700
Totals—South Coastal Area	8,031	8,658	11,978	15,048	17,255	19,387	21,176	22,730
Santa Barbara County[c]	123.5	148	207	283	385	520	695	915
San Luis Obispo County[c]	66.5	70	92	130	205	340	520	700
Totals—Santa Barbara and San Luis Obispo Counties	190.0	218	299	413	590	860	1,215	1,615
Antelope-Mojave Service Area[d]	142.0	157	330	726	1,188	1,619	1,951	2,222
Whitewater-Coachella Service Area[e]	54.0	60	99	159	249	367	488	575
Kern County	279.4	291	385	480	620	850	1,150	1,480
Kern County Service Area	241.4	249	325	395	503	685	922	1,184
Totals—Southern California Region	8,706	9,380	13,100	16,838	19,920	23,080	25,955	28,550

[a] Median population projection.
[b] That portion of Coastal Riverside County that will be served from the San Diego Aqueduct is tabulated with San Diego County.
[c] Differences in the population projected in these counties and the corresponding service areas are negligible.
[d] Comprises portions of Kern, Los Angeles and San Bernardino Counties.
[e] Portion of Colorado Desert Area in Riverside County.

populations to be realized. This is indicated by high and low southern California region population forecasts, which show a four per cent variation from the median population in 1980. Over the full study period, the probable deviation from the median projection increases, with the difference between the high and low projections being about 12 per cent in 2020.

Economic Development

In California, as in other areas, net in-migration, population growth, and economic expansion are interdependent. Intermittently in the past, the State's population has momentarily surged ahead of employment opportunity. However, considering the last 50 years as a whole, California's population growth has been accompanied by a related increase in economic activity and employment. As a necessary phase in accurately estimating the levels of in-migration to California and to aid in evaluating the reasonableness of the statistical projections of the State's population, the probable future economic activity in the State and southern California was studied. These studies enabled relationships to be derived between economic activity, employment, and population.

The results of these studies indicate that the economy of the State and that of the nine southern California counties through 1980, at least, would expand at a rate that would attract the projected in-migration and support the forecast populations.

IRRIGATED AGRICULTURAL DEVELOPMENT

The southern California area has experienced an intensive development of irrigated agriculture wherever water supplies have been available. Because of favorable climatic conditions, coastal portions of the area have supported agriculture of types which produce high financial returns. Inland portions of the area, particularly Kern County and the Antelope-Mojave Service Area, have a more limited crop adaptability.

Forecasts of irrigated acreage related localized climatic limitations on crops to factors of land adaptability and availability, anticipated gross and net financial returns by crops, costs of water to the farmer, and general patterns of development established by precedent and environment. Because California's agricultural products are utilized throughout the nation, studies of the national market and this State's participation therein were also necessary.

Land adaptability was determined from the land classification surveys. Available irrigable land indicated in the surveys was reduced over time by the urban development projected to occur on agricultural land.

As outlined earlier, the full costs at the main aqueduct, associated with delivering water to each service area, were used in projecting land use and attendant water demands.

Projection of Irrigated Acreage

The projection of irrigated agricultural acreage for each service area was made after compiling and analyzing the following factors:

1. Availability and quality of land, with consideration of encroachment by urban and industrial development.
2. Crop adaptability.
3. Present agricultural development patterns.
4. Market for farm products.
5. Residual income available to the farmer for payment of water charges and for incentive to farm, and probable return on investment.
6. Cost of water, including distribution costs.
7. Existence of local water development organizations.

TABLE 5

PRESENT AND PROJECTED NET AREAS OF IRRIGATED CROPS IN THE SOUTHERN CALIFORNIA AREA [a]

(In thousands of acres)

Area	1957	1960	1970	1980	1990	2000	2010	2020
Coastal San Diego County and Southwestern Riverside County[b]	[c]61	61	95	121	151	166	174	178
Present Metropolitan Water District Service Area	[c]48	47	75	108	128	134	129	117
Coastal Riverside County[b]	76	75	70	66	64	62	56	46
Present Metropolitan Water District Service Area	72	72	67	63	62	60	54	44
Coastal San Bernardino County	82	80	67	48	31	18	8	0
Present Metropolitan Water District Service Area	46	45	40	32	21	11	5	0
Coastal Los Angeles County	58	22	5	1	0	0	0	0
Present Metropolitan Water District Service Area	44	14	3	0	0	0	0	0
Orange County	97	87	54	18	11	6	1	0
Present Metropolitan Water District Service Area	93	83	51	16	10	5	1	0
Totals—Present Metropolitan Water District Service Area	303	261	236	219	221	210	189	161
Totals—Southern California Coastal Plain and Coastal San Diego County	374	325	291	254	257	252	239	224
Ventura County	117	122	124	111	94	84	63	51
Totals—South Coastal Area	491	447	415	365	351	336	302	275
Santa Barbara Service Area[d]	72	72	72	83	89	89	92	93
San Luis Obispo Service Area[e]	18	20	23	31	43	44	42	38
Totals—Santa Barbara and San Luis Obispo Service Areas[d,e]	90	92	95	114	132	133	134	131
Antelope-Mojave Service Area	89	90	87	78	66	50	32	28
Whitewater-Coachella Service Area[f]	----	----	----	----	----	----	----	----
Kern County Service Area	335	358	432	606	771	831	810	797
Totals—Southern California Area	916	988	1,028	1,161	1,319	1,350	1,279	1,231

[a] Net area excludes roads, highways, farm lots, and nonirrigable lands within gross irrigated land areas.
[b] That portion of coastal Riverside County that will be served from the San Diego Aqueduct is tabulated with San Diego County.
[c] Estimate based on San Diego County Agricultural Commissioner Report, 1957.
[d] Excludes Cuyama area of Santa Barbara County.
[e] Excludes Santa Maria, Carrizo Plain, and Cuyama areas of San Luis Obispo County.
[f] Agricultural acreages for Whitewater-Coachella area not tabulated.

The future pattern and extent of crops were estimated by decades after study of the foregoing factors. Those crops that may be expected to produce maximum net returns on the required investments were of prime importance in establishing future cropping patterns, while analyses of future markets enabled estimates to be made on extent of acreages of each crop. The estimated rate of growth of irrigated acreage was governed both by the magnitude of the average net returns on investments in the various subunits as compared with historical growth rates, under differing rates of return, and by local organizational factors.

The projections of irrigated acreages resulting from these studies are summarized for selected subdivisions of the investigational area in Table 5, and are shown graphically on Figure 2, entitled "Projected Areas of Irrigated Crops in the Southern California Area". The effect of urban encroachment is evident from values shown for the coastal counties, with coastal Los Angeles County showing a decrease to a mere 5,000 irrigated acres by 1970. However, the areas containing large expanses of presently nonirrigated land, such as southwestern Riverside, San Diego, Santa Barbara, San Luis Obispo, and Kern Counties, may be expected to experience an increase in irrigated agriculture. Projections of irrigated land were not made for the portion of the Whitewater-Coachella Service Area considered for northern California water service, since it was estimated that crops climatically adapted to this area would not have sufficient ability to pay for this water. Similarily, the areal extent of irrigated agriculture in the Antelope-Mojave Service Area is shown to decrease with time for this reason and because of encroachment of urban lands.

WATER REQUIREMENTS

Total future water requirements were estimated by applying appropriate values of unit water use to the projections of population and irrigated acreages. These estimates were prepared without regard to source of water supply, and are to be differentiated from estimates of "economic demand for imported water".

Unit Urban Water Use

Estimates of future unit values of urban water use were prepared from analyses of historical trends in these values and relating thereto the factors of climate, levels of industrial development, personal income, and price of water. These trends were developed from data obtained for some 30 communities in the southern Califorina area covering the period from 1930 through 1955. It was found that per capita use of water has been increasing. On the basis of analyses of the foregoing influencing factors, it was considered that this general trend would continue in the future. The values of unit urban water use so derived are averages representing all uses in economically balanced urban areas including industrial, commercial, residential and municipal, as well as losses within local distribution systems, expressed on a per capita basis.

Presented in Table 6 are the projected values of unit urban water use employed in the study. These values are considered conservative and are substantially below those that would result from extrapolation of the rate of increase in unit urban water use exhibited during the period from 1930 to 1955.

In certain parts of the southern California area, a portion of the water delivered for use returns to underground storage basins and is available for reuse. Under such conditions the net areal water requirement would be less than the requirements computed by employment of the foregoing values of per capita water use. Also, the manner and procedures followed in disposing of sewage affect the net areal water requirements. The experience of highly developed southern California communities, such as Los Angeles

TABLE 6

PROJECTED AVERAGE UNIT VALUES OF URBAN WATER USE IN SELECTED AREAS

	San Luis Obispo, Santa Barbara, Ventura and Orange Counties, Coastal Plain of Los Angeles County		San Fernando and San Gabriel Valleys		Upper Santa Ana River Basin, Antelope-Mojave Service Area		Whitewater-Coachella Service Area		San Diego Metropolitan Area		Remainder of Coastal San Diego County	
Year	Gallons per capita per day	Acre-feet per capita per annum	Gallons per capita per day	Acre-feet per capita per annum	Gallons per capita per day	Acre-feet per capita per annum	Gallons per capita per day	Acre-feet per capita per annum	Gallons per capita per day	Acre-feet per capita per annum	Gallons per capita per day	Acre-feet per capita per annum
1960	166	0.186	198	0.222	225	0.252	300	0.336	140	0.157	190	0.212
1970	176	.197	210	.235	240	.269	310	.347	154	.173	200	.224
1980	186	.208	220	.246	250	.280	320	.358	168	.188	200	.224
1990	192	.215	230	.258	255	.286	330	.370	182	.204	200	.224
2000	198	.222	235	.263	260	.291	340	.381	196	.220	200	.224
2010	202	.226	240	.269	260	.291	345	.386	200	.224	200	.224
2020	206	.231	240	.269	260	.291	350	.392	200	.224	200	.224

NOTE: The values in this table represent all uses in urban areas, and include estimated losses within local distribution systems.

County, has been that as communities approach a high degree of land utilization, aesthetic conditions force the disposal of sewage to the ocean. Another important factor forcing ocean disposal of wastes is the threat of pollution of underground water by highly mineralized or toxic industrial wastes. It is anticipated that in other areas, where substantial population growth is forecast, and which now discharge their sewage to underground basins, sewage facilities will be constructed with ocean outfalls.

Of particular significance in this regard are the communities in the Upper Santa Ana Valley area of Riverside and San Bernardino Counties, the inland valleys of Ventura County, and the Santa Maria Valley of Santa Barbara County. Projected unit values of net urban water use in these areas are presented in Table 7.

TABLE 7

PROJECTED UNIT VALUES OF NET URBAN WATER USE IN SELECTED SOUTHERN CALIFORNIA AREAS

(In acre-feet per capita per annum)

Year	Upper Santa Ana River Basin in Riverside and San Bernardino Counties	Ojai and Santa Clara Valleys in Ventura County and Santa Maria Valley in Santa Barbara County	Calleguas Creek Basin in Ventura County
1960	0.106	0.078	0.078
1970	.133	.083	.083
1980	.118	.087	.087
1990	.172	.129	.090
2000	.233	.178	.133
2010	.262	.203	.181
2020	.262	.208	.208

Net Urban Water Requirements

Projected net urban water requirements were derived by application of appropriate unit values of net water use to the population projections. Set forth in Table 8 are the resulting estimates of net urban water requirements by decades for the service areas in the southern California area.

Unit Agricultural Water Use

For many years, the Department of Water Resources and other agencies have made field investigations and compiled data relative to the unit use of water by irrigated agriculture. These data were utilized in this investigation. In areas where return flows from applied irrigation water would not be recovered for re-use, unit values of total applied water were utilized to estimate net water requirements. In areas overlying unconfined ground water basins, where excess irrigation applicaitons return to ground water storage and thus are available for re-use, water requirements were based on unit values of consumptive use of applied water.

Unit values of consumptive use of applied water by representative crops so employed are set forth in Table 9. Table 10 sets forth unit values of applied water for these crops.

Net Agricultural Water Requirements

Appropriate unit values of water use from Tables 9 and 10 were applied to projected acreages of irrigated crops to estimate net agricultural water requirements. These estimates are presented in Table 11 for the various service areas of the southern California area.

GROWTH IN ECONOMIC DEMAND FOR IMPORTED WATER

Estimates of the growth of economic demand for imported water were prepared from the projections of urban and irrigated agricultural development and water requirements therefor, giving consideration to the present and probable future magnitude of local water supplies. Other than in the service area of The Metropolitan Water District of Southern California, these estimates represent the demand for surplus northern California water. After the date of full utilization of the available supply of Colorado River water, demands for imported water in the Metropoli-

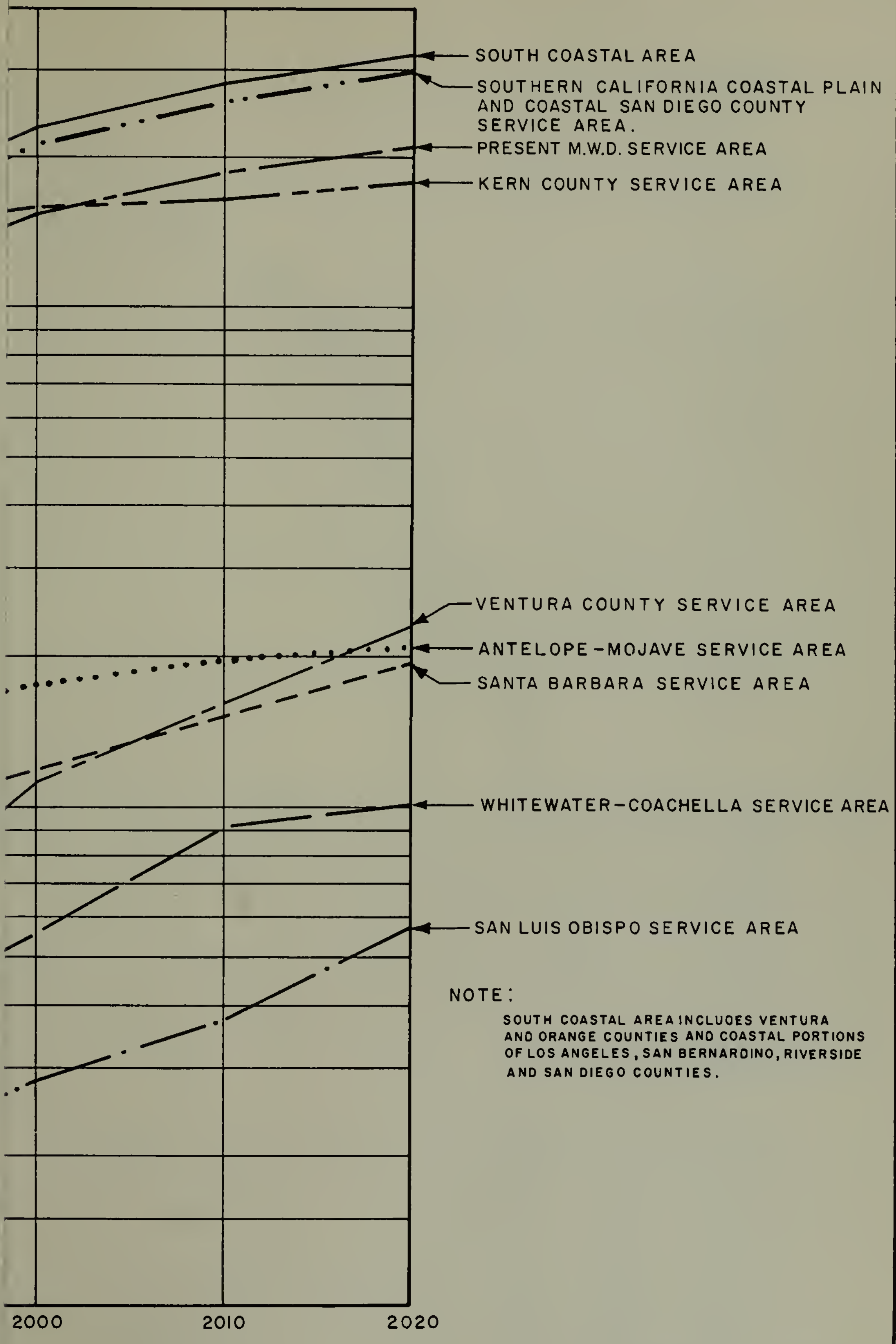
TABLE 8

ESTIMATED FUTURE NET URBAN WATER REQUIREMENTS IN SOUTHERN CALIFORNIA SERVICE AREAS

(In acre-feet per annum)

Year	Kern County	Southern California Coastal Plain and Coastal San Diego County	Present Service Area Metropolitan Water District	Ventura County	Whitewater-Coachella	Antelope-Mojave	Santa Barbara	San Luis Obispo
1960	50,000	1,539,000	1,365,000	25,000	12,000	17,000	21,000	8,000
1970	79,000	2,239,000	1,976,000	43,000	21,000	37,000	31,000	11,000
1980	103,000	2,911,000	2,544,000	67,000	34,000	86,000	43,000	17,000
1990	139,000	3,490,000	2,986,000	111,000	55,000	143,000	62,000	31,000
2000	198,000	4,119,000	3,465,000	193,000	81,000	197,000	93,000	59,000
2010	280,000	4,601,000	3,822,000	275,000	112,000	238,000	132,000	97,000
2020	365,000	4,927,000	4,078,000	362,000	135,000	271,000	178,000	135,000

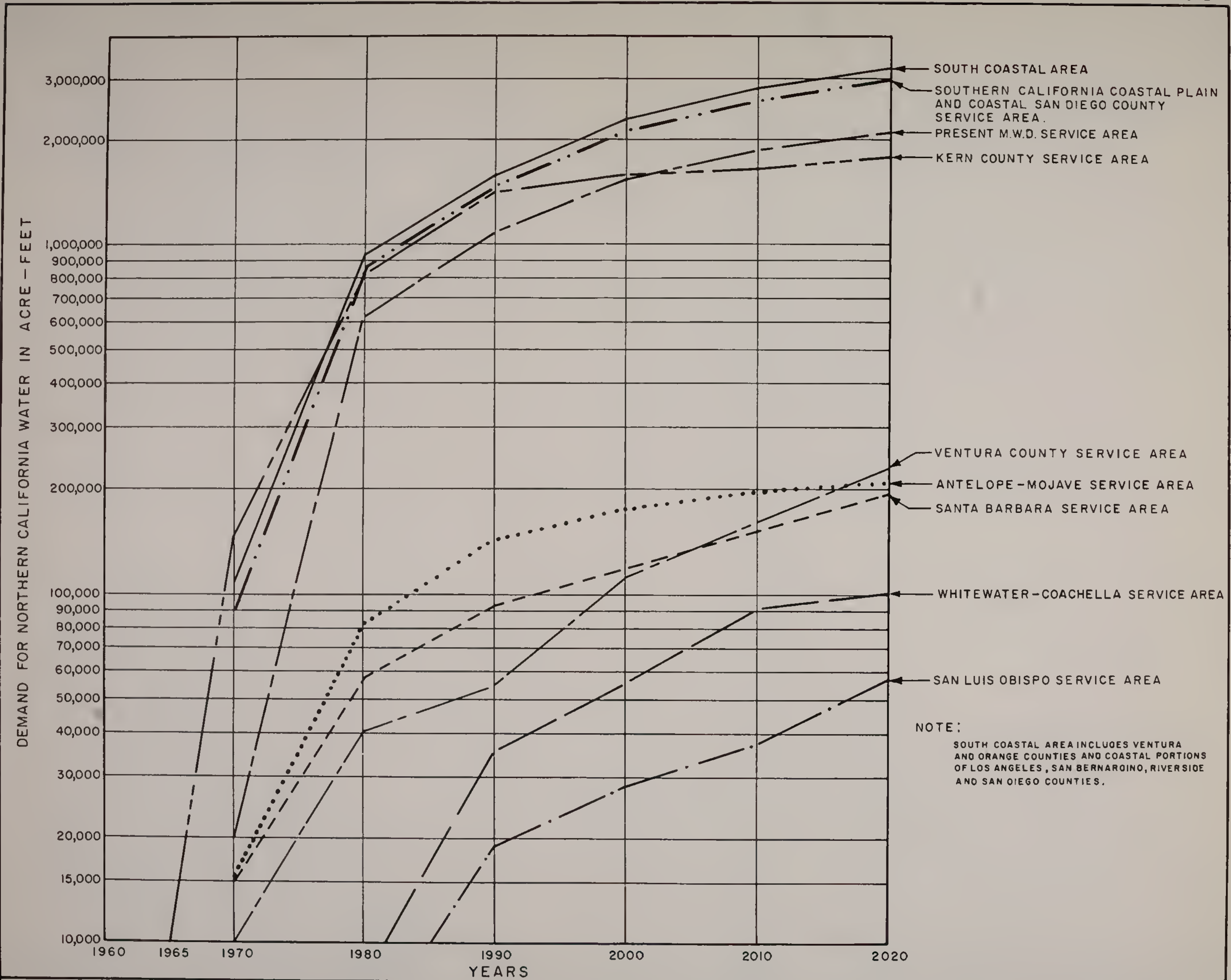
FIGURE 4



NOTE:

SOUTH COASTAL AREA INCLUDES VENTURA AND ORANGE COUNTIES AND COASTAL PORTIONS OF LOS ANGELES, SAN BERNARDINO, RIVERSIDE AND SAN DIEGO COUNTIES.

ERN CALIFORNIA WATER IN SOUTHERN CALIFORNIA AREAS



NOTE:

SOUTH COASTAL AREA INCLUDES VENTURA AND ORANGE COUNTIES AND COASTAL PORTIONS OF LOS ANGELES, SAN BERNARDINO, RIVERSIDE AND SAN DIEGO COUNTIES.

PROJECTED GROWTH IN DEMAND FOR SURPLUS NORTHERN CALIFORNIA WATER IN SOUTHERN CALIFORNIA AREAS

TABLE 9

ESTIMATED UNIT VALUES OF CONSUMPTIVE USE OF APPLIED WATER BY REPRESENTATIVE CROPS IN SOUTHERN CALIFORNIA AREA

(In feet of depth per annum)

County	Alfalfa	Citrus, subtropical	Walnuts, deciduous	Truck crops[a]	Field crops	Hay and grain	Flowers, nursery
San Luis Obispo							
Coastal	1.9	---	0.7	3.0	0.8	0.1	---
Inland	2.6	---	1.3	2.8	1.3	0.5	---
Santa Barbara							
Coastal	2.1	1.3	1.3	2.0	1.0	---	1.0
Inland	2.3	1.3	1.5	3.0	1.0	0.5	---
Ventura							
Coastal	2.1	1.3	1.6	2.0	1.1	0.6	3.0
Inland	2.4	1.4	1.6	2.4	1.2	0.8	3.0
Los Angeles							
Coastal	2.4	1.5	1.5	2.4	1.2	0.7	---
Antelope Valley	3.0	---	2.2	1.4	2.0	0.8	---
Orange	2.4	1.5	1.5	2.4	1.2	0.7	---
Riverside							
Upper Santa Ana	2.8	1.6	1.3	1.3	0.7	0.6	---
San Bernardino							
Upper Santa Ana	2.1	1.5	1.3	1.3	0.7	0.5	---
Mojave Area	2.8	---	2.1	1.5	2.2	0.9	---
Kern							
Kern County Service Area	3.1	2.3	2.3	1.0	1.6[b]	0.8	---
Antelope Valley	3.0	---	2.2	1.4	2.0	0.8	---
San Diego							
Coastal	2.4	1.4	1.9	3.0	1.4	0.4	2.0
Inland	2.5	1.5	1.8	2.8	1.5	0.5	2.0

[a] Double-cropping of truck crops assumed in all areas with the exception of the Antelope Valley and Mojave areas and Kern County.

[b] Excluding weighted average value of consumptive use for cotton. This crop requires 2.3 acre-feet per acre.

TABLE 10

ESTIMATED UNIT VALUES OF APPLIED IRRIGATION WATER ON REPRESENTATIVE CROPS IN SOUTHERN CALIFORNIA AREA[a]

(In feet of depth per annum)

County	Alfalfa	Citrus, subtropical	Walnuts, deciduous	Truck crops[b]	Field crops	Hay and grain	Flowers, nursery
San Luis Obispo							
Coastal	2.9	---	0.9	3.8	1.1	0.1	---
Inland	3.7	---	1.6	3.6	1.9	0.6	---
Santa Barbara							
Coastal	3.0	1.6	1.6	3.4	2.0	---	1.5
Inland	2.9	---	1.9	4.6	1.4	0.7	---
Ventura							
Coastal	3.0	1.5	1.7	2.8	1.8	0.9	4.3
Inland	2.7	1.6	1.8	3.2	1.6	1.1	4.3
Los Angeles							
Coastal	3.4	2.1	2.1	3.4	1.7	1.0	---
Antelope Valley	6.0	---	4.4	2.8	4.0	1.6	---
Orange	3.4	2.1	2.1	3.4	1.7	1.0	---
Riverside							
Upper Santa Ana	4.7	2.7	2.2	2.2	1.4	1.0	---
San Bernardino							
Upper Santa Ana	3.5	2.5	2.2	2.2	1.4	0.8	---
Mojave Area	5.6	---	4.2	3.0	4.4	1.8	---
Kern							
Kern County Service Area	3.9	2.9	2.9	1.8	2.3[c]	1.1	---
Antelope Valley	6.0	---	4.4	2.8	4.0	1.6	---
San Diego							
Coastal	3.5	2.4	3.1	5.0	2.4	0.7	3.3
Inland	3.6	2.5	3.0	4.7	2.5	0.8	3.3

[a] Expressed as net duty of applied water measured at the farmer's headgate.

[b] Double-cropping of truck crops assumed in all areas with the exception of Antelope Valley and Mojave areas and Kern County.

[c] Excluding weighted average value of applied use for cotton. This crop requires 2.7 acre-feet per acre.

tan Water District area must also be satisfied by water from the north.

These estimates of economic demand are to be distinguished from estimates of overdraft or other measures of need which may be developed without regard to the cost of water available to satisfy that need. Estimates of economic demand for imported water developed herein reflect the cost-price relationship assumed for purposes of the investigation and, also, the individual factors peculiar to each service area which would tend to stimulate or inhibit the use of imported water.

Table 12 presents the resulting estimates of growth in economic demand for imported water by decades to year 2020 for the several service areas. Figure 3, entitled, "Historical and Projected Growth in Demand for Imported Water in Present Metropolitan Water District Service Area" shows the growth in demand for imported water in the present service area of The Metropolitan Water District of Southern California and demonstrates the need for additional imported water in the District service area by 1970. Figure 4, entitled, "Projected Growth in Demand for Surplus Northern California Water in Southern California Areas" graphically presents the estimated growth in demand for surplus northern California water in selected southern California areas.

As shown in Table 12 and Figure 4, it was estimated that the 1,800,000 acre-feet of water per annum considered for delivery to the area south of the Tehachapi Mountains in the 1955 report on the Feather River and Delta Diversion Projects will be sufficient only for about twenty years after northern California water is introduced into this area. Further, the economic demand for water from northern California therein was estimated to continue to grow, reaching nearly three and one-half million acre-feet annually by 2020. The table and figure also show that by year 2020 the economic demand for this water was estimated to approach the following annual amounts: Kern County Service Area, 1,800,000 acre-feet; Antelope-Mojave and Whitewater-Coachella Service Areas, 300,000 acre-feet; Santa Barbara and San Luis Obispo

TABLE 11

ESTIMATED FUTURE NET REQUIREMENTS FOR WATER BY IRRIGATED AGRICULTURE IN SOUTHERN CALIFORNIA SERVICE AREAS [a]

(In acre-feet per annum)

Year	Kern County	Southern California Coastal Plain and Coastal San Diego County	Ventura County	Present service area Metropolitan Water District	Antelope-Mojave	Santa Barbara	San Luis Obispo
1960	896,000	519,000	182,000	412,000	216,000	143,000	46,000
1970	1,174,000	494,000	186,000	395,000	209,000	145,000	52,000
1980	1,644,000	445,000	165,000	338,000	190,000	170,000	72,000
1990	2,072,000	458,000	143,000	339,000	160,000	183,000	103,000
2000	2,220,000	468,000	126,000	329,000	110,000	183,000	104,000
2010	2,148,000	459,000	97,000	308,000	87,000	188,000	99,000
2020	2,092,000	454,000	78,000	280,100	68,000	188,000	90,000

[a] Agricultural water requirements for Whitewater-Coachella area not tabulated.

TABLE 12

HISTORICAL AND PROJECTED ECONOMIC DEMAND FOR IMPORTED WATER IN THE SOUTHERN CALIFORNIA AREA [a]

(In thousands of acre-feet per annum)

Area	1950	1960	1970	1980	1990	2000	2010	2020
Coastal San Diego County and Southwestern Riverside County [b]	69.3	136	319	474	659	826	914	993
Present Metropolitan Water District Service Area	69.3	127	289	418	565	695	753	794
Coastal Riverside County [b]	0.0	33	45	60	114	261	405	480
Present Metropolitan Water District Service Area	0.0	33	45	58	109	242	366	426
Coastal San Bernardino County	0.0	8	21	26	154	317	451	519
Present Metropolitan Water District Service Area	0.0	8	21	26	64	135	203	243
Coastal Los Angeles County	60.6	303	662	1,191	1,384	1,484	1,551	1,602
Present Metropolitan Water District Service Area	60.6	303	662	1,067	1,209	1,295	1,349	1,394
Orange County	35.7	132	193	263	352	421	465	511
Present Metropolitan Water District Service Area	35.7	132	193	259	341	395	432	472
Totals—Present Metropolitan Water District Service Area [c]	165.6	603	1,210	1,828	2,288	2,762	3,103	3,329
Totals—Southern California Coastal Plain and Coastal San Diego County	165.6	612	1,240	2,014	2,663	3,309	3,786	4,105
Ventura County	0.0	0	10	41	55	115	168	236
Totals—South Coastal Area	165.6	612	1,250	2,055	2,718	3,424	3,954	4,341
Santa Barbara Service Area	0.0	0	15	58	93	121	154	196
San Luis Obispo Service Area	0.0	0	0	5	19	28	37	55
Totals—Santa Barbara and San Luis Obispo Service Areas	0.0	0	15	63	112	149	191	251
Antelope-Mojave Service Area	0.0	0	15	80	142	175	195	208
Whitewater-Coachella Service Area	0.0	0	0	0	35	55	90	100
Kern County Service Area [d]	0.0	0	146	823	1,409	1,606	1,700	1,785
Totals—Southern California Area	165.6	612	1,426	3,021	4,416	5,409	6,130	6,685

[a] Values include demands for net Colorado River Aqueduct supply amounting to a maximum of 1,150,000 acre-feet annually, but exclude demands for Los Angeles Aqueduct supply of 320,000 acre-feet annually, which is treated herein as part of the local water supply.

[b] That portion of Coastal Riverside County that will be served from the San Diego Aqueduct is tabulated with San Diego County.

[c] First delivery of Colorado River water to the Metropolitan Water District area occurred in 1941.

[d] Values do not include supply from Friant-Kern Canal.

Service Areas, 250,000 acre-feet; Ventura County, 240,000 acre-feet; coastal plain of southern California and coastal San Diego County, 3,000,000 acre-feet.

Factors Affecting Estimates

The foregoing projections of growth in economic demand for imported water necessarily were developed on the basis of many estimates and assumptions, variations from which would tend to increase or decrease these projections. Basic assumptions included those relating to factors of aqueduct location and timing of construction, population forecasts, manner of sewage disposal, rate of overdraft on ground water basins, rates of unit water use, availability of local water supplies, climate, cost of imported water, and water quality considerations. It is believed that, although variations in any of these items would change the demand for imported water at any given time, there is a greater probability for an increase than for a decrease in the projected demands for imported water.

Possible variations in three of the basic assumptions and the resulting effects thereof on the estimated rate of growth in demand for imported water are discussed herein.

Climate. Since the entire investigational area experiences a climate of a cyclic nature, the use of imported water will vary during wet and dry portions of the cycle because of differences in the availability of local water supplies. The demands developed herein reflect long-term mean conditions of climate. Annual variations in the use of water in urban areas during periods of differing weather conditions are comparatively small. Agricultural uses, wherein a greater proportion of the annual moisture requirements are supplied by rainfall during wet periods, generally may experience a substantial variation. In general, however, although variations will occur from year to year, the projected long-term trend of water requirements may be expected to prevail.

Cyclic climatic conditions may cause a substantial variation in the relative magnitude of use of imported and local water in portions of the South Coastal Area. The estimates of growth in economic demand for imported water were based on the eventual "safe yield" operation of local water supply facilities, including underground basins with, however, the continuance of overdraft in most underground basins postulated for varying periods into the future. Notwithstanding this continued overdraft, the occurrence of a series of wet years in all probability would reduce the amounts of imported water purchased both for direct use and for ground water recharge. Conversely, an ensuing dry period would occasion greater deliveries of imported water than would be postulated on the "average". It is believed that over a long-term period the demand for imported water, based on average water supply conditions, would prevail even with respect to recharge of ground water basins with imported water. In those ground water basins wherein extractions are limited by court decree or by stipulation of the users, the weather conditions of a given year have a comparatively limited effect on the amounts of imported water utilized.

In San Diego County, where relatively large surface storage reservoirs have been constructed on most streams, the opportunity exists for operation of these reservoirs in conjunction with imported water so as to realize a yield therefrom greater than the safe yield which would be estimated for conditions of no imported water supply. This can be done only so long as excess aqueduct capacity supplying imported water is available to make up ensuing deficiencies in supply that would result from overdrawing the surface storage. When the full delivery capacity of import facilities together with the safe yield of local water resource developments approaches the total water requirements of the area, this practice would have to be discontinued. The long-term effect on the use of imported water by this method of operation was considered to be of relatively small magnitude.

Price of Imported Water. Within the range of costs estimated for delivery of surplus northern California water by the alternative aqueduct systems, it does not appear that there would be a significant variation in the magnitude of demand for water by urban entities. However, it was estimated that use of imported water by irrigated agriculture in the central coastal counties, coastal San Diego and southwestern Riverside Counties and, most particularly, in Kern County would be significantly affected by variations in the price of water charged to the irrigators.

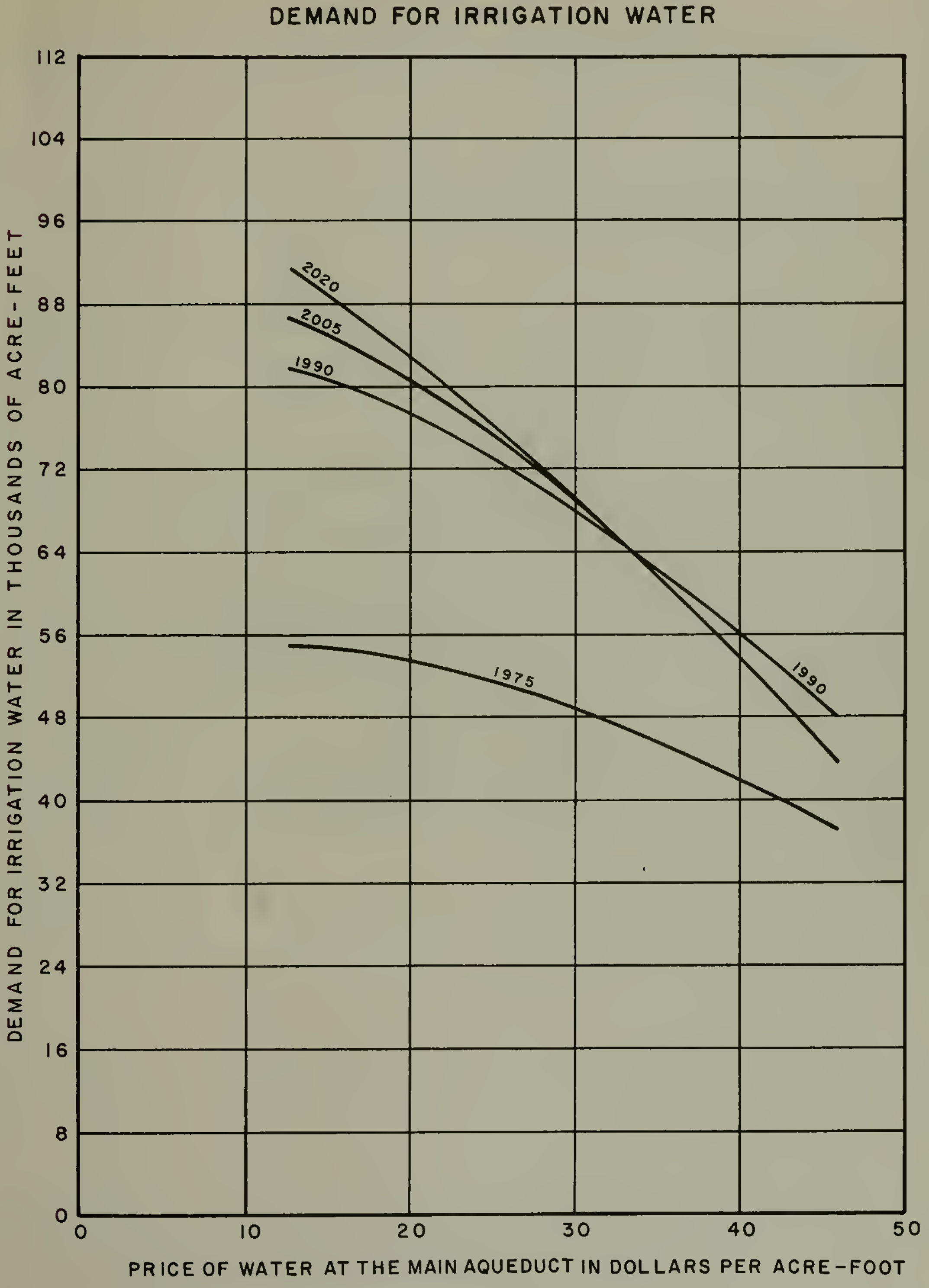
In support of the foregoing conclusion with respect to use of surplus northern California water for urban purposes, selected communities in the Southern California Area were investigated to ascertain the present cost of water to consumers therein. It was found that the actual cost to the consumers in the sampled areas ranged from a low of about $35 per acre-foot to a high of $168 per acre-foot. The majority of communities sampled indicated costs to the consumers on the order of about $75 per acre-foot. These costs are not directly comparable to the computed costs of northern California water presented in this Bulletin, as they reflect the many expenses associated with distribution beyond the principal conveyance systems. Included among these are costs of distribution, meters and services, customer accounting, taxes, and general administrative expense which, it was estimated, averaged between $40 and $70 per acre-foot. Production, treatment, and conveyance expenses were estimated to average from about $20 to $40 per acre-foot. Thus, although direct comparisons of present water costs with probable future costs, after introduction of northern California water to supplement the other available supplies, are difficult to prepare, the foregoing values would indicate that the resultant change in the direct cost to the ultimate consumer would be comparatively small.

Results of studies of the variation in growth of irrigated acreage and demand for imported water with price are presented in Figures 5, 6, and 7. As shown on these figures, this variation would be the greatest in the Kern County Service Area, where residual income from production of climatically adapted crops available for payment of water and incentive to farm, is less than for the higher value crops which can be grown in other portions of the area.

The relationships shown on Figures 5, 6, and 7 were utilized in adjusting capacities of alternative aqueduct systems in consistency with the estimated economic demand for imported water.

Water Quality. A basic assumption in the projections of water demand was that water adequate in quality as well as in quantity would be available to all service areas. A further discussion of the economic implications of variations in the quality of water imported for use in the Upper Santa Ana Valley and coastal San Diego County is presented in Chapter III.

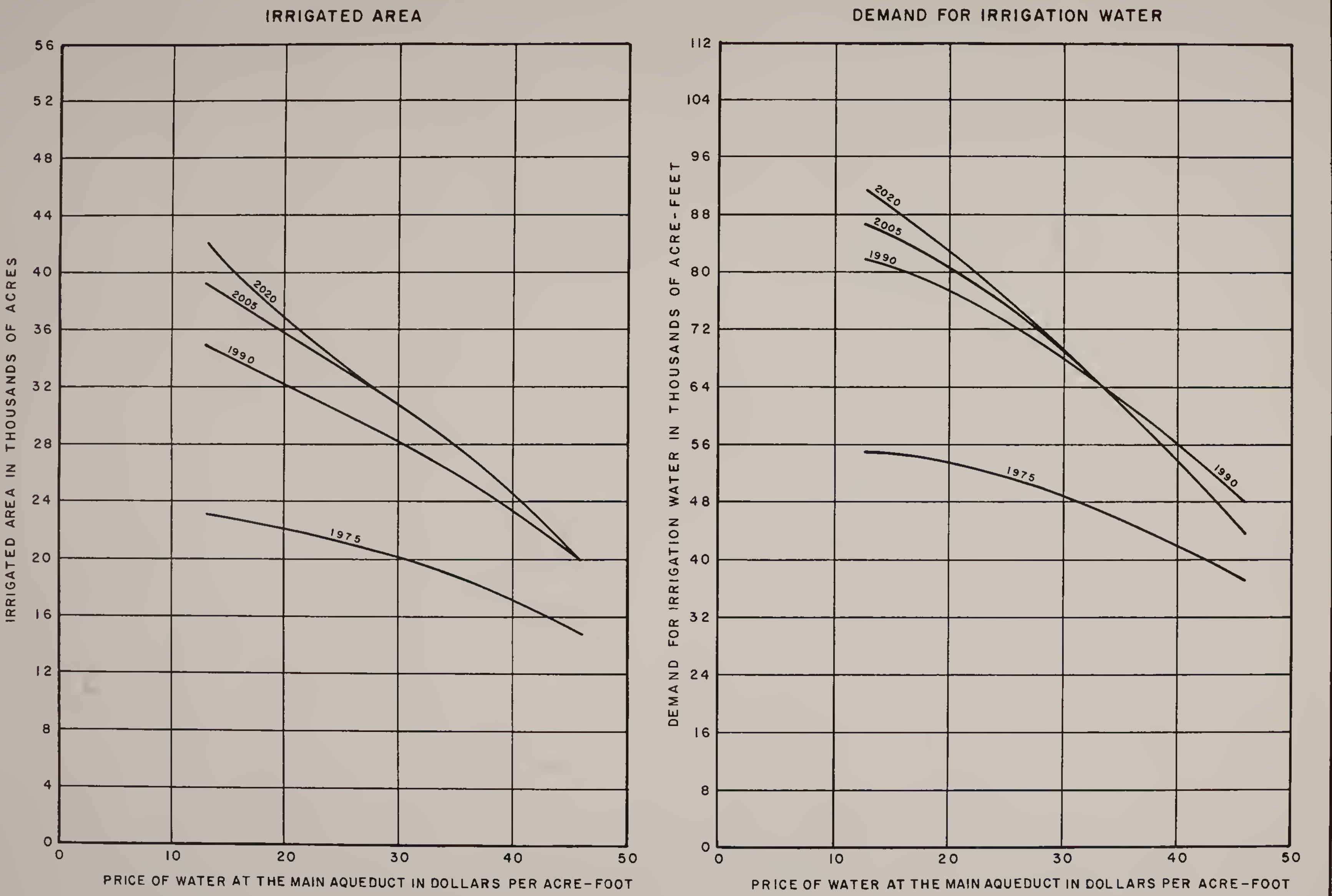
The estimates of demand for imported water in the Antelope-Mojave Service Area do not reflect consideration of possible salt balance problems in the underground basins in these areas. Depending on the exact physical conditions in these basins, the manner in which they are operated in the future, and other factors which are unknown at this time, it is possible that the cited estimate of demand for surplus northern California water would be increased by about ten per cent, or in the order of 25,000 acre-feet annually by year 2020.



IPS BETWEEN

D PRICE OF SURPLUS NORTHERN CALIFORNIA WATER

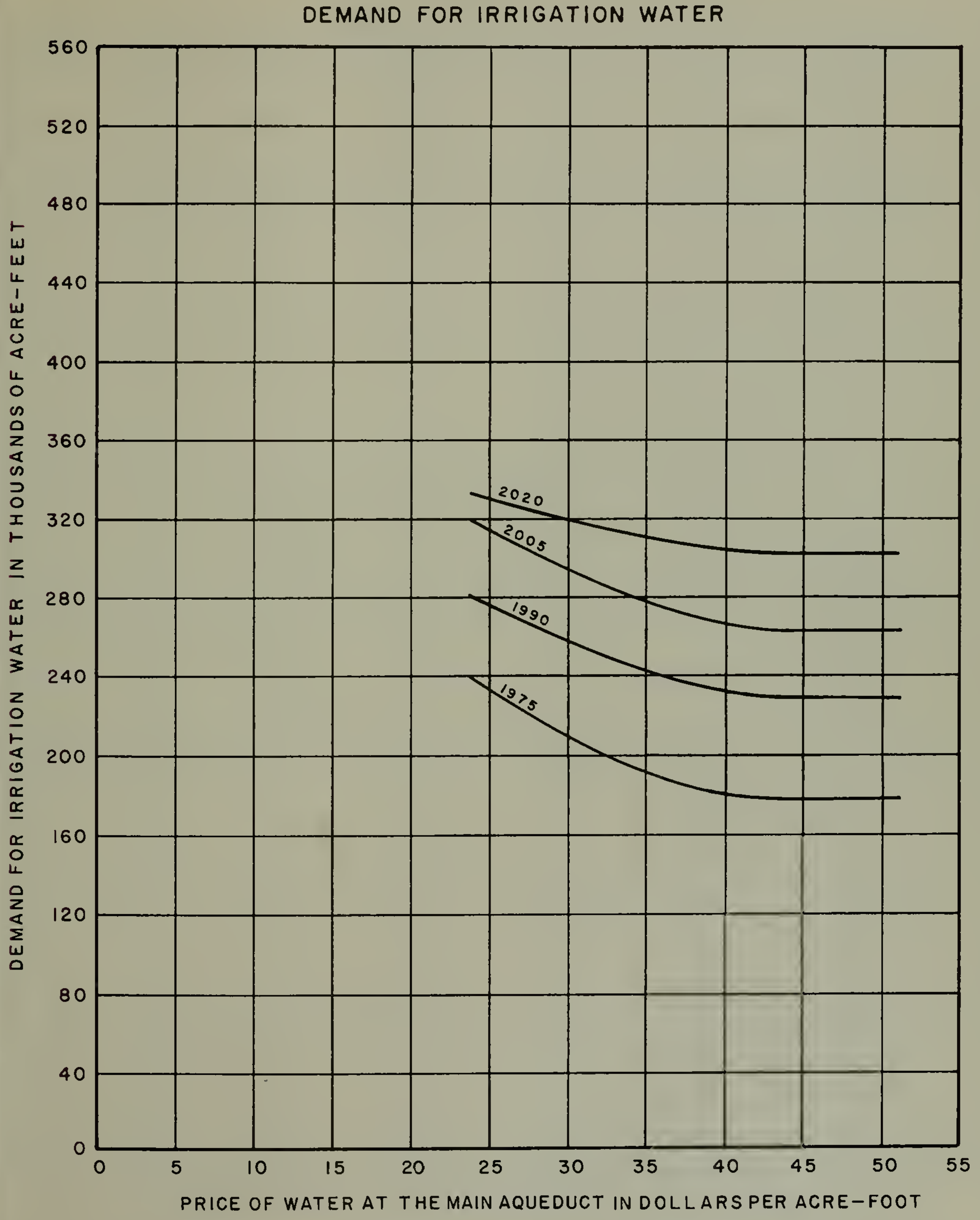
SANTA BARBARA COUNTIES



RELATIONSHIPS BETWEEN
IRRIGATED AREA, DEMAND FOR IRRIGATION WATER, AND PRICE OF SURPLUS NORTHERN CALIFORNIA WATER
IN SAN LUIS OBISPO AND SANTA BARBARA COUNTIES

FIGURE 6

ALUES REFLECT USE OF BOTH COLORADO RIVER WATER AND

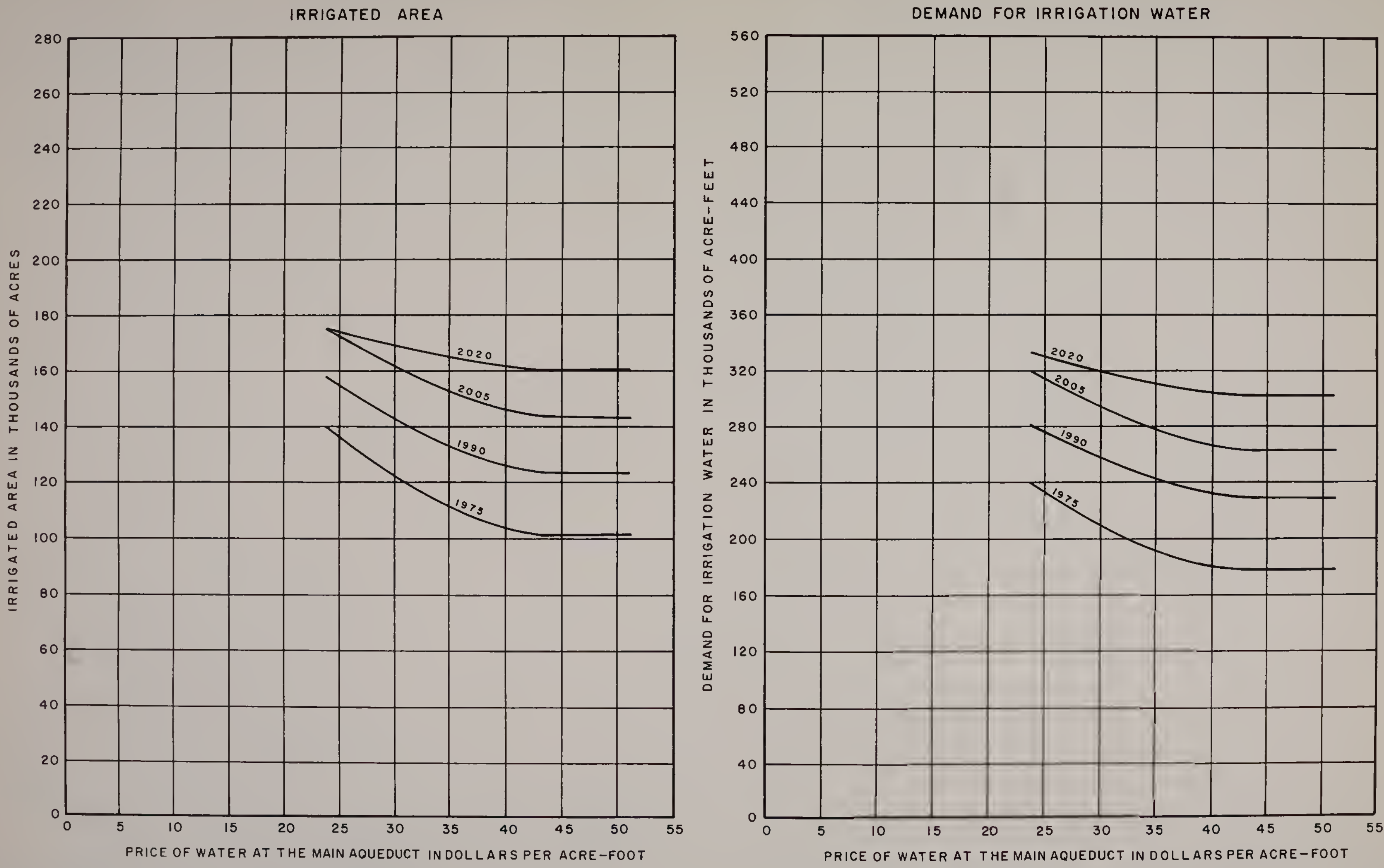


S BETWEEN

N WATER, AND PRICE OF IMPORTED WATER

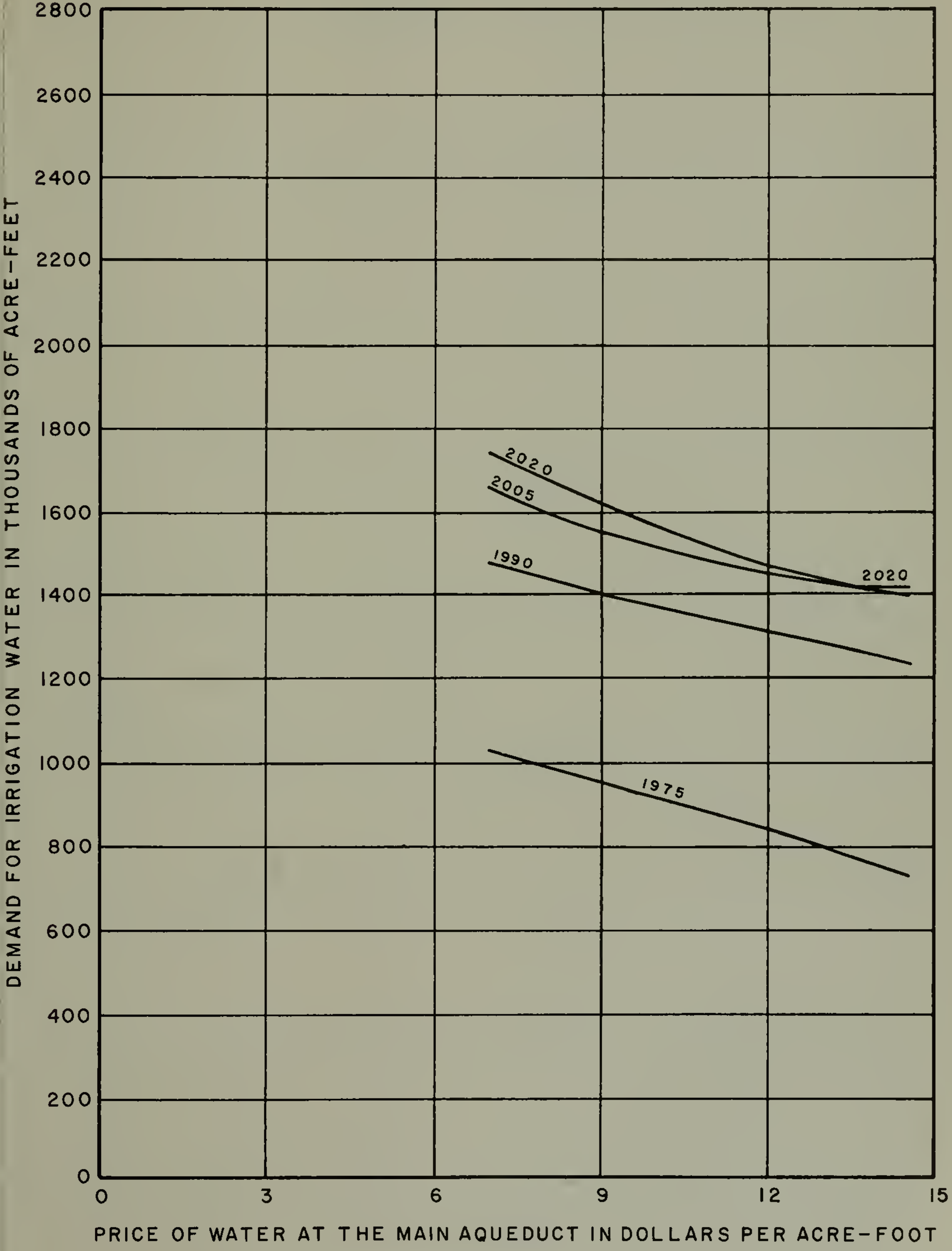
AND SAN DIEGO COUNTIES

NOTE:
IN THE METROPOLITAN WATER DISTRICT SERVICE AREA, VALUES REFLECT USE OF BOTH COLORADO RIVER WATER AND NORTHERN CALIFORNIA WATER.



RELATIONSHIPS BETWEEN
IRRIGATED AREA, DEMAND FOR IRRIGATION WATER, AND PRICE OF IMPORTED WATER
IN VENTURA, COASTAL RIVERSIDE AND SAN DIEGO COUNTIES

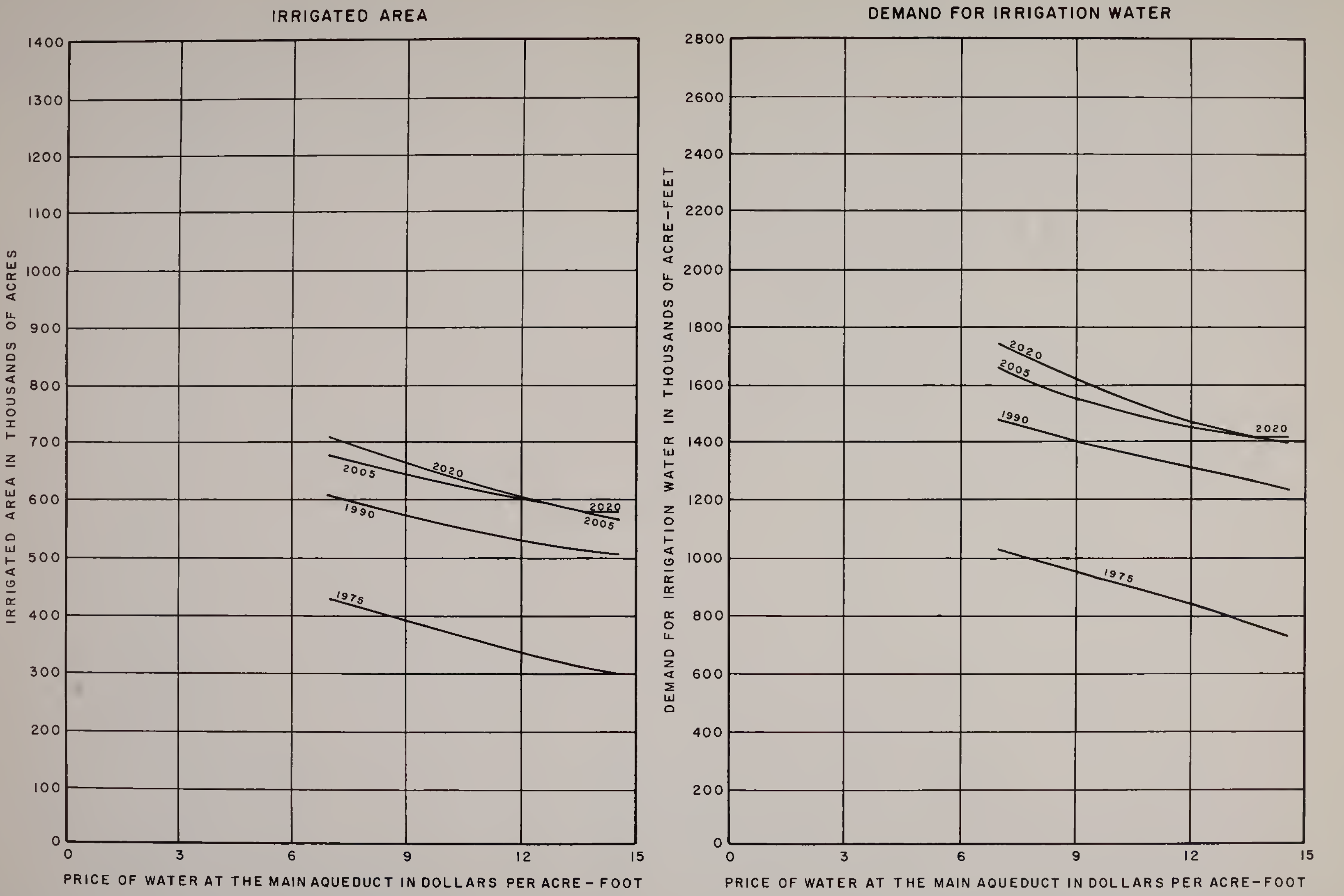
DEMAND FOR IRRIGATION WATER



S BETWEEN

) PRICE OF SURPLUS NORTHERN CALIFORNIA WATER

AN JOAQUIN VALLEY)



RELATIONSHIPS BETWEEN
IRRIGATED AREA, DEMAND FOR IRRIGATION WATER, AND PRICE OF SURPLUS NORTHERN CALIFORNIA WATER
IN KERN COUNTY (SAN JOAQUIN VALLEY)

DEPARTMENT OF WATER RESOURCES 1959

CHAPTER III

WATER QUALITY CONSIDERATIONS

With the introduction of northern California water to the area south of the Tehachapi Mountains, there will be available throughout a large portion of this area three major sources of water supply, namely, local water obtained largely from underground sources,* Colorado River water from The Metropolitan Water District of Southern California, and northern California water. In planning for the proper location and capacity of facilities to deliver this new supply of water from the north, not only must recognition be taken of the quantitative needs of the area for water but also, since each of these three supplies varies markedly in its mineral quality, consideration must be given to the water quality requirements of the beneficial uses to which this water will be put.

Water quality considerations therefore are a determinant, in this area, in the development of a plan for optimum utilization of these various sources of water supply. The purposes of the studies described in this chapter were to identify present or potential water quality problems, to evaluate these problems with respect to the selection of an aqueduct system, and to determine the influence of these problems on the timing and magnitude of deliveries of northern California water to portions of the Southern California Coastal Plain and Coastal San Diego County Service Area.

Of particular importance in regard to the physical and economic effects of utilizing the cited sources of water supply in the future and in developing an optimum plan of utilization therefor, are the Upper Santa Ana Valley and coastal San Diego County areas. The studies reported on herein were therefore concentrated in these areas although consideration was given to the entire area where the three sources of water supply will be available in the future.

The specialized nature of the water quality study and the need for research in developing basic data therefor made it desirable to have an outside research organization perform this work. The Stanford Research Institute conducted this study under contract with the Department of Water Resources and prepared a report, published as Appendix B to this Bulletin, entitled "Effects of Differences in Water Quality, Upper Santa Ana Valley and Coastal San Diego County, January, 1959". The findings of this report are summarized in this chapter and were employed in analyses presented hereinafter.

WATER QUALITY PROBLEMS

The problems of water quality are generally classified as mineral, physical, and sanitary. Many municipal water systems treat their water supplies to eliminate undesirable conditions resulting from one or more of these problems. Industrial users also find it necessary to treat water before use, particularly for boiler-feed purposes. Agriculture generally experiences difficulty only with mineral problems. With respect to selection of the location and capacity of an aqueduct system to deliver northern California water, it is only the mineral quality problems that are pertinent. However, as in any source of water supply, physical and sanitary quality conditions must also be considered in the utilization of northern California water for urban use.

Mineral Quality

The mineral content of a water supply can be highly significant with respect to beneficial uses thereof, and the amounts and compositions of the mineral constituents will result in limitations in varying degrees on the type and extent of its use. The United States Public Health Service has established recommended and mandatory upper limits of concentrations of certain mineral constituents for drinking water, generally applicable to municipal uses. These are reproduced in Table 13.

Based upon projections of the factors influencing the mineral quality of waters entering the Sacramento-San Joaquin Delta, an estimate was made of the probable long-term maximum mineral content of northern California water to be diverted therefrom for conveyance to the south, which is also presented in Table 13. This estimate of the future quality of northern California water is predicated on the eventual construction of works in the Delta to separate saline return irrigation waters. Should these works not be constructed, an increase in the concentration of mineral constituents shown in Table 13 may be expected.

There are also presented in Table 13 data on the mineral constituents in Colorado River water delivered to the treatment plant at La Verne through the Colorado River Aqueduct. These data represent historical conditions and are the mean of 16 yearly averages of constituents in Colorado River water delivered to the treatment plant. No consideration was given to any possible future change of the mineral quality of this water supply.

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* In addition, water from the Owens Valley-Mono Lake Basin is available to the City of Los Angeles.

TABLE 13

RECOMMENDED LIMITS OF MINERAL CONSTITUENTS IN DRINKING WATER AND MINERAL CONSTITUENTS OF COLORADO RIVER AQUEDUCT WATER SUPPLY AND SURPLUS NORTHERN CALIFORNIA WATER

(In parts per million)

Constituent	Limiting concentrations of mineral constituents for drinking water[a]	Mineral quality of imported water supplies	
		Colorado River Aqueduct water[b]	Surplus northern California water[c]
Fluoride	1.5[d]	0.4	Less than 1.5
Iron and Manganese together	0.3	Trace	Trace
Magnesium	125	31	--
Chloride	250	90	30
Sulfate	250	328	34
Lead	0.1[d]	--	--
Selenium	0.05[d]	--	--
Hexavalent Chromium	0.05[d]	--	--
Copper	3.0	--	--
Arsenic	0.05[d]	--	--
Zinc	15	--	--
Phenol	0.001	--	--
Silica	--	7.4	20
Calcium	--	86	--
Sodium and Potassium	--	112	28
Bicarbonate	--	141	100
Nitrate	--	0.4	2
Boron	--	0.13	Less than 0.5
Total Dissolved Solids	500 (1,000 permitted)	726	200
Hardness as $CaCO_3$ (ppm)			
Total	--	343[e]	100
Noncarbonate	--	226	20

[a] United States Public Health Service Drinking Water Standards, 1946.
[b] Mean of 16 yearly averages of mineral quality of water delivered to treatment plant at La Verne.
[c] Estimated quality of water to be diverted from the Sacramento-San Joaquin Delta during an eight-year drought period when mineral content would be highest, assuming full upstream development of water storage and utilization, and construction of Delta improvement works.
[d] Mandatory upper limits; others are recommended.
[e] Softened Colorado River water has hardness of 125 ppm.

It will be noted that the United States Public Health Service specifies a total dissolved solids content of 1,000 parts per million as an upper limit for drinking water standards. This compares with a total dissolved solids content of 200 parts per million for northern California water and 726 parts per million for Colorado River water, as shown in the table.

Hardness * is another expression of mineral content of water which is significant in its use for urban purposes. Hardness is generally evidenced to the domestic consumer by inability to develop suds when using soap; it also causes scaling problems in boilers. Waters containing 100 parts per million or less of hardness are considered soft; those containing 101 to 200 parts per million, moderately hard; and those containing in excess of 201 parts per million as very hard. The long-term historical records of quality of Colorado River water and the estimated future quality of surplus northern California water from the Delta indicate the respective degrees of hardness, as tabulated in Table 13. The Metropolitan Water District softens Colorado River water at its La Verne treatment plant to a hardness of 125 parts per million. However, with the District's existing distribution system, this softened water would not be available to most communities in the Upper Santa Ana Valley and coastal San Diego County. Therefore, if softening is required in these latter areas, additional treatment plants would be required.

It should be noted that under both mineral concentration and hardness standards, northern California water is considered to be of excellent mineral quality.

The quantity of total dissolved solids in a water supply for agricultural use is also important, as is the presence of specific mineral elements in varying proportions, such as the sodium percentage † and the presence of boron, lithium, fluoride, and chloride. Care must be exercised to avoid the accumulation of excessive concentrations of salts in the root zone. The higher the mineral content of the irrigation water, the greater the problems will be in this respect. Disregarding effects upon underlying ground water basins and downstream re-uses of the water, irrigation water to be used on relatively free draining soil may contain up to 1,000 parts per million of dissolved solids. Under special conditions, waters of higher solids concentrations may be utilized satisfactorily for production of the more salt-tolerant crops. The greater the quantity of dissolved solids in the irrigation water, the greater will be the amount of additional water necessary for leaching the solids from the soil.

In areas where tight soils are being utilized for irrigated agriculture, such as on the hillside slopes of northern San Diego County and areas in the San Jacinto Valley, increased applications of water would be required for removal of salts and, in many instances, installation of soil drainage facilities would also be required to remove the excess water containing the leached salts.

Mineral quality may be a critical factor in supplemental water supplies used for municipal or agricultural purposes in areas overlying unconfined ground water basins such as those in the Upper Santa Ana Valley. Use of water for urban purposes results in an increase in the dissolved solids content of the return flows from these uses, as does the evaporation and transpiration inherent in use of water for irrigation. The return flows from these uses percolate to the underlying ground water, mingle with natural supplies, and are re-used through ground water pumping. If water supplies of high mineral content are imported for use in a basin, degradation of the quality of the water in underground storage to unusable con-

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* Hardness is a measure of total calcium and magnesium salts expressed as equivalent parts per million of calcium carbonate ($CaCO_3$).

† The sodium percentage is 100 times the quantity of sodium ions in a water divided by the total positive ions in the water.

centrations will be more rapid. Under continuation of these conditions, combined with limited natural outflow from the basin to carry away accumulated salts, the ground water may eventually build up a dissolved solids content so great as to destroy the utility of the ground water basin.

This condition may be alleviated by increasing the outflow from the basin, thus removing additional quantities of dissolved solids. The construction of an ocean outfall sewer from the Upper Santa Ana Valley, postulated in Chapter II for primarily aesthetic reasons, would also serve to stabilize and even reduce the salt content in local ground water basins. However, the greater the mineral content of the source water, the greater the required outflow.

Physical Quality

Physical properties of water include temperature, color, turbidity, odor, and electrical conductance. Electrical conductance is often used as a measure of total dissolved solids. Turbidity, color, and odor are sometimes caused by the type and amount of aquatic organisms present in water.

Other than electrical conductance, these physical properties generally are of no consequence in the use of water for agricultural purposes. However, urban use generally requires the disinfection and treatment of water to remove offensive odors, color, and turbidity.

Physical quality problems will be encountered and treatment will be required in the use of both northern California and Colorado River water for urban purposes. Therefore, this particular problem will not result in significant differences in economic effect by use of either of these two water supplies. A later section of this chapter discusses treatment of northern California water.

ECONOMIC EFFECTS OF WATER QUALITY PROBLEMS

Studies were made of the economic effects of the use of imported water supplies of differing quality for the Upper Santa Ana Valley and coastal San Diego County. These studies evaluated differences in economic effects as reflected in: (1) ground water basins, (2) agricultural use of water, and (3) urban use of water. The general approach consisted of evaluating the over-all cost differential to water users in the Upper Santa Ana Valley and coastal San Diego County if projected demands for imported water therein were met with water supplies of qualities equivalent to those shown in Table 13 for Colorado River water and for surplus northern California water. The following discussion is based on the data and conclusions reported by Stanford Research Institute in Appendix B.

Ground Water Basins

An analysis was made of Bunker Hill, Riverside, San Timoteo, and Chino ground water basins in Upper Santa Ana Valley. The San Jacinto area, being practically a closed ground water basin with localized problems, will require further detailed study before the economic effect of quality of imported waters therein can be evaluated. In the San Diego County coastal area, ground water basins are of limited extent and return flows from imported water do not find their way into usable ground water basins in significant amounts.

An operation study over time, from 1960 to 2020, was made for each of the four basins including inflow from natural sources; applications of local and imported water in accordance with projected water demands; estimated interchanges between basins by export, import, and surface or underground inflow and outflow; flood flows and ground water effluent from the entire Upper Santa Ana Valley to Orange County by way of the Santa Ana River; and, in increasing quantities after 1985, outflow by way of an outfall sewer discharging into the ocean. Assumptions were made as to the volume of ground water that could reasonably be considered subject to the mixing of natural waters and return flows.

Results of the operation study indicated that, with importation of water equivalent in quality to that of Colorado River water to meet all projected demands for imported water, ground water in the Chino Basin would have exceeded 1,000 parts per million of total dissolved solids by about year 1982. At that time, outflow through the Santa Ana Narrows to Orange County would have reached the same quality. It was further found that, under the study conditions, ground water in San Timoteo Basin would not have exceeded 1,000 parts per million total dissolved solids until several years after the year 2000. Bunker Hill Basin ground waters, while steadily increasing in concentrations of dissolved solids, would not have exceeded concentrations of 1,000 parts per million during the study period.

The Stanford Research Institute study also indicated that in the Riverside Basin, which is the smallest of the four in terms of estimated total storage capacity and mixing volume, the total dissolved solids content of the ground water would reach 1,000 parts per million by 1976, increasing to about 1,300 parts per million by 1982.

On the contrary, the study estimated that, if northern California water were to be utilized for meeting imported water demands, the ground water quality would not reach the 1,000 parts per million limit in any of the basins. Estimated maximum concentrations would be 830 parts per million in 1995 in the Chino Basin, 470 parts per million in 1990 in the San Timoteo Basin, 390 parts per million in 2020 in the Bunker

Hill Basin, and 950 parts per million in 1990 in the Riverside Basin. After reaching these estimated peak values it was estimated the quality of ground water would thereafter improve.

Based upon the foregoing study, it is considered reasonable to assume that if importation of northern California water to these basins were to begin no later than the year 1982, continuity of the utility of ground water therein would be assured and the total dissolved solids in the ground waters of the various basins would be reduced over time, eventually reaching a stabilized value well below 1,000 parts per million. However, water quality conditions in certain localized areas may necessitate the advancement in the date when northern California water should be made available to the Upper Santa Ana Valley.

The economic effect of use of Colorado River water in the Upper Santa Ana Valley, from the standpoint of ground water development, was estimated on the basis of eventual loss of the use of the Riverside, Chino, and San Timoteo ground water basins, and the loss of the use of water entering Orange County at the Santa Ana Narrows. The safe yield of these basins and the annual supply to Orange County is estimated to be 176,000 acre-feet per year. The economic loss to the area was computed by evaluating this water at an estimated cost of importation of an equal amount of water at $25 per acre-foot, which value is less than the actual cost of imported northern California water. This economic loss would amount to a total annual value of $4,400,000.

Not evaluated in the study is the possible loss of utility of these ground water basins for conservation, regulation, and distribution of local and imported water supplies. Should degradation of the waters in the basins to the point of unusability occur, large capital expenditures for surface reservoirs and distribution facilities would have to be made to replace these important functions.

Agricultural Uses

The economic effects in agricultural uses were determined by computing, for the two basic water qualities considered, the excess water applications required to leach salts from the root zones of the various crops grown in the study area and, where applicable, the costs of fertilizer washed away by leaching water and the costs of tile drains to remove the leachate. Estimates of necessary excess water applications were based upon projections of irrigated acreage by crops and the soil types upon which these crops would be grown. Fertilizer losses were estimated by relating crops and fertilizer applications to the volume of leaching required. Excess water costs were assumed to be $25 per acre-foot for the purposes of the study. Costs of tile drain systems were averaged over the 60-year period of study from 1960 to 2020.

It was found that the annual increase in costs to agriculture would be between three and four million dollars over this 60-year period as a result of the use of imported water supplies of a quality equivalent to Colorado River water rather than water supplies of a quality equivalent to that of northern California water.

Urban Uses

The economic effects of water quality in urban areas were computed for three major types of such uses: industrial, commercial, and residential and public purposes. Differences in costs of industrial operations were evaluated on the basis of costs of such items as water treatment, operating expenses for removing boiler scale or other deposits in industrial equipment, and the relative number of times water could be re-used in industrial processes.

Differences in costs for commercial establishments and for residential and public uses were estimated on the basis of costs of treatment to reduce hardness. These costs were based on estimates of the long-term average costs of construction and operation of centralized water softening plants.

The increased cost to urban entities in the Upper Santa Ana Valley and coastal San Diego County, which would result from use of waters of the quality of Colorado River water rather than that of northern California water, was found to increase steadily through the study period. This increase would result from both the projected urban expansion and the increasing dependence upon imported water. The cost differentials obtained ranged from $828,000 per year in 1960 to more than $19,000,000 per year in 2020.

Although not evaluated in Appendix B, similar differences of economic effects would be experienced with use of the two water supplies in urban areas in the westerly coastal plain areas. These latter differences were considered, however, in evaluating the effect of water quality problems on aqueduct system selection, as described in Chapter IV.

EFFECTS OF WATER QUALITY ON SELECTION OF AN AQUEDUCT SYSTEM

From the standpoint of meeting projected demands for imported water, it would be possible to delay delivery of northern California water to the Upper Santa Ana Valley and coastal San Diego County from 1982 until about 1992, by utilizing in these easterly areas, including those areas where Colorado River water is not presently available, the entire claimed rights of the Metropolitan Water District in and to the Colorado River supply and by utilizing northern California water in the coastal plain areas to the west. Thereafter, the former areas would require northern California water to sustain further growth.

However, the economic effects of differences in water quality have a definite bearing upon the proper timing of delivery of northern California water in the Upper Santa Ana Valley. Further, these economic effects are significant in determining the relative quantities of northern California water to be delivered in the easterly and westerly portions of the Southern California Coastal Plain and Coastal San Diego County Service Area.

The economic effects of water quality differences were employed in Chapter IV along with main aqueduct and local distribution costs in determination of timing and relative quantities of northern California water delivered in the easterly and westerly areas. Determination of sizing and timing of construction of facilities in Aqueduct System "B" and "C", hereinafter described, was based in part on analysis of the effects from a water quality standpoint of delaying introduction of northern California water to the easterly portion of the service area from 1982 until 1992.

In delaying the delivery of northern California water to the Upper Santa Ana Valley, about 600,000 acre-feet annually of northern California water would have to be delivered to the San Fernando Valley after 1992 for service in the westerly coastal plain area rather than to Upper Santa Ana Valley and coastal San Diego County. This is equivalent to the incremental amount of Colorado River water served to the easterly areas which otherwise would have been delivered to the westerly coastal plain area.

It was estimated that such a delay would result in both loss of the utility of certain of the ground water basins in Upper Santa Ana Valley and the safe yield thereof, and increased costs to urban and agricultural users in the easterly areas. The total increased cost to the Upper Santa Ana Valley and coastal San Diego County which would result from the ten-year delay, measured as the value of the safe yield of the local supply which would be lost, and increased costs to urban and agricultural users from differences in water quality, was estimated to amount to nearly $200,000,000, or an average of about $20,000,000 per year. This is equivalent to about $25 per acre-foot for the estimated amount of imported water required during this period. Not included in this estimate is the value of the utility of the ground water basins for regulatory storage purposes and for distribution of local and imported water supplies.

Furthermore, the plan of delaying introduction of northern California water to the easterly areas would result in long-term mineral quality of the mixed water supplies of 50 parts per million higher in coastal Riverside, San Bernardino, and San Diego Counties, and an equal decrease in mineral concentration in the Orange and Los Angeles Counties area. Without the delay and with the eventual delivery of a greater supply of northern California water into the easterly areas, the long-term quality throughout all portions of the service area would be equivalent and satisfactory for all projected uses. This factor is discussed further in Chapter IV.

TREATMENT OF NORTHERN CALIFORNIA WATER

Water delivered to southern California from the Delta through the San Joaquin Valley-Southern California Aqueduct System may be expected to have a maximum concentration of about 200 parts per million of total dissolved solids with a hardness, measured as calcium carbonate, of up to 100 parts per million under the postulated adverse conditions. Softening of this water will not be necessary for most domestic, commercial and industrial uses. Certain uses found in industry would require special treatment of the water. For the principal urban, commercial and industrial uses, however, the only treatment necessary will be filtration and chlorination. It is considered that no treatment would be required for agricultural use.

The turbidity in Delta water exhibits a wide variation during the year, being the greatest during periods of winter rain floods. Although additional turbidity may be added in regulatory reservoirs in southern California during periods of local storm water inflow, the over-all effect of storage in the aqueduct system reservoirs will be beneficial in reducing turbidity. The range in concentrations of turbidity carried in the supply delivered to the service areas will probably be from 20 to 100 on a turbidity index. The acceptable maximum level of turbidity for drinking purposes is generally set at 10. It is considered that filtration and chlorination would be necessary before distribution of the supply within the service areas for urban purposes. It is probable that rapid sand filter plants with chemical coagulants added would be used for filtration purposes.

Cost of Processing Water in Filtration Plants

Based upon the large capacity filtration plants operated by The Metropolitan Water District of Southern California and the City of San Diego, it was estimated that the cost of filtering and chlorinating northern California water for urban use would approximate $7.00 per acre-foot. This cost was estimated on the basis of a plant of 250 million gallons per day capacity at a construction cost of $66,000 per million gallons per day of capacity plus $10,000 per acre for the necessary land. Operation and maintenance costs were estimated to be $1.75 per acre-foot, and chemical costs, including chlorine, were estimated to be $3.00 per acre-foot. These costs were included in the economic analyses discussed in Chapter VII. As stated both in Chapters VI and VII, such costs were assumed to be a local responsibility and required facilities were not considered features of the main aqueduct system.

CHAPTER IV

ALTERNATIVE AQUEDUCT SYSTEMS

The "aqueduct system" concept was set forth in Chapter I as the logical basis for planning aqueduct facilities to convey surplus northern California water from the Delta to the southern California area. The selection of an aqueduct system resolved itself into two phases: the selection of an aqueduct route, or routes, to serve areas where an economic demand for supplemental water will exist; and determination of proper staging and sizing of aqueduct system facilities consistent with projected demands for water and basic economic principles.

This chapter presents the alternative aqueduct systems which could best meet forecast economic demands for imported water in the southern California area, the procedures by which these systems were developed, and the estimated costs thereof. The locations of these aqueduct systems are shown on Plate 7, "Alternative Aqueduct Systems".

DESIGN AND COST ESTIMATING CRITERIA

Design and cost estimating procedures of two degrees of detail were utilized in this investigation: (a) reconnaissance-type designs and cost estimates used for preliminary evaluation of numerous aqueduct routes; and (b) more refined designs and estimates for those aqueduct systems selected for detailed study.

In the first instance, planning was based on available United States Geological Survey maps supplemented by field reconnaissance. Costs were obtained from estimating curves specifically developed for the particular facilities considered.

In the second case, more detailed mapping and field examination were conducted for aqueduct layout and design. Preliminary designs of structures were based on filed data and quantities were determined from the detailed topographic data. These designs were carried to a degree of refinement sufficient to assure engineering feasibility and provide reasonably accurate estimates of cost. A detailed discussion of design criteria and cost estimating data are presented in Appendix G of this bulletin, which is published separately.

Design Criteria

The design criteria employed for various items of construction are described in the ensuing paragraphs. These criteria provided the basis for development of the cost estimating curves and for the more detailed designs.

Selection of Hydraulic Grade Lines. Because of the requirements of multiple pumping lifts on any possible aqueduct route, coupled with power recovery considerations, and the character of the terrain which would have to be traversed, direct determination of definite elevation control points on the optimum hydraulic grade lines of the aqueduct routes, or of the most economical pumping lifts and power drops, was not possible. The establishment of the position of the hydraulic grade lines for aqueducts considered in this investigation was accomplished by a unique method developed by Department of Water Resources engineers. The method, which has its basis in a branch of mathematics, the calculus of variations, enables the development of criteria for determining the optimum elevation and slope of the hydraulic grade line at any point along an aqueduct route. By this method, it was possible within the limits of accuracy of the data and for a given design capacity in any aqueduct, to make a rapid determination of the optimum hydraulic grade line therein, together with the corresponding minimum combined cost of aqueduct and pumping and the economical proportioning of size and type of aqueduct over a given ground profile.

Canals. Wherever topographic and hydraulic conditions were favorable, it was determined that canal represented the most economical method of conveyance. It was found that canal in occasional cuts of up to 100 feet in common excavation was more economical than closed conduit, and that canal construction could feasibly be employed for transverse ground slopes of up to about 40 per cent. Hydraulic designs were based on concrete lined trapezoidal sections. Typical canal sections are shown on Plates 5 and 6, entitled "Alternative Coastal Aqueduct Plan and Profile" and "Alternative Inland Aqueduct Plan and Profile", respectively. Canal sections having bottom widths of up to 42 feet and depths of water as great as 28 feet were considered.

Bench Flumes. In certain reaches, topographic conditions indicated the economic desirability of using reinforced concrete rectangular bench flume construction since a trapezoidal canal was not feasible and pipe line construction was found to be more expensive. This would occur generally in limited areas of rocky mountainous terrain having transverse slopes greater than 40 per cent.

Pipe Lines. Pipe line construction was assumed in those instances where neither open channel nor monolithic conduit construction would be feasible. Included in this category are inverted siphon crossings of streams and valleys.

Estimates of cost were based on the use of either steel or precast reinforced concrete pipe, depending on the hydrostatic head in the particular location. For purposes of this investigation, concrete pipe was assumed for heads up to about 200 feet, and steel pipe for greater heads. It was necessary to give consideration to pipe up to 22 feet in diameter, and to hydrostatic heads up to about 1,000 feet. Both steel and concrete pipe manufacturers provided great assistance to the Department of Water Resources in developing typical designs for pipe sections. With few exceptions, pipe lines were assumed to be buried in excavated trenches. Shown on Plates 5 and 6, are typical sections of pipe siphons in trenches.

Monolithic Construction. Under certain conditions, where staged conveyance of multiple precast pipes or open channel conveyance was not economical, and where hydrostatic heads would be low, concrete conduit of monolithic construction was assumed. This conduit would be either a cut and cover horseshoe gravity flow section, or a multiple box section.

Pump Discharge Lines and Penstocks. Special study was given to these items because of the great hydrostatic heads involved. High strength steel pipe was assumed for these facilities. Considered in the designs were static heads of up to 2,200 feet.

Tunnels. Because of the great influence geologic conditions have on the design and cost of tunnels and since many miles of tunnel construction are inherent in any route for delivering water to southern California, special consideration was given to tunneling and tunnel costs.

Department of Water Resources geologists developed a method of correlating tunnel design and costs with geologic information. This method, together with the cost estimating data developed therewith, is reproduced separately as Appendix C of this bulletin.

Three types of tunnels were considered, all of which would be concrete lined: (a) gravity flow tunnels with moderate external pressures, which would be horseshoe in section; (b) gravity flow tunnels designed to resist great external pressure, which would be circular in section; and (c) pressure flow tunnels which would also be circular in section and would have a steel liner plate as well as concrete lining. Tunnels with internal diameters up to 23.5 feet were studied. Typical tunnel sections are shown on Plates 5 and 6.

Wasteways. The purposes of wasteways are to provide a means of safely disposing of excess water and of draining the aqueduct for repairs. Wasteways were located to discharge into natural drainage channels where possible, and into constructed conveyance channels where natural channels were not available, and costs were estimated therefor.

Pumping and Power Plants. Several methods of pumping and power recovery were considered in the investigation, as outlined in Chapter V. Pumping and power plants would be of the semi-outdoor type. Studied were pump lifts varying from about 100 feet to 2,200 feet and power drops of up to 1,100 feet. Individual consideration was given to the selection of the most economical pump or turbine installation consistent with the particular conditions at each site. The bases for designs were developed with the assistance of equipment manufacturers and Departmental consultants, and from investigation of existing installations.

Dams and Reservoirs. The dam sites investigated were found best suited to construction of fill-type structures. Dams up to 410 feet in height and containing as much as 18 million cubic yards of fill were considered. The preliminary designs of these structures varied from homogeneous sections to zoned earthfill and rockfill types. On the basis of foundation drilling, where considered necessary, and laboratory analyses of borrow area materials, typical designs were prepared and carried to a degree of detail sufficient to establish the stability of the section and obtain a preliminary estimate of cost for the structure. Hydrologic analyses were made to determine required spillway capacities.

Miscellaneous. Typical designs were prepared for bridges, turnouts, gates, valves, drainage facilities and other appurtenances of the aqueducts. These facilities were largely of conventional design.

Cost Estimates

The estimates of cost shown hereinafter were based on construction prices prevailing in the fall of 1958. It was considered impractical for this report to project long-term price levels and the effect thereof on aqueduct system cost. It is recognized, however, that a long-term inflationary trend does exist. The effect of this trend would be to favor near future expenditures over deferred costs in evaluating staged construction of facilities.

Capital Costs. The capital costs of facilities were based upon quantities obtained from the preliminary designs previously described and estimated unit costs for various items of construction. In addition to the estimated construction cost, allowances were provided in the amount of 15 per cent for contingencies and 10 per cent for engineering and supervision, or a total of 25 per cent for facilities to be constructed south of Avenal Gap. For construction north of that point, a total allowance of up to 30 per cent for engineering and contingencies was provided because of the greater uncertainties involved in constructing the aqueduct through certain of the extensive subsidence areas north of Kettleman City.

Unit costs for construction items were obtained from several sources. Reports of the Daily Construction Service on recent construction contracts throughout the western United States were employed as a guide in selecting unit prices. These prices were modified, where required, in order to reflect particular conditions for the item under consideration.

The costs of both reinforced concrete and steel pipe were supplied by major pipe manufacturers in the southern California area. In consultation with personnel of the Department of Water Resources, certain of these companies made field inspections of the job sites and prepared detailed cost schedules.

Contacts were made with numerous other manufacturers, and costs obtained for special items such as valves, gates, and other aqueduct appurtenances, and for pumping and power plant equipment.

Annual Costs. The annual costs for operation, maintenance, and replacement, excluding the cost of energy for pumping and interest and amortization on the capital investment of conveyance and storage facilities, were developed largely from the experience of agencies operating large water supply projects. These included the United States Bureau of Reclamation, The Metropolitan Water District of Southern California, the Los Angeles Department of Water and Power, the East Bay Municipal Utility District, and others.

On the basis of the experiences of the foregoing agencies, factors were developed to be applied to the capital costs of aqueduct facilities in order to estimate these annual costs.

Operation and maintenance costs for pumping and power plants were obtained largely from information available from the Federal Power Commission. Replacement costs for these facilities were developed independently.

Annual costs of energy for pumping, and of interest and amortization of the capital investment, were estimated as described in Chapters V and VII, respectively.

Operational Criteria

In long aqueducts, economic considerations generally dictate a continuous flow operation with the use of terminal storage to regulate this flow to the delivery demand schedule. Although this basic concept was used generally for facilities south of Avenal Gap, certain variances were necessary.

As described more fully in Chapter VI, a peaking operation was required in the main aqueduct for service to the Kern County Service Area. Consequently, aqueduct facilities in the San Joaquin Valley were designed to deliver to this area a monthly supply equal to 21½ per cent of the annual irrigation demand. Additionally, an allowance of ten per cent of this peak demand was provided for flexibility of operation. In certain other instances the capacities of aqueducts, beyond terminal storage regulation, were sized to meet monthly peaks.

Intermittent and reversible operation of pumping plants and power recovery developments were considered as described in Chapter V. Reaches of the aqueduct under these schemes required oversizing to various degrees depending on the particular scheme under consideration.

In addition to providing storage required for regulation of flows for normal operation, certain reservoirs were sized to also provide a three weeks emergency water supply. Consideration was given in some cases to the provision of excess storage capacity to firm up hydroelectric generation where this was engineeringly feasible and could be done without incurring excessive costs.

Maintenance of Aqueducts. It is anticipated that, in general, maintenance requirements for the aqueducts will be similar in nature and magnitude to those experienced in the normal operation of existing major aqueduct systems in the San Joaquin Valley and southern California. However, there are instances where it is recognized that special maintenance problems may exist. An example of such a case is the aforementioned subsidence areas in the San Joaquin Valley, where investigations are now under way to develop specialized design and construction techniques for the aqueduct.

Appropriate maintenance costs for all aqueduct facilities are included in financial analyses presented in Chapter VII. Normal maintenance costs were developed using factors as described in a foregoing section under ''Annual Costs''. The costs attributable to special maintenance problems were developed through analysis of each particular situation.

During maintenance outages, as well as during unscheduled periods when the aqueduct might be inoperative, the water demands on the aqueduct in certain areas could be met from the terminal storage reservoirs. In other areas, the contracting agencies would provide the necessary storage.

Staging of Aqueduct Facilities

The staging of aqueduct facilities was based on the estimated rates of growth in economic demand for imported water and the time value of money with respect to effects thereof on the sizing of initial facilities and the timing of subsequent stages. The proper staging of aqueduct conveyance facilities, and selection of proper initial capacities thereof, are important factors in financing and have a direct bearing on unit costs of water that would be delivered by the San Joaquin Valley-Southern California Aqueduct System. Estimates of cost were prepared for a wide range of capacities for all types of conveyance conduits, as well as for pumping and power plants, to arrive at a practical schedule of staging that would result in a minimum cost of water.

The hydraulic characteristics, methods of construction, and costs per unit of capacity for various types of aqueduct facilities are inherently different. The economical initial capacity and the capacities of subsequent stages of these facilities also will differ. The staging assumed for these various facilities is discussed in the ensuing paragraphs.

Canals. Because of the hydraulic characteristics of canals, wherein large increases in capacity are realized for relatively small increases in cost, it is generally not economical to stage this type of aqueduct. However, because of the great distances postulated for canal construction, the large capacities contemplated, and the recognized long-term demand considered for service, analyses were made of the economics of two-stage construction of canals.

Of particular importance in this regard was the almost continuous reach of canal from the Delta to the Tehachapi Mountains, a distance of about 300 miles. A series of analyses was made of this canal for conditions of Aqueduct System "B", hereinafter described. Single-stage construction, two-stage construction with the second canal built in 1990 to serve the increment in demand until year 2020, and a two-stage plan with the second canal built in year 2005, were considered. These three alternatives were compared by present worth analyses, discounting costs to 1965, and using interest rates of 2½, 3, 3½, and 4 per cent. The analyses were made for each of twelve reaches between the Delta and the Tehachapi Mountains, and for this section of the aqueduct as a whole.

Considering the entire length of canal, single-stage construction appeared to be more economical than either of the two-stage plans for each of the interest rates employed. Similar results were found for all of the individual reaches, with exception of one 34-mile reach of canal north of Avenal Gap. In this instance it was found that two-stage construction would be slightly more economical under both plans at a 4 per cent interest rate, but that single-stage construction was more economical at a 3½ per cent rate. The results of these analyses for the entire length of canal from Pumping Plant I to Pumping Plant In-VI are summarized in Figure 8, entitled "Relationship between Costs of Single-Stage and Two-Stage Canal in the San Joaquin Valley".

It should be noted that the increase in cost of this canal from a capacity designed for the 1990 demand to that estimated for 2020 would be about 81 million dollars, or 31 per cent. Thus, for an initial increase in cost of 31 per cent, the total annual delivery capacity would be increased about 100 per cent or from about 4 million acre-feet to about 8 million acre-feet.

In view of the foregoing, for purposes of the analyses necessary for aqueduct system selection, single-stage construction was assumed for all canal sections. It is recognized that in the final design phase, it may be found desirable or necessary to reduce postulated initial canal capacities for reasons that cannot be ascertained at this time and to provide for staged construction.

Related to the matter of canal staging in the San Joaquin Valley is an alternative plan, under consideration at this time, for providing water service to the Kings River Conservation District. The growth in demand for imported water in this area was estimated to be very slow but reaching large quantities late in the study period. Consequently, the revenues to pay for this necessary capacity would not be forthcoming for many years in the future. Preliminary analyses indicate that it may be desirable to serve this area by a separate aqueduct and not provide capacity for the area in the main aqueduct south of San Luis Reservoir.

Tunnels. The relationship of the hydraulic characteristics of tunnels and the costs of construction, as in canals, generally favors single-stage construction. Economic analyses made for the various considered tunnels confirmed the probable economy of single-stage construction, which was used in the analyses presented herein.

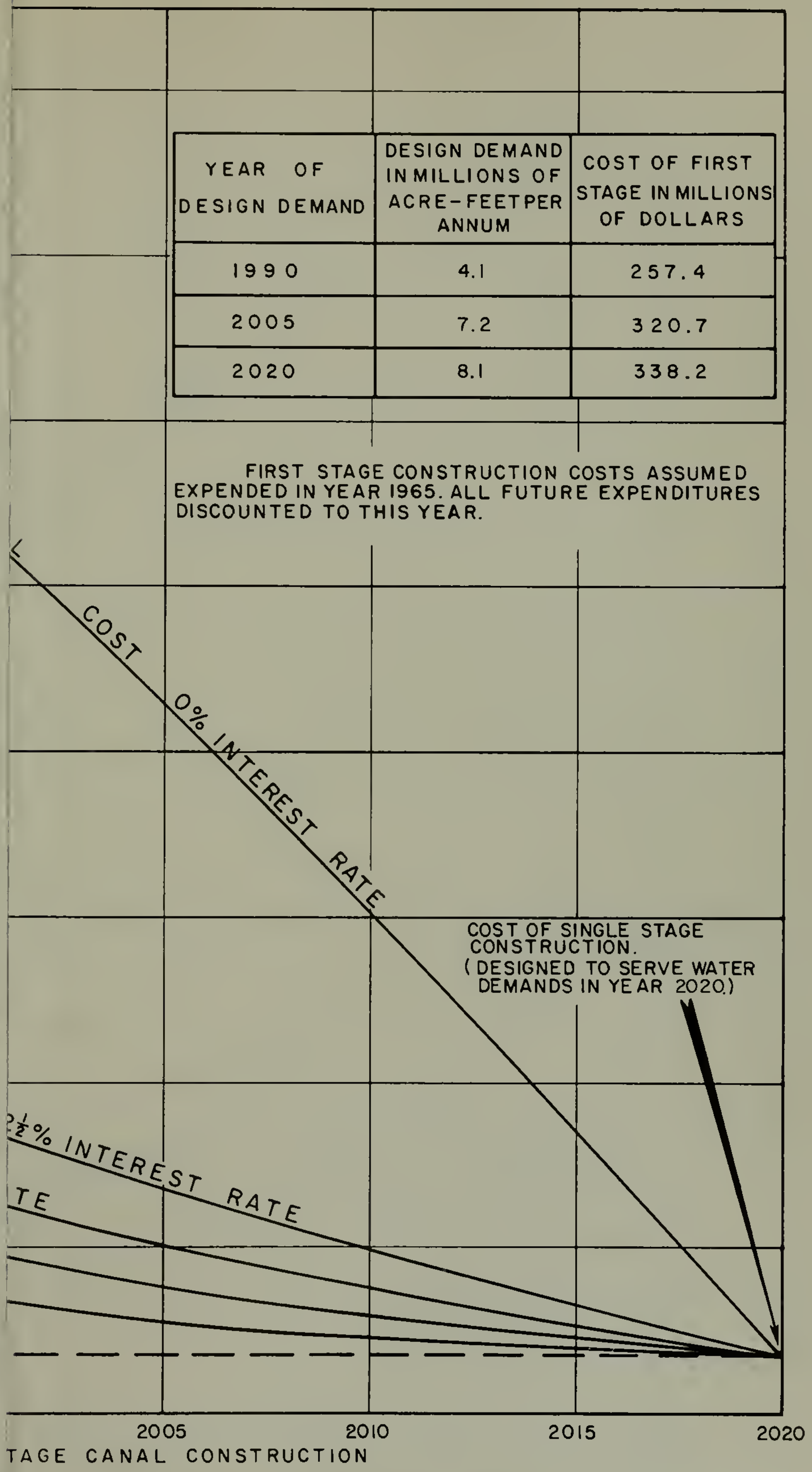
Pipe Lines. On all aqueduct routes, the long build-up in water demands and the inherent ease of staging by successive installation of parallel pipe lines dictated multiple unit construction of this type of facility in most cases. Staging has the further advantage of avoiding installation in rough terrain of the almost unprecedented sizes of conduit that would be required to carry several thousand second-feet of flow in a single line. The exceptions to multiple-stage construction would be short, low-head siphons where the additional cost of the transition sections from canal to multiple-barrel conduit would more than offset possible savings in multi-unit pipe line construction.

Although a detailed study was made of optimum combinations of unequal stages, it was decided that the savings effected were of such a marginal nature that for purposes of the preliminary design and estimates of cost, only equal staging of pipe lines should be considered.

The time of installation of each stage of pipe line construction was coordinated with the installation of pumping units. Staged development of pipe line reaches of the aqueducts would result in the installation of from two to four barrels.

Pumping and Power Plants. Pumping and power plants were sized and staged so that additions to capacity would closely match build-up in water demand yet would provide adequate allowance for nec-

FIGURE 8



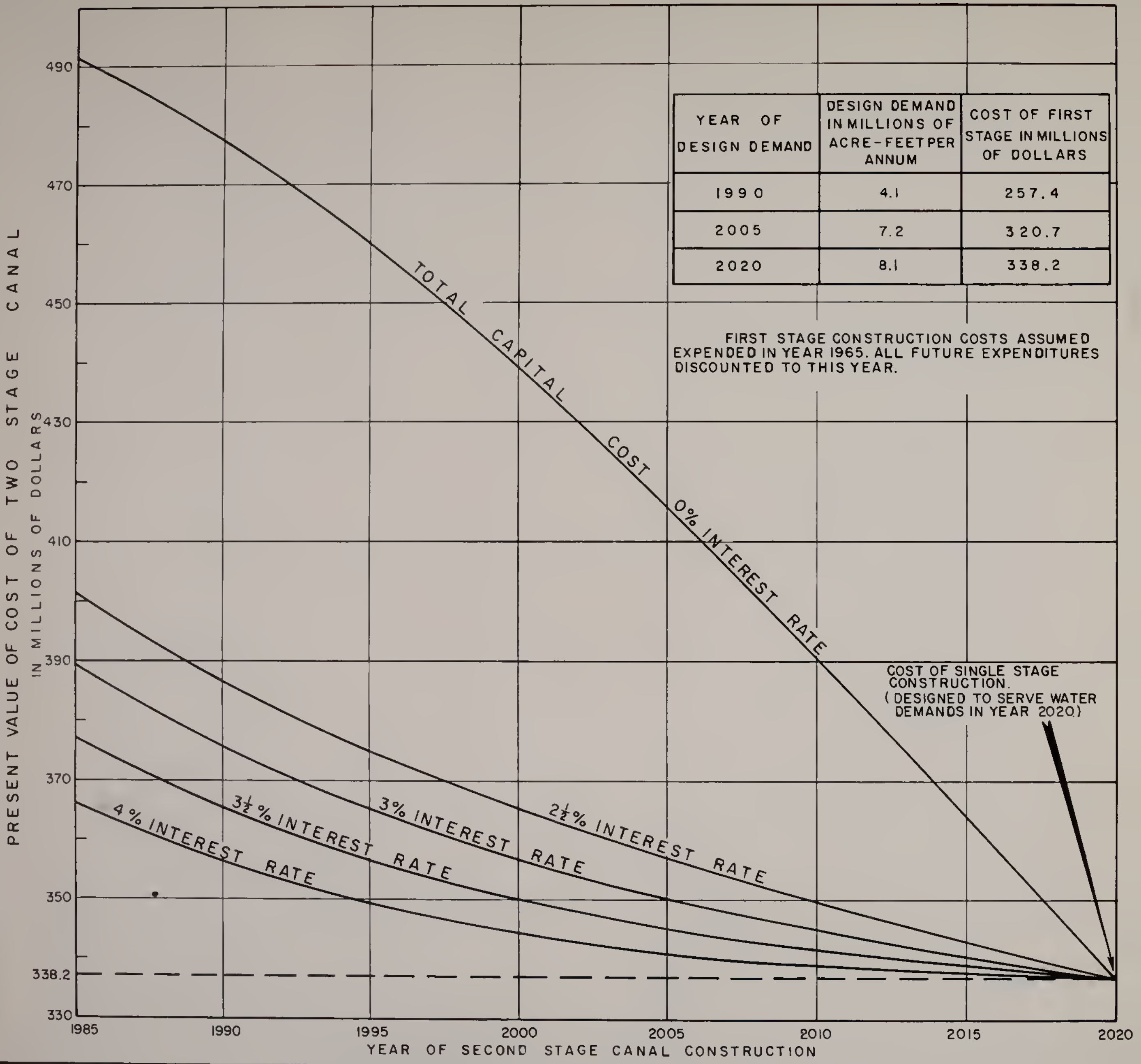
YEAR OF DESIGN DEMAND	DESIGN DEMAND IN MILLIONS OF ACRE-FEET PER ANNUM	COST OF FIRST STAGE IN MILLIONS OF DOLLARS
1990	4.1	257.4
2005	7.2	320.7
2020	8.1	338.2

FIRST STAGE CONSTRUCTION COSTS ASSUMED EXPENDED IN YEAR 1965. ALL FUTURE EXPENDITURES DISCOUNTED TO THIS YEAR.

COST OF SINGLE STAGE CONSTRUCTION.
(DESIGNED TO SERVE WATER DEMANDS IN YEAR 2020.)

OSTS OF SINGLE-STAGE AND
HE SAN JOAQUIN VALLEY

FIGURE 8



YEAR OF DESIGN DEMAND	DESIGN DEMAND IN MILLIONS OF ACRE-FEET PER ANNUM	COST OF FIRST STAGE IN MILLIONS OF DOLLARS
1990	4.1	257.4
2005	7.2	320.7
2020	8.1	338.2

FIRST STAGE CONSTRUCTION COSTS ASSUMED EXPENDED IN YEAR 1965. ALL FUTURE EXPENDITURES DISCOUNTED TO THIS YEAR.

RELATIONSHIP BETWEEN COSTS OF SINGLE-STAGE AND TWO-STAGE CANAL IN THE SAN JOAQUIN VALLEY

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essary maintenance outages of pumping and generating units. Additions to pumping plants were scheduled one unit at a time, except in a few cases where anticipated rapid build-up in water demand was found to give greater economy for a two-unit installation. Construction of successive pumping and power plants along an aqueduct reach was scheduled to be concurrent so that all pumping units in the "string" could be completed and placed in service simultaneously. Pumping installations considered herein would have as many as 16 units. Power plants would have a maximum of six units.

AQUEDUCT ROUTES

Between the Delta and the coastal plain of southern California there are numerous alignments over which aqueducts could be constructed. The relative merit of any given alignment must be evaluated in terms of its cost and the degree of water service provided to areas of need as compared to other possible alignments. There are three general route areas which might be considered for an aqueduct from the Delta to southern California: the west side of the San Joaquin Valley; the east side of the San Joaquin Valley; or to the west through the coastal counties.

From the Delta to the latitude of the Kings-Kern County line, it was concluded in prior studies of the Division of Water Resources, that an inland alignment along the west side of the San Joaquin Valley was definitely superior to any other route. Such an alignment, which would traverse smooth gentle sloping valley lands, would be less costly than other possibilities and would provide service to areas of great water need en route. Also, advantage could be taken of the San Luis Reservoir site near Los Banos, where provision for about 2,100,000 acre-feet of offstream storage would be possible. Such a facility is needed to provide economical conservation of the surplus waters available in the Delta.

South of the Kings-Kern County line, however, two general aqueduct routes to the area south of the Tehachapi Mountains are apparent, each with obvious advantages and disadvantages. The continuation of the inland route along the west side of the San Joaquin Valley, although shorter and with a minimum of construction problems, would require crossing of the formidable barrier at the southern end of the valley posed by the Tehachapi Mountains. A crossing of these mountains would require pumping water up to an elevation of about 3,400 feet. The other possibility, a coastal route, would extend to the west from the San Joaquin Valley, in the vicinity of Avenal Gap near the Kings-Kern County line, and follow an alignment through San Luis Obispo, Santa Barbara and Ventura Counties, and thence into the San Fernando Valley in Los Angeles County. This route, although requiring lesser pump lifts than the inland route, would involve more expensive aqueduct construction because of inherent topographic and geologic conditions.

As stated, both of the general route areas contain geologic and topographic features that present problems in the alignment, design, and construction of an aqueduct. The coastal route would encounter difficult tunneling conditions in crossing the Coast and Transverse Ranges, particularly at the San Marcos Pass area near Santa Barbara and the Polonio Pass area in the Temblor Range on the west side of the San Joaquin Valley. Unstable slopes also pose problems, particularly on the seaward slopes of the Santa Lucia Range between the Cities of San Luis Obispo and Santa Maria. The inland aqueduct would pass through areas in the San Joaquin Valley near Taft and Maricopa and Wheeler Ridge, where surface soils consolidate and subside rapidly when wetted. Leakage of water from canals proposed through these areas could cause damaging settlement to structures. Another problem along the inland aqueduct route area is encountered at the Tehachapi Mountains crossing where faults and some unfavorable tunneling ground would be encountered. Both the coastal and inland aqueduct routes cross not only the San Andreas fault, the largest fault system in California, but other smaller faults. Consequently, careful consideration must be given to seismic hazards throughout most of the area traversed by the routes. Further, along both route areas, there is a paucity of good dam sites and suitable reservoir storage sites required for aqueduct operation.

The foregoing problems and others too numerous to mention were identified and feasible solutions thereto were developed. Estimates of cost presented herein reflect any unusual design considerations, and the resulting preliminary aqueduct plans represent minimization of over-all cost consistent with safety and security of the aqueduct.

Route Evaluation

Over 100 aqueduct alignments were investigated south of Avenal Gap. These included 57 coastal alignments, 42 inland alignments, and seven "intermediate" alignments. The principal alignments investigated are shown on Plate 3 entitled, "General Locations of Investigated Aqueduct Alignments".

Preliminary Studies. Preliminary estimates of cost were prepared for each of these routes. Consideration was given to both capital costs and annual costs, the latter including costs of operation and maintenance and of energy for pumping. The various possibilities of recovering energy to reduce net pumping costs were studied.

The geology along the various alignments was examined by field reconnaissance to determine probable tunneling conditions, to classify materials for excavation, and to evaluate foundation conditions at locations considered for structures. Faults and other geologic hazards near aqueduct alignments and structures were located and studied.

More refined studies were made of the alternative routes found to be superior.

From these geologic and engineering analyses, there was developed for each alternative route area an aqueduct alignment which would be engineeringly feasible of construction, exhibit a minimum potential hazard that might cause failure of the aqueduct and disruption of water service, and which would have a lesser cost and provide a greater degree of water service than other feasible possibilities.

The Coastal Area. In the coastal area four general alignments were selected for further analyses, namely, the "shoreline", "foothill", "tunnel", and "Carrizo Plain" routes, as shown on Plate 3. Of these, the foothill route was selected as the optimum location for a coastal aqueduct as it has the least capital and annual costs and provides the highest degree of water service en route.

San Joaquin Valley. In the San Joaquin Valley, three routes were subjected to more refined study: one leaving the vicinity of San Luis Reservoir at an elevation of about 540 feet; another at 360 feet; and the third, a "trough" route, at about 220 feet. It was found that the "360" route, which would be at an elevation of 325 feet at Avenal Gap, and would follow an alignment similar to that presented in the 1955 report, was superior to the other two from the standpoint of over-all cost, including the cost of water service to lands in the San Joaquin Valley, and was selected as the optimum location therein. In this selection, recognition was given to the problem of subsidence along the "360" route and to the additional construction costs in areas where this might occur.

The Tehachapi Mountains. The proper location and elevation for a tunnel, or tunnels, through the Tehachapi Mountains was given careful consideration. The selection of the proper location and elevation of the tunnel is a function of the location and elevation of service areas to the south, particularly in the Antelope-Mojave Service Area, the cost of pumping, and the geologic conditions of the area considered for tunneling.

The Tehachapi Mountains is an area of high seismic activity, with numerous large faults, such as the Pastoria, Garlock, German and San Andreas as shown on Plate 3, in this area which may be considered active. Therefore, in locating a tunnel a major consideration is the future security of the facility. Further, tunneling conditions vary widely. Because of the extensive faulting, rocks have been crushed in many areas, which would result in expensive tunnel construction.

In view of the foregoing, programs of subsurface exploration were concentrated in this area during both the prior investigation and the current investigation. As a result of this exploration work, it was found that the tunnel alignment that would provide a maximum of security to the aqueduct and probably would have minimum costs would extend from the vicinity of Pastoria Creek on the north to Cottonwood Creek on the south.

For delivery of water to the Antelope-Mojave Service Area, it was determined that the optimum elevation for a tunnel through the Tehachapi Mountains would be about 3,000 feet. However, this elevation would place the tunnel about 260 feet underground at the point where it would cross the Garlock fault. The inherent hazards of such a crossing were felt to outweigh the economic disadvantages of pumping to a higher elevation. Therefore, it was concluded that the tunnel elevation should be not less than about 3,300 feet in order to effect a surface crossing of the Garlock fault.

In the 1955 report, in order to avoid the high pumping lift, a study was made of a tunnel at elevation 1,870 feet which would terminate in Elizabeth Lake Canyon, a distance of some 26.7 miles from the north portal thereof in the San Joaquin Valley. Since this tunnel would intersect nearly all the major fault systems in the area, and would have cover up to 3,900 feet, such an alignment was considered from this standpoint to be too hazardous for the construction of a major aqueduct system. Further, there is great uncertainty as to the actual cost of construction of such a tunnel.

Tehachapi Mountains to Coastal Plain. South of the Tehachapi Mountains, two general alignments described in the 1955 report were found definitely superior to the others considered. One of these would pass through Castaic reservoir site and into northern San Fernando Valley, and the other would follow along the north side of the San Gabriel and San Bernardino Mountains and into the Upper Santa Ana Valley through Devil Canyon. These routes were selected for further detailed analyses.

Detailed Studies. For detailed studies of the selected alignments as shown on Plate 4, entitled "Locations of Coastal and Inland Aqueduct Routes", and possible dam and reservoir sites, about 664 square miles of mapping at scales ranging from 1 inch:100 feet to 1 inch:400 feet were obtained, largely by photogrammetric methods. Supplemental map coverage was also obtained from other agencies where available.

Nearly 12 thousand feet of diamond drilling was performed at critical tunnel locations, dam sites, and other contemplated structures. In addition, 123 shallow borings were made at various reservoir sites to determine availability of borrow materials. Each aqueduct alignment was walked in the field and materials to be excavated were classified.

In the San Joaquin Valley extensive soil testing was performed on samples obtained from exploratory borings along the alignment, and plots of ponded water were installed as part of a continuing study to evaluate the problem of shallow subsidence caused by settlement of soils when saturated. Laboratory analyses were made of material in potential borrow areas for earth-fill dams. In addition, a search for concrete aggregate which would be needed for construction purposes was made along the alternative aqueduct alignments. Estimates of cost were prepared on the basis of this more detailed information, as described previously.

It is recognized that during subsequent phases of engineering study of the aqueduct system, modifications in detail will be made of the selected aqueduct routes. Such modifications may be found necessary at the time of selection of the operational scheme to be employed on the aqueduct system which, as hereinafter described, cannot be selected at this time.

The Coastal Route

The selected coastal aqueduct route, shown in plan and profile on Plate 5, would divert from the San Joaquin Valley-Southern California Aqueduct at elevation 325 feet about five miles north of the Kings-Kern County line. A forebay, designated Las Perillas Reservoir, which would vary in capacity depending on the operational scheme employed, would regulate diversions to a coastal aqueduct. The aqueduct would proceed westerly, largely in canal section, a distance of 24 miles to the east portal of the Polonio Pass Tunnel. In this reach, three pumping plants, C-3, C-4, and C-5, would be required to raise the water to an elevation of about 1,200 feet at the tunnel portal.

The Polonio Pass Tunnel would be about five miles in length and would be constructed through folded and faulted sandstone, shale, and serpentine. Movement along the San Andreas fault, which lies 4,000 feet west of the tunnel site, and along smaller associated faults cutting across the alignment, has fractured much of the rock in the area. Exploratory drill holes indicate that approximately 75 per cent of the rock that would be penetrated by the tunnel would be moderately to very blocky and seamy, with the remainder being crushed. Squeezing ground conditions during tunnel construction should be anticipated.

From the west portal of the Polonio Pass Tunnel the aqueduct would proceed southwesterly across the Upper Salinas Valley mostly in canal section to Cuesta Pass in the Santa Lucia Range. The aqueduct would cross the San Andreas rift zone on the surface.

The Cuesta Pass Tunnel would be at about elevation 1,040 feet and would have a length of approximately two miles. The tunnel would penetrate very blocky and seamy sandstone, shale, diabase, and volcanic rocks. An existing water supply tunnel parallels the proposed alignment about 2,000 feet to the southeast. Construction history of this tunnel indicates that although small water inflows, running ground in small fault zones, and heavy ground in small serpentine seams were encountered, these problems did not seriously impede construction. It is anticipated that similar conditions would be encountered along the proposed tunnel alignment.

Beyond Cuesta Pass, economic analyses indicate the desirability of lowering the hydraulic grade line in the aqueduct approximately 500 feet by means of a power drop near the City of San Luis Obispo. This would make it possible to construct the aqueduct primarily in canal section and low head pipe line southward along the gentle slopes at the base of the Santa Lucia Range to the Santa Maria River. Power recovered at this drop on a continuous basis could be transmitted for delivery to the pumping plants required both to the north and south. This possibility is discussed more fully in Chapter V.

The aqueduct would pass north and east of the City of Santa Maria, and would cross the Cuyama River above its confluence with the Sisquoc River in a siphon. There, Pumping Plant C-6 would raise the hydraulic grade line to about elevation 540 feet. From this point, a canal would continue to a siphon crossing of the Sisquoc River where Pumping Plant C-7 would lift the water to about elevation 890 feet. This would place the hydraulic grade line at the general elevation of the rolling foothill area extending south from Santa Maria Valley to the Santa Ynez River, permitting canal and low head conduit construction, as well as enabling a gravity delivery into Cachuma Reservoir, if desired.

After crossing the Santa Ynez River in siphon, the alignment would turn eastward to a tunnel through the rugged Santa Ynez Mountain Range at San Marcos Pass, with a hydraulic grade line elevation of about 850 feet.

The San Marcos Pass Tunnel would be about five miles in length, and would penetrate moderately to very blocky and seamy sandstone and shale. Exploratory drill holes indicate that large water inflows would be encountered during construction of this tunnel. Although abnormally high temperatures and gas were not detected in these exploratory drill holes, high heading temperatures and occasional gas pockets might be encountered during construction. Such conditions were experienced during construction of the existing Tecolote Tunnel, located approximately five miles to the west at an elevation of about 650 feet.

The south slopes of the Santa Ynez range fall away steeply to the ocean and in many places are being subdivided rapidly for residential development near the elevation considered for aqueduct construction. It was concluded that economies of construction would be effected if the aqueduct were placed in a series of tunnels paralleling the coastal front of the mountains. These tunnels would have a total length of about 14 miles, proceeding eastward from the San Marcos Pass area to the Carpinteria area, where the aqueduct would continue in siphon to two short tunnels in the Casitas Pass area. Geologic conditions encountered by the Santa Barbara Tunnels would be similar to San Marcos Pass Tunnel, although smaller water inflows may be expected.

The hydraulic grade line elevation in the vicinity of Casitas Pass would be about 715 feet. The tunnels at Casitas Pass would penetrate sandstones, conglomerates, and shales. Although no serious tunneling difficulties are anticipated in this area, some squeezing ground might occur in the shales. From these tunnels, the alignment would continue in siphon crossing the Ventura River and through several short tunnels east of the Ventura River to Sexton Canyon, where the grade line elevation would be about 650 feet.

From Sexton Canyon, the aqueduct would continue southeasterly in siphon crossing the Santa Clara River near Saticoy, and thence across the Santa Rosa Valley to Conejo reservoir site.

The maximum head on the Santa Clara River siphon would be about 500 feet. The aqueduct could discharge water by gravity into Conejo Reservoir, which was considered for capacities up to 205,000 acre-feet with dam heights up to 390 feet.

Conejo dam and reservoir site is underlain by volcanic rocks, sandstone, and shale. The dam would be on volcanic rock, a foundation material whose strength is more than adequate for the structures considered. Although insufficient volumes of alluvial borrow are available to build the larger structures considered, ample supplies of material suitable for rockfill construction are present. Water pressure tests conducted in diamond drill holes in the volcanic rock at the dam site showed low water losses. Logs of numerous unsuccessful water wells drilled in the reservoir area show that little or no water was encountered in the volcanic rock, suggesting that the rock has low permeability. It was concluded that leakage probably would not be great at this site.

Water would be released from Conejo Reservoir and lifted, by means of Pumping Plant C-8 booster pump, into the aqueduct before Pumping Plant C-8. Pumping Plant C-8, located near Conejo dam site, would lift water from the aqueduct to about elevation 1,100 feet. During months of maximum delivery, a portion of the water lifted by Pumping Plant C-8 would come from storage in Conejo Reservoir, and, in the event of a shut-down of the aqueduct north of this point, emergency deliveries could be made. The aqueduct alignment would continue eastward to a terminal point at the west edge of the San Fernando Valley and would deliver water at a hydraulic grade line elevation of about 1,000 feet into local conveyance and distribution systems as described in Chapter VI. Also, part of the aqueduct flow could be lifted by Pumping Plant C-9 into Bell Canyon Reservoir for regulatory and emergency storage purposes. Reservoirs considered at this site would have a maximum water surface elevation of about 1,320 feet and a storage capacity of 117,000 acre-feet. The maximum height of dam at this site would be 410 feet.

The foundation at the Bell Canyon dam site is composed of hard sandstone and conglomerate which provide adequate foundation strength for the considered structures. Sufficient quantities of borrow material are available for an earthfill dam of moderate height; however, for larger dams some supplemental rockfill material would have to be transported for distances of up to ten miles. The City of Los Angeles Department of Water and Power has conducted extensive exploration work at this site. Data available from the exploratory work of this agency were utilized in this investigation.

Inland Route

The best inland route, shown in plan and profile on Plate 6, would extend southward in canal about 68 miles from Las Perillas Reservoir, where the water surface elevation would be about 325 feet, to Pumping Plant In-III. A forebay would be constructed in the vicinity of Buena Vista Lake to supply this pumping plant. Pumping Plant In-III would lift the water to about elevation 500 feet. Several schemes of operation have been considered for this pumping plant and for the other pumping and power recovery facilities on the inland aqueduct route, as described in Chapter V.

The aqueduct would then swing southerly and easterly across the south end of the San Joaquin Valley, a distance of about 27 miles to Pumping Plant In-IV. Pumping Plant In-IV, located on the north slope of Wheeler Ridge, would lift the water to an elevation of about 700 feet into a short reach of canal extending to Pumping Plant In-V. Pumping Plant In-V would lift the water to an elevation of about 1,245 feet across Wheeler Ridge. The aqueduct would then continue in canal section eastward about 12 miles across Highway 99 to a point about one mile to the east of Pastoria Creek, where Pumping Plant In-VI would be located.

The proposed canal alignment, for a total distance of approximately 15 miles, would traverse areas where shallow subsidence has been observed, notably in the vicinity of Taft and Maricopa and on the north side of Wheeler Ridge. Because the ground surface in these shallow subsidence areas is subject to rapid settlement when wetted, some method of preconsolidation will be required prior to canal construction. Extensive studies to determine the most desirable method of preconsolidation of these materials are now being conducted by the Department of Water Resources.

Pumping Plant In-VI would lift the water from elevation 1,240 feet to elevation 3,415 feet. A pumping lift of this height is entirely without precedent for the large flow rate contemplated. The delivery pipes from this plant would discharge to a series of four tunnels having an aggregate length of about six and one-half miles, with the longest being 3.7 miles in length. The tunnels would be connected by short reaches of siphon.

The Tehachapi Tunnels would be constructed through gneiss, schist, and granite. Most of the rock is very fractured. Some zones of moderately fractured and of crushed materials also occur. It is expected that some water inflows would be encountered in the schist and granite. As stated, the Garlock fault present in this area would be crossed on the surface.

From the south portal of the Tehachapi Tunnels, the aqueduct would either swing southerly toward the San Fernando Valley or continue southeasterly along the southerly edge of Antelope Valley. As subsequently related, combinations of these two routes were given consideration.

Castaic Route. For this route, the alignment would proceed southward from the Tehachapi Tunnels in canal section skirting the westerly edge of the Antelope Valley and would cross the San Andreas fault zone on the surface east of Gorman. From Antelope Valley southward, the topography is rugged and mountainous, but the steep slopes provide good sites for hydroelectric developments to recover power from the aqueduct flow as it enters the coastal slope.

In this area, the route as herein described is particularly adapted to a continuous flow scheme of operation. With certain modifications, the route is also suitable for most of the operational schemes involving the sale of recovered power. However, should the pumped storage concept of system operation, presented in Chapter V, be adopted for installation, the aqueduct route in this area would be located differently in order to permit full development of power potentialities inherent in this scheme.

A series of tunnels connected by siphons would lead southward through the Ridge Basin area and the Castaic Power Development. These tunnels would penetrate sandstones, siltstones, and shales. It is anticipated that good tunneling conditions would prevail throughout most of this area, although some water inflows should be expected in the most southerly and longest of these tunnels which would be 5.2 miles in length.

A forebay would be constructed above the Castaic Power Development for flexibility of operation. The Castaic Power Development would consist of two plants. Castaic Power Plant No. 1 would lower the hydraulic grade line from about elevation 3,300 feet to about 2,500 feet and would discharge into Beartrap Reservoir on Piru Creek, about 10 miles south of Gorman. Construction of this reservoir would require relocation of a portion of U. S. Highway 99. The reservoir considered at the Beartrap site would have a maximum water surface elevation of about 2,500 feet and a storage capacity of about 56,000 acre-feet, to be utilized in the event of an emergency shutdown on the aqueduct to the north or possibly for regulation purposes in addition to Castaic Reservoir. A 56,000 acre-foot reservoir would require a dam about 235 feet in height.

The foundation at the Beartrap dam site is in dense, hard shales that dip upstream and strike parallel to the axis, thus providing adequate foundation conditions. Suitable construction materials for an earthfill dam are available immediately upstream from the site.

Castaic Power Plant No. 2 located at Castaic Reservoir would lower the hydraulic grade line elevation about 1,000 feet to about elevation 1,400 feet. Castaic Reservoir was considered for storage capacities of up to about 280,000 acre-feet for regulation of the aqueduct flows to the monthly demand schedule. Castaic Dam would be of earthfill construction and would be about 314 feet in height for the maximum reservoir capacity studied.

Castaic dam site and the entire reservoir area are underlain by soft sandstones and silty and clayey shales. Laboratory tests available at this time indicate that these materials would provide a suitable foundation for the proposed structure. Exploratory drilling indicates that permeable sands and gravels constituting the alluvial fill in the channel section at the dam site reach a depth of about 110 feet. Ample quantities of good pervious borrow material are available immediately upstream from the dam site. Impervious borrow is available in terrace deposits and in finer grained sediments surrounding the reservoir area. Consideration in final design must be given to possible seismic activity both in the vicinity of this dam site and the Beartrap site.

From Castaic dam site, the aqueduct would cross the Santa Clara River Valley in siphon, and tunnel through the Santa Susana Mountains which separate the Santa Clara River watershed from the San Fernando Valley. This tunnel would be about 5.3 miles in length and would penetrate folded shale, mudstone, sandstone, and conglomerate. Although minor pockets of gas and oil might be encountered from place to place throughout the tunnel and the Santa Susana fault would be penetrated near the south portal, it is anticipated that tunneling conditions generally would be good. An existing railroad tunnel and a water tunnel paralleling the alignment two miles to the east successfully penetrated similar geologic conditions.

The aqueduct would extend a short distance from the south portal of this tunnel and join local distribution systems near Balboa Boulevard in the north San Fernando Valley. This junction point, designated Balboa Terminus, would be a reinforced concrete

Aqueduct Facilities. Diversion of surplus waters from the Delta would be accomplished by Pumping Plant I which would lift the water to elevation 243 feet into a canal extending southerly along the west side of the San Joaquin Valley, a distance of about 72 miles to the proposed San Luis Reservoir near the City of Los Banos. Pumping Plant II would either lift the water from the canal into the 2,100,000 acre-foot capacity reservoir, or into a canal leading therefrom. The maximum lift into the reservoir would be about 325 feet and into the canal about 149 feet. From Pumping Plant II, the canal would continue southward to Avenal Gap. It was assumed for purposes of the report that Pumping Plants I and II would be operated by a steam-electric generating plant.

It was assumed that, under contractual arrangement with the United States, use would be made of the existing Delta-Mendota Canal of the Federal Central Valley Project which parallels the proposed aqueduct from the Delta to a point south of San Luis Reservoir. This would enable an early delivery of water to the southern San Joaquin Valley, while the new aqueduct is under construction. The new aqueduct would be available to meet water demands which will develop by 1970. Construction of the San Luis Dam and Reservoir and the aqueduct leading southward to Avenal Gap would be started immediately and completed as soon as possible. It was also assumed that the San Joaquin Valley-Southern California Aqueduct System, north of the Avenal Gap area, would be integrated in part with the Federal Government's proposed San Luis Project. An estimated amount of about $100,000,000 was assumed in the studies as the Federal Government's share of cost in the aqueduct and San Luis Reservoir.

Between San Luis Reservoir and Avenal Gap, the aqueduct would deliver water to the Kings River Conservation District and adjacent areas in Fresno and Tulare Counties, to lands in the southwestern portion of Kings County in the vicinity of Avenal Gap, and to the Federal Government's proposed service area in the Westlands Water District in western Fresno County. Total annual water deliveries from the reach of aqueduct between the Delta and Avenal Gap by year 2020 would be about 2,594,000 acre-feet, including about 1,250,000 acre-feet for the Federal service area.

The estimated capital costs of the aqueduct including storage facilities between the Delta and Avenal Gap are shown on Table 14.

TABLE 14

SUMMARY OF ESTIMATED CAPITAL COSTS OF SAN JOAQUIN VALLEY-SOUTHERN CALIFORNIA AQUEDUCT FROM THE DELTA TO AVENAL GAP

(Based on prices prevailing in the fall of 1958)

Stations in miles	Items	Costs
0.0 to 72.3	Intake at Delta to San Luis Reservoir Capacity 13,000 cfs, Canal 69.8 miles, San Luis Reservoir $89,511,000, Pumping Plant I $43,811,000, Pumping Plant II $43,886,000, Steam Plant I $35,600,000, Steam Plant II $44,320,000	$338,510,000
72.3 to 120.5	San Luis Reservoir to Panoche Creek Capacity 20,875 cfs, Canal 48.2 miles	64,710,000
120.5 to 154.5	Panoche Creek to Five Points Capacity 20,019 cfs, Canal 34.0 miles	44,210,000
154.4 to 167.3	Five Points to Arroyo Pasajero Capacity 14,288 cfs, Canal 12.8 miles	10,760,000
167.3 to 183.3	Arroyo Pasajero to Kettleman City Capacity 13,288 cfs, Canal 15.9 miles	13,610,000
183.3 to 194.7	Kettleman City to Avenal Gap Capacity 12,280 cfs, Canal 11.4 miles	7,900,000
	Subtotal Construction Costs	$479,700,000
	Engineering and Contingencies	130,030,000
	Total Capital Cost	*$609,730,000

* Capital costs include estimated Federal investment of about $100,000,000 in facilities for the San Luis service area.

Aqueduct System "A"

This system would comprise a large coastal aqueduct designed to convey water to the southern California coastal plain and coastal San Diego County as well as to the coastal counties of San Luis Obispo, Santa Barbara, Ventura, and to the Upper Antelope Plain area in the San Joaquin Valley. A shorter inland aqueduct, proceeding through the San Joaquin Valley, crossing the Tehachapi Mountains and reaching as far as Little Rock Creek in the Antelope Valley, would convey water for most of the San Joaquin Valley portion of Kern County, and the Antelope-Mojave and Whitewater-Coachella Service Areas.

The general features of this system with "steam-electric and feedback" operational scheme are shown on Plate 7, and the lengths of various types of conveyance works, pumping lifts, power drops, and regulatory storage reservoirs, are summarized following:

AQUEDUCT

	Length in miles				
	Canal and flume	Tunnel	Siphon and penstock	Miscellaneous	Total
Delta to Avenal Gap	192	0	2	1	195
Coastal Aqueduct	116	31	113	0	260
Inland Aqueduct	153	6	10	3	172
Totals	461	37	125	4	627

PUMPING PLANTS

	Number of plants	Net operating head, in feet
Delta to Avenal Gap	2	395 to 571
Coastal Aqueduct	7	1,836 to 2,374
Inland Aqueduct	4	3,171

POWER RECOVERY PLANTS

	Number of plants	Net operating head, in feet
Delta to Avenal Gap	0	0
Coastal Aqueduct	1	503
Inland Aqueduct	1	325

REGULATORY RESERVOIRS

Reservoir	*Gross storage capacity, in acre-feet*	*Height of dam above streambed, in feet*
San Luis	2,100,000	310
Conejo	205,000	390
Bell Canyon	117,000	410

Aqueduct facilities in the San Joaquin Valley would be constructed with the objective of reaching the Wheeler Ridge area and beginning water deliveries in Kern County about the year 1965. Concurrently, construction would progress on the first stage of the large coastal aqueduct to the San Fernando Valley and deliveries would be made in the Central and South Coastal Areas by about 1971, with additional stages constructed to meet the water demand build-up to the year 2020. Construction would be continued on the inland aqueduct from the San Joaquin Valley through the Tehachapi Mountains to deliver water into the Antelope Valley, beginning about the year 1972.

Regulatory and emergency storage for the large coastal aqueduct would be provided in Conejo and Bell Canyon Reservoirs, with the latter primarily devoted to emergency service. During the early period of build-up of water demand, only Conejo Reservoir would be needed, and completion of construction of Bell Canyon Reservoir would be delayed until about 1994.

Projected water deliveries over time to the various service areas from Aqueduct System "A" are presented in Table 15 and are illustrated on Plate 8, entitled "Schematic Diagram of Water Deliveries from Aqueduct System 'A' ".

The estimated capital costs of this aqueduct system with the "steam-electric and feedback" operational scheme are presented by aqueduct reaches in Table 16, and are summarized following:

Aqueduct reach	*Capital cost**
Delta to San Luis Reservoir	$314,000,000
San Luis Reservoir	112,000,000
San Luis Reservoir to Avenal Gap	184,000,000
Coastal Aqueduct	
Avenal Gap to San Fernando Valley	1,663,000,000
Inland Aqueduct	
Avenal Gap to Little Rock Creek	189,000,000
Total	$2,462,000,000

* Includes estimated Federal investment of about $100,000,000 in facilities for San Luis service area.

TABLE 15

SCHEDULE OF WATER DELIVERIES FROM AQUEDUCT SYSTEM "A"

Service area	First water delivery	Water deliveries in thousands of acre-feet							
		First year	1965	1970	1980	1990	2000	2010	2020
Kern County (San Joaquin Valley)									
Upper Antelope Plain	1971	9	----	----	95	301	370	370	370
Avenal Gap to Pumping Plant In-III	1965	8	8	68	448	684	743	751	759
Pumping Plant In-III to Pumping Plant In-IV	1966	11	----	41	211	340	414	507	593
Pumping Plant In-IV to Pumping Plant In-VI	1967	7	----	14	34	53	58	61	63
Subtotals			8	123	788	1,378	1,585	1,689	1,785
San Luis Obispo									
Upper Salinas Valley	1971	1	----	----	3	10	11	14	15
San Luis Obispo-Arroyo Grande	1991	1	----	----	----	----	7	13	29
Nipomo Mesa	1972	1	----	----	2	9	10	11	11
Subtotals			----	----	5	19	28	38	55
Santa Barbara									
Santa Maria Valley	1971	17	----	----	35	46	58	69	90
Santa Ynez Valley	1971	1	----	----	9	22	24	27	35
South Coastal Area	1971	1	----	----	12	20	32	48	61
Subtotals			----	----	56	88	114	144	186
Ventura County									
Ventura River Area	1991	1	----	----	----	----	6	10	11
Santa Clara-Calleguas Area	1971	13	----	----	41	55	109	158	225
Subtotals			----	----	41	55	115	168	236
Antelope-Mojave									
Kern County	1972	1	----	----	5	14	20	26	33
Los Angeles County	1972	26	----	----	70	87	90	88	86
San Bernardino County	1982	12	----	----	----	41	65	81	89
Subtotals			----	----	75	142	175	195	208
Whitewater-Coachella	1982	18	----	----	----	35	55	90	100
Southern California Coastal Plain and Coastal San Diego County	1971	95	----	----	864	1,513	2,160	2,635	2,955
Totals			8	123	1,829	3,230	4,232	4,959	5,525

TABLE 16

SUMMARY OF ESTIMATED CAPITAL COSTS OF FEATURES OF AQUEDUCT SYSTEM "A" FOR THE "STEAM-ELECTRIC AND FEEDBACK" OPERATIONAL SCHEME

(Based on prices prevailing in the fall of 1958)

Stations in miles	Items	Cost
	DELTA TO AVENAL GAP	[a]$479,700,000
	COASTAL AQUEDUCT	
0 to 13	Avenal Gap to Pumping Plant C-4 Capacity 6,147 cfs, Canal 12.4 miles, Steam Plant No. 1 $57,600,000, Pumping Plant C-3 $16,512,000—16 units @ 384 cfs, Penstocks $2,304,000—8 stages @ 768 cfs	84,980,000
13 to 18	Pumping Plant C-4 to Pumping Plant C-5 Capacity 5,250 cfs, Canal 5.0 miles, Pumping Plant C-4 $16,768,000—16 units @ 328 cfs, Penstocks $1,728,000—8 stages @ 656 cfs	25,600,000
18 to 38	Pumping Plant C-5 to Shandon Capacity 4,724 cfs, Canal 10.9 miles, Polonio Pass Tunnel 5.0 miles, Siphon 3.8 miles—4 stages @ 1,181 cfs, Pumping Plant C-5 $14,464,000—16 units @ 295 cfs, Penstocks $2,944,000—8 stages @ 590 cfs	92,270,000
38 to 56	Shandon to Huerhuero Creek Capacity 4,717 cfs, Canal 14.9 miles, Siphon 2.7 miles—4 stages @ 1,179 cfs	29,020,000
56 to 79	Huerhuero Creek to Santa Margarita Capacity 4,708 cfs, Canal 9.1 miles, Siphon 14.0 miles—4 stages @ 1,177 cfs	86,920,000
79 to 87	Santa Margarita to San Luis Obispo Capacity 4,704 cfs, Cuesta Pass Tunnel 2.2 miles, Siphon 5.6 miles—4 stages @ 1,176 cfs, San Luis Obispo Power Plant $14,976,000—4 units @ 1,176 cfs, Penstocks $1,920,000—4 stages @ 1,176 cfs, Transmission Lines $9,152,000	77,670,000
87 to 103	San Luis Obispo to Arroyo Grande Capacity 4,685 cfs, Canal 12.0 miles, Siphon 4.2 miles—4 stages @ 1,171 cfs	36,700,000
103 to 113	Arroyo Grande to Nipomo Capacity 4,664 cfs, Canal 5.5 miles, Siphon 4.4 miles—4 stages @ 1,166 cfs	26,820,000
113 to 125	Nipomo to Santa Maria Valley Capacity 4,648 cfs, Canal 10.0 miles, Siphon 1.5 miles—4 stages @ 1,162 cfs	16,880,000
125 to 137	Santa Maria Valley to Pumping Plant C-7 Capacity 4,537 cfs, Canal 9.7 miles, Siphon 2.4 miles—4 stages @ 1,134 cfs, Pumping Plant C-6 $11,136,000—16 units @ 283 cfs, Penstocks $704,000—8 stages @ 566 cfs	32,780,000
137 to 143	Pumping Plant C-7 to Cuaslui Creek Capacity 4,524 cfs, Canal 6.3 miles, Pumping Plant C-7 $15,232,000—16 units @ 283 cfs, Penstocks $1,408,000—8 stages @ 566 cfs	29,760,000
143 to 167	Cuaslui Creek to Cachuma Dam Capacity 4,496 cfs, Canal 15.9 miles, Siphon 7.5 miles—4 stages @ 1,124 cfs	71,750,000
167 to 181	Cachuma Dam through San Marcos Pass Capacity 4,476 cfs, Canal 4.2 miles, San Marcos Pass Tunnel 5.4 miles, Siphon 5.3 miles—4 stages @ 1,119 cfs	90,910,000
181 to 195	San Marcos Pass through Santa Barbara Tunnels Capacity 4,408 cfs, Santa Barbara Tunnels 13.7 miles	85,090,000
	COASTAL AQUEDUCT—Continued	
195 to 207	Santa Barbara Tunnels to Casitas Reservoir Capacity 4,392 cfs, Casitas Pass Tunnels 1.9 miles, Siphon 10.2 miles—4 stages @ 1,098 cfs	64,670,000
207 to 239	Casitas Reservoir to Conejo Reservoir Capacity 4,377 cfs, Ventura Tunnels 1.0 mile, Siphon 30.8 miles—4 stages @ 1,094 cfs, Conejo Reservoir $31,519,000	240,070,000
239 to 241	Conejo Reservoir through Pumping Plant C-8 Capacity 4,886 cfs, Siphon 1.4 miles—4 stages @ 1,221 cfs, Pumping Plant C-8 $22,144,000—16 units @ 305 cfs, Booster Pump $2,176,000—4 units @ 184 cfs, Penstocks $4,800,000—8 stages @ 610 cfs, Steam Plant No. 2 $38,400,000	80,160,000
241 to 250	Pumping Plant C-8 to Ventura-Los Angeles County Line Capacity 4,774 cfs, Siphon 8.9 miles—4 stages @ 1,194 cfs	54,100,000
250 to 254	Ventura-Los Angeles County Line to Liberty Canyon Capacity 4,760 cfs, Siphon 4.3 miles—4 stages @ 1,190 cfs	22,300,000
254 to 258	Liberty Canyon through Woodland Hills Tunnels Capacity 4,599 cfs, Woodland Hills Tunnels 1.6 miles, Siphon 2.0 miles—4 stages @ 1,150 cfs	24,850,000
258 to 260	Woodland Hills Tunnels to Bell Canyon Reservoir Capacity 2,844 cfs, Siphon 2.8 miles—4 stages @ 711 cfs, Bell Canyon Reservoir $39,555,000, Pumping Plant C-9 $3,616,000—4 units @ 150 cfs	57,050,000
	Subtotal	$1,330,350,000
	INLAND AQUEDUCT	
0 to 68	Avenal Gap to Pumping Plant In-III Capacity 5,275 cfs, Canal 67.0 miles	$32,190,000
68 to 95	Pumping Plant In-III to Pumping Plant In-IV Capacity 2,356 cfs, Canal 26.3 miles, Pumping Plant In-III $6,016,000—8 units @ 294 cfs, Penstocks $448,000—4 stages @ 590 cfs, Steam Plant $21,600,000, Transmission Lines $1,760,000	41,940,000
95 to 110	Pumping Plant In-IV to Pumping Plant In-VI Capacity 683 cfs, Canal 11.6 miles, Pumping Plant In-IV $2,144,000—4 units @ 171 cfs, Pumping Plant In-V $3,360,000—4 units @ 171 cfs, Penstocks $2,256,000—2 stages @ 342 cfs	13,630,000
110 to 172	Pumping Plant In-VI to Little Rock Creek Capacity 441 cfs, Tehachapi Tunnels 6.3 miles, Canal 47.6 miles, Siphon 5.9 miles—1 stage @ 441 cfs, Pumping Plant In-VI $6,560,000—2 units @ 220 cfs, Cottonwood Power Plant $1,360,000—2 units @ 220 cfs, Penstocks $1,928,000—2 stages @ 220 cfs	63,250,000
	Subtotal	$151,010,000
	Subtotal, construction costs	1,961,060,000
	Engineering and contingencies	500,370,000
	Total Capital Cost	[b]$2,461,430,000

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[a] Cost of facilities from Delta to Avenal Gap based on continuous operation of Pumping Plants I and II using electric motor drive with energy supplied by steam-electric generation. Summarized costs of aqueduct features from the Delta to Avenal Gap are presented in Table 14.

[b] Capital costs include estimated Federal investment of about $100,000,000 in facilities for the San Luis service area.

The estimated portion of these capital costs required for the described initial construction sequence is about $1,390,000,000, of which about $90,000,000 represents the estimated Federal expenditures in facilities for the San Luis service area. This sum represents all expenditures on the system through year 1971 and would permit construction of the inland aqueduct to Little Rock Creek in Antelope Valley and the first stage of construction of the coastal aqueduct to San Fernando Valley.

Equivalent annual costs of capital recovery and interest at 3½ per cent, operation and maintenance, replacement and general expense, and energy for pumping over the economic life of the aqueduct system would be about $88,000,000.

Aqueduct System "B"

This system would comprise a large inland aqueduct traversing the San Joaquin Valley and delivering water to Kern County en route and, after crossing the Tehachapi Mountains, dividing into west and east branches. The west branch would extend southward through Castaic Reservoir to the Balboa Terminus in the San Fernando Valley. The east branch would proceed along the southerly edge of the Antelope-Mojave Service Area to Cedar Springs Reservoir, delivering water en route in that area as well as serving a turnout near Hesperia for the Whitewater-Coachella Service Area. From Cedar Springs Reservoir the aqueduct would be in tunnel through the San Bernardino Mountains into Devil Canyon near San Bernardino, and thence in pipe line to Perris Reservoir in Riverside County. A coastal aqueduct extending as far south as the Santa Maria Valley would serve water to San Luis Obispo and Santa Barbara Counties.

Division of Water Deliveries Between East and West Branches. The relative quantities and timing of water deliveries conveyed through the east and west branches of the inland aqueduct were given special study.

The South Coastal Area has a general east-west dimension in excess of one hundred miles. For this reason, the entire delivery of northern California water to this area from either Balboa or Perris alone would require long conveyance lines crossing highly developed urban areas. As discussed in Chapter VI, existing feeders of the Metropolitan Water District main distribution system cross the coastal plain area from east to west. Examination was made of the elevation and geographical distribution of the projected water demands in the over-all South Coastal Area, which it was estimated would total about 3.2 million acre-feet in the year 2020. Based upon maximum possible utilization of existing Metropolitan Water District east-west feeders, it was found that it would be necessary to deliver a minimum of about 1.2 million acre-feet per year, out of the foregoing total, through the west branch to Balboa and the balance of 2 million acre-feet through the east branch to Perris to avoid construction of another major east-west feeder. Furthermore, it was found that it would be possible to increase the deliveries through the west branch to Balboa to as much as 1.8 million acre-feet per year, with the balance of 1.4 million acre-feet to Perris Reservoir, without necessity of constructing a major west to east feeder across the entire coastal plain area.

Based upon the foregoing considerations, an analysis was made of dividing the flow in the inland aqueduct between east and west branches under two plans operated by the "steam-drive and feedback" scheme, which are summarized as follows:

	Water delivery to South Coastal Area, in year 2020, in millions of acre-feet*		
	West branch	*East branch*	*Total*
Plan 1			
Existing Colorado River Aqueduct Distribution System used to maximum capacity for east to west flow	1.2	2.0	3.2
Plan 2			
West end of existing Upper and Middle Feeders used to serve west to east flow to San Gabriel Valley. Existing Middle-Cross Feeder and west end of Lower Feeder used for west to east flow to Orange County	1.8	1.4	3.2

* Includes Ventura County.

Presented following are capital costs for full installation of all portions of the main aqueduct and local conveyance and distribution facilities south of and including Pumping Plant In-VI, which would be affected by variations in water deliveries through the east and west branches of the inland aqueduct:

Facilities affected by variations in water deliveries through East and West Branches of Inland Aqueduct	*Capital costs, in millions of dollars*	
	Plan 1	*Plan 2*
Main aqueduct facilities	714	713
Distribution facilities	450	505
Totals	1,164	1,218

The foregoing tabulation shows total capital costs of Plan 1 to be lower without consideration of timing of construction. However, the timing of projected water demands in the southern California coastal plain and in coastal San Diego County indicates the possibility, in Plan 2, of delaying completion of construction of the east branch to Perris until year 1992, although based upon water quality considerations discussed in Chapter III, it is considered desirable to commence delivery of northern California water through the east branch to Perris by year 1982. Therefore, a study was made of the two plans in which the staging of aqueduct construction was considered.

For Plan 1, it was assumed that staged conveyance units of the west branch to Balboa Terminus would be completed in years 1971 and 1977, and that staged conveyance units of the east branch to Perris Reservoir would be completed in years 1982 and 1997. Similarly, for Plan 2, it was assumed that one-half capacity of the west branch to Balboa Terminus would be completed in 1971 and one-half capacity in 1981; also, one-half capacity of the east branch would be completed in 1992 and the remaining capacity would be provided in the year 2000. Distribution system facilities were assumed to be constructed as needed and all construction costs were discounted to present worth in the year 1960. All annual costs of operation and maintenance, replacement, and energy for pumping, were also discounted to this year. The following tabulation sets forth the results of this study:

	Present worth of all capital and annual costs discounted to the year 1960, in millions of dollars
Plan 1	900
Plan 2	891

The preceding results show that there would be a relatively small advantage of Plan 2 over Plan 1 because of the delay in construction of the east branch of the aqueduct to Perris Reservoir for a period of 10 years. However, as discussed in Chapter III, the delay of deliveries of northern California water to the Upper Santa Ana Valley and coastal San Diego County, beyond the year 1982, could result in estimated economic losses averaging $20,000,000 per year for the 10-year period from 1982 to 1992. The economic effects of differences in water quality in urban uses would also apply in the westerly coastal plain areas, therefore, for the purpose of comparison of Plan 1 with Plan 2, the foregoing estimate was reduced to approximately $13,000,000 per year by elimination of the effects on urban water uses in the Upper Santa Ana Valley and coastal San Diego County.

The latter estimate of average annual economic losses discounted to present worth in the year 1960 amounts to about $55,000,000. It was further shown that Plan 1, which contemplates the larger quantities of water delivered through the east branch, would provide opportunity for a greater degree of mixing of northern California water with Colorado River water and a resulting better quality to the over-all service area, as shown in the following tabulation:

Area	*Estimated annual amount of imported water required in year 2020, in millions of acre-feet*	*Mineral concentration in parts per million in mixed imported water supply*	
		Plan 1	*Plan 2*
Coastal Riverside, San Bernardino, and San Diego Counties	2.0	380	430
Orange and Coastal Los Angeles Counties	2.1	330	285

It was therefore concluded that Plan 1 represented the more economical diversion of deliveries between the east and west branches of the inland aqueduct, and this plan was adopted for Aqueduct System "B". Shown graphically in Figure 9, entitled "Relationship Between Costs of and Water Deliveries Through East and West Branches of the Inland Aqueduct", are the results of the study of these two plans and of other possible diversions in deliveries between the east and west branches. As noted, Figure 9 does not reflect water quality considerations.

General Features of System. The general features of Aqueduct System "B" are shown on Plate 7. The lengths of various types of conveyance works, pumping lifts, power drops, and regulatory storage reservoirs for the "steam-drive and feedback" operational scheme are summarized following:

AQUEDUCT

	Length in miles				
	Canal and flume	*Tunnel*	*Siphon and penstock*	*Miscellaneous*	*Total*
Delta to Avenal Gap	192	0	2	1	195
Coastal Aqueduct	78	7	46	0	131
Inland Aqueduct	209	24	66	13	312
Totals	479	31	114	14	638

PUMPING PLANTS

	Number of plants	*Net operating head, in feet*
Delta to Avenal Gap	2	395 to 571
Coastal Aqueduct	3	918
Inland Aqueduct		
Avenal Gap to South Portal of Tehachapi Tunnels	4	3,166
West Branch	0	0
East Branch	1	525

POWER RECOVERY PLANTS

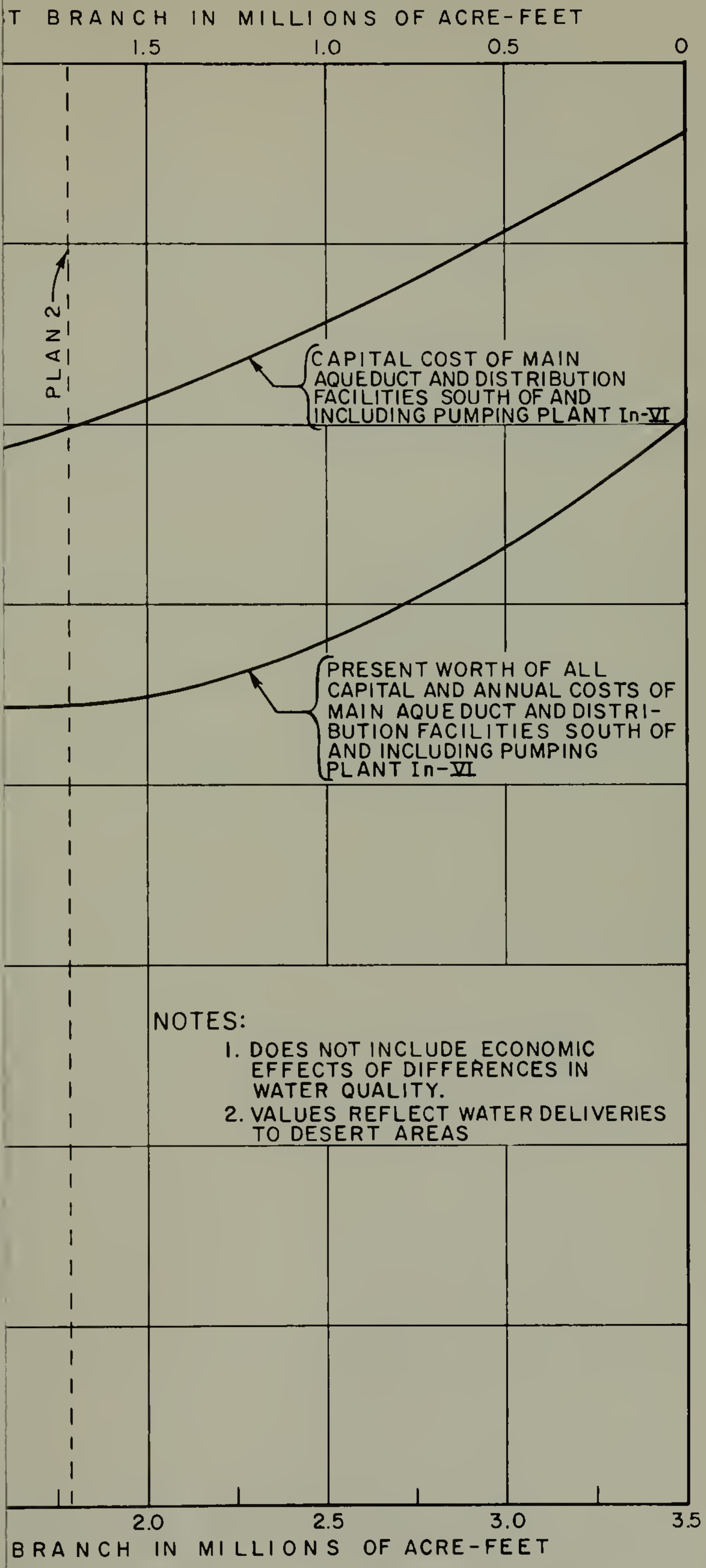
	Number of plants	*Net operating head, in feet*
Delta to Avenal Gap	0	0
Coastal Aqueduct	1	482
Inland Aqueduct		
Avenal Gap to South Portal of Tehachapi Tunnels	0	0
West Branch	2	1,834
East Branch	3	1,988

REGULATORY RESERVOIRS

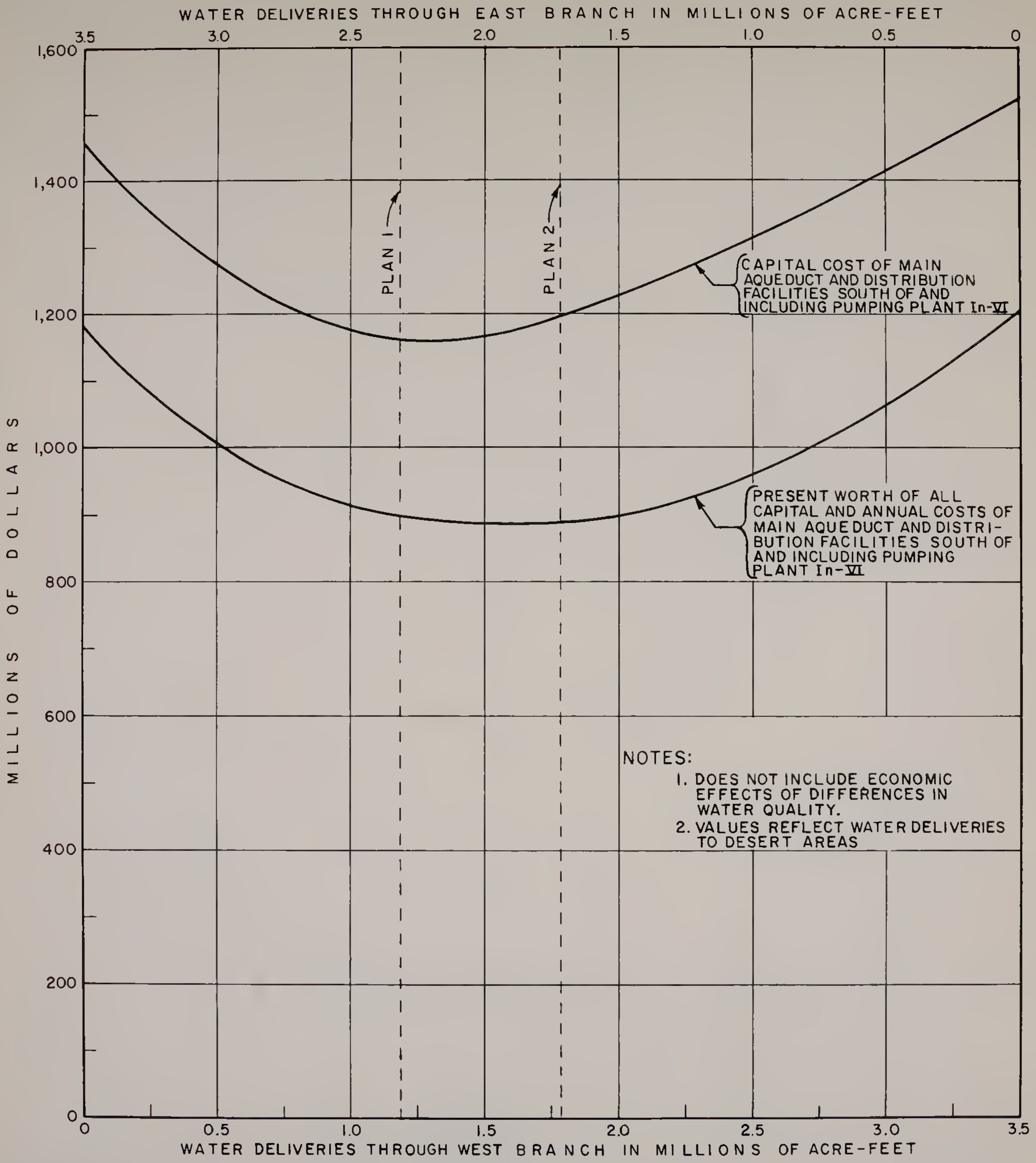
Reservoir	*Gross storage capacity, in acre-feet*	*Height of dam above stream bed, in feet*
San Luis	2,100,000	310
Beartrap	56,000	235
Castaic	150,000	247
Cedar Springs	216,000	290
Perris	148,000	140

Construction Sequence and Timing of Water Deliveries. The general sequence of aqueduct construction and water deliveries for Aqueduct System "B" would entail completion of construction of the aqueduct southward through the San Joaquin Valley and into the Kern County Service Area by about 1965. Concurrent and continuing work would complete the aqueduct through the Tehachapi Mountains and the west branch through Castaic Reservoir to Balboa Terminus to deliver water at that point for Ventura

FIGURE 9



OF AND WATER DELIVERIES THROUGH
S OF THE INLAND AQUEDUCT



RELATIONSHIP BETWEEN COSTS OF AND WATER DELIVERIES THROUGH EAST AND WEST BRANCHES OF THE INLAND AQUEDUCT

County and for the southern California coastal plain in 1971. The initial reach of canal on the east branch, from the south portal of the Tehachapi Tunnels to the vicinity of Pearblossom, would also be completed by 1971 to permit water deliveries to the Antelope Valley by that date. Concurrently with the work on the inland aqueduct, the coastal aqueduct would be constructed to the Santa Maria Valley, making initial water deliveries to San Luis Obispo and Santa Barbara Counties possible by about 1971. A second phase of the activity would consist of continuing the aqueduct in the Antelope-Mojave Service Area from Pearblossom through Cedar Springs Reservoir, delivering en route water to the Mojave River area and the Whitewater-Coachella Service Area, and on to Perris with initial water deliveries thereto by 1982.

Water deliveries over time in the various service areas from facilities of Aqueduct System "B" are set forth by decades in Table 17 and are illustrated on Plate 9, "Schematic Diagram of Water Deliveries from Aqueduct System 'B' ".

Costs. The estimated capital costs for this aqueduct system with the "steam-drive and feedback" operational scheme are presented for reaches of the aqueducts in Table 18, and are summarized following:

Aqueduct reach	*Capital cost **
Delta to San Luis Reservoir	$314,000,000
San Luis Reservoir	112,000,000
San Luis Reservoir to Avenal Gap	184,000,000
Coastal Aqueduct	
Avenal Gap to Santa Maria River	111,000,000
Inland Aqueduct	
Avenal Gap to South Portal of Tehachapi Tunnels	505,000,000
West Branch to Balboa Terminus	224,000,000
East Branch to Perris Reservoir	458,000,000
Total	$1,908,000,000

* Capital costs include estimated Federal investment of about $100,000,000 in facilities for the San Luis service area.

Construction costs for the described initial sequence of construction through year 1971 were estimated to be about $1,020,000,000, of which about $90,000,000 is the estimated Federal investment in facilities for the San Luis service area and $76,000,000 represents expenditures on the coastal aqueduct. These sums represent all expenditures on the system through 1971,

TABLE 17

SCHEDULE OF WATER DELIVERIES FROM AQUEDUCT SYSTEM "B"

Service area	First water delivery	Water deliveries in thousands of acre-feet							
		First year	1965	1970	1980	1990	2000	2010	2020
Kern County (San Joaquin Valley)									
Upper Antelope Plain	1971	9	----	0	95	301	370	370	370
Avenal Gap to Pumping Plant In-III	1965	13	13	88	476	708	759	759	759
Pumping Plant In-III to Pumping Plant In-IV	1966	11	----	42	213	342	416	508	593
Pumping Plant In-IV to Pumping Plant In-VI	1967	8	----	16	39	58	61	63	63
Subtotals			13	146	823	1,409	1,606	1,700	1,785
San Luis Obispo									
Upper Salinas Valley	1971	1	----	----	2	9	9	11	12
San Luis Obispo-Arroyo Grande	1991	1	----	----	0	0	7	13	29
Nipomo Mesa	1972	1	----	----	2	8	10	10	11
Subtotals			----	----	4	17	26	34	52
Santa Barbara									
Santa Maria Valley	1971	16	----	----	26	32	39	54	74
Santa Ynez Valley	1971	1	----	----	11	16	18	20	28
South Coastal Area	1971	1	----	----	10	18	28	44	57
Subtotals			----	----	47	66	85	118	159
Ventura County									
Ventura River Area	1991	1	----	----	0	0	6	10	11
Santa Clara-Calleguas Area	1971	13	----	----	41	55	109	158	225
Subtotals			----	----	41	55	115	168	236
Antelope-Mojave									
Kern County	1971	1	----	----	5	14	20	26	33
Los Angeles County	1971	20	----	----	70	87	90	88	86
San Bernardino County	1982	12	----	----	0	41	65	81	89
Subtotals			----	----	75	142	175	195	208
Whitewater-Coachella	1982	18	----	----	----	35	55	90	100
Southern California Coastal Plain and Coastal San Diego County	1971	95	----	----	864	1,513	2,160	2,635	2,955
Totals			13	146	1,854	3,237	4,222	4,940	5,495

TABLE 18

SUMMARY OF ESTIMATED CAPITAL COSTS OF FEATURES OF AQUEDUCT SYSTEM "B" FOR THE "STEAM-DRIVE AND FEEDBACK" OPERATIONAL SCHEME

(Based on prices prevailing in the fall of 1958)

Stations in miles	Items	Cost
	DELTA TO AVENAL GAP	[a]$479,700,000
	COASTAL AQUEDUCT	
0 to 13	Avenal Gap to Pumping Plant C-4 Capacity 1,717 cfs, Canal 12.4 miles, Pumping Plant C-3 $5,136,000—8 units @ 215 cfs, Penstocks $835,000—4 stages @ 429 cfs, Steam Plant $7,200,000	19,540,000
13 to 18	Pumping Plant C-4 to Pumping Plant C-5 Capacity 820 cfs, Canal 5.0 miles, Siphon 0.4 mile—2 stages @ 410 cfs, Pumping Plant C-4 $2,976,000—4 units @ 205 cfs, Penstocks $327,000—2 stages @ 410 cfs	6,700,000
18 to 39	Pumping Plant C-5 to Shandon Capacity 294 cfs, Canal 7.8 miles, Polonio Pass Tunnel 5.1 miles, Pumping Plant C-5 $1,504,000—4 units @ 74 cfs, Penstocks $349,000—2 stages @ 147 cfs	19,420,000
39 to 57	Shandon to Huerhuero Creek Capacity 285 cfs, Canal 12.4 miles, Siphon 5.8 miles—2 stages @ 142 cfs	7,260,000
57 to 82	Huerhuero Creek to Santa Margarita Capacity 278 cfs, Canal 12.5 miles, Siphon 12.1 miles—2 stages @ 139 cfs	10,890,000
82 to 89	Santa Margarita to San Luis Obispo Capacity 274 cfs, Cuesta Pass Tunnel 2.2 miles, Siphon 3.6 miles—2 stages @ 137 cfs, San Luis Obispo Power Plant $1,096,000—2 units @ 137 cfs, Penstocks $298,000—2 stages @ 137 cfs, Transmission Lines $752,000	10,020,000
89 to 105	San Luis Obispo to Arroyo Grande Capacity 254 cfs, Canal 10.7 miles, Siphon 4.9 miles—2 stages @ 127 cfs	5,520,000
105 to 118	Arroyo Grande to Nipomo Capacity 234 cfs, Canal 6.9 miles, Siphon 6.2 miles—2 stages @ 117 cfs	5,690,000
118 to 131	Nipomo to Santa Maria Valley Capacity 219 cfs, Canal 9.9 miles, Siphon 3.2 miles—2 stages @ 109 cfs	3,870,000
	Subtotal	$88,910,000
	INLAND AQUEDUCT	
	Avenal Gap to South Portal of Tehachapi Tunnels	
0 to 68	Avenal Gap to Pumping Plant In-III Capacity 9,667 cfs, Canal 67.0 miles	$42,410,000
68 to 95	Pumping Plant In-III to Pumping Plant In-IV Capacity 6,747 cfs, Canal 26.3 miles, Pumping Plant In-III $15,104,000—16 units @ 422 cfs, Penstocks $1,512,000 — 8 stages @ 844 cfs, Steam Plant $14,400,000, Transmission Lines $1,200,000	48,770,000
95 to 110	Pumping Plant In-IV to Pumping Plant In-VI Capacity 5,075 cfs, Canal 11.6 miles, Pumping Plant In-IV $12,800,000—16 units @ 317 cfs, Pumping Plant In-V $23,808,000—16 units @ 317 cfs, Penstocks $13,704,000—8 stages @ 634 cfs	63,010,000
	INLAND AQUEDUCT—Continued	
110 to 120	Pumping Plant In-VI to South Portal Tehachapi Tunnels Capacity 4,833 cfs, Tehachapi Tunnels 6.3 miles, Siphon 1.0 mile—4 stages @ 1,208 cfs, Pumping Plant In-VI $140,800,000—16 units @ 302 cfs, Penstocks $45,536,000—8 stages @ 605 cfs	249,650,000
	Subtotal	$403,840,000
	West Branch	
120 to 153	South Portal Tehachapi Tunnels to Castaic Reservoir Capacity 1,636 cfs, Canal 11.0 miles, Ridge Basin Tunnels 8.9 miles, Siphon 5.0 miles—2 stages @ 818 cfs, Castaic Power Plant No. 1 $8,256,000—3 units @ 545 cfs, Castaic Power Plant No. 2 $9,744,000—3 units @ 545 cfs, Penstocks $5,416,000—3 stages @ 545 cfs, Transmission Lines $2,640,000, Beartrap Reservoir $13,883,000, Castaic Reservoir $20,494,000	$118,670,000
153 to 159	Castaic Reservoir to Santa Clara River Capacity 2,112 cfs, Siphon 5.9 miles—2 stages @ 1,056 cfs	19,700,000
159 to 170	Santa Clara River to Balboa Terminus Capacity 2,068 cfs, Santa Susana Tunnel 5.3 miles, Siphon 5.7 miles—2 stages @ 1,034 cfs	40,700,000
	Subtotal (West Branch)	$179,070,000
	East Branch	
120 to 172	South Portal of Tehachapi Tunnels to Little Rock Creek Capacity 3,197 cfs, Canal 47.6 miles, Siphon 4.9 miles—3 stages @ 1,051 cfs. Cottonwood Power Plant $6,720,000—3 units @ 1,066 cfs, Penstocks $2,056,000—3 stages @ 1,066 cfs	74,680,000
172 to 225	Little Rock Creek to Cedar Springs Reservoir Capacity 3,033 cfs, Canal 45.2 miles, Siphon 6.4 miles—3 stages @ 1,011 cfs, Pumping Plant In-VII $14,304,000—12 units @ 253 cfs, Penstocks $5,635,000—6 stages @ 506 cfs	69,810,000
225 to 232	Cedar Springs Reservoir to Devil Canyon Power Plant No. 2 Capacity 3,005 cfs, San Bernardino Tunnel 3.9 miles, Power Plant No. 1 $18,936,000—3 units @ 1,001 cfs, Power Plant No. 2 $11,544,000—3 units @ 1,001 cfs, Penstocks $13,624,000—3 stages @ 1,001 cfs, Transmission Lines $7,200,000, Cedar Springs Reservoir $23,418,000	104,140,000
232 to 262	Devil Canyon Power Plant No. 2 to Perris Reservoir Capacity 2,074 cfs, Siphon 29.2 miles—2 stages @ 1,037 cfs, Perris Reservoir $28,642,000	$117,770,000
	Subtotal, East Branch	$366,400,000
	Subtotal, Inland Aqueduct	949,310,000
	Subtotal, construction costs	1,517,920,000
	Engineering and contingencies	389,590,000
	Total Capital Cost	[b]$1,907,510,000

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[a] Cost of facilities from Delta to Avenal Gap based on continuous operation of Pumping Plants I and II using electric motor drive with energy supplied by steam-electric generation. Summarized costs of aqueduct features from the Delta to Avenal Gap are presented in Table 14.

[b] Capital costs include estimated Federal investment of about $100,000,000 in facilities for the San Luis service area.

and would permit construction of the inland aqueduct to Balboa Terminus in San Fernando Valley and to Little Rock Creek in Antelope Valley, as well as construction of the coastal aqueduct to the Santa Maria Valley. More detailed information on the sequence of construction, timing of water deliveries and annual requirements for outlay of construction funds for Aqueduct System "B" is presented hereafter in Chapter VIII.

Equivalent annual costs of capital recovery and interest at $3\frac{1}{2}$ per cent, operation and maintenance, replacement and general expense, and energy for pumping, over the economic life of the aqueduct system, would be about $78,000,000.

The estimated capital costs of this aqueduct system for the "off-peak electric and feedback" operational scheme contemplated purchases of off-peak power only supplemented with on-peak recovered power are pre-

TABLE 19

SUMMARY OF ESTIMATED CAPITAL COSTS OF FEATURES OF AQUEDUCT SYSTEM "B" FOR THE "OFF-PEAK ELECTRIC AND FEEDBACK" OPERATIONAL SCHEME

(Based on prices prevailing in the fall of 1958)

Stations in miles	Items	Cost
	DELTA TO AVENAL GAP	[a]$479,700,000
	COASTAL AQUEDUCT	
0 to 13	Avenal Gap to Pumping Plant C-4 Capacity 3,122 cfs, Canal 12.4 miles, Pumping Plant C-3 $7,168,000—8 units @ 390 cfs, Penstocks $1,024,000—4 stages @ 780 cfs	19,620,000
13 to 18	Pumping Plant C-4 to Pumping Plant C-5 Capacity 1,490 cfs, Canal 5.0 miles, Siphon 0.4 mile—2 stages @ 745 cfs, Pumping Plant C-4 $4,256,000—4 units @ 373 cfs, Penstocks $416,000—2 stages @ 746 cfs	9,950,000
18 to 39	Pumping Plant C-5 to Shandon Capacity 294 cfs, Canal 7.8 miles, Polonio Pass Tunnel 5.1 miles, Pumping Plant C-5 $1,504,000—4 units @ 74 cfs, Penstocks $352,000—2 stages @ 148 cfs	20,550,000
39 to 131	Shandon to Santa Maria Valley (Same as shown in Table 18)	43,250,000
	Subtotal	$92,350,000
	INLAND AQUEDUCT	
	Avenal Gap to South Portal of Tehachapi Tunnels	
0 to 68	Avenal Gap to Pumping Plant In-III (Same as shown in Table 18)	$42,410,000
68 to 95	Pumping Plant In-III to Pumping Plant In-IV Capacity 8,232 cfs, Canal 26.3 miles, Pumping Plant In-III $17,024,000—16 units @ 513 cfs, Penstocks $1,536,000—8 stages @ 1,026 cfs	39,710,000
95 to 110	Pumping Plant In-IV to Pumping Plant In-VI Capacity 6,192 cfs, Canal 11.6 miles, Pumping Plant In-IV $13,824,000—16 units @ 386 cfs, Pumping Plant In-V $24,832,000—16 units @ 386 cfs, Penstocks $14,656,000—8 stages @ 772 cfs	66,880,000
110 to 120	Pumping Plant In-VI to South Portal Tehachapi Tunnels Capacity 6,138 cfs, Tehachapi Tunnels 6.3 miles, Siphon 1.0 mile—4 stages @ 1,535 cfs, Pumping Plant In-VI $83,072,000—16 units @ 383 cfs, Penstocks $54,656,000—8 stages @ 766 cfs	210,710,000
	Subtotal	$359,710,000
	INLAND AQUEDUCT—Continued	
	West Branch	
120 to 153	South Portal Tehachapi Tunnels to Castaic Reservoir Capacity 3,636 cfs, Canal 11.0 miles, Ridge Basin Tunnels 8.9 miles, Siphon 5.0 miles—2 stages @ 1,818 cfs, Castaic Power Plant No. 1 $18,240,000—6 units @ 606 cfs, Castaic Power Plant No. 2 $21,456,000—6 units @ 606 cfs, Penstocks $11,040,000—6 stages @ 606 cfs, Transmission Lines $3,840,000, Quail Lake Afterbay $1,161,000, Beartrap Reservoir $14,786,000, Castaic Reservoir $20,494,000	$181,400,000
153 to 170	Castaic Reservoir to Balboa Terminus (Same as shown in Table 18)	60,400,000
	Subtotal (West Branch)	$241,800,000
	East Branch	
120 to 172	South Portal of Tehachapi Tunnels to Little Rock Creek Capacity 4,088 cfs, Canal 47.6 miles, Siphon 4.9 miles—3 stages @ 1,051 cfs, Cottonwood Power Plant $8,384,000—4 units @ 1,022 cfs, Penstocks $2,848,000—4 stages @ 1,022 cfs, Cottonwood Afterbay $4,944,000	82,900,000
172 to 225	Little Rock Creek to Cedar Springs Reservoir (Same as shown in Table 18)	69,790,000
225 to 232	Cedar Springs Reservoir to Devil Canyon Power Plant No. 2 Capacity 6,678 cfs, San Bernardino Tunnel 3.9 miles, Power Plant No. 1 $44,976,000—6 units @ 1,113 cfs, Power Plant No. 2 $25,584,000—6 units @ 1,113 cfs, Penstocks $27,504,000—6 stages @ 1,113 cfs, Transmission Lines $17,280,000, Cedar Springs Reservoir $25,328,000, Devil Canyon Afterbay $67,688,000	$253,930,000
232 to 262	Devil Canyon Power Plant No. 2 to Perris Reservoir (Same as shown in Table 18)	117,770,000
	Subtotal, (East Branch)	$524,390,000
	Subtotal, Inland Aqueduct	1,125,900,000
	Subtotal, construction costs	1,697,950,000
	Engineering and contingencies	434,590,000
	Total Capital Cost	[b]$2,132,540,000

[a] Cost of facilities from Delta to Avenal Gap based on continuous operation of Pumping Plants I and II using electric motor drive with energy supplied by steam-electric generation. Summarized costs of aqueduct features from the Delta to Avenal Gap are presented in Table 14.

[b] Capital costs include estimated Federal investment of about $100,000,000 in facilities for the San Luis service area.

sented by aqueduct reaches in Table 19 and summarized following:

Aqueduct reach	*Capital cost **
Delta to San Luis Reservoir	$314,000,000
San Luis Reservoir	112,000,000
San Luis Reservoir to Avenal Gap	184,000,000
Coastal Aqueduct Avenal Gap to San Fernando Valley	115,000,000
Inland Aqueduct Avenal Gap to Little Rock Creek	1,407,000,000
Total	$2,132,000,000

* Includes estimated Federal investment of about $100,000,000 in facilities for San Luis service area.

Equivalent annual costs of capital recovery and interest at 3½ per cent, operation and maintenance, replacement and general expense, and energy for pumping over the economic life of the aqueduct system would be about $86,000,000.

Aqueduct System "C"

This system would comprise both coastal and inland aqueducts of major proportions. The coastal aqueduct was designed to transport water to the Upper Antelope Plain in the San Joaquin Valley, San Luis Obispo and Santa Barbara Counties and to deliver 1,184,000 acre-feet, by the year 2020, to Ventura County and the southern California coastal plain. The inland aqueduct was designed to convey the water demands of the Kern County Service Area, excluding the Upper Antelope Plain, and of the Antelope-Mojave and Whitewater-Coachella Service Areas, as well as to convey eastward to Perris Reservoir the balance of the estimated 2020 water demands of the Southern California Coastal Plain and Coastal San Diego County Service Area amounting to about 2,000,000 acre-feet per year. Water quantities conveyed via the coastal and inland aqueducts for the South Coastal Area were based upon the division worked out for the east and west branches of Aqueduct System "B".

The general features of Aqueduct System "C" are shown on Plate 7. The lengths of various types of conveyance works, pumping lifts, power drops, and regulatory storage reservoirs for the "steam-drive and feedback" operational scheme in the inland aqueduct

TABLE 20

SCHEDULE OF WATER DELIVERIES FROM AQUEDUCT SYSTEM "C"

Service area	First water delivery	Water deliveries in thousands of acre-feet							
		First year	1965	1970	1980	1990	2000	2010	2020
Kern County (San Joaquin Valley)									
Upper Antelope Plain	1971	9	----	----	95	301	370	370	370
Avenal Gap to Pumping Plant In-III	1965	10	10	78	461	696	751	755	759
Pumping Plant In-III to Pumping Plant In-IV	1966	11	----	42	213	342	416	508	593
Pumping Plant In-IV to Pumping Plant In-VI	1967	7	----	15	37	56	60	62	63
Subtotals			10	135	806	1,395	1,597	1,695	1,785
San Luis Obispo									
Upper Salinas Valley	1971	1	----	----	3	10	11	14	15
San Luis Obispo-Arroyo Grande	1991	1	----	----	0	0	7	13	29
Nipomo Mesa	1971	0	----	----	2	9	10	11	11
Subtotals			----	----	5	19	28	38	55
Santa Barbara									
Santa Maria Valley	1971	17	----	----	35	46	58	69	90
Santa Ynez Valley	1971	1	----	----	9	22	24	27	35
South Coastal Area	1971	1	----	----	12	20	32	48	61
Subtotals			----	----	56	88	114	144	186
Ventura County									
Ventura River Area	1991	1	----	----	0	0	6	10	11
Santa Clara-Calleguas Area	1971	13	----	----	41	55	109	158	225
Subtotals			----	----	41	55	115	168	236
Antelope-Mojave									
Kern County	1975	3	----	----	5	14	20	26	33
Los Angeles County	1975	42	----	----	70	87	90	88	86
San Bernardino County	1982	12	----	----	0	41	65	81	89
Subtotals			----	----	75	142	175	195	208
Whitewater-Coachella	1982	18	----	----	----	35	55	90	100
Southern California Coastal Plain and Coastal San Diego County	1971	95	----	----	864	1,513	2,160	2,635	2,955
Totals			10	135	1,847	3,247	4,244	4,965	5,525

TABLE 21

SUMMARY OF ESTIMATED CAPITAL COSTS OF FEATURES OF AQUEDUCT SYSTEM "C" FOR THE "STEAM-DRIVE AND FEEDBACK" AND "STEAM-ELECTRIC AND FEEDBACK" OPERATIONAL SCHEMES [a]

(Based on prices prevailing in the fall of 1958)

Stations in miles	Items	Cost
	DELTA TO AVENAL GAP	[b]$479,700,000
	COASTAL AQUEDUCT	
0 to 13	Avenal Gap to Pumping Plant C-4 Capacity 3,392 cfs, Canal 12.4 miles, Steam Plant No. 1 $28,800,000, Pumping Plant C-3 $11,152,000—12 units @ 283 cfs, Penstocks $1,545,000—6 stages @ 565 cfs	48,790,000
13 to 18	Pumping Plant C-4 to Pumping Plant C-5 Capacity 2,495 cfs, Canal 5.0 miles, Pumping Plant C-4 $7,360,000—10 units @ 250 cfs, Penstocks $974,100—5 stages @ 499 cfs	13,000,000
18 to 38	Pumping Plant C-5 to Shandon Capacity 1,969 cfs, Canal 10.9 miles, Polonio Pass Tunnel 5.0 miles, Siphon 3.8 miles—2 stages @ 984 cfs, Pumping Plant C-5 $5,840,000—8 units @ 244 cfs, Penstocks $1,382,000—4 stages @ 492 cfs	47,560,000
38 to 56	Shandon to Huerhuero Creek Capacity 1,962 cfs, Canal 14.9 miles, Siphon 2.7 miles—2 stages @ 981 cfs	16,500,000
56 to 79	Huerhuero Creek to Santa Margarita Capacity 1,953 cfs, Canal 9.1 miles, Siphon 14.0 miles—2 stages @ 977 cfs	40,760,000
79 to 87	Santa Margarita to San Luis Obispo Capacity 1,949 cfs, Cuesta Pass Tunnel 2.2 miles, Siphon 5.6 miles—2 stages @ 975 cfs, San Luis Obispo Power Plant $6,218,000—4 units @ 488 cfs, Penstocks $1,078,000—4 stages @ 488 cfs, Transmission Lines $9,152,000	42,800,000
87 to 103	San Luis Obispo to Arroyo Grande Capacity 1,929 cfs, Canal 12.0 miles, Siphon 4.2 miles—2 stages @ 965 cfs	18,820,000
103 to 113	Arroyo Grande to Nipomo Capacity 1,909 cfs, Canal 5.5 miles, Siphon 4.4 miles—2 stages @ 955 cfs	13,050,000
113 to 125	Nipomo to Santa Maria Valley Capacity 1,893 cfs, Canal 10.0 miles, Siphon 1.5 miles—2 stages @ 946 cfs	10,260,000
125 to 137	Santa Maria Valley to Pumping Plant C-7 Capacity 1,782 cfs, Canal 9.7 miles, Siphon 2.4 miles—2 stages @ 891 cfs, Pumping Plant C-6 $4,412,000—8 units @ 223 cfs, Penstocks $323,600—4 stages @ 445 cfs	15,820,000
137 to 143	Pumping Plant C-7 to Cuaslui Creek Capacity 1,769 cfs, Canal 6.3 miles, Pumping Plant C-7 $6,080,000—8 units @ 221 cfs, Penstocks $611,000—4 stages @ 442 cfs	17,820,000
143 to 167	Cuaslui Creek to Cachuma Dam Capacity 1,741 cfs, Canal 15.9 miles, Siphon 7.5 miles—2 stages @ 870 cfs	42,280,000
167 to 181	Cachuma Dam through San Marcos Pass Capacity 1,721 cfs, Canal 4.2 miles, San Marcos Pass Tunnel 5.4 miles, Siphon 5.3 miles—2 stages @ 860 cfs	47,140,000
181 to 195	San Marcos Pass through Santa Barbara Tunnels Capacity 1,653 cfs, Santa Barbara Tunnels 13.7 miles	51,650,000
	COASTAL AQUEDUCT—Continued	
195 to 207	Santa Barbara Tunnels to Casitas Reservoir Capacity 1,637 cfs, Casitas Pass Tunnels 1.9 miles, Siphon 10.2 miles—2 stages @ 818 cfs	$29,550,000
207 to 239	Casitas Reservoir to Conejo Reservoir Capacity 1,622 cfs, Ventura Tunnels 1.0 mile, Siphon 30.8 miles—2 stages @ 811 cfs, Conejo Reservoir $23,969,000	102,840,000
239 to 241	Conejo Reservoir through Pumping Plant C-8 Capacity 1,912 cfs, Siphon 1.4 miles—2 stages @ 956 cfs, Pumping Plant C-8 $7,658,000—8 units @ 239 cfs, Booster Pump $1,310,000—4 units @ 130 cfs, Penstocks $1,526,000—4 stages @ 478 cfs, Steam Plant No. 2 $12,864,000	29,060,000
241 to 250	Pumping Plant C-8 to Ventura-Los Angeles County Line Capacity 1,800 cfs, Siphon 8.9 miles—2 stages @ 900 cfs	23,830,000
250 to 254	Ventura-Los Angeles County Line to Liberty Canyon Capacity 1,785 cfs, Siphon 4.3 miles—2 stages @ 892 cfs	9,830,000
254 to 258	Liberty Canyon through Woodland Hills Tunnels Capacity 1,624 cfs, Woodland Hills Tunnels 1.6 miles, Siphon 2.0 miles—2 stages @ 812 cfs	11,570,000
258 to 260	Woodland Hills Tunnels to Bell Canyon Reservoir Capacity 920 cfs, Siphon 2.8 miles—2 stages @ 460 cfs, Bell Canyon Reservoir $11,314,000, Pumping Plant C-9 $696,000—4 units @ 50 cfs	17,460,000
	Subtotal	$650,390,000
	INLAND AQUEDUCT	
0 to 68	Avenal Gap to Pumping Plant In-III Capacity 8,031 cfs, Canal 67.0 miles	$38,600,000
68 to 95	Pumping Plant In-III to Pumping Plant In-IV Capacity 5,112 cfs, Canal 26.3 miles, Pumping Plant In-III $12,576,000—16 units @ 319 cfs, Penstocks $928,000—8 stages @ 638 cfs, Steam Plant $20,400,000, Transmission Lines $2,400,000	51,580,000
95 to 110	Pumping Plant In-IV to Pumping Plant In-VI Capacity 3,439 cfs, Canal 11.6 miles, Pumping Plant In-IV $9,433,000—12 units @ 287 cfs, Pumping Plant In-V $16,424,000—12 units @ 287 cfs, Penstocks $9,183,000—6 stages @ 574 cfs	45,490,000
110 to 120	Pumping Plant In-VI to South Portal Tehachapi Tunnels Capacity 3,197 cfs, Tehachapi Tunnels 6.3 miles, Siphon 1.0 mile—3 stages @ 1,066 cfs, Pumping Plant In-VI $93,106,000—12 units @ 267 cfs, Penstocks $32,560,000—6 stages @ 533 cfs	172,730,000
120 to 172	South Portal of Tehachapi Tunnels to Little Rock Creek Capacity 3,197 cfs, Canal 47.6 miles, Siphon 4.9 miles—3 stages @ 1,051 cfs, Cottonwood Power Plant $6,705,000—3 units @ 1,066 cfs, Penstocks $2,055,000—3 stages @ 1,066 cfs	74,660,000

TABLE 21—Continued

SUMMARY OF ESTIMATED CAPITAL COSTS OF FEATURES OF AQUEDUCT SYSTEM "C" FOR THE "STEAM-DRIVE AND FEEDBACK" AND "STEAM-ELECTRIC AND FEEDBACK" OPERATIONAL SCHEMES

(Based on prices prevailing in the fall of 1958)

Stations in miles	Items	Cost
	INLAND AQUEDUCT—Continued	
172 to 225	Little Rock Creek to Cedar Springs Reservoir Capacity 3,033 cfs, Canal 45.2 miles, Siphon 6.4 miles—3 stages @ 1,011 cfs, Pumping Plant In-VII $14,285,000—12 units @ 253 cfs, Penstocks $5,635,000—6 stages @ 506 cfs	69,790,000
225 to 232	Cedar Springs Reservoir to Devil Canyon Power Plant No. 2 Capacity 3,005 cfs, San Bernardino Tunnel 3.9 miles, Power Plant No. 1 $18,932,000—3 units @ 1,001 cfs, Power Plant No. 2 $11,530,000—3 units @ 1,001 cfs, Penstocks $13,623,000—3 stages @ 1,001 cfs, Transmission Lines $4,800,000, Cedar Springs Reservoir $23,418,000	101,720,000
	INLAND AQUEDUCT—Continued	
232 to 262	Devil Canyon Power Plant No. 2 to Perris Reservoir Capacity 2,074 cfs, Siphon 29.2 miles—2 stages @ 1,037 cfs, Perris Reservoir $28,642,000	$117,770,000
	Subtotal	$672,340,000
	Subtotal, construction costs	1,802,430,000
	Engineering and contingencies	460,710,000
	Total Capital Cost	[c]$2,263,140,000

[a] "Steam-drive and feedback" operational scheme on the Inland Aqueduct and "steam-electric and feedback" operational scheme on the Coastal Aqueduct.

[b] Cost of facilities from Delta to Avenal Gap based on continuous operation of Pumping Plants I and II using electric motor drive with energy supplied by steam-electric generation. Summarized costs of aqueduct features from the Delta to Avenal Gap are presented in Table 14.

[c] Capital costs include estimated Federal investment of about $100,000,000 in facilities for the San Luis service area.

and "steam-electric and feedback" scheme in the coastal aqueduct are summarized following:

AQUEDUCT

	Length in miles				
	Canal and flume	*Tunnel*	*Siphon and penstock*	*Miscellaneous*	*Total*
Delta to Avenal Gap	192	0	2	1	195
Coastal Aqueduct	116	31	113	0	260
Inland Aqueduct	198	10	48	6	262
Totals	506	41	163	7	717

PUMPING PLANTS

	Number of plants	*Net operating head, in feet*
Delta to Avenal Gap	2	395 to 571
Coastal Aqueduct	7	1,864 to 2,221
Inland Aqueduct	5	3,695

POWER RECOVERY PLANTS

	Number of plants	*Net operating head, in feet*
Delta to Avenal Gap	0	0
Coastal Aqueduct	1	503
Inland Aqueduct	3	1,988

REGULATORY RESERVOIRS

Reservoir	*Gross storage capacity, in acre-feet*	*Height of dam above streambed, in feet*
San Luis	2,100,000	310
Conejo	170,000	365
Bell Canyon	35,000	275
Cedar Springs	216,000	290
Perris	148,000	140

The initial sequence of aqueduct construction would comprise an immediate start on the coastal aqueduct with completion of the first stage to San Fernando Valley by 1971 to initiate water deliveries to San Luis Obispo and Santa Barbara Service Areas and the South Coastal Area by that date. The inland aqueduct in the San Joaquin Valley would also be constructed to commence water deliveries to Kern County by 1965. It was assumed that Pumping Plant In-VI, and aqueduct facilities to the south, would be constructed so as to commence water deliveries to Perris Reservoir and the Mojave River area and the Whitewater-Coachella Service Area by 1982. This would result in commencing water deliveries in the Antelope Valley by about 1975. For reasons similar to those previously stated under Aqueduct System "A", it would be possible to delay completion of construction of Bell Canyon Reservoir until about 1982.

Water deliveries over time to the various service areas from Aqueduct System "C" are presented in Table 20 and are illustrated on Plate 10, "Schematic Diagram of Water Deliveries from Aqueduct System 'C' ".

The estimated capital costs of this system, with the "steam-drive and feedback" and "steam-electric and feedback" operational schemes, are presented in Table 21, and are summarized following:

Aqueduct reach	*Capital cost **
Delta to San Luis Reservoir	$314,000,000
San Luis Reservoir	112,000,000
San Luis Reservoir to Avenal Gap	184,000,000
Coastal Aqueduct	
Avenal Gap to San Fernando Valley	813,000,000
Inland Aqueduct	
Avenal Gap to Perris Reservoir	840,000,000
Total	$2,263,000,000

* Capital costs include estimated Federal investment of about $100,000,000 in facilities for the San Luis service area.

Construction costs for the described initial sequence of construction through the year 1971 were estimated to be about $1,140,000,000 of which about $90,000,000 is the estimated Federal investment in facilities for

TABLE 22

SUMMARY OF ESTIMATED CAPITAL COSTS OF FEATURES OF AQUEDUCT SYSTEM "C" FOR THE "OFF-PEAK ELECTRIC AND FEEDBACK" OPERATIONAL SCHEME

(Based on prices prevailing in the fall of 1958)

Stations in miles	Items	Cost
	DELTA TO AVENAL GAP	$479,700,000
	COASTAL AQUEDUCT	
0 to 13	Avenal Gap to Pumping Plant C-4 Capacity 6,167 cfs, Canal 12.4 miles, Pumping Plant C-3 $14,720,000—16 units @ 386 cfs, Penstocks $2,176,000—8 stages @ 772 cfs	31,580,000
13 to 18	Pumping Plant C-4 to Pumping Plant C-5 Capacity 4,536 cfs, Canal 5.0 miles, Siphon 0.4 mile—4 stages @ 1,134 cfs, Pumping Plant C-4 $13,568,000—16 units @ 284 cfs, Penstocks $1,408,000—8 stages @ 568 cfs	22,570,000
18 to 38	Pumping Plant C-5 to Shandon Capacity 3,580 cfs, Canal 8.2 miles, Polonio Pass Tunnel 5.0 miles, Siphon 3.8 miles—4 stages @ 895 cfs, Pumping Plant C-5 $12,480,000—12 units @ 298 cfs, Penstocks $2,112,000—6 stages @ 596 cfs	70,670,000
38 to 207	Shandon to Casitas Reservoir (Same as shown in Table 21)	346,450,000
207 to 239	Casitas Reservoir to Conejo Reservoir Capacity 1,622 cfs, Ventura Tunnels 1.0 mile, Siphon 31.0 miles—2 stages @ 811 cfs, Conejo Reservoir $23,057,000	102,290,000
239 to 246	Conejo Reservoir through Upper Lake Sherwood Reservoir Capacity 3,476 cfs, Siphon 6.2 miles—4 stages @ 869 cfs, Pumping Plant C-8A $18,336,000—12 units @ 290 cfs, Pumping Plant C-8B $12,288,000—12 units @ 290 cfs, Penstocks $4,080,000—6 stages @ 580 cfs, Upper Lake Sherwood Reservoir $6,361,000	68,660,000
246 to 250	Upper Lake Sherwood Reservoir to Ventura-Los Angeles County Line Capacity 1,912 cfs, Siphon 3.9 miles—2 stages @ 956 cfs	7,140,000
250 to 260	Ventura-Los Angeles County Line to Bell Canyon Reservoir (Same as shown in Table 21)	38,860,000
	Subtotal	688,220,000
	INLAND AQUEDUCT	
	Avenal Gap to South Portal of Tehachapi Tunnels	
0 to 68	Avenal Gap to Pumping Plant In-III (Same as shown in Table 21)	$38,600,000
	INLAND AQUEDUCT—Continued	
68 to 95	Pumping Plant In-III to Pumping Plant In-IV Capacity 6,682 cfs, Canal 26.3 miles, Pumping Plant In-III $13,824,000—16 units @ 418 cfs, Penstocks $1,408,000—8 stages @ 835 cfs	$33,670,000
95 to 110	Pumping Plant In-IV to Pumping Plant In-VI Capacity 4,506 cfs, Canal 11.6 miles, Pumping Plant In-IV $10,080,000—12 units @ 375 cfs, Pumping Plant In-V $18,048,000—12 units @ 375 cfs, Penstocks $10,512,000—6 stages @ 750 cfs	51,200,000
110 to 120	Pumping Plant In-VI to South Portal Tehachapi Tunnels Capacity 4,450 cfs, Tehachapi Tunnels 6.3 miles, Siphon 1.0 mile—4 stages @ 1,113 cfs, Pumping Plant In-VI $60,288,000—12 units @ 371 cfs, Penstocks $39,840,000—6 stages @ 742 cfs	158,870,000
120 to 172	South Portal of Tehachapi Tunnels to Little Rock Creek Capacity 4,450 cfs, Canal 47.6 miles, Siphon 4.9 miles—3 stages @ 1,051 cfs, Cottonwood Power Plant $9,152,000—4 units @ 1,113 cfs, Penstocks $3,488,000—4 stages @ 1,113 cfs, Cottonwood Afterbay $5,688,000	85,350,000
172 to 225	Little Rock Creek to Cedar Springs Reservoir (Same as shown in Table 21)	69,790,000
225 to 232	Cedar Springs Reservoir to Devil Canyon Power Plant No. 2 Capacity 6,677 cfs, San Bernardino Tunnel 3.9 miles, Power Plant No. 1 $44,976,000—6 units @ 1,113 cfs, Power Plant No. 2 $25,584,000—6 units @ 1,113 cfs, Penstocks $27,504,009—6 stages @ 1,113 cfs, Transmission Lines $17,280,000, Cedar Springs Reservoir $25,328,000, Devil Canyon Afterbay $67,672,000	253,910,000
232 to 262	Devil Canyon Power Plant No. 2 to Perris Reservoir (Same as shown in Table 21)	117,770,000
	Subtotal	$809,160,000
	Subtotal, construction costs	1,977,070,000
	Engineering and contingencies	504,370,000
	Total Capital Cost	[b]$2,481,440,000

[a] Cost of facilities from Delta to Avenal Gap based on continuous operation of Pumping Plants I and II using electric motor drive with energy supplied by steam-electric generation. Summarized costs of aqueduct features from the Delta to Avenal Gap are presented in Table 14.

[b] Capital costs include estimated Federal investment of about $100,000,000 in facilities for the San Luis service area.

the San Luis service area and $53,000,000 represents expenditures on the coastal aqueduct. As stated, the first sequence of construction would include completion of the first of the staged units of the coastal aqueduct to San Fernando Valley and extension of the inland aqueduct to the base of the Tehachapi Mountains in the San Joaquin Valley.

Equivalent annual costs of capital recovery and interest at 3½ per cent, operation and maintenance, replacement and general expense, and energy for pumping, over the economic life of the aqueduct system would be about $88,000,000.

The estimated capital costs of Aqueduct System "C" for the "off-peak electric and feedback" operational scheme, contemplating purchases of off-peak power only supplemented with on-peak recovered power are presented by aqueduct reaches in Table 22 and summarized following:

Aqueduct reach	*Capital cost* *
Delta to San Luis Reservoir	$314,000,000
San Luis Reservoir	112,000,000
San Luis Reservoir to Avenal Gap	184,000,000
Coastal Aqueduct	
Avenal Gap to San Fernando Valley	860,000,000
Inland Aqueduct	
Avenal Gap to Little Rock Creek	1,011,000,000
Total	$2,481,000,000

* Includes estimated Federal investment of about $100,000,000 in facilities for San Luis service area.

Equivalent annual costs of capital recovery and interest at 3½ per cent, operation and maintenance, replacement and general expense, and energy for pumping over the economic life of the aqueduct system would be about $93,000,000.

CHAPTER V

PUMPING AND POWER RECOVERY

Conveyance of surplus northern California water to southern California, because of the nature of the terrain encountered and the economic and engineering aspects of aqueduct location, will require substantial pumping regardless of route. It is therefore important that the aqueduct system selected for construction be such that it is possible to employ an operational scheme which minimizes pumping costs and net expenditures of energy, consistent with over-all system economy and operational reliability.

It was the purpose of this phase of the investigation to develop, for each alternative aqueduct system, the operational scheme or schemes that would meet the tests of economy and reliability, and to determine the influence that choice of operational scheme would exert on aqueduct system selection. In doing this, the comparative results obtained for the several operational schemes studied were not intended to form the basis for a conclusion as to the scheme that finally should be employed. Such a conclusion will depend upon the answers to several major unresolved questions which will be the object of special study early in the design phase of the project.

The operational schemes found physically feasible of adaptation differed for each of the three considered aqueduct systems because of inherently different combinations of physical conditions peculiar to each system. Further, there exist alternative possibilities with respect to the procurement of power for pumping and the disposition of power in those instances where its recovery is feasible. These alternatives are: (1) the purchase of power from existing utilities, public or private, and the possible sale of recovered power thereto; and (2) development of power for pumping independent of utility connection, and the use of recovered power internally for pumping purposes. Operational schemes employing each of these alternatives as well as combinations and variations thereof have been considered in this investigation.

AQUEDUCT OPERATIONAL SCHEMES

Chapter IV describes the required pumping lifts and the potential power drops for the three alternative aqueduct systems. Pumping Plants I and II are located between the Delta and Avenal Gap. South of this point an inland aqueduct would require a maximum of five pumping lifts, varying from 190 feet to 2,200 feet. Consideration was given to a maximum of five power drops. Coastal aqueducts in the systems south of Avenal Gap would require a maximum of seven lifts and one power drop.

At the present time it is considered necessary that Pumping Plant I be operated on a continuous flow basis, while Pumping Plant II may be operated on an off-peak basis if the cost of off-peak power is found to result in lowest over-all pumping costs. It is also possible to operate Pumping Plant II on a continuous basis using steam-electric power for pumping. For purposes of this report, it was assumed that both Pumping Plants I and II would be operated continuously using steam-electric generation as the source of energy. In any event, since facilities north of Avenal Gap would be identical for all aqueduct systems, the assumption of a particular scheme of operation for these facilities will have no bearing on aqueduct system selection.

The facilities studied south of Avenal Gap were found to be adaptable to several alternative operational schemes. It was therefore necessary to evaluate on a preliminary basis the various alternative possibilities in order to ascertain the effect, if any, of operational scheme upon selection of the most economical aqueduct system. Based upon this evaluation, the selection of aqueduct system was verified for operational schemes employing both of the cited possibilities for power procurement and disposal.

Schemes Requiring Purchase and/or Sale of Electric Power

For facilities south of Avenal Gap, the operational schemes which would involve purchase from a utility or utilities of pumping power and/or sale thereto of recovered power are summarized as follows:

(1) **Off-Peak Electric and Sale of Power**—Pump only during off-peak hours and generate at power recovery plants during peak hours, with sale of recovered power. This scheme would require eventual sizing of the pumping facilities at approximately twice the capacity required for continuous pumping, and the construction of forebay and afterbay regulatory storage to provide for continuous aqueduct flow into, and away from, a pumping plant or series of pumping plants. Power recovery plants and appurtenant penstocks would be sized with sufficient capacity to permit peaking operation, and forebays and afterbays would be constructed upstream and downstream of the power drops to regulate for the intermittent power plant discharge.

(2) **Off-Peak Electric and Feedback**—Pump continuously, using electric motor drive. Use purchased power during off-peak hours and feedback power from recovery plants during peak hours. This scheme would also require purchase of some continuous power or provision of partial oversizing of conveyance facilities and storage since, on the applicable systems, insufficient feedback power would be generated to run all of the pumping units during peak hours. Also, oversizing of power recovery plants and construction of afterbays and forebays for the power drops as described in (1) would be required.

(3) **Steam-Drive and Sale of Power**—Pump continuously, using steam turbines to drive high-head pumps, and using power either from steam-electric generators or from steam turbines and reduction gears to drive low-head pumps. Generate at recovery hydro plants during peak hours, selling the recovered power. This would require oversizing of power plants and construction of afterbays and forebays for the power drops as described in (1). Oversizing of pumping plants and related conveyance would not be necessary.

(4) **Pumped Storage**—Pump only during off-peak hours; provide reversible pump-turbine units and the necessary forebay and afterbay storage at the power recovery plants to firm up the peaking capability of these plants. By installing such reversible units also in the pumping plants, these facilities could be utilized, when not required for the delivery of water, to generate additional peaking power. All such peaking power would be sold to the utility systems. Forebays and afterbays would be required at the pumping plants. These plants would, of necessity, have greater installed capacities than those in either (1) or (2).

The relative merits of the foregoing operational schemes can be determined finally only after full evaluation of economic, design and operational aspects of each, for which evaluation firm data on cost of purchased power and value of recovered power are essential. Preliminary analyses of these schemes were based upon estimates of cost and value of power furnished by the power companies early in the investigation and adjusted subsequently to reflect a postulated future increase in the price of fuel oil, as discussed later in this chapter.

Aqueduct operational schemes (1) and (3) involve consideration of the future feasibility of selling recovered power generated at power drops on the seaward slopes of the Transverse Ranges. It is probable that during seasons of heavy precipitation and runoff in southern California a variation in aqueduct system water deliveries will occur as discussed in Chapter II. Such occurrences would tend to depreciate the dependability of recovered power supplies, thereby reducing the return under a power sale contract.

A possible solution to this problem involving integration of aqueduct pumping and power recovery operations with pumping on the Colorado River Aqueduct was given preliminary consideration. The general procedure would be to reduce water conveyance and pumping on the Colorado River Aqueduct during the previously mentioned wet seasons, resulting in the following:

(1) Northern California water deliveries through aqueduct power recovery plants could continue unimpaired or with but a slight reduction, making possible complete or near complete fulfillment of power sale commitments.

(2) The portion of Metropolitan Water District generating capacity at Hoover Dam unloaded by cutback of Colorado River Aqueduct pumping could be utilized to assist the power recovery plants on the San Joaquin Valley-Southern California Aqueduct System in meeting contractual power sale commitments.

This type of integrated operation would have other advantages regardless of the operational scheme selected and will be given further consideration in final design of aqueduct facilities.

Another possibility for assuring dependability of recovered power would be the incorporation of pumped storage facilities into the power recovery plants making possible reversal of their operation at times when water demands in southern California might be low. Pumped storage might also be applied at the several pumping plants on the alternative aqueduct systems. The principle of pumped storage has been applied at operating installations in both Europe and the United States.

Basically, pumped storage power generation consists of pumping water from a lower storage reservoir to a higher storage reservoir utilizing off-peak power from generating capacity otherwise temporarily idle and releasing the stored water back to the lower reservoir through power generating facilities during short time periods of peak power load. In its application to the aqueduct systems, the aqueduct pumping plants would be equipped to reverse the flow of water and generate power. During each pumping cycle, the total water lifted at each plant would exceed the quantity of water to be conveyed southward. The excess pumped water would be stored and released back through the plant during the generating cycle. Power for pumping would be purchased on an off-peak basis, and low capacity factor power would be sold to electric utility agencies.

Reconnaissance studies were conducted of the application of pumped storage to the alternative aqueduct systems. Based upon these studies, it was found that pumping and power plant sites and adjacent storage sites could be developed for the pumped storage application in the inland route area. The coastal route area was found to be lacking in suitable storage sites to the extent that pumped storage application on this route was considered impracticable.

As described in a later section of this chapter, preliminary information was developed regarding cost and value, respectively, of off-peak pumping power and recovered peaking power. It was found, however, that extension of these data for the pumped storage application necessitated assumptions regarding availability of large quantities of off-peak pumping power and marketability of large quantities of peaking power at capacity factors considerably lower than have been employed in power sale contracts to date. It therefore became evident that even a preliminary evaluation of the pumped storage application would require more information regarding procurement and disposal of power. It is intended to obtain such information and make more detailed evaluation of the possibilities of a pumped storage application during the design phase of the project, in cooperation with the Power Advisory Committee.

It is believed that power utility participation in both pumping and power recovery aspects of the southern portion of the San Joaquin Valley-Southern California Aqueduct System would offer certain definite advantages, among which would be the improved power dependability which would result from interconnection with large systems and the possibility of power wheeling arrangements for joint use of existing and future transmission facilities of the major utility agencies. Recognizing these advantages, but also taking account of the fact that firm data were lacking on the conditions under which recovered power would be salable, it was concluded that scheme (2), ''off-peak electric and feedback'' would best represent ''utility participation'' for purposes of aqueduct system selection, since a minimum of economic and financial uncertainty would be involved.

Schemes Not Requiring Purchase or Sale of Electric Power

The operational schemes for facilities south of Avenal Gap which would not require purchase of electric power or sale of recovered power are summarized as follows:

(1) **Steam-Drive and Feedback**—Pump continuously, using steam turbines direct-connected to the high-head pumps and continuous feedback of power from power recovery plants to the electrically-driven low-head pumps. Conventional oil or gas fired boilers would provide necessary steam to the turbines. This scheme would require minimum capacities in conveyance and pumping facilities and in regulatory reservoirs.

(2) **Steam-Electric and Feedback**—Pump continuously with electrically-driven pumps; utilize feedback power generated continuously at power recovery plants; provide one or more steam-electric generating plants and necessary transmission facilities to supply the balance of electric power requirements. This scheme also would require minimum capacities in conveyance and pumping facilities and in regulatory storage.

Scheme (1), ''steam-drive and feedback'', would apply mainly around Pumping Plants In-III, IV, V, and VI, all in the southern portion of the San Joaquin Valley, and Plant In-VII in the Antelope Valley. The steam-drive application, unique to the high lift at Pumping Plant In-VI, was worked out with advice of electrical and mechanical consultants and manufacturers of heavy rotating equipment. Power recovered on the seaward slopes of the Transverse Ranges would be transmitted back to Plants In-III, IV, V and VII.

For the inland aqueduct, scheme (2) would differ from scheme (1) only in the substitution of steam-electric generating facilities to supply the electric motor-driven pumping units at Pumping Plant In-VI. On the coastal aqueduct the low pumping lifts would not be adaptable to the direct steam-drive application, therefore, both schemes would employ steam-electric generating capacity to supply all pumping power requirements in excess of available amounts of feedback power. It would be possible to integrate the power generation and feedback operations for either scheme on the coastal and inland aqueducts by transmission interconnection. Application of nuclear energy could be made by substitution of nuclear reactor and heat exchanger for the conventional steam boilers should this source of energy become economically competitive in the future.

Based upon preliminary economic comparisons, the direct steam-drive application at Pumping Plant In-VI was found to be superior to the steam-electric application from standpoints of both capital investment and annual operating costs. Therefore, scheme (1), ''steam-drive and feedback'', modified where necessary, was selected as the scheme best representing those requiring no purchase or sale of power and was utilized, where applicable, for the aqueduct systems analyses.

AQUEDUCT SYSTEMS APPLICATIONS

The applications of the ''off-peak electric and feedback'' and the ''steam-drive and feedback'' or ''steam-electric and feedback'' schemes to the aqueduct systems are described in the following sections.

It will be noted that the physical characteristics of individual aqueduct systems are such that variations in the application of operational schemes are necessitated. Estimates of costs of the alternative aqueduct systems employing both the "off-peak electric and feedback" and "steam-drive and feedback" schemes are presented in Chapter IV.

Aqueduct System "A"

It was found that employment of the "off-peak electric and feedback" scheme would be impracticable on this system owing to the lack of economical forebay and afterbay sites of the capacity required. Accordingly, the analyses of this system were made using the "steam-electric and feedback" scheme, with electric motor driven pumping units at all plants on both inland and coastal aqueducts. All plants would be electrically interconnected by transmission lines following the general coastal and inland route areas, tying into San Luis Obispo Power Plant on the coastal line and Cottonwood Power Plant at the south end of the Tehachapi Mountains crossing. Power from these plants would be fed into the line, thereby reducing required steam-electric generating capacity. The balance of the pumping power would be supplied by steam-electric generating plants located at Pumping Plant C-3 near Avenal Gap, near Pumping Plant C-8 at Conejo dam site, and at Pumping Plant In-III near Buena Vista Lake. The energy balance for these pumping and power generation facilities, considering main aqueduct pumping only, is presented in Table 23 for conditions estimated in the year 2000, illustrating a typical year of operation during the build-up period of water demand.

TABLE 23

ENERGY BALANCE FOR MAIN AQUEDUCT PUMPING AND POWER RECOVERY SCHEMES APPLIED TO ALTERNATIVE AQUEDUCT SYSTEMS FOR YEAR 2000

	Energy in millions of kilowatt hours				
	Aqueduct System "A"	Aqueduct System "B"		Aqueduct System "C"	
	Steam-electric and feedback	Off-peak electric and feedback	Steam-drive and feedback	Off-peak electric and feedback	Steam-drive and feedback
Pumping Plants					
In-III	161	695	678	447	436
In-IV	75	646	646	377	377
In-V	193	1,680	1,680	986	986
In-VI	613	6,600	----	3,800	----
In-VII	----	832	832	832	832
C-3	669	119	116	419	376
C-4	1,052	102	102	548	548
C-5	935	50	49	506	463
C-6	301	----	----	143	143
C-7	986	----	----	468	468
C-8	1,301	----	----	984	605
C-9	5	----	----	6	6
Subtotals	6,291	10,724	4,103	9,516	5,240
Equivalent energy input to steam-drive at In-VI	----	----	6,600	----	3,800
Total Energy Required	6,291	10,724	10,703	9,516	9,040
Power Plants					
Cottonwood	64	401	401	395	401
Castaic No. 1	----	721	740	----	----
Castaic No. 2	----	910	910	----	----
Devil Canyon No. 1	----	1,088	1,092	1,087	1,092
Devil Canyon No. 2	----	594	595	593	595
San Luis Obispo	1,018	41	41	500	500
Total Recovered Energy[a]	1,082	3,755	3,779	2,575	2,588
Steam-Drive Input	----	----	6,600	----	3,800
Steam Generation	5,209	----	324	----	2,652
Energy Purchase	----	6,969	----	6,941	----
Total Energy Supplied	6,291	10,724	10,703	9,516	9,040
NET ENERGY INPUT[b]	5,209	6,969	6,924	6,941	6,452

[a] Gross generation minus 3 per cent transmission loss.

[b] "Total Energy Required" minus "Total Recovered Energy."

Aqueduct System "B"

Analyses were made of Aqueduct System "B" employing both the "steam-drive and feedback" and the "off-peak electric and feedback" schemes of operation.

Steam-Drive and Feedback. The application of the "steam-drive and feedback" operational scheme to Aqueduct System "B" embodies the use of direct steam-drive at Pumping Plant In-VI and the use of electric motor-drive at all other plants on both inland and coastal aqueducts. The electric motors for pumps at inland aqueduct plants would be supplied by hydroelectric power fed back from the Castaic, Cottonwood, and Devil Canyon Power Developments, supplemented during the early years of operation and when starting up after shutdown by a relatively small amount of steam-electric power. The electric motors for pumps at coastal aqueduct plants would, in the absence of a transmission tie with the inland system, be supplied by steam-electric power in combination with hydroelectric power fed back from San Luis Obispo Power Plant.

However, as planned, the inland and coastal aqueducts would be joined by a transmission tie and would operate as an integrated system with only a small proportion of total power supplied by steam-electric generation. The operation would therefore be essentially the "steam-drive and feedback" scheme, and is referred to as such herein.

Later study may indicate the desirability of consolidating the steam-electric generating plants for coastal and inland aqueducts. Further, it might be possible to completely eliminate the need for steam-electric plant construction through some type of power exchange agreement with one or more electric utility agencies. An interconnection of the coastal and inland transmission system with electric utility systems could be made wherein: (1) generating reserves of the electric utility system could be utilized on an interruptible basis to perform the service described previously for the steam-electric plants, and (2) generating capacity on the aqueduct system, particularly at the Devil Canyon Power Plants where Cedar Springs Reservoir would assure dependable output, could be made available to the utilities for emergency use as "spinning reserve capacity" defined subsequently herein.

The build-up of requirements, through year 2020, for generating capacity and energy for pumping, reflecting water deliveries presented in Chapter IV, together with the combination of hydroelectric, steam-electric, and steam-drive capacity and energy which would be provided to meet those requirements, is shown for Aqueduct System "B" under the "steam-drive and feedback" scheme in Figure 10. As a further illustration of energy requirements and transfers, an energy balance for estimated conditions in year 2000 is shown schematically on Plate 11 and in Table 23.

Off-Peak Electric and Feedback. Application of the "off-peak electric and feedback" scheme to Aqueduct System "B" would embody electric motor drive at all pumping plants. Castaic and Devil Canyon power recovery plants would be sized to pass the required daily flow during peak energy hours and therefore would generate only at times of the day when off-peak energy could not be purchased. This peaking power would be transmitted to Pumping Plants In-III, In-IV, In-V, In-VI, and In-VII. Off-peak power would be purchased to supplement this peaking feedback power. Because of the limited quantity of feedback power, the combination of recovered peaking power and purchased off-peak power would not be enough to accomplish continuous flow pumping at all inland aqueduct pumping plants. Therefore, each pumping plant, with the exception of Pumping Plant In-VII near Pearblossom, would be oversized by about 25 per cent and the oversized portion of the facility would be operated on an off-peak basis to make up the balance of water conveyance.

In this operation, a forebay of about 10,000 acre-feet capacity would be constructed upstream from the Castaic Power Development to regulate flow from the aqueduct to the intermittent power releases. Castaic Reservoir would serve as an afterbay. The Devil Canyon Power Development would employ Cedar Springs as a forebay and would require an afterbay at the mouth of the canyon to regulate the power releases to uniform flow. Also, a forebay at the west edge of Buena Vista Lake and an afterbay at the south end of the Tehachapi Tunnels would be required to permit the partial off-peak operation of Plants In-III, In-IV, In-V, and In-VI.

On the coastal aqueduct, suitable afterbay and forebay sites for the San Luis Obispo power recovery development could not be found, so continuous flow generation was assumed at this plant. The developed power would be fed back to Pumping Plants C-3, C-4, and C-5, and some of the units at each of these plants would be operated continuously. The remaining units would be operated only during off-peak hours using purchased off-peak energy. This type of operation would necessitate construction of regulatory storage capacity at Las Perillas Reservoir and a similar storage facility near the entrance to the Polonio Pass Tunnel to provide for uniform flow in the aqueduct leading up to and away from the pumping lifts.

The build-up of requirements, through year 2020, for generating capacity and energy for pumping, reflecting water deliveries presented in Chapter IV, together with the combination of hydroelectric and purchased off-peak capacity and energy which would be provided to meet these requirements, is shown for Aqueduct System "B" under the "off-peak electric and feedback" scheme in Figure 11. As a further illustration of energy requirements and transfers, an energy balance for estimated conditions in year 2000 is shown schematically on Plate 12 and in Table 23.

Aqueduct System "C"

The application of the "steam-drive and feedback" scheme to Aqueduct System "C" assumes all pumping plants on the coastal aqueduct equipped with electric motor drive and interconnected by a transmission line from Avenal Gap to the San Fernando Valley, including connection to the San Luis Obispo Power Development. The inland aqueduct would have pumping arrangements similar to those for Aqueduct System "B" but with smaller sizes and with the elimination of west branch features. Transmission lines would interconnect the Devil Canyon power recovery plants, Pumping Plants In-VII, In-V, In-IV, In-III, and the Cottonwood power recovery plant. Pumping Plant In-VI would be equipped with direct steam-drive pumping facilities as in System "B". It would be necessary to construct steam-electric generating plants on the coastal aqueduct at Pumping Plant C-3 near Avenal Gap and near Pumping Plant C-8 (Conejo dam site) and on the inland aqueduct near Pumping Plant In-III (Buena Vista Lake). The possibilities for interconnection with utility systems described for System "B" would also be applicable to System "C".

Facilities for the "off-peak electric and feedback" scheme applied to Aqueduct System "C" would be similar to but of smaller capacity than pumping facilities described for Systems "A" and "B".

The energy balance for pumping and power recovery operations of Aqueduct System "C" estimated for the year 2000 is set forth in Table 23 for each of the two schemes.

PUMPING AND POWER PLANT FACILITIES

Estimates of costs and studies of operational aspects of pumping and power recovery installations were based upon preliminary designs and layouts of the equipment carried to sufficient degree of detail to establish engineering feasibility and provide reliable cost estimates, as described generally in Chapter IV. The general design features of the pumping and power generation equipment are described in the following sections.

Pumping Plants

Under the ''off-peak electric and feedback'' and the ''steam-electric and feedback'' schemes of operation, electric motor drive would be employed at all the pumping installations. Under the ''steam-drive and feedback'' scheme, direct steam-drive as developed in this investigation would be applied to the high head lift at Pumping Plant In-VI, and electric motor drive would be used for all other pumping installations. In either case, it should be pointed out that Pumping Plant In-VI embodies an unprecedented combination of high head and large flow rate. No prototype exists of pumps of the type and size contemplated. Therefore, in the design and selection of prime mover and pumping equipment for this plant, it will be necessary, regardless of type of drive selected, to perform considerable developmental work, including model testing.

Electric Motor Drive. For all low-head pumping units, of which those at Pumping Plants C-3 and In-III are typical, synchronous electric motors would be employed to drive vertical single-stage single-suction centrifugal pumps. Units pumping against a moderately high head, as at Pumping Plants C-8 and In-V, would consist of two single-stage pumps in series, the first of vertical single-suction type, and the second of horizontal single or double-suction type, both driven by synchronous electric motors. For the very high head encountered only at Pumping Plant In-VI, each unit would consist of three single-stage pumps in series, the first of vertical single-suction type, and the other two of horizontal single or double-suction type, each driven by an individual synchronous electric motor.

Direct Steam Drive. For the high head application at Pumping Plant In-VI, each pumping unit would consist of three pumps in series, the final-stage pump being driven by a horizontal direct-connected 1800 RPM steam turbine. The first pump in the series would be of low head driven by a vertical synchronous electric motor, as in the all-electric drive arrangement previously described. The intermediate pump would develop sufficient head to prevent cavitation in the suction of the final-stage high-head pump and could be driven either by an electric motor or, through reduction gears, by a steam turbine. This scheme would employ a conventional reheat steam cycle of high efficiency with turbines in a cross-compound arrangement, the high pressure turbine driving either the intermediate pump through reduction gears or an electric generator, and the low pressure turbine driving the final-stage pump. Cooling water would be supplied by routing a portion of the flow of the aqueduct through the condenser before its entry into the suction of the intermediate pump. The boiler, turbine, condenser, and all auxiliary equipment would be of conventional central station type, although simpler in that some of the control features normally used in electric utility service would not be required. The boiler would normally be fired with heavy fuel oil, but provision would be made for conversion to gas or coal firing at any time this might become desirable. Unit type of construction would be employed so that future additions might be modified to take advantage of technological improvements or changing conditions.

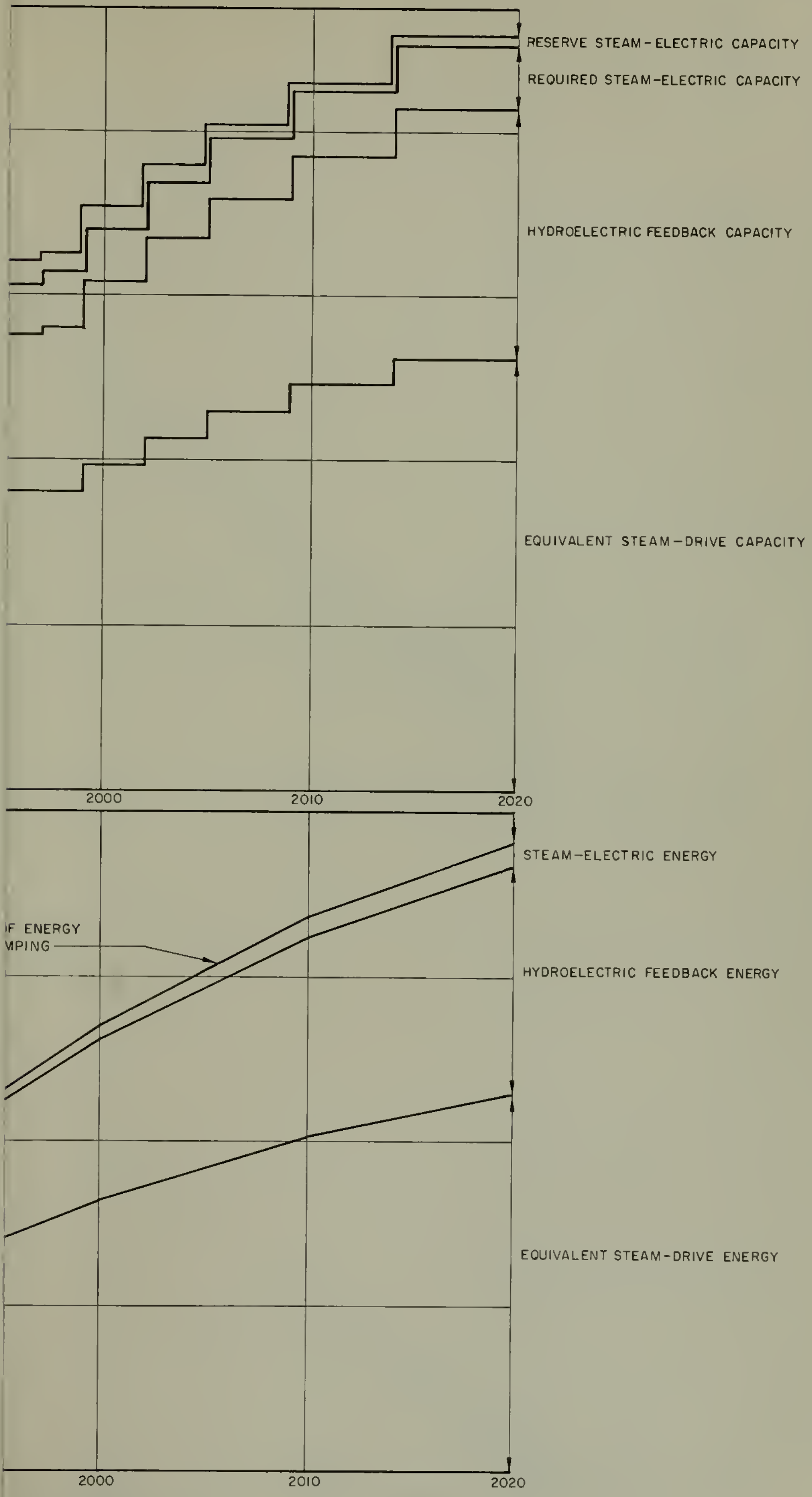
Steam-Electric Generating Plants

The steam-electric generating plants for either the ''steam-electric and feedback'' or the ''steam-drive and feedback'' operational schemes would follow conventional designs used in the electric utility industry for base load units operated continuously for long periods at near full load. Cooling water would be provided by routing a portion of the aqueduct flow directly through the condensers. Unit-type construction would be employed so that designs for successive units could be modified, if desired, to take advantage of improved technology or changing conditions of fuel supply. For the initial units, and probably for most of the subsequent units, heavy fuel oil would be used. Provision would be made, however, for the boilers to be converted to gas-firing or coal-firing should it be found advantageous to do so. Later, it might become desirable to install units which would employ nuclear fuels for steam-raising, and the layout of plants could provide for this possibility.

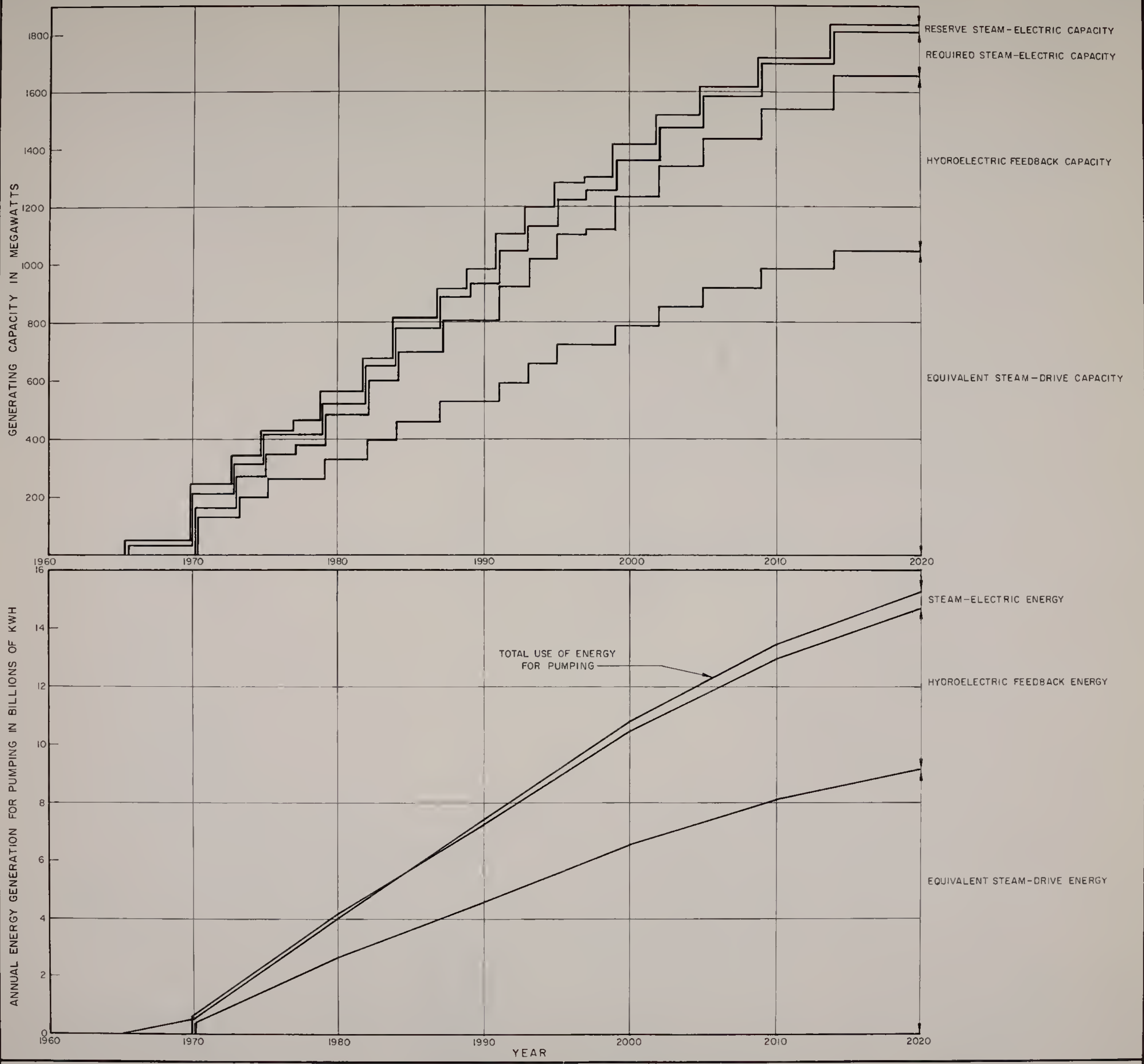
Hydroelectric Generating Plants

The hydroelectric generating plants used for the recovery of power on the downward slopes of the Transverse Ranges, would, under the ''steam-drive and feedback'' or the ''steam-electric and feedback'' operational schemes be designed for continuous operation. For ''off-peak and feedback'' operation, the plants would be designed for peaking operation and would accordingly be sized to discharge the required water quantities operating during on-peak hours only. At Devil Canyon Power Plant No. 1, where an operating head of approximately 1,100 feet is available, the installation for either continuous or peaking operation would consist of from three to six turbine units of the six-jet vertical impulse turbine type coupled to the generators. At each of the other hydroelectric plants, where operating heads cover the approximate

FIGURE 10



STEM "B"
CITY AND ENERGY FOR FACILITIES
AND FEEDBACK OPERATIONAL SCHEME



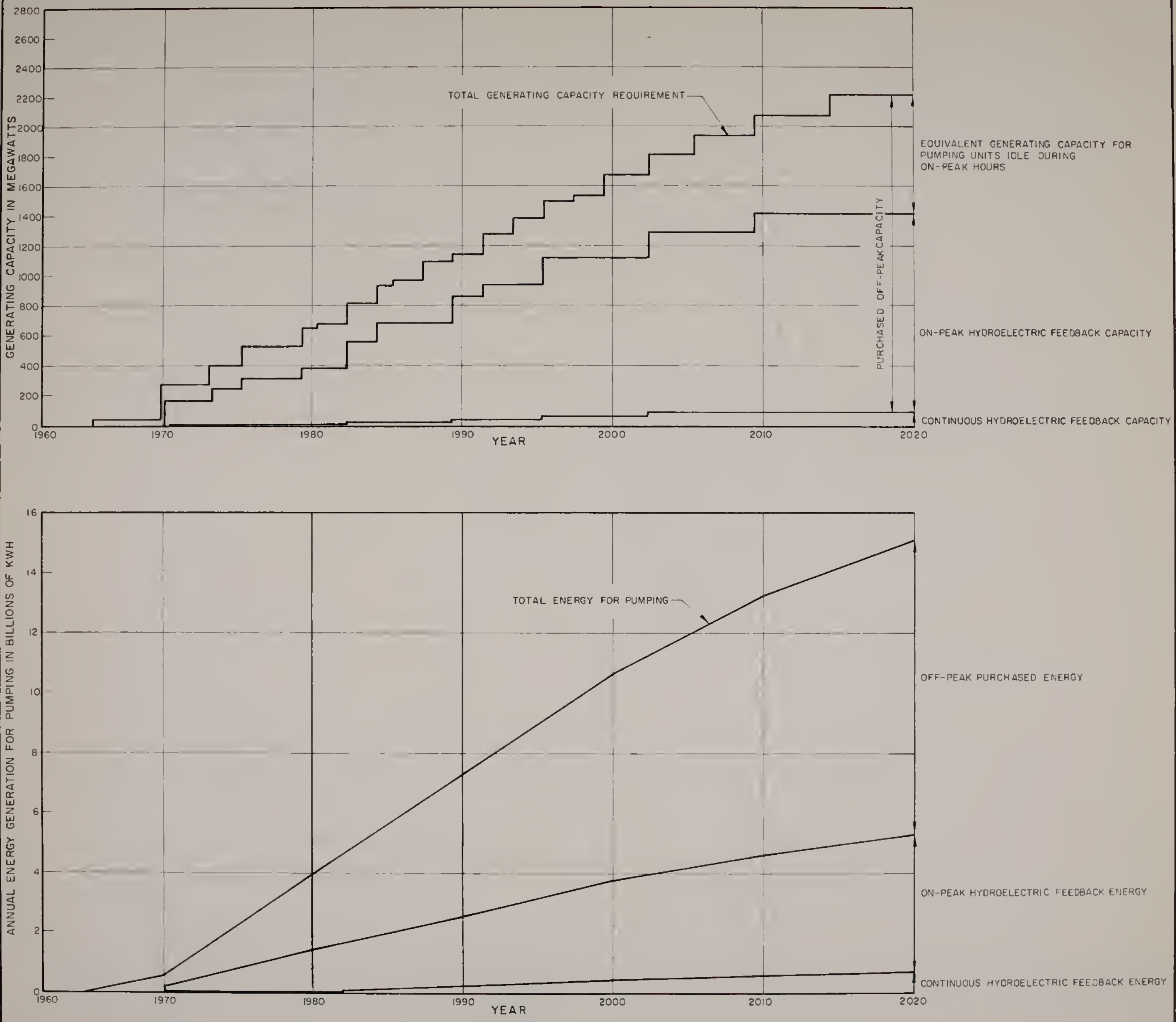
AQUEDUCT SYSTEM "B"
BUILD-UP IN USE OF GENERATING CAPACITY AND ENERGY FOR FACILITIES
SOUTH OF AVENAL GAP UNDER STEAM-DRIVE AND FEEDBACK OPERATIONAL SCHEME

DEPARTMENT OF WATER RESOURCES 1959

FIGURE 11

STEM "B"
ITY AND ENERGY FOR FACILITIES
RIC AND FEEDBACK OPERATIONAL SCHEME

FIGURE 11



AQUEDUCT SYSTEM "B"
BUILD-UP IN USE OF GENERATING CAPACITY AND ENERGY FOR FACILITIES
SOUTH OF AVENAL GAP UNDER OFF-PEAK ELECTRIC AND FEEDBACK OPERATIONAL SCHEME

DEPARTMENT OF WATER RESOURCES 1959

range of 300 to 1,000 feet, the installation would consist of from two to six units of the vertical Francis turbine type coupled to the generators.

POWER AND ENERGY RESOURCES AND COSTS

The cost analyses of the schemes involving purchase and/or sale of power required estimates of the future availability and cost of off-peak power for pumping. Also, analyses of the schemes involving no purchase or sale of power necessitated estimates of the availability and cost of fuels.

It was possible, based upon data previously obtained from individual utility agencies, and with the advice of a committee composed of representatives of these agencies, to develop preliminary information for use in evaluating the operational schemes involving utility participation. Based upon contacts with major oil companies and research organizations, estimates of future availability and cost of fuels were developed for use in evaluating schemes which do not involve utility participation. The results of these studies are described in this section.

The Power Advisory Committee, on which Pacific Gas and Electric Company, Southern California Edison Company, and Los Angeles Department of Water and Power are represented, was formed during May, 1958, for the purpose of advising the Department of Water Resources on power aspects of the Feather River and Delta Diversion Projects, particularly with respect to the availability and cost of pumping power purchased from utility systems, and the marketability and value of recovered power, both under the various operational schemes outlined previously. The committee held several meetings during 1958 and 1959, and in connection therewith, working representatives of the utilities have familiarized themselves with the planning for the project, and have given assistance to Department personnel on certain phases of its work. It is expected that the committee will continue its efforts during the design phase of work on aqueduct facilities to southern California.

California Power Load

Projections were made of the California power load, with particular emphasis on southern California, in order to provide a basis for estimates of future availability of power for pumping purposes and probable market for recovered power. Results of these projections were employed in advance of the more definite results which are expected to result from efforts of the previously mentioned committee of power utility representatives. As stated earlier, assistance in the studies described herein was provided by working representatives of the agencies participating on the committee.

The first step in the procedure employed was the application of estimates of per capita consumption of electric energy, comparable to estimates prepared by the Federal Power Commission, to median population projections presented in Chapter II. In this manner a projection of total energy consumption over time to the year 1990 was obtained.

There are wide variations in the rate of utilization of electric power in any load system from month to month, day to day, and throughout each day. Experience has shown that the variations in rate of energy utilization follow a characteristic pattern over each year. The peak rate of utilization of electric energy, or maximum power demand, of a power load system is the best measure of the need for more power generating capacity.

The relationship of the average utilization of energy, through a given year, to the maximum demand for power during the year is expressed as a ratio designated "load factor". After consultation with operating electric utility agencies, estimates of future load factor conditions were developed and the foregoing projection of total energy consumption was converted to a projection of peak power demand. The future power demands so projected are shown in Figure 12, entitled "Historical and Projected Annual Maximum Power Demand in California", and also in Table 24, for "northern" and "southern" California, as defined in publications of the California Public Utilities Commission.

TABLE 24

HISTORICAL AND ESTIMATED FUTURE ANNUAL MAXIMUM POWER DEMAND IN CALIFORNIA

(Quantities in millions of kilowatts)

Year	Northern California	Southern California	Total for State
1920	0.4	0.3	0.7
1930	1.0	0.8	1.8
1940	1.3	1.2	2.5
1945	1.7	1.9	3.6
1950	2.5	2.8	5.3
1955	3.7	4.4	8.1
1956	4.0	4.8	8.8
1960	5.1	6.4	11.5
1970	9.3	11.4	20.7
1980	16.7	19.0	35.7
1990	28.2	28.8	57.0

The estimated growth of power demand in southern California shown in Table 24 indicates that generating resources therein must be increased by as much as 5,000,000 kilowatts between 1960 and 1970 and by at least three times this much between 1970 and 1990. During these periods, the maximum generating potential of the power recovery plants on the aqueduct systems investigated was estimated to represent less than 10 per cent of this increased demand. It may therefore be assumed that there would be a market for the estimated quantities of recovered power for peaking purposes, if it should be found financially advantageous to sell it rather than utilize it within the system for pumping purposes; however, the value or selling price for such power cannot be forecast with any degree of certainty at this time.

It has been suggested previously, and analyses presented in the cited 1955 report were based upon the assumption, that power to supply aqueduct pumping plants would be purchased from the power utilities only during the "off-peak" period. The characteristic variation of electric power load requirements throughout each day, previously referred to, generally comprises high demand through the daylight and early evening hours of each weekday and low demand through the remaining night time hours and during the week-end. The hours of low power demand are commonly referred to as "off-peak" time on a power generation-load system. During these off-peak hours, a certain portion of a power utility's generating capacity is idle. The steam-electric portion of this idle generating capacity could be kept operating during off-peak hours to supply project pumping power, at an additional cost approximately equal to the cost of the fuel consumed.

The growth of power demand in California shown in Table 24 indicates a need for total generating resources therein of more than 20,000,000 kilowatts in 1970 and several times this amount by 1990. Since a major part of the hydroelectric potential of the State has already been developed, it appears that this increase of generating capacity must be largely from steam-electric or similar equipment. It was estimated that between the years 1970 and 1990, steam-electric capacity in peaking service and therefore idle during off-peak hours will increase from about 6,000,000 kilowatts to 20,000,000 kilowatts. The estimated off-peak pumping requirements of the aqueduct systems for the same period would represent less than 10 per cent of the possible off-peak output of this estimated peaking steam capacity. Therefore, it appears reasonable to assume that there would be sufficient off-peak power for aqueduct system pumping should its cost be such as to justify its purchase rather than employment of other sources or kinds of power.

A power utility as a matter of necessity must maintain installed generating capacity somewhat in excess of its load commitments. Generally, this reserve is maintained at between 10 and 15 per cent of the total demand on the system. It is common utility practice to maintain a portion of this reserve capacity as "spinning reserve" ready to pick up load in event of forced outage of other generating units, generally accomplished by operating several units at less than full load ready to pick up load should an emergency shutdown occur. The possibility of purchase of the output of this reserve capacity on an interruptible basis was studied. After consultation with the power utility agencies it was concluded that this could not be considered a significant source of power for pumping.

Fuel Requirements

One of the most frequently discussed questions with regard to the study of aqueduct routes to southern California is that of relative pumping requirements for the various routes, particularly the lift over the Tehachapi Mountains, and the net effect thereof upon energy-producing fuel oil reserves of the State and of the nation.

Net energy requirements of Aqueduct Systems "A", "B", and "C", for the "steam-electric and feedback" or "steam-drive and feedback" schemes, were converted to equivalent barrels of fuel oil using estimated heat rates of 620 kilowatt hours per barrel of oil for steam-electric generation and 600 kilowatt hours per barrel for the direct steam-drive application. The comparison of net annual equivalent fuel oil consumption for the systems south of Avenal Gap, including that of the main conveyance and distribution systems within service areas, and reflecting estimated build-up of water demands to year 2020, is presented graphically in Figure 13 for the "steam-electric and feedback", or "steam-drive and feedback" schemes. It will be noted that the maximum difference in fuel oil consumption between Aqueduct System "A", primarily a coastal system, and Aqueduct System "B", primarily an inland system, including the effect of required local pumping, is only about 14 per cent.

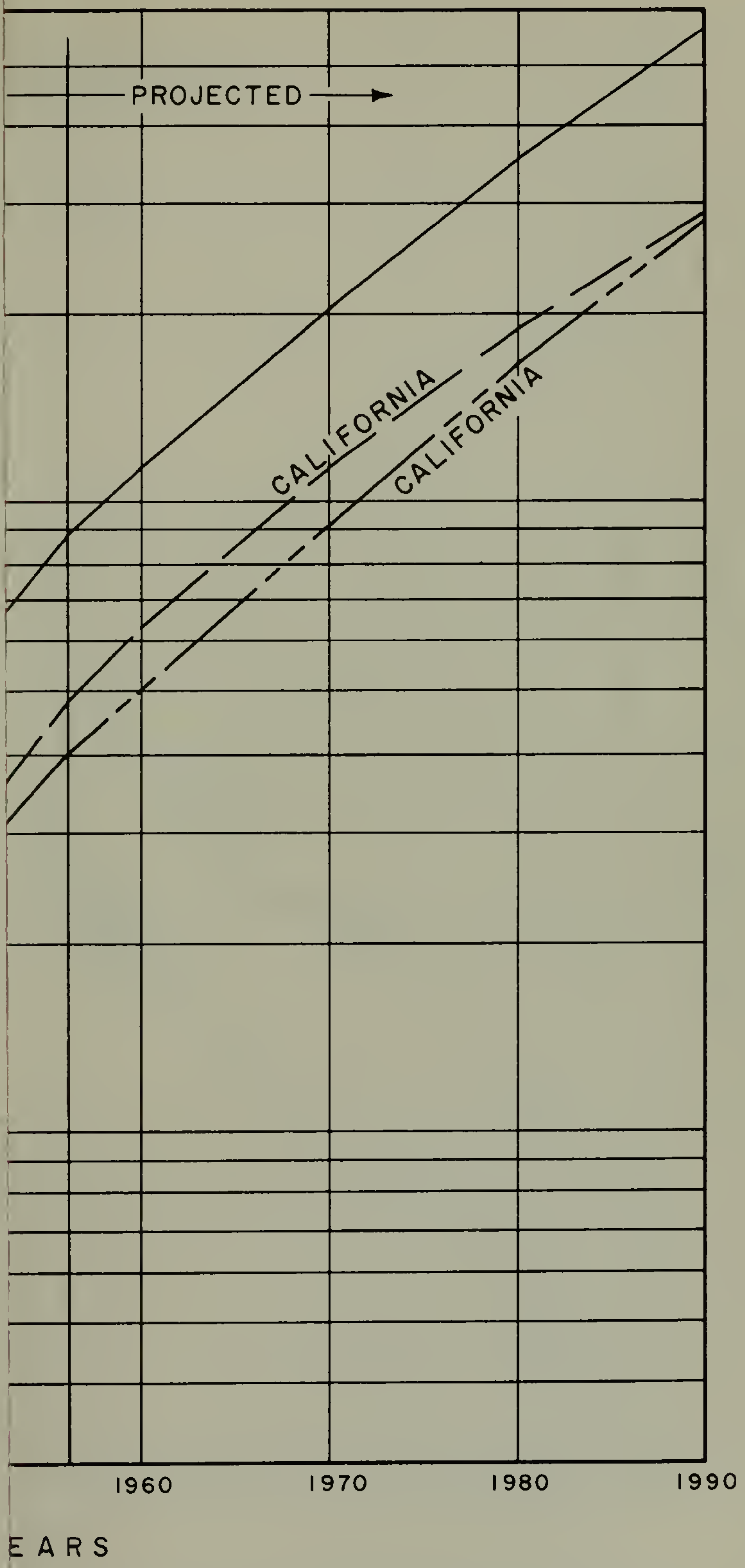
Fuel Resources

The production of crude oil in California during the year 1957 was 340 million barrels. Residual oils obtained from this total, that is oils remaining after removal of the lighter and more valuable constituents of crude oil, probably approximated 100 million barrels. The heavy residual oil is the general type of fuel utilized by oil burning steam-electric plants. The estimated average annual fuel oil consumption of Aqueduct System "B" over the period from 1970 through 2020 under the "steam-drive and feedback" operation would represent less than one-tenth of present California production of this commodity.

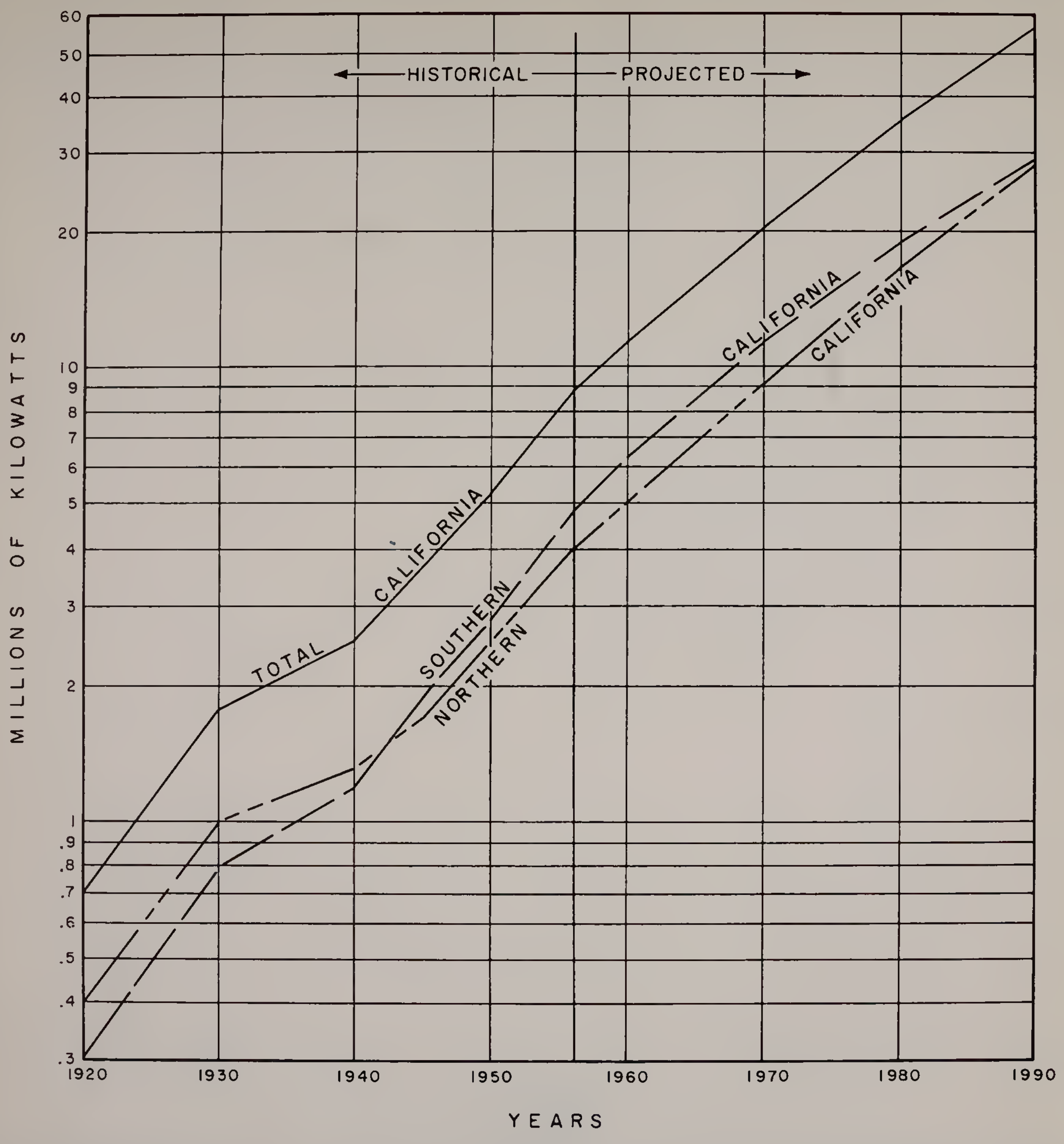
Several major oil companies, operating in the southern California area, were contacted in regard to the matter of long-term availability of fuel oil resources. The consensus of these companies was that crude oil production in the San Joaquin Valley could continue unabated and probably grow at least until 1980. Some estimates indicated sustained production for the next 50 years. It was further indicated that foreign imports of oil refined in Los Angeles and the San Francisco Bay area represent a large and continuing source of heavy residual fuel oils for steam plant use. These fuel oil supplies could be conveyed to Pumping Plant In-VI or other sites in the southern San Joaquin Valley by pipe line.

Natural gas is also utilized in firing steam-electric plants in California. However, competition for this commodity will be high from residential and indus-

FIGURE 12



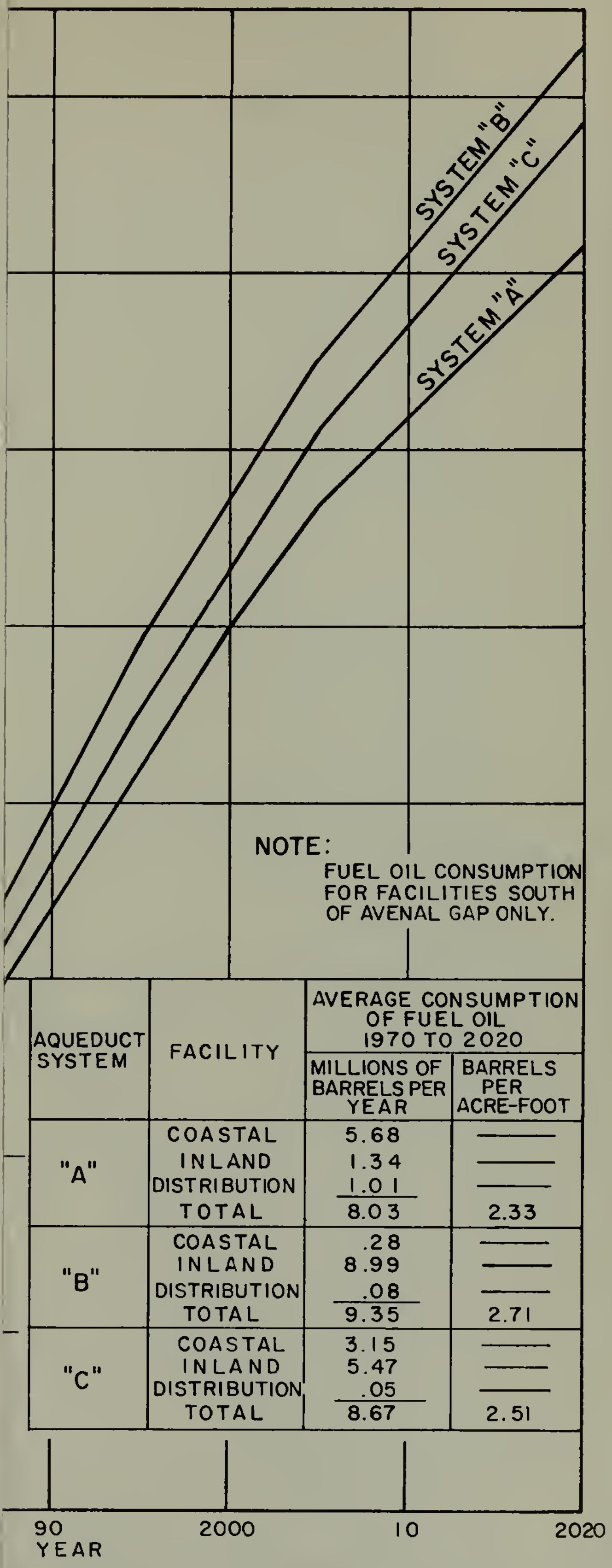
ND PROJECTED
R DEMAND IN CALIFORNIA



HISTORICAL AND PROJECTED
ANNUAL MAXIMUM POWER DEMAND IN CALIFORNIA

DEPARTMENT OF WATER RESOURCES 1959

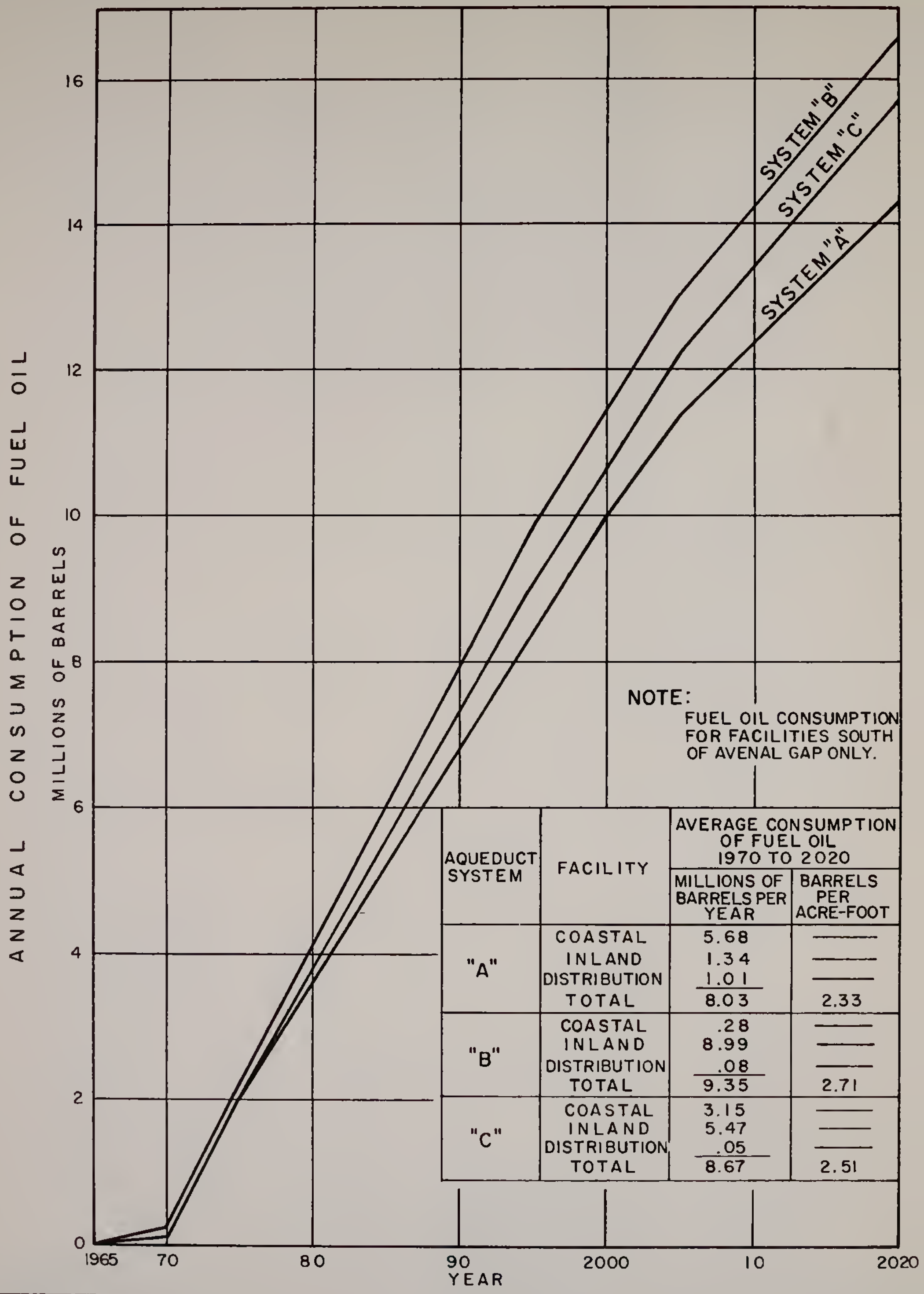
FIGURE 13



AQUEDUCT SYSTEM	FACILITY	AVERAGE CONSUMPTION OF FUEL OIL 1970 TO 2020	
		MILLIONS OF BARRELS PER YEAR	BARRELS PER ACRE-FOOT
"A"	COASTAL	5.68	—
	INLAND	1.34	—
	DISTRIBUTION	1.01	—
	TOTAL	8.03	2.33
"B"	COASTAL	.28	—
	INLAND	8.99	—
	DISTRIBUTION	.08	—
	TOTAL	9.35	2.71
"C"	COASTAL	3.15	—
	INLAND	5.47	—
	DISTRIBUTION	.05	—
	TOTAL	8.67	2.51

CONSUMPTION ON ALTERNATIVE
D MAIN CONVEYANCE
ON FACILITIES

FIGURE 13



NOTE:
FUEL OIL CONSUMPTION FOR FACILITIES SOUTH OF AVENAL GAP ONLY.

AQUEDUCT SYSTEM	FACILITY	AVERAGE CONSUMPTION OF FUEL OIL 1970 TO 2020	
		MILLIONS OF BARRELS PER YEAR	BARRELS PER ACRE-FOOT
"A"	COASTAL	5.68	———
	INLAND	1.34	———
	DISTRIBUTION	1.01	———
	TOTAL	8.03	2.33
"B"	COASTAL	.28	———
	INLAND	8.99	———
	DISTRIBUTION	.08	———
	TOTAL	9.35	2.71
"C"	COASTAL	3.15	———
	INLAND	5.47	———
	DISTRIBUTION	.05	———
	TOTAL	8.67	2.51

ESTIMATED ANNUAL FUEL OIL CONSUMPTION ON ALTERNATIVE AQUEDUCT SYSTEMS AND MAIN CONVEYANCE AND DISTRIBUTION FACILITIES

DEPARTMENT OF WATER RESOURCES 1959

trial heating customers and also from utility agencies operating in metropolitan areas. Therefore, it can only be considered a supplementary source of energy that might be utilized on a "when-available" basis.

Additional considerations with regard to fuel resources are the recent advances in the field of nuclear energy utilization. The Stanford Research Institute, under contract with the Department of Water Resources, was requested to research the question of the applicability of nuclear energy production to aqueduct pumping. Based upon this study, it is considered that nuclear energy as a source of heat could be employed in the steam-raising operations for the direct steam-drive application at Pumping Plant In-VI or for steam-electric plants referred to previously for the various aqueduct systems applications. The extent of resources of fuels for the nuclear process is not well defined at this time, but various estimates have been made which indicate almost unlimited resources.

The nuclear application would include nuclear reactor and heat exchanger equipment replacing the conventional steam boilers and heat exchanger equipment presently contemplated at the foregoing locations, and the steam turbines, which would drive either pumping units or generators, could be readily adapted to pressures and temperatures selected for the nuclear operation. Despite advances of the science, nuclear power generation is at present more costly than conventional steam-electric generating methods, and a firm prediction cannot be made as to when it may become competitive. However, should competitive nuclear equipment be developed, such equipment could be installed when additional pumping plant units were required or whenever it would become necessary to replace worn out units.

Cost of Fuel

The cost of fuel oil utilized by steam-electric generating plants has experienced historical fluctuations generally reflecting economic conditions. Also over the years, temporary shortages or surpluses of fuel oil supplies have affected costs thereof. However, the over-all trend has been a steady rise.

Informed sources in the oil industry were consulted for advice on the projection of long-term fuel oil costs. The consensus was that the many factors affecting such costs make it difficult to support a long-term projection. It was generally agreed that the cost trend will be gradually upward but that there are certain factors which will tend to suppress the upward rise.

One of these factors which can be evaluated to some extent is the assured availability for many years of competitive fuels such as coal and shale oil. It is considered that costs of these fuels will be relatively stable because large reserves are known to exist and because continuing improvements of mining and extractive techniques can be expected. Based upon published literature dealing with mining and processing of such fuel resources, it was estimated that Utah coal or residual oil from Colorado shales could be imported to the southern California area at a cost equivalent to a fuel oil price of from $3.00 to $3.50 per barrel.

Current posted prices of fuel oil in the southern California area are near the $2.00 per barrel level, and actual costs to quantity consumers are known to be substantially lower than $2.00 per barrel. In projecting the price of fuel oil into the future, it was considered reasonable to assume a figure near the average of the current price and the estimated ceiling imposed by competitive fuels. Accordingly, a price of $2.50 per barrel was adopted as an average figure for use in aqueduct systems analyses.

In order to evaluate the effect of variation of fuel oil cost from the assumed price on aqueduct system selection, water costs for the alternative systems were determined for a range of fuel costs from $2.00 per barrel to $4.00 per barrel. Curves showing the variation of cost of water with cost of fuel oil for the alternative aqueduct systems are presented in Chapter VII.

Cost and Value of Electric Power

Estimates of rates that might apply to off-peak power for pumping were contained in a letter from Pacific Gas and Electric Company to the State Engineer, dated August 17, 1954. With regard to these estimated rates, the letter states that "These figures are not to be taken as a firm proposal but as the best estimates we (Pacific Gas and Electric Company) can make at this time." Estimates of the return that might be realized from the sale of recovered power to the operating utilities were contained in a letter from Southern California Edison Company, dated November 4, 1955. Qualification of the estimate of value of power, similar to that made by Pacific Gas and Electric Company, was included in this latter communication.

Analyses of the "off-peak electric and feedback" scheme were made utilizing costs of purchased power estimated by Pacific Gas and Electric Company adjusted to the postulated average price of fuel oil of $2.50 per barrel. An additional adjustment was made in the previously estimated costs to reflect increases in construction cost index for power transmission lines. Costs of off-peak power estimated in the Company's letter of August 17, 1954 and the adjusted values of those rates are presented following:

	Demand charge per kilowatt-year		*Energy charge per kilowatt-hour*	
Pumping plant	*P.G. & E. estimate*	*Adjusted rate*	*P.G. & E. estimate*	*Adjusted rate*
In-III, In-IV, In-V	$3.90	$4.60	$0.0030	$0.0040
In-VI	4.20	5.00	0.0030	0.0040

The cost of off-peak power at Pumping Plants C-3, C-4, and C-5, near Avenal Gap, and for the remainder of the pumping plants on the Coastal Aqueduct, was assumed to be the same as that cited for Pumping Plant In-III. Aqueduct construction costs included provision for a transmission intertie of all coastal pumping plants.

It has been previously indicated that future costs of nuclear energy generation cannot be determined at this time. Therefore, no attempt was made to evaluate the effect of nuclear generation applications in the aqueduct system analyses.

Similar adjustment was made of estimates of the value of recovered power furnished by Southern California Edison Company. These modified data were employed in preliminary evaluations of schemes involving sale of power, particularly the pumped storage application discussed previously.

In the absence of firm estimates of power costs and values no definite conclusions can be drawn at this time as to the pumping scheme that should actually be employed. Decision on this matter will be made early in the final design phase. At that time the current uncertainties as to the availability and price of electrical energy from the utility systems for pumping and the market for and value of recovered power can be resolved, as they relate to the economics of the pumping and power recovery facilities to be provided.

CHAPTER VI

CONVEYANCE AND DISTRIBUTION OF IMPORTED WATER WITHIN SERVICE AREAS

A major objective of the investigation was to select an aqueduct system that would provide surplus northern California water to the ultimate consumer within the total area concerned at the lowest average cost. In order to make a proper economic comparison of the various alternative systems, particularly with respect to the area south of the Transverse Ranges, consideration had to be given to the costs of local conveyance and distribution beyond the main aqueduct and terminal reservoirs thereon. The alternative main aqueduct systems in themselves would not provide comparable water service and would require substantially different local conveyance and distribution systems in most areas served. The cost of these secondary facilities must be included to properly test the economic justification of each system and to enable proper comparisons of the systems. It is emphasized that while the costs were considered herein for purposes of comparison, it was assumed that facilities beyond the main aqueduct would be locally financed and constructed.

It is recognized that in certain areas use of substantial quantities of imported water, as estimated herein, will require construction of drainage facilities at some time in the future. This is particularly true in the San Joaquin Valley, where studies by the Department of Water Resources are now under way to ascertain the nature and extent and timing of construction of these required facilities. Although the costs of drainage facilities were not included in the analyses presented in this bulletin, their omission is not believed to alter the conclusions thereof.

This chapter describes the results of studies of facilities that would be required to convey and distribute water from each of the three alternative main aqueduct systems within the various service areas. In these studies consideration was given to factors of sequence and staging of construction, the relative timing of the need for imported water in the different service areas and portions thereof, the influence of water quality requirements on source of imported water, and provision for maximum integration with, and utilization of, existing water service facilities to avoid unnecessary overlap and duplication.

The locations of those facilities required for Aqueduct System "B" are shown on Plates 13, 14, and 15.

PLANNING CRITERIA

The conveyance and distribution systems considered herein for the most part represent the primary facilities needed to convey water from the main aqueduct systems and terminal reservoirs thereon to key distribution points within the various service areas. Facilities required to deliver water to individual consumers beyond this point were not considered except for agricultural lands where new distribution systems would be required for northern California water.

Design Criteria

The general basis for the design of the various types of conveyance facilities was as described in Chapter IV. Preliminary designs of secondary irrigation distribution facilities required to deliver water from the major conveyance units within the service areas to the farmers' headgates were not prepared. Costs of such facilities were estimated as described hereinafter.

In most instances, the main aqueduct systems, either through provision of storage or excess capacity in the aqueducts, would meet the average flow requirements during the month of maximum demand in the various service areas. Main distribution lines from the aqueduct in most of the service areas were sized to deliver this demand, with weekly and daily fluctuations being met by local storage facilities. Where suitable storage facilities were unavailable near the main aqueduct, and provision for excess aqueduct capacities was found to be uneconomical, seasonal regulation in storage reservoirs within the service areas was postulated.

Storage reservoirs and local conveyance facilities for urban areas were designed to deliver from 11.3 to 13.4 per cent of the annual delivery requirements in any one month, in accordance with local conditions and the character of projected urban development. For irrigated agriculture, facilities were designed to deliver up to 21.5 per cent of the annual demand in one month. For irrigation service in the San Joaquin Valley only, an additional capacity allowance of 10 per cent was provided.

In addition to regulatory storage, provision was made, where possible, for emergency storage in the amount of three weeks average supply, under year 2020 demand, to provide continuity of supply in the event of aqueduct shutdown. San Luis Reservoir, to some extent, would offer this assurance for service areas to the south. Set forth in Table 25 are the principal reservoirs considered for each aqueduct system and the amounts of storage provided for both regulatory and emergency purposes.

It is recognized that in many portions of the area, underground storage capacity exists which may be utilized for peaking purposes, thereby reducing the surface storage requirements and the need for oversized conveyance facilities. In certain areas where water service is largely from the underground, and where there was little question as to the utility of the basin for regulating and distributing forecast required amounts of imported water, it was assumed that peaking conveyance and regulatory surface storage facilities would not be needed. However, in most of the area, adequate data as to the extent to which underground reservoirs could be utilized for this purpose were not available and the peaking requirements were assumed to be met by surface facilities.

Estimates of Cost

Estimates of capital and annual costs were made for the major conveyance facilities required in each service area, which facilities, it was assumed, would be locally financed and constructed. These estimates were prepared in the same manner as for the main aqueduct facilities described in Chapter IV.

In certain of the analyses described in Chapters II and VII, it was necessary to reflect the costs of secondary distribution facilities required to deliver irrigation water from the major conveyance units to the farmers' headgates. For service in the San Joaquin Valley where new distribution systems would be required, values of capital cost per acre of irrigated land were derived for each subunit of the service area. These values range from $88 to $390 per acre, depending on the particular conditions in the service area under consideration, such as topography, distance from the major conveyance facility, and other factors. In the remainder of the southern California area, derived values of cost per acre-foot of water delivered were employed, which ranged from about $5 to $15 and represented interest and amortization of the capital investment in the facilities as well as operation and maintenance expenses. As in the San Joaquin Valley, these values also varied in accordance with the particular conditions in the service area under consideration. While capital costs for these latter facilities were not directly estimated in each instance, total annual costs were estimated from the foregoing values.

For northern California water which would be served to urban entities, additional costs were assigned for necessary treatment, including filtration and chlorination. Capital costs of facilities required for this treatment were not developed, but total annual costs were estimated from the unit values set forth in Chapter III.

In those instances where pumping would be required, it was assumed that this would be accomplished on a continuous basis with purchased electrical energy.

In addition to the capital costs, annual costs of the facilities were estimated, which included interest and amortization of the capital investment, operation, maintenance, replacement, general expense, and energy required for pumping. In order to determine the increment in the equivalent annual cost of water to the consumer, attributable to the considered conveyance and distribution facilities, the computed annual costs over the period of economic analyses were discounted to a common time base using an interest rate of 3½ per cent per annum. This is more fully described in Chapter VII.

TABLE 25

PRINCIPAL RESERVOIRS IN SOUTHERN CALIFORNIA AREA WHICH WOULD BE OPERATED IN CONJUNCTION WITH MAIN AQUEDUCT SYSTEMS[a]

(Capacities in acre-feet)

Reservoir	System "A"			System "B"			System "C"		
	Regulatory	Emergency[b]	Total	Regulatory	Emergency[b]	Total	Regulatory	Emergency[b]	Total
Conejo[e]	190,000	15,000	205,000	27,000	13,000	[c]40,000	134,600	35,400	170,000
Bell Canyon	57,600	59,400	117,000	----	----	----	0	35,000	35,000
Beartrap	----	----	----	0	56,000	56,000	----	----	----
Castaic	----	----	----	107,600	42,400	150,000	----	----	----
Cedar Springs	----	----	----	54,000	[d]162,000	216,000	54,000	[d]162,000	216,000
Perris[e]	115,700	32,300	[c]148,000	137,700	10,300	148,000	137,700	10,300	148,000
Lake Mathews[e] (Existing)	81,900	68,800	150,700	118,900	63,100	182,000	118,900	63,100	182,000
Morris[e] (Existing)	0	22,000	22,000	----	----	----	----	----	----
Totals	445,200	197,500	642,700	445,200	346,800	792,000	445,200	305,800	751,000

[a] Includes terminal storage requirement for existing Colorado River Aqueduct System.

[b] Includes 11,000, 62,000, and 18,000 acre-feet provided for dead storage and siltation for Systems "A", "B", and "C", respectively.

[c] These reservoirs would be operated as part of local distribution facilities in some systems.

[d] Includes 100,000 acre-feet, which could be utilized for dependability of power generation or for additional emergency storage.

[e] Not all of available capacity of these reservoirs used in all systems.

KERN COUNTY SERVICE AREA

The San Joaquin Valley portion of Kern County was subdivided, for analytical purposes, into four subareas, as shown on Plate 2. About 80 per cent of the 1,785,000 acre-feet of water projected for delivery in these areas in year 2020 would be for agricultural purposes and the remainder for municipal and industrial uses, mainly in the Bakersfield metropolitan area. The main aqueduct, which would be in canal section in this area, would be sized south of the proposed San Luis Reservoir to convey the average flow requirement during the month of maximum demand. For the Kern County Service Area, this provision is equal to 253 per cent of the continuous flow equivalent of the annual demand. Further, as stated, a 10 per cent additional capacity allowance for irrigation service was assumed in the canal for flexibility of operation.

The location and capacity of water service facilities in Kern County Service Area would be identical for all systems. However, the buildup of water demand would be different for each system because of variations in the cost of water.

The total capital cost of major local conveyance facilities including that of the secondary distribution facilities required to deliver irrigation water to the farmers' headgates, which cost would be the same for Systems "A", "B", and "C", was estimated to be about 118 million dollars. The breakdown of this cost for each subdivision of the Kern County Service Area is shown in Table 27.

Upper Antelope Plain

This area is in the northwesterly portion of Kern County and lies generally above the inland aqueduct route, between elevations 450 feet and 1,200 feet. There are now no surface distribution facilities of any consequence in this area.

It was found that this portion of the Kern County Service Area could be more economically served from a coastal aqueduct utilizing Pumping Plants C-3 and C-4 than from a main inland aqueduct. The area would be served by two canals extending south, generally parallel to but at a higher elevation than the main inland aqueduct. One canal would turn out from the coastal aqueduct after Pumping Plant C-3 and would serve lands between elevations 450 feet and 750 feet. A turnout for the second canal would be placed after Pumping Plant C-4 and would serve lands between elevations 750 feet and 1,200 feet. Water service in this area would commence in all systems in 1971. A maximum of 370,000 acre-feet of agricultural water per annum would be served.

Avenal Gap to Pumping Plant In-III

Lands considered for service in this area lie largely below the main inland aqueduct route. The recently formed Semitropic Water Storage District is to the east and below the elevation of the main aqueduct. A maximum of 759,000 acre-feet of water per annum would be served in this area, with service commencing in 1965-66. It was considered that the entire supply would be for irrigation.

Six turnouts would be provided on the main aqueduct. One at the Kings-Kern County line would serve lands above the aqueduct in the Antelope Plain area. Two turnouts in the vicinity of Lost Hills would serve the northerly portion of the Semitropic area and the southerly portion of the Antelope Plain. Two turnouts near Tupman would serve the southerly portion of the Semitropic area and the Kern River Delta area. A turnout near Pumping Plant In-III would serve agricultural lands in the vicinity of Taft. Water service for the Bakersfield metropolitan area would originate in the next reach of aqueduct beyond Pumping Plant In-III and thus was considered as being a part of the Pumping Plant In-III to Pumping Plant In-IV Service Area.

Pumping Plant In-III to Pumping Plant In-IV

Included in this area is a large portion of the proposed Maricopa-Wheeler Ridge Water Storage District. A maximum of 593,000 acre-feet of water per annum would be delivered to this area with service commencing in 1966. Approximately 20 turnouts would be provided to serve lands both above and below the aqueduct and to serve agricultural and urban lands near Taft. Water would be delivered into local distribution systems, consisting largely of canal. Immediately before Pumping Plant In-IV, a turnout would be provided at about the 500-foot elevation to convey urban water in a gravity canal which would extend northeasterly and thence northerly to the City of Bakersfield. There would be an eventual delivery of 340,000 acre-feet of water for municipal and industrial purposes through this lateral.

Pumping Plant In-IV to Pumping Plant In-VI

This area includes the remainder of the proposed Maricopa-Wheeler Ridge Water Storage District together with other lands which might be served from an inland aqueduct. A maximum of 63,000 acre-feet of water per annum would be served to this area, with service commencing in 1967. No turnouts would be provided between Pumping Plants In-IV and In-V. Between Pumping Plants In-V and In-VI nine turnouts would be provided serving lands, both above and below the main aqueduct, through local distribution systems.

SAN LUIS OBISPO SERVICE AREA

Water supplies in San Luis Obispo County are presently obtained primarily from ground water. Other than municipal facilities, of which the principal ones serve the City of San Luis Obispo, there are no major water conveyance or distribution systems in the County.

The location of local conveyance and distribution facilities to serve imported water to areas of projected need within San Luis Obispo Service Area would be essentially the same for Aqueduct Systems "A", "B", and "C".

Maximum deliveries of water to San Luis Obispo Service Area from the three main aqueduct systems would be 55,000, 52,000, and 55,000 acre-feet per annum, respectively. Of the contemplated delivery, about 25 per cent would be for agricultural purposes. Water deliveries would commence in the Upper Salinas Valley and Nipomo Mesa area in 1971, and in the remainder of the County in 1991.

Local regulation would be provided by reservoirs on Huerhuero Creek near Paso Robles, on Little Morro Creek, and at Corbett Canyon near the City of Arroyo Grande. A pipe line about seven miles in length, designated the "Paso Robles Lateral", would convey water to the vicinity of the City of Paso Robles. Beginning at the tailrace of the San Luis Obispo Power Plant, the "Morro Bay Lateral", a lateral pipe line would extend westerly thirteen miles to the vicinity of Morro Bay. The "Pismo Beach Lateral", about nine miles in length, would serve Arroyo Grande, Pismo Beach, and Shell Beach. The "Nipomo Mesa Lateral", seven miles in length, would serve Nipomo Mesa.

As shown on Table 27 the estimated capital cost for local conveyance facilities required by Aqueduct Systems "A" and "C" would be about 10.9 million dollars. The comparable cost for Aqueduct System "B" would be about 10.5 million dollars. Construction expenditures for these facilities until year 1991 would be about 4.3 million dollars under Systems "A" and "C" and about 3.9 million dollars under System "B".

SANTA BARBARA SERVICE AREA

Water supplies in Santa Barbara Service Area are presently obtained from ground water sources and from surface storage developments on the Santa Ynez River, as well as from the recently completed Twitchell Reservoir on the Cuyama River which will be operated in conjunction with ground water storage in the Santa Maria Valley.

Water deliveries to Santa Barbara Service Area would commence under all systems in 1971. Maximum water deliveries from Systems "A", "B", and "C" would be 186,000, 159,000, and 186,000 acre-feet per annum, respectively, the major portion of which would be for urban purposes.

The manner of serving imported water in the County would be different under Aqueduct System "B", with a termination of the coastal aqueduct in the Santa Maria Valley area, than under Systems "A" and "C" where a major coastal aqueduct would extend through the County to the south.

Systems "A" and "C"

Under these systems, imported water would be served directly into local conveyance and distribution facilities by gravity from the main aqueducts. In northern Santa Barbara County, water would be discharged from the main aqueduct into the Santa Maria River for ground water replenishment and laterals from the main aqueduct would convey water to other areas of need, with local regulation being provided by reservoirs near the communities of Orcutt, Los Alamos, and Santa Ynez.

A pipe line designated the "Orcutt Lateral", extending from the main aqueduct east of the City of Santa Maria would convey water to the vicinity of Orcutt, a distance of about 10 miles. Los Alamos Valley, Santa Rita Valley, and Vandenberg Air Force Base would be served by a "Vandenberg Lateral" extending westerly from a turnout on the main aqueduct east of the community of Los Alamos, a total distance of 25 miles. The Santa Ynez Valley would be served by means of a pipe line designated the "Santa Ynez Lateral", 11 miles in length extending from a turnout on the main aqueduct near Santa Ynez to the community of Buellton.

Water supplies for the south coastal portion of Santa Barbara County would be regulated in the existing Cachuma Reservoir and served from turnouts from the main aqueduct between the south portal of San Marcos Pass Tunnel and Carpinteria, and by a short lateral extending westerly from the existing Tecolote Tunnel to Eagle Canyon near Ellwood.

As shown in Table 27, the capital cost of the local conveyance facilities required by Systems "A" and "C" would be about 18.5 million dollars.

System "B"

As in Systems "A" and "C", water would be discharged from the main aqueduct into the Santa Maria River for ground water replenishment. A local main conveyance facility, designated the "Santa Maria-Santa Barbara Conduit", following an alignment westerly of the main coastal aqueduct route of Systems "A" and "C" would extend from the Santa Maria terminus of the main aqueduct south for about 20 miles through Los Alamos and Santa Rita Valleys, then easterly along the Santa Ynez River to discharge into Cachuma Reservoir. At a point about 3 miles south of the Santa Maria River, a pumping plant would lift the water to an elevation of 1,120 feet. This alignment provides more economical service to all portions of the County than the "main aqueduct route" of Systems "A" and "C". Water would be regulated in local reservoirs near Orcutt, Sisquoc, in Los Alamos and Santa Rita Valleys, and near Solvang. Service to the Orcutt area would be identical to that described for Systems "A" and "C". The Sisquoc River Valley would be served by the "Sisquoc Lateral", a gravity pipe line 9 miles in length extending easterly from the Santa Maria-Santa Barbara Conduit to a reservoir near the confluence of Tepusquet Creek and the Sisquoc River. Service to Vandenberg Air Force Base would be by means of the "Vandenberg Lateral", a 7-mile long pipe line extending from a turnout on the Santa Maria-Santa Barbara Conduit near the crossing of San Antonio Creek.

Water for the south coastal portion of Santa Barbara County would be discharged from the Santa Maria-Santa Barbara Conduit into Cachuma Reservoir on a continuous flow basis. Water stored in the reservoir would be withdrawn through the existing Tecolote Tunnel, which would be altered to permit pressure flow and the conveyance of the maximum month water demand of the area. Regulation of the continuous flow of the conduit to the peak demands of the area would require about 10,000 acre-feet of storage in this existing facility in the year 2020, which it is estimated would reduce the safe yield thereof by a relatively small amount. Service would be provided from east and west laterals constructed from the south portal of the tunnel to several existing water districts and adjacent lands.

An alternative method of serving the south coastal portion of the County under Aqueduct System "B" would be by construction of a lateral from the Balboa Terminus of the inland aqueduct, a portion of which could be jointly used with Ventura County. It was found that service in this manner would be more costly than from the coastal aqueduct.

As shown in Table 27, the estimated capital cost of local conveyance facilities required by Aqueduct System "B" would be 41.2 million dollars. Of this amount, 29.8 million dollars represents the first stage of construction of the Santa Maria-Santa Barbara Conduit to Cachuma Reservoir, plus remaining local facilities required to meet water demands until year 1995.

VENTURA COUNTY SERVICE AREA

Ventura County now obtains its water supplies largely from ground water sources. Some surface water is obtained from storage developments in the Ventura River watershed. Santa Felicia Reservoir in the Santa Clara River watershed is operated to augment ground water supplies.

Distribution facilities are under construction in the Ventura River watershed and have been constructed to serve a limited area on the Oxnard Plain. There are three major water districts in the County: the Calleguas Municipal Water District; the United Water Conservation District; and the Ventura River Municipal Water District.

Water deliveries under all systems would commence in 1971 in the Calleguas Municipal Water District and United Water Conservation District areas, and in 1991 in the Ventura River Municipal Water District. A maximum delivery of water for all systems of 236,000 acre-feet was projected for the County, all of which would be for urban and suburban uses in year 2020. As in Santa Barbara County, local conveyance and distribution of imported water would require substantially different facilities from System "B" than from Systems "A" and "C".

Systems "A" and "C"

For most portions of the County where an economic demand for imported water was projected, deliveries would be made directly from the main aqueduct. The Simi Valley and adjacent areas would be served by the "Simi Valley Lateral", a gravity pipe line extending from a turnout of the main aqueduct after Pumping Plant C-8, a distance of about 12 miles. The cost of this facility was estimated to be about 2.6 million dollars.

System "B"

Ventura County and the areas of western Los Angeles County adjacent thereto would be served under this system by means of a main gravity feeder line, designated the "Ventura County Feeder", which would extend westerly about 26 miles from the Balboa Terminus of the inland aqueduct. This feeder would pass through northerly San Fernando Valley, tunnel through the Santa Susana Mountains, and eventually discharge into a reservoir at the Conejo site, with a storage capacity of 40.000 acre-feet. It would be operated on a continuous flow basis and regulation would be provided by the reservoir. Turnouts would be provided on the feeder to serve Simi and Conejo Valleys. A "Saticoy-Ventura Lateral", extending westerly from Conejo Reservoir, would convey water to existing spreading grounds and distribution faciliites near Saticoy and continue to the City of Ventura, a total distance of 21 miles.

The estimated capital cost of the local conveyance facilities required by Aqueduct System "B" would be 41.4 million dollars. Of this amount, 30.2 million dollars represents the first stage of construction of the Ventura County Feeder from Balboa Terminus to Conejo Reservoir plus remaining local facilities required to meet water demands until year 1991.

There are alternative possibilities of serving either part or all of the water for Ventura County from Aqueduct System "B" which might prove advantageous. Imported water for the Oxnard Plain area could be discharged into the Santa Clara River system directly from Castaic Reservoir, or a pipe line might be constructed for all or part of the distance from this reservoir to areas of need in the United Water Conservation District area. It would also be possible to terminate this pipe line at Conejo Reservoir and serve both the United Water Conservation

District and Calleguas areas by laterals extending easterly and westerly from this facility.

Another alternative method of service would be to construct a "peaking line" from Balboa Terminus to a relatively small terminal reservoir in Ventura County in lieu of the construction of Conejo Dam and Reservoir. Tierra Rejada Reservoir in the Calleguas Creek watershed, currently proposed under a plan for diversion of water from Sespe Creek, might also be considered as an alternative terminal storage site for imported water.

Other possible alternatives include diverting to Piru Creek all or part of the water for Ventura County from the west branch of the inland aqueduct at points above Castaic Reservoir. One possibility would be to divert a short distance below Beartrap Reservoir at about elevation 2,500 feet, with recovery of power at a site on Piru Creek.

The possibility of diverting water for Ventura County from the west branch of the main aqueduct at about elevation 3,400 feet above the Castaic Power Development into Piru Creek was investigated. It was found that this plan, even with consideration of power recovery along Piru Creek, would result in a greater unit cost of water in the service area than the plan described.

ANTELOPE-MOJAVE SERVICE AREA

The Antelope-Mojave Service Area includes portions of Kern, Los Angeles and San Bernardino Counties. The present water needs of the area are met almost entirely from ground water. Service to this area could readily be provided from the east branch of the inland main aqueduct. For all systems, a maximum delivery to this area of 208,000 acre-feet of water per annum was projected. Service of agricultural water in this area was not contemplated.

Under System "A", service to the Antelope Valley area in Kern and Los Angeles Counties would commence in 1972, and service to the Mojave River area in San Bernardino County in 1982. Under System "B", service to the Antelope Valley area would start in 1971 and to the Mojave River area in 1982. System "C" would provide service to the Antelope Valley area in 1975, and, as in the other two systems, to the Mojave River area in 1982.

It is probable that a portion of the imported water contemplated for service to this area could be discharged to and regulated in the underground. However, since there is a lack of definite knowledge of geologic conditions in the underground basins in the area, such a method of operation was not postulated and surface distribution facilities were assumed.

System "A"

Under this system, the inland aqueduct would terminate at Little Rock Creek. Turnouts would be provided for service in Kern and Los Angeles Counties between the south portal of the Tehachapi Tunnels and the terminus of the aqueduct. The Kern County area would be served by the "Soledad Mountain Lateral", a gravity pipe line extending from the main aqueduct near the Los Angeles-Kern County line to a terminal reservoir near the town of Mojave. This facility would be about 33 miles in length and would traverse the northwesterly edge of the Antelope Valley at an elevation of about 3,000 feet. The Los Angeles County area would be served by the "Antelope Buttes Lateral" and the "Lovejoy Buttes Lateral", two gravity pipe lines extending northerly from the main aqueduct near Fairmont Reservoir and near Little Rock Creek to regulatory reservoirs located near Antelope Buttes and Lovejoy Buttes. These laterals would be three miles and eight miles in length, respectively.

Gravity service to the Mojave River area in San Bernardino County would be provided from a "Whitewater-Coachella Lateral", a canal at about the 3,000-foot elevation extending easterly from Little Rock Creek for a distance of 48 miles to the Mojave River. This lateral was considered for joint use by both the Mojave River area and Whitewater-Coachella Service Area. Two sublaterals extending northerly from this canal to regulatory reservoirs would serve the Mojave River area. The area westerly of the Mojave River would be served by the "Gray Mountain Lateral", a gravity pipe line eight miles in length extending northerly from a point on the lateral canal near the Los Angeles-San Bernardino County line to a reservoir near Mirage Lake. The area easterly of the Mojave River would be served from a gravity pipe line, designated the "Granite Mountain Lateral", four miles in length extending northerly from the lateral canal to a reservoir near Apple Valley.

As shown in Table 27, the proportionate share of the estimated capital cost of these facilities for service of water within the Antelope-Mojave Service Area would be about 37.6 million dollars.

System "B"

Service in the Antelope Valley area between the south portal of the Tehachapi Tunnels and Little Rock Creek from the first sequence of main aqueduct construction would be as in System "A". Between Pumping Plant In-VII and Cedar Springs Reservoir, two turnouts would be provided for service in the Mojave River area. One near the Los Angeles-San Bernardino County line would serve a gravity pipe line extending to the Mirage Lake area and the second near Hesperia would serve a gravity pipe line extending toward the Apple Valley area. Regulatory reservoirs, as described under System "A", would regulate the supply for the Mojave River area. The proportionate share of the estimated cost of local conveyance facilities for this area under System "B" would be about 32.4 million dollars.

System "C"

Local water service facilities for System "C" would be identical to those of System "B" differing in operation only with respect to the dates when first water deliveries would be made in the Antelope Valley. Cost of these facilities would be the same as for System "B".

WHITEWATER-COACHELLA SERVICE AREA

The Whitewater-Coachella Service Area consists of the Coachella Valley and adjacent areas, including a portion of the San Gorgonio Pass area. Colorado River water is imported principally for irrigation use within Improvement District No. 1 of the Coachella Valley County Water District through the Coachella Branch of the All-American Canal. Improvement District No. 1 is located immediately northwest of the Salton Sea. The remainder of this service area, including the Palm Springs and Banning areas, is dependent on limited ground water supplies. A maximum of 100,000 acre-feet of water per annum for urban and suburban uses would be delivered to this area by all systems, with initial service commencing in 1982.

System "A"

In System "A", service to the area would be from the "Whitewater-Coachella Lateral", largely in canal section, extending from Little Rock Creek at about elevation 3,000 feet through Lucerne, Yucca, and Morongo Valleys. Pump lifts of 133 feet and 316 feet would be required at the Mojave River and at Yucca Valley, respectively. The maximum hydraulic grade line elevation on this lateral would be 3,345 feet. It was assumed that power would be developed at two sites on Little Morongo Creek above Desert Hot Springs before distribution at about elevation 1,500 feet. The total head available at these power development sites is 1,575 feet. As shown in Table 27, the proportionate share of the estimated capital cost of these facilities for service to the Whitewater-Coachella Service Area under this system would be about 42.9 million dollars. Of this amount, 36.3 million dollars represents the first stage of construction which would provide service until 1995.

Systems "B" and "C"

Service under Systems "B" and "C" would be from a lateral largely in canal section, originating at the east branch of the main aqueduct near Hesperia at elevation 3,465 feet. This facility, designated the "Whitewater-Coachella Lateral", would extend through Lucerne, Yucca, and Morongo Valleys. No additional pumping lifts would be required on this aqueduct; however, power could be recovered as in System "A". The alignment under these systems would be identical to that of System "A" beyond Yucca Valley. The proportionate share of the estimated capital cost of these facilities for this area would be 34.1 million dollars. First stage costs were estimated to be 27.2 million dollars.

Consideration was given to serving the Whitewater-Coachella Service Area from a lateral extending southeasterly from the tailrace of the Devil Canyon Power Development through Yucaipa and the San Gorgonio Pass. Water service was found to be more expensive under this plan largely because of a net increase in pumping requirements.

SOUTHERN CALIFORNIA COASTAL PLAIN AND COASTAL SAN DIEGO COUNTY SERVICE AREA

Included in this service area are more than a thousand organizations presently engaged in the development and distribution of water, the largest of which are The Metropolitan Water District of Southern California and the Department of Water and Power of the City of Los Angeles, an original member agency of the District. The District serves Colorado River water to member agencies in Orange County and the coastal portions of Los Angeles, San Bernardino, Riverside and San Diego Counties. Included within the boundaries of the Metropolitan Water District is an area of 3,200 square miles.

The Colorado River Aqueduct of the Metropolitan Water District terminates at Lake Mathews in western Riverside County and serves portions of San Bernardino, Riverside, Orange, and Los Angeles Counties through a network of feeder lines extending westerly toward the coast. The Colorado River supply to San Diego County is delivered through the San Diego Aqueduct to the San Diego County Water Authority. A second San Diego Aqueduct is now under construction. Principal existing conveyance and distribution facilities in the area are shown on Plate 15.

Two large highly developed portions of this service area, San Gabriel Valley in Los Angeles County, and the San Bernardino Valley Municipal Water District in San Bernardino County, are not in the Metropolitan Water District. Also, portions of San Diego County, southwestern Riverside County, and westerly Los Angeles County, as well as a portion of Orange County, are not included within the District and do not receive Colorado River water.

The service of surplus northern California water to this large area with its complicated pattern of existing distribution facilities was given special consideration in this investigation. The local conveyance and distribution facilities that would be requred to serve northern California water from Systems "A", "B", and "C" are substantially different. The costs of these essentially different local conveyance and distribution systems have a significant bearing on aqueduct system selection.

The magnitude of water deliveries to the area under each system would be identical, amounting to nearly three million acre-feet per annum in year 2020, with initial deliveries commencing in 1970-71. The alternative points of delivery for this supply and postulated timing of deliveries for the three systems have previously been discussed and are shown schematically on Plates 16, 17, and 18.

For each main aqueduct system, a series of analyses was made to ascertain the most economical plan of conveyance and distribution within the area, with the objective of providing maximum utilization of, and integration with, existing and planned water supply facilities of local agencies.

A basic consideration in selection of the location and capacity of additional conveyance and distribution facilities within the area was the relative rate of growth in demand for imported water in the various portions of the area, and the relationship of the location and elevation of these demands to location and capacity of and supply available from existing import facilities.

It was found that there will be an insufficient supply of Colorado River water to serve fully the projected demands for imported water in the Upper Santa Ana Valley and southwestern Riverside and coastal San Diego Counties, and that surplus northern California water must physically be made available therein by about 1990 or before. In order to avoid unnecessary construction of overlapping and uneconomical local conveyance facilities, it was found necessary under certain of the systems to schedule the first deliveries of northern California water to these areas in 1982. Further, as has been discussed in Chapter III, the delivery of northern California water to these areas no later than 1982 and possibly earlier is also required by water quality considerations. In planning all local conveyance and distribution systems, consideration was given to staging of facilities in accordance with projected demands and to the proper economic balance between capital investment and continued costs of pumping.

Evaluation of this latter factor required correlating the elevation of lands throughout the area with the location and elevation of principal points of delivery from the main aqueducts. Set forth in Table 26 are the estimated demands for imported water for year 2020, including both Colorado River water as well as northern California water, in various portions of the area by elevation zones.

In addition to the foregoing elevations, an allowance of about 200 feet of additional head must be provided for municipal and industrial users. Since the principal points of delivery from the main aqueduct systems would generally be a substantial distance from points of use, provision for a considerable head loss in local conveyance facilities must also be made.

TABLE 26

ESTIMATED DEMAND FOR IMPORTED WATER IN YEAR 2020 BY ELEVATION ZONES IN SOUTHERN CALIFORNIA COASTAL PLAIN AND COASTAL SAN DIEGO COUNTY SERVICE AREA

(In thousands of acre-feet)

Elevation zones, in feet above sea level	Coastal Los Angeles County	Orange County	Coastal San Bernardino County	Coastal Riverside County	Coastal San Diego County	Total
0–500	962	433	0	0	604	2,009
500–1,000	370	42	137	212	142	903
1,000–1,500	179	18	282	208	61	748
1,500–2,000	77	4	61	147	33	322
2,000–2,500	12	2	20	38	6	78
Over 2,500	2	2	19	18	4	45
Totals	1,602	511	519	623	850	4,105

System "A"

Aqueduct System "A" would deliver the entire quantity of imported water from northern California to this service area via a coastal aqueduct route terminating in the west end of the San Fernando Valley at about elevation 1,000 feet. Regulatory and emergency storage would be provided in Conejo, Bell Canyon, and Perris reservoirs. The plan of local conveyance and distribution of water from System "A" found to be most economical is shown on Plate 16.

The terminal elevation of the main coastal aqueduct of 1,000 feet and the necessity, under this system, of transporting large quantities of water to higher elevations over a distance of about 100 miles results in a substantial amount of pumping within the local distribution system.

It will be noted on Plate 16 that service of surplus northern California water to the Upper Santa Ana Valley would not be accomplished until 1990, at which time a connection would also be made to the second San Diego Aqueduct thereby permitting deliveries of this water to San Diego County. This plan assumes the availability of Colorado River water throughout the Upper Santa Ana Valley and does not give consideration to the need, from a water quality standpoint, of delivery of the better quality northern California water to the area, which is required no later than 1982, as stated in Chapter III. Were the date of construction of a lateral to Upper Santa Ana Valley advanced to 1982, there would be a resulting greater cost of water because of this earlier investment.

The first stage of construction from the terminus of the coastal aqueduct would be a "Foothill Feeder" extending to Eagle Rock and a "Coastal Plain Feeder" to 92nd and Figueroa Streets, which facilities would be put in service in 1971. The extreme westerly part of Los Angeles County would be served by a "Malibu Lateral" extending southerly from the main aqueduct in Liberty Canyon to Stokes Canyon in the Santa Monica Mountains above Malibu. As the demand for imported water in the eastern areas increased and the extent of the area capable of being served from the Colorado River supply is thereby decreased, the area served with northern California water would correspondingly expand toward the east. By the year 1980, water from the coastal aqueduct would be conveyed to the easterly boundary of the City of Pasadena through the Upper Feeder, to the City of West Covina through the Middle Feeder, and the San Gabriel River through the Middle-Cross and Lower Feeders. This is the limit of the area which could be served from a westerly direction without duplication of existing facilities across the coastal plain and is designated as "Area Served by First Stage in Conjunction with Existing Systems" on Plate 16. Beginning in 1980 with the second stage of construction, a necessary duplication of existing local conveyance facilities would occur.

The second stage of construction would include an extension of the Coastal Plain Feeder from 92nd and Figueroa Streets to the Orange County line, and an extension of the Foothill Feeder from Eaton Wash easterly to La Verne. The Foothill Feeder would utilize a portion of the existing Upper Feeder between Eagle Rock and Eaton Wash. From 1980 until 1990, units of the second stage of construction would serve a progressively larger area toward the east, as shown on Plate 16.

The third stage of construction, which would provide service beginning in 1990, would consist of an "Upper Foothill Feeder", 106 miles in length, extending easterly from the terminus of the coastal aqueduct at Bell Canyon across the San Fernando Valley, the foothill area, and Upper Santa Ana Valley to Perris Reservoir with a capacity of 148,000 acre-feet. Pumping plants would be required at Bell Canyon and near the City of Riverside, with a total lift of 1,200 feet. Of this lift, about 600 feet represents friction loss in the conveyance facilities. A connection from Perris Reservoir to the intersection of the existing Colorado River and Second San Diego Aqueducts near San Jacinto would integrate the eastern portion of the Colorado River Aqueduct with the new system. After this connection is made, the area easterly of the limit of service by the second stage of construction could be served with either Colorado River water or northern California water, or a mixture of the two supplies. The San Bernardino Valley Municipal Water District was assumed to participate in construction of the third stage of construction. It will be noted on Plate 16 that additional stages of construction of the Second San Diego Aqueduct south of Auld Valley would be completed as required to convey this supply and the Colorado River supply.

By year 2000 a fourth and last stage of construction would be required. This unit would have the same alignment as the third stage of construction.

As shown in Table 27, the estimated capital cost of these facilities would be about 874 million dollars.

Alternative Plan of Local Conveyance and Distribution for System "A"

An alternative method of serving the southern California coastal plain, but one which would not accomplish the same results particularly with respect to the water quality considerations, was studied as an attempt to avoid the substantial pumping required in the plan previously described.

The system would deliver water from the San Fernando Valley terminus of the main coastal aqueduct to San Diego County through a main gravity feeder line across the coastal plain of Los Angeles and Orange Counties and thence to San Diego County, at a relatively low elevation, to tie in with the existing Second San Diego Aqueduct near San Marcos. A reservoir with a capacity of 140,000 acre-feet would be constructed on Cristianitos Creek north of San Clemente in lieu of Perris Reservoir. Under this plan, Colorado River water only would be served in the Upper Santa Ana Valley, southwestern Riverside County, and the northerly portion of San Diego County. Satisfaction of forecast water demands under this plan would necessitate use of Colorado River water in areas not presently within the Metropolitan Water District.

A study of this alternative showed that, although pumping requirements would be less than in the other plan, the greater required initial capital expenditures would result in a somewhat greater unit cost of water. Further, the economic value of providing northern California water to Upper Santa Ana Valley and to the principal agricultural areas of southwestern Riverside and coastal San Diego Counties, as in the former plan, would definitely render this alternative undesirable.

System "B"

Aqueduct System "B" would deliver a maximum of 948,000 acre-feet per annum to the service area through the west branch of the inland aqueduct and 2,007,000 acre-feet per annum through the east branch. Deliveries to the San Fernando Valley would commence in 1971 and to Perris Reservoir in 1982.

As shown on Plate 17, the first stage of construction of local distribution facilities from the Balboa Terminus of the west branch would be a "West Foothill Feeder" extending to Eagle Rock and a "West Coastal Plain Feeder" to 92nd and Figueroa Streets. The extreme westerly part of Los Angeles County would be served by a "Malibu Lateral" extending southerly from the Ventura County Feeder at the east portal of Santa Susana Pass Tunnel, to Stokes Canyon in the Santa Monica Mountains above Malibu. The first stage of construction in conjunction with the existing Colorado River supply could serve the area until 1982, at which time water would be conveyed as far east as the Central Basin and the San Gabriel Valley through existing facilities.

By 1982, demands in the easterly portion of the area would have increased so that additional facilities would have to be constructed to the east boundaries of the San Gabriel Valley and Central Basin areas or additional water would have to be introduced into the Metropolitan Water District facilities conveying water from east to west. As stated in Chapter IV, it was found to be more economical to complete construction of the east branch to Perris Reservoir at this time, so that additional water would be available at the upper or easterly end of the Metropolitan Water District distribution system.

Facilities for local distribution of water from the east branch of the inland aqueduct would include an "East Foothill Feeder" extending from the tailrace of the Devil Canyon Power Development to the Metropolitan Water District's softening and filtration plant at La Verne, a connection from Perris Reservoir to the Colorado River Aqueduct, an "East Coastal Plain Feeder" extending from Lake Mathews to Santiago Control Structure in northeastern Orange County, and a "Redlands-Yucaipa Feeder" extending from the tailrace of the Devil Canyon Power Development in a southeasterly direction to Mentone and the Yucaipa Valley. The east branch of the inland aqueduct would be connected to the Second San Diego Aqueduct through a 15-mile-long facility from Perris Reservoir, consisting of 5 miles of canal and 10 miles of siphon. The total capital cost of this connection with a capacity in the order of 1,000 second-feet would be about 15 million dollars. The connections to the main Colorado River Aqueduct at the west portal of the Bernasconi Tunnel and to the Second San Diego Aqueduct would permit mixing of the two sources of water supply. All of the foregoing facilities would have gravity flow, with the exception of a portion of the Redlands-Yucaipa Feeder.

As shown in Table 27, the estimated capital cost of these facilities would be about 352 million dollars.

System "C"

Aqueduct System "C" would deliver a maximum of 948,000 acre-feet of water annually to the San Fernando Valley via a coastal aqueduct and, as in System "B", the remainder of the forecast demand for year 2020 by an inland aqueduct to Perris Reservoir. Bell Canyon Reservoir would provide 35,000 acre-feet of emergency storage above the elevation of the coastal aqueduct. Water service from the coastal aqueduct would commence in year 1971 and from the inland aqueduct in 1982 as in System "B".

TABLE 27

ESTIMATED CAPITAL AND EQUIVALENT ANNUAL COSTS OF CONVEYANCE AND DISTRIBUTION SYSTEMS WITHIN SERVICE AREAS

(In millions of dollars)

	Aqueduct system								
	"A"			"B"			"C"		
		Equivalent annual costs			Equivalent annual costs			Equivalent annual costs	
Service area	Total capital costs	In millions of dollars	In dollars per acre-foot	Total capital costs	In millions of dollars	In dollars per acre-foot	Total capital costs	In millions of dollars	In dollars per acre-foot
Delta to Avenal Gap	$116.0	$4.90	$10	$116.0	$4.90	$10	$116.0	$4.90	$10
Kern County									
Upper Antelope Plain	39.0	2.16	13	39.0	2.16	13	39.0	2.16	13
Avenal Gap to Pumping Plant In-III	37.5	1.71	4	37.5	1.72	4	37.5	1.72	4
Pumping Plant In-III to Pumping Plant In-IV	36.0	3.22	14	36.0	3.24	14	36.0	3.24	14
Pumping Plant In-IV to Pumping Plant In-VI	5.2	0.25	8	5.2	0.25	7	5.2	0.25	7
San Luis Obispo[a]	10.9	0.32	21	10.5	0.31	22	10.9	0.32	21
Santa Barbara[a]	18.5	1.08	16	41.2	1.72	32	18.5	1.07	16
Ventura County	2.6	0.50	7	41.4	1.42	21	2.6	0.50	7
Antelope-Mojave	37.6	1.47	17	32.4	1.36	15	32.4	1.31	15
Whitewater-Coachella	42.9	1.23	43	34.1	0.81	28	34.1	0.81	28
Southern California Coastal Plain and Coastal San Diego County[a]	874.2	28.62	26	352.1	17.08	15	371.0	17.75	16
Totals	$1,220.3	$45.46	[b]$17	$745.4	$34.96	[b]$13	$703.2	$34.02	[b]$13

[a] Capital costs in these areas do not include costs of secondary distribution facilities required to deliver irrigation water from the major conveyance facilities to the farmers' headgates. These costs are included in the equivalent annual costs.

[b] Weighted average.

As shown on Plate 18, local conveyance and distribution facilities for this system would be similar to those described for System "B", with the exception that a pump lift of 165 feet would be required on the West Foothill Feeder from the terminus of the coastal aqueduct. This lift was not required from Balboa Terminus on the west branch of the inland aqueduct since this terminus would be approximately 200 feet higher than the coastal aqueduct terminus.

As shown in Table 27, the estimated capital cost of these facilities would be 371 million dollars.

SUMMARY OF COST ESTIMATES

The estimated capital costs of the additional local facilities needed for conveyance and distribution of imported water after the introduction of surplus northern California water in the various service areas are set forth in Table 27. Also shown in Table 27 are the equivalent annual costs of these facilities and the cost of local conveyance facilities north of Avenal Gap. These costs were utilized in Chapter VII for deriving the total unit costs of northern California water in the various service areas.

CHAPTER VII

FINANCIAL AND ECONOMIC ANALYSES

Financial and economic analyses were employed to develop the relative accomplishments and costs of the three alternative aqueduct systems and to determine the financial feasibility and the economic justification thereof. Comparison of these factors resulted in the selection of the optimum system. The criteria employed are those heretofore adopted by the Department of Water Resources for project evaluation, and are presented in this chapter. With respect to the objectives of this investigation, limited changes in these criteria would not affect the selection of system location; but, as stated in Chapter II, modifications of the criteria employed herein could result in a variance in required aqueduct capacity.

FINANCIAL ANALYSES

Financial analyses, which in effect are cost recovery schedules, were prepared for each alternative main aqueduct system for the purpose of ascertaining (a) the financial feasibility, apart from considerations as to sources of capital investment funds, of constructing each system, (b) the portion of the total capital investment in each system attributable to delivering water to each service area, and (c) the annual revenue per acre-foot of water delivered required for meeting annual expenses of operation and for servicing the capital investment, referred to herein as ''unit cost of water''.

It is emphasized that the unit cost information presented herein is not to be considered as a suggested pricing schedule for sale of water to agencies which will contract with the State for a water supply. It is possible that actual pricing schedules might reflect the State's bond amortization requirements, with repayment of capital required independent of amounts of water actually used. In this eventuality, because of the build-up period in water use postulated for all service areas, the actual unit cost of water to the service areas during the early years of project operation would be higher than the values derived herein; however, in subsequent years actual unit costs to the service areas would be lower. Thus, the resultant average costs over the long-term period would be equivalent to the values presented in this report.

The costs utilized in the financial analyses represent all those that would be incurred in construction of the main aqueduct facilities south of the Delta, including interest on capital investment and annual costs of operation and maintenance, including energy for pumping, replacement, and general expense. It was assumed that all such costs, including interest, would be reimbursable.

The capital costs of storage facilities supplying the Delta, such as Oroville Dam and Reservoir and proposed Delta improvement works were not included in the cost allocation. However, an estimated unit cost of water in the Delta at the intake to the aqueduct system of $1.00 was assumed in the analyses for study purposes. The possible variations or any future increase in cost of water in the Delta because of necessary augmentation in supply thereto to meet the continuing demands of the aqueduct system were not reflected in the analyses. As to possible future construction above the Delta to meet increased demands, is is estimated that a substantial period of time would elapse before augmentation would be required, and that the maximum effect on cost of water in the Delta would neither be substantial nor adversely affect the conclusions reached herein.

For purposes of this report, it is considered that financial feasibility of a project is demonstrated if the costs which would be incurred therefor would be recovered within an established repayment period. Each of the three aqueduct systems was sized in accordance with the forecast economic demand for water therefrom, with this forecast, as explained in Chapter II, reflecting the ability of the water user to repay all costs. Each system was then subjected to financial analysis to determine its financial feasibility under the assumptions made for cost allocation and cost recovery periods.

The elements of the financial analyses are set forth following and are briefly discussed in the ensuing paragraphs.

1. Financing of Project Facilities
2. Allocation of Costs
3. Recovery of Costs

Financing of Project Facilities

Although it is not within the scope of this investigation and report to develop or propose a method of financing construction of the aqueduct system, certain assumptions as to financing were required to develop relative costs of water for aqueduct system comparisons. For purposes of the analyses, the year by year capital requirements for aqueduct construction were employed without regard to the source of these funds. It was assumed that regardless of source, these funds would bear interest at a rate of $3\frac{1}{2}$ per cent per annum. It was further assumed that capital recovery would be consummated within 50 years after the expense was incurred. However, for the first 10 years after the capital outlay only interest would be paid on the investment. Payment of interest or other annual expenses were assumed to be met by an increase in capital outlay during the initial construction period when project revenues would not be available, and at such times thereafter when the revenues might be insufficient to meet expenses.

Allocation of Costs

The costs of each aqueduct system were allocated to those service areas tabulated in Chapter I and shown on Plate 2, for the purpose of determining the unit cost of water, delivered at the main aqueduct system, to each area. As stated in Chapter I, these areas were chosen for analytical purposes only and do not represent proposed agencies for contracting of water from the San Joaquin Valley-Southern California Aqueduct.

For the purposes of this study, costs were allocated among the cited areas by the "Proportionate Use of Facilities" method. By this method, the ratio of the cost allocated to a given service area to the total cost of the system is the same as the ratio of the capacity provided in the system for that service area to the total capacity. The utilization of this method of cost allocation herein is not intended to suggest that it will be that which is ultimately selected as the basis for the establishment of charges for water.

Allocation of costs for staged units of the systems did not reflect differences in rates of growth in demand for water among the areas served by a particular staged unit. Thus, the derived unit costs of water would tend to be somewhat higher for areas with forecast lower rates of build-up in demand than if this factor were considered. Conversely, for areas with the faster build-up rates, derived unit costs of water at the aqueduct actually would be somewhat lower than shown. The magnitude of these differences, however, would be relatively minor.

For pumping plants, costs were allocated among the various service areas in the same proportion that the peak capacity requirements for each area bore to the summation of peak requirements of all service areas. As the power recovery plants were assumed to be employed on the aqueduct systems for the sole purpose of supplying a portion of the power requirements of the pumping plants, the costs of the power recovery plants were added directly to the cost of the pumping plants which they would serve, and costs were allocated as described for the pumping installations.

Energy costs were allocated directly to each area as the net cost thereof for pumping the service area's water from the Delta to the point of delivery. For areas which would receive water pumped in part by recovered power and which would not contribute falling water to the power plants, a cost for energy was imputed for the portion thereof provided by recovered power. This cost was equal to the value of the additional energy which would have to be obtained for pumping this increment of water supply.

Recovery of Allocated Costs

The financial analyses were carried out with recovery from each individual service area of its allocated portion of the capital investment in each stage of construction accomplished by a series of uniform payments at an interest rate of 3½ per cent per annum over a total repayment period of 50 years. Repayment would commence on the date of first water delivery to the areas. The interest components on the allocated portion of capital requirements for project construction and on allocated operating expenses deferred for the period prior to commencement of water deliveries were included in the repayment obligation of the service areas.

As staged construction was assumed for certain units of all systems, the foregoing procedure was repeated for each stage thereof. Although the cost of each unit was assumed to be recovered in 50 years, full recovery of the cost of the entire system would not be accomplished until 50 years after completion of the last of the staged units.

It must be recognized that certain service areas have limited development at the present time or are unorganized and have limited financial capacity. The build-up in water demand may be slow. For such areas, a modification of the foregoing assumption might be to delay capital recovery during the early years of project water service. However, if any unpaid interest accruing during this period together with deferred principal payments were subsequently recovered, with interest thereon, during the cited 50-year period, the derived equivalent annual costs of water presented in this report would not be changed.

Unit Costs of Water

The unit cost of water derived by the outlined procedure represents the value which, if assigned to water served to each area under the forecast delivery schedule, would recover all capital costs with interest over the cited cost recovery period, together with the cost of annual operation, maintenance, replacement, and other current expenses. This value is termed "equivalent annual cost" of water.

It is again emphasized that the unit costs stated do not reflect any suggestions as to ultimate charges or prices for water; nor does this report essay to indicate the methods or results of cost allocation which will be utilized for establishing charges for water. To the extent that it was required, allocations of cost made herein for study purposes were on an area basis. Obviously, allocation of costs on a functional or other basis would affect the ultimate charges which will be made for water service.

Results of Financial Analyses

There are set forth in Tables 28, 29, and 30 the financial analyses of Aqueduct Systems "A", "B" and "C", respectively. These analyses show for each system, from the Delta south, the capital requirements necessary for construction, annual expenses for all purposes, a summary of projected revenues from the service areas under the cited cost recovery criteria, and the application of these revenues to repay all project costs. In the analyses, during those years when annual revenues received would be in excess of annual expenses, excess revenues were assumed to be applied first to repayment with interest of capital outlay for prior deficits in annual revenues. With completion of repayment of this deficit, it was assumed that annual revenues in excess of annual expenses would be invested at an interest rate of 3½ per cent per annum to be used to make up any deficits in annual revenues occurring during later years of project operation.

It may be noted that each system, although having differing capital requirements and annual expenses, would be fully repaid from the assumed revenue received from the service areas, fifty years after the last stage of construction and, therefore, by definition, each system can be considered to exhibit financial feasibility.

Presented in Table 31 is a summary of the results of the financial analyses of the alternative aqueduct systems showing the portion of the total construction cost of each system allocated to each service area and the derived equivalent annual costs to the service areas, expressed in dollars and in dollars per acre-foot of water delivered. Variations in the derived equivalent annual costs of water result, not only from differences in magnitude of allocated costs, but also from postulated differences in rates of water delivery to the various service areas. Should actual delivery rates be greater than estimated in this Bulletin, the resulting equivalent annual costs of water would be lower than shown herein. The values shown in Table 31 reflect the costs of the systems operated with either the "steam-electric" or "steam-drive and feedback" schemes.

For purposes of evaluating the future of an operational scheme involving the "utility participation" concept, analyses were made using the "off-peak electric and feedback" scheme. These analyses were made for the purpose of deriving the average unit cost of water for the portions of Aqueduct Systems "B" and "C" south of Avenal Gap. The physical conditions inherent in Aqueduct System "A" as stated in Chapter V do not economically lend themselves to "off-peak" operation.

Set forth in Table 32 are the results of these analyses. It may be noted in Table 32, which also sets forth comparable values for the "steam-electric" and "steam-drive and feedback" schemes, that the capital costs and equivalent annual costs, at the main aqueduct, for Aqueduct System "B" are less than those for Aqueduct System "C" under either method of operation.

ECONOMIC ANALYSES

Economic analyses were made of the three alternative aqueduct systems for the purpose of testing the economic justification of these systems and units thereof, and to provide a basis for comparing the relative costs and accomplishments of the systems.

Under the concept of public project evaluation, a project may be deemed economically justified if the value of benefits expected to be produced thereby exceed all costs associated in producing the benefits. The aqueduct system chosen for construction must not only meet the test of financial feasibility to insure recovery of costs incurred by the State, but it must also be demonstrated that the investment is worthwhile in that the value of benefits to be derived exceeds the cost. Further, the system chosen should be such that its location and capacity are, from an economic standpoint, the optimum among possible alternatives for comparable service. In determining this, consideration must be given not only to the costs of the main aqueduct system but also to the costs of local facilities required to convey and to distribute water within each service area.

The procedure employed in the economic analyses was to estimate and compare benefits and costs on a common time basis. A period of analysis of 105 years extending from 1960 to 2065 was employed, together with a discount rate of 3½ per cent. The year 2065 is approximately the end of the payout period of the last stage of construction of certain of the systems. Although it is recognized that benefits estimated to occur 100 years hence are extremely conjectural, it is to be noted that such benefits have little discounted value at the present time. The use of such a lengthy period produces results nearly equivalent to capitalizing recurring annual costs in perpetuity.

Economic Relationships

Generally the optimum project is that which exhibits a maximization of benefits with a minimization of costs. Various economic relationships may be developed which are of assistance in the evaluation and comparison of alternative projects and in the selection among alternatives.

The Benefit-Cost Ratio. This relationship, if in excess of unity, is an indication of economic justification. However, in choosing among alternatives it cannot be employed without consideration of other factors since the ratio does not reflect increases in benefits with increase in project size.

TABLE 28—FINANCIAL ANALYSIS OF AQUEDUCT SYSTEM "A" * (values in thousands)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	Capital requirements								Debt status			Annual expense	
	Construction				For deficit in annual revenue							Debt service	
Year	Construction cost	Interest during construction	Annual	Cumulative	Required for year	Interest	Annual	Cumulative	Construction	Deficit in annual revenue	Total	Interest	Principal
1960	$4,678	$164	$4,842	$4,842					$4,842		$4,842	$169	
1961	17,571	615	18,186	23,028	$169		$169	$169	23,028	$169	23,197	806	
1962	72,991	2,555	75,546	98,573	806	$6	812	981	98,573	981	99,554	3,450	
1963	120,803	4,228	125,031	223,604	3,476	34	3,510	4,491	223,604	4,491	228,095	7,826	
1964	202,663	7,093	209,756	433,361	8,246	157	8,403	12,894	433,361	12,894	446,255	15,168	
1965	193,765	6,782	200,547	633,907	16,289	451	16,740	29,634	633,907	29,634	663,541	22,187	
1966	147,721	5,170	152,891	786,799	22,053	1,037	23,090	52,724	786,799	52,724	837,523	27,538	
1967	139,930	4,898	144,828	931,626	22,112	1,845	23,957	76,681	931,626	76,681	1,008,307	32,807	
1968	146,417	5,125	151,542	1,083,168	25,801	2,684	28,485	105,166	1,083,168	105,166	1,188,334	37,911	
1969	110,716	3,875	114,591	1,197,759	31,617	3,681	35,298	140,464	1,197,759	140,464	1,338,223	41,922	
1970	78,850	2,760	81,610	1,279,369	35,509	4,916	40,425	180,889	1,279,369	180,889	1,460,258	44,778	$57
1971	63,684	2,229	65,913	1,345,282	34,706	6,331	41,037	221,926	1,345,224	221,926	1,567,150	47,083	274
1972	7,404	259	7,663	1,352,945				221,926	1,352,613	216,341	1,568,954	47,341	1,177
1973	13,496	472	13,968	1,366,913				221,926	1,365,404	207,164	1,572,568	47,789	2,697
1974	11,873	416	12,289	1,379,202				221,926	1,374,995	199,045	1,574,040	48,125	5,273
1975	10,798	378	11,176	1,390,378				221,926	1,380,898	193,039	1,573,937	48,331	7,829
1976	7,003	245	7,248	1,397,626				221,926	1,380,317	189,128	1,569,445	48,311	9,911
1977	57,022	1,996	59,018	1,456,643				221,926	1,429,424	186,835	1,616,259	50,030	11,971
1978	114,886	4,021	118,907	1,575,550				221,926	1,536,359	185,725	1,722,084	53,773	14,183
1979	62,736	2,196	64,932	1,640,482				221,926	1,587,108	185,469	1,772,577	55,549	16,034
1980	12,658	443	13,101	1,653,583		596	596	222,522	1,584,175	186,065	1,770,240	55,446	17,561
1981	9,273	325	9,598	1,663,181		1,489	1,489	224,011	1,576,212	187,554	1,763,766	55,167	18,955
1982	11,071	387	11,458	1,674,639		1,680	1,680	225,691	1,568,716	189,234	1,757,950	54,905	19,709
1983	15,582	545	16,127	1,690,767				225,691	1,565,134	187,851	1,752,985	54,780	20,564
1984	13,994	490	14,484	1,705,250				225,691	1,559,054	186,463	1,745,517	54,567	21,429
1985	13,440	470	13,910	1,719,161				225,691	1,551,535	185,061	1,736,596	54,304	22,311
1986	16,472	577	17,049	1,736,209				225,691	1,546,272	183,636	1,729,908	54,120	23,178
1987	12,956	453	13,409	1,749,619				225,691	1,536,504	182,116	1,718,620	53,778	24,687
1988	63,628	2,227	65,855	1,815,474				225,691	1,577,672	181,140	1,758,812	55,219	26,958
1989	117,389	4,109	121,498	1,936,971				225,691	1,672,212	181,032	1,853,244	58,527	28,669
1990	65,580	2,295	67,875	2,004,847				225,691	1,711,418	180,761	1,892,179	59,900	29,827
1991	9,640	337	9,977	2,014,824				225,691	1,691,568	180,117	1,871,685	59,205	30,985
1992	12,329	432	12,761	2,027,585				225,691	1,673,344	179,489	1,852,833	58,567	32,205
1993	29,890	1,046	30,936	2,058,521				225,691	1,672,075	178,877	1,850,952	58,523	33,523
1994	32,540	1,139	33,679	2,092,200				225,691	1,672,231	178,197	1,850,428	58,528	34,867
1995	13,789	483	14,272	2,106,471				225,691	1,651,635	177,407	1,829,042	57,807	36,252
1996	5,591	196	5,787	2,112,258				225,691	1,621,170	176,682	1,797,852	56,741	37,723
1997	5,520	193	5,713	2,117,971				225,691	1,589,160	176,053	1,765,213	55,621	39,202
1998	10,211	357	10,568	2,128,540				225,691	1,560,527	175,516	1,736,043	54,618	41,353
1999	8,967	314	9,281	2,137,820		144	144	225,835	1,528,455	175,660	1,704,115	53,496	44,237
2000	4,686	164	4,850	2,142,670		1,515	1,515	227,350	1,489,068	177,175	1,666,243	52,117	46,588
2001	61,755	2,162	63,917	2,206,588		2,332	2,332	229,682	1,506,417	179,507	1,685,924	52,725	48,337
2002	112,357	3,932	116,289	2,322,877		2,045	2,045	231,727	1,574,370	181,552	1,755,922	55,103	50,179
2003	57,638	2,017	59,655	2,382,532		1,382	1,382	233,109	1,583,846	182,934	1,766,780	55,435	52,301
2004	4,239	148	4,387	2,386,920		1,340	1,340	234,449	1,535,932	184,274	1,720,206	53,758	54,530
2005	11,571	405	11,976	2,398,896		1,752	1,752	236,201	1,493,378	186,026	1,679,404	52,268	56,808
2006	13,310	466	13,776	2,412,672		1,892	1,892	238,093	1,450,546	187,918	1,638,464	50,769	58,657
2007	14,988	525	15,513	2,428,184		1,920	1,920	240,013	1,407,402	189,838	1,597,240	49,259	60,778
2008	5,927	207	6,134	2,434,319		1,937	1,937	241,950	1,352,758	191,775	1,544,533	47,347	63,030
2009				2,434,319		2,083	2,083	244,033	1,289,728	193,858	1,483,586	45,140	65,346
2010				2,434,319		2,265	2,265	246,298	1,224,382	196,123	1,420,505	42,853	67,464
2011				2,434,319		2,175	2,175	248,473	1,156,918	198,298	1,355,216	40,492	69,730
2012	2,160	76	2,236	2,436,554		2,156	2,156	250,629	1,089,424	200,454	1,289,878	38,130	70,008
2013	4,328	151	4,479	2,441,034		52	52	250,681	1,023,896	200,506	1,224,402	35,836	67,309
2014	2,160	76	2,236	2,443,269					958,823	195,377	1,154,200	33,559	59,894
2015									898,928	180,281	1,079,209	31,462	52,741
2016									846,187	157,922	1,004,109	29,617	47,591
2017									798,597	133,526	932,123	27,951	42,658
2018									755,939	103,245	859,184	26,458	37,127
2019									718,812	65,793	784,605	25,158	33,061
2020									685,752	22,238	707,990	24,001	30,396
2021									655,355	0	655,355	22,937	28,373
2022									626,982		626,982	21,944	29,034
2023									597,948		597,948	20,928	29,449
2024									568,499		568,499	19,897	29,931
2025									538,568		538,568	18,850	30,455
2026									508,113		508,113	17,784	31,182
2027									476,931		476,931	16,693	29,509
2028									447,422		447,422	15,660	24,974
2029									422,448		422,448	14,786	22,808
2030									399,640		399,640	13,987	22,992
2031									376,648		376,648	13,183	23,348
2032									353,300		353,300	12,366	23,628
2033									329,672		329,672	11,539	23,700
2034									305,972		305,972	10,709	23,851
2035									282,120		282,120	9,874	24,035
2036									258,086		258,086	9,033	24,078
2037									234,008		234,008	8,190	24,292
2038									209,716		209,716	7,340	22,059
2039									187,657		187,657	6,568	17,142
2040									170,515		170,515	5,968	14,563
2041									155,952		155,952	5,458	14,606
2042									141,347		141,347	4,947	14,519
2043									126,828		126,828	4,439	13,579
2044									113,249		113,249	3,964	12,477
2045									100,772		100,772	3,527	12,245
2046									88,527		88,527	3,098	12,403
2047									76,124		76,124	2,664	12,569
2048									63,554		63,554	2,224	12,514
2049									51,040		51,040	1,786	12,518
2050									38,522		38,522	1,348	12,729
2051									25,793		25,793	903	10,180
2052									15,613		15,613	546	5,091
2053									10,522		10,522	368	2,476
2054									8,046		8,046	281	2,358
2055									5,688		5,688	199	1,879
2056									3,809		3,809	133	1,300
2057									2,509		2,509	88	619
2058									1,890		1,890	66	353
2059									1,537		1,537	53	366
2060									1,171		1,171	41	378
2061									793		793	27	392
2062									401		401	14	300
2063									101		101	4	101
2064									0		0	0	0
TOTALS	$2,361,000	$82,000	$2,443,000		$201,000	$50,000	$251,000					$2,989,000	$2,443,000

* *Values reflect "steam-electric and feedback" operation.*

TABLE 28—FINANCIAL ANALYSIS OF AQUEDUCT SYSTEM "A" * (values in thousands)—Continued

(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)
Annual expense					Revenue received from service areas			Difference between revenue and annual expense	Application of excess revenue toward repayment of deficit			Value of invested revenue	Year
Debt service	Annual operating cost												
Subtotal	Net pumping cost	Oper. main. replacements, gen. expenses	Subtotal	Total	For debt service	For operating expenses	Total		To interest	To principal	Total		
$169				$169				$—169					1980
806				806				—806					1961
3,450				3,450				—3,450					1962
7,828		$26	$26	7,852				—7,852					1963
15,188		420	420	15,588				—15,588					1984
22,187	$28	1,312	1,340	23,526	$2,514	$219	$2,733	—20,793					1965
27,538	117	3,489	3,608	31,144	8,257	1,226	9,483	—21,661					1968
32,607	242	4,188	4,430	37,037	9,823	1,599	11,422	—25,615					1967
37,911	327	4,374	4,701	42,612	10,736	1,684	12,420	—30,192					1968
41,922	428	8,578	7,004	48,926	11,312	2,562	13,874	—35,052					1969
44,835	393	7,139	7,532	52,367	11,452	2,833	14,085	—38,282					1970
47,357	1,745	7,944	9,689	57,048	61,262	8,386	69,628	12,582	$7,767	$5,585	$13,352		1971
48,518	3,275	10,170	13,445	61,964	65,819	12,892	78,711	16,747	7,571	9,177	16,748		1972
50,488	4,476	10,170	14,646	85,133	66,409	14,093	80,502	15,369	7,250	8,119	15,389		1973
53,398	5,628	10,927	16,553	69,951	66,925	15,999	82,923	12,972	6,966	6,006	12,972		1974
56,160	6,800	10,956	17,756	73,917	67,397	17,201	84,597	10,680	8,756	3,911	10,667		1975
58,222	7,974	11,647	19,621	77,844	67,705	19,052	86,756	8,912	6,819	2,293	8,912		1976
62,001	9,149	11,647	20,796	82,797	70,219	20,226	90,444	7,647	6,539	1,110	7,649		1977
67,956	10,322	11,647	21,969	89,924	75,284	21,400	96,683	6,759	6,500	258	6,758		1978
71,583	11,497	12,919	24,416	96,000	78,050	23,843	101,892	5,892	5,895		5,895		1979
73,007	12,870	12,919	25,589	98,598	78,606	25,017	103,622	5,026	5,023		5,023		1980
74,122	13,623	13,569	27,192	101,314	79,006	26,616	105,621	4,307	4,884		4,884		1981
74,814	15,548	13,569	29,117	103,731	82,619	29,117	111,736	8,005	6,623	1,383	8,005		1982
75,344	16,628	14,575	31,203	106,547	83,306	31,203	114,509	7,962	6,574	1,388	7,962		1983
75,998	17,751	15,587	33,318	109,314	83,923	33,318	117,241	7,927	6,526	1,402	7,927		1984
76,615	18,874	15,567	34,441	111,058	84,517	34,441	118,958	7,902	6,477	1,425	7,902		1985
77,298	19,997	15,858	35,855	113,153	85,245	35,855	121,100	7,947	6,427	1,520	7,947		1988
78,485	21,130	17,427	38,557	117,022	85,815	38,557	124,372	7,350	6,374	978	7,350		1987
82,177	22,253	17,876	40,129	122,306	88,624	40,129	128,753	6,447	6,339	108	6,447		1988
87,198	23,372	17,886	41,258	128,455	93,804	41,258	135,082	6,607	6,336	271	8,607		1989
89,727	24,501	19,300	43,801	133,528	96,697	43,801	140,498	6,970	6,326	644	8,970		1990
90,190	25,520	19,300	44,820	135,010	97,122	44,820	141,942	6,932	8,304	628	8,932		1991
90,772	26,540	19,301	45,841	136,613	97,886	45,841	143,507	6,894	6,282	612	8,894		1992
92,046	27,429	20,475	47,904	139,950	98,986	47,904	146,890	6,940	6,260	880	6,940		1993
93,395	28,443	20,475	48,918	142,314	100,422	48,918	149,340	7,026	6,238	790	7,026		1994
94,059	29,604	21,229	50,833	144,892	101,029	50,833	151,862	6,934	6,209	725	8,934		1995
94,464	30,620	21,853	52,473	146,937	101,276	52,473	153,749	6,812	8,183	829	6,812		1996
94,823	31,838	21,853	53,491	148,313	101,520	53,491	155,011	6,698	8,161	537	6,698		1997
95,971	32,561	21,862	54,423	150,395	101,969	54,423	156,392	5,992	5,999		5,999		1998
97,733	33,440	22,411	55,851	153,584	102,365	55,851	158,216	4,632	4,633		4,633		1999
98,705	34,319	22,411	56,730	155,435	102,573	56,730	159,303	3,868	3,868		3,868		2000
101,062	34,999	22,490	57,489	158,551	105,298	57,489	162,787	4,237	4,237		4,237		2001
105,282	35,310	22,623	57,933	163,215	110,254	57,933	168,187	4,972	4,972		4,972		2002
107,736	34,985	24,415	59,400	167,136	112,798	59,400	172,198	5,062	5,062		5,062		2003
108,288	36,860	24,415	61,075	169,363	112,985	61,075	174,060	4,697	4,697		4,697		2004
108,876	37,335	24,415	61,750	170,826	113,495	61,750	175,245	4,619	4,619		4,619		2005
109,426	38,009	24,907	62,916	172,342	114,083	62,916	176,999	4,657	4,857		4,657		2006
110,037	38,684	25,861	64,345	174,382	114,744	64,345	179,089	4,707	4,707		4,707		2007
110,377	39,359	26,350	65,709	176,086	115,006	65,709	180,715	4,629	4,629		4,629		2008
110,488	40,034	26,350	66,384	176,870	115,008	66,384	181,390	4,520	4,520		4,520		2009
110,317	40,709	26,350	87,059	177,376	115,006	67,059	182,065	4,689	4,689		4,689		2010
110,222	41,173	26,350	67,523	177,745	115,008	67,523	182,529	4,784	4,784		4,784		2011
108,138	41,837	26,350	87,987	176,125	115,101	67,987	183,088	4,963	6,963		6,963		2012
103,145	42,101	26,350	88,451	171,596	115,292	68,451	183,743	12,147	7,018	5,129	12,147		2013
93,453	42,585	26,540	69,105	162,558	115,387	69,105	184,492	21,934	8,838	15,096	21,934		2014
84,203	43,030	26,540	89,570	153,774	112,873	69,570	182,443	28,669	6,310	22,359	28,669		2015
77,208	43,494	26,540	70,034	147,241	107,131	70,034	177,165	29,924	5,527	24,397	29,924		2016
70,609	43,959	26,540	70,499	141,108	105,564	70,499	176,063	34,955	4,674	30,281	34,955		2017
63,585	44,423	26,540	70,963	134,548	104,651	70,963	175,614	41,066	3,614	37,452	41,068		2018
58,219	44,887	26,540	71,427	129,646	104,076	71,427	175,503	45,857	2,302	43,555	45,857		2019
54,397	45,351	26,540	71,891	126,288	103,935	71,891	175,826	49,538	778	22,238	23,017	$28,521	2020
51,310	45,351	26,540	71,891	123,202	54,126	71,891	126,017	2,815				30,264	2021
50,978	45,351	26,540	71,891	122,869	49,568	71,891	121,459	—1,410				29,914	2022
50,377	45,351	26,540	71,891	122,268	48,978	71,891	120,869	—1,399				29,582	2023
49,828	45,351	26,540	71,891	121,719	48,463	71,891	120,354	—1,385				29,231	2024
49,305	45,351	26,540	71,891	121,196	47,991	71,891	119,882	—1,314				28,940	2025
48,966	45,351	26,540	71,891	120,857	47,884	71,891	119,575	—1,282				28,671	2026
48,202	45,351	26,540	71,891	118,093	45,169	71,891	117,060	—1,033				28,642	2027
40,834	45,351	28,540	71,891	112,525	40,104	71,891	111,995	—530				29,114	2028
37,594	45,351	26,540	71,891	109,484	37,338	71,891	109,229	—255				29,878	2029
38,979	45,351	28,540	71,891	108,871	36,782	71,891	108,673	—198				30,726	2030
38,531	45,351	26,540	71,891	108,421	36,382	71,891	108,273	—148				31,653	2031
35,994	45,351	26,540	71,891	107,885	32,769	71,891	104,660	—3,225				29,536	2032
35,239	45,351	26,540	71,891	107,130	32,082	71,891	103,973	—3,157				27,413	2033
34,560	45,351	26,540	71,891	106,451	31,464	71,891	103,355	—3,096				25,276	2034
33,909	45,851	26,540	71,691	105,800	30,871	71,891	102,762	—3,038				23,123	2035
33,111	45,351	26,540	71,891	105,002	30,145	71,891	102,036	—2,966				20,966	2038
32,482	45,851	26,540	71,891	104,374	29,573	71,891	101,464	—2,910				18,790	2037
29,399	45,351	26,540	71,891	101,290	26,765	71,891	98,856	—2,634				16,814	2038
23,710	45,351	26,540	71,891	95,800	21,585	71,891	93,476	—2,124				15,278	2039
20,531	45,351	26,540	71,891	92,422	18,692	71,891	90,583	—1,839				13,974	2040
20,064	45,351	26,540	71,891	91,955	18,266	71,891	90,157	—1,798				12,865	2041
19,466	45,351	26,540	71,891	91,357	17,722	71,891	89,613	—1,744				11,364	2042
18,018	45,351	26,540	71,891	89,909	16,403	71,891	88,294	—1,615				10,147	2043
16,441	45,351	26,540	71,891	88,332	14,987	71,891	86,658	—1,474				9,028	2044
15,772	45,351	26,540	71,891	87,663	14,359	71,891	86,250	—1,413				7,931	2045
15,501	45,351	26,540	71,891	87,392	14,112	71,891	86,003	—1,389				6,820	2046
15,233	45,351	26,540	71,891	87,125	13,869	71,891	85,760	—1,365				5,693	2047
14,738	45,351	36,540	71,891	86,630	13,418	71,891	85,309	—1,321				4,571	2048
14,304	45,351	26,540	71,891	86,195	13,022	71,891	84,913	—1,282				3,449	2049
14,077	45,351	26,540	71,891	85,968	12,816	71,891	84,707	—1,261				2,309	2050
11,083	45,351	26,540	71,891	82,974	10,091	71,891	81,982	—992				1,398	2051
5,637	45,351	26,540	71,891	77,529	5,133	71,891	77,024	—505				942	2052
2,844	45,351	26,540	71,891	74,735	2,589	71,891	74,480	—255				720	2053
2,839	45,351	26,540	71,891	74,530	2,402	71,891	74,293	—237				508	2054
2,078	45,351	26,540	71,891	73,969	1,892	71,891	73,783	—186				340	2055
1,433	45,351	26,540	71,891	73,324	1,304	71,891	73,195	—129				223	2056
707	45,351	26,540	71,891	72,597	643	71,891	72,534	—63				168	2057
419	45,351	26,540	71,891	72,310	382	71 891	72 273	—37				136	2058
419	45,351	26,540	71,891	72,310	382	71,891	72,273	—37				104	2059
419	45,351	26,540	71,891	72,310	382	71,891	72,273	—37				71	2060
419	45,351	26,540	71,891	72,310	382	71,891	72,273	—37				36	2061
314	45,351	26,540	71,891	72,205	286	71,891	72,177	—28				10	2062
105	45,351	26,540	71,891	71,996	95	71,891	71,986	—10				0	2063
0	45,351	26,540	71,891	71,891	0	71,891	71,891	0					2064
$5,432,000	$3,373,000	$2,191,000	$5,564,000	$10,996,000	$5,769,000	$5,538,000	$11,307,000	$311,000	$283,000	$251,000	$534,000		

TABLE 29—FINANCIAL ANALYSIS OF AQUEDUCT SYSTEM "B" * (values in thousands)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	Capital requirements								Debt status			Annual expense	
	Construction				For deficit in annual revenue							Debt service	
Year	Construction cost	Interest during construction	Annual	Cumulative	Required for year	Interest	Annual	Cumulative	Construction	Deficit in annual revenue	Total	Interest	Principal
1960	$3,796	$133	$3,929	$3,929					$3,929		$3,929	$138	
1961	16,410	574	16,984	20,913	$138		$138	$138	20,913	$138	21,051	732	
1962	52,691	1,844	54,535	75,448	732	$5	737	875	75,448	875	76,323	2,641	
1963	93,314	3,266	96,580	172,028	2,667	31	2,698	3,573	172,028	3,573	175,601	6,021	
1964	110,834	3,879	114,713	286,741	6,047	125	6,172	9,745	286,742	9,745	296,487	10,036	
1965	87,825	3,074	90,899	377,640	10,595	341	10,936	20,681	377,640	20,681	398,321	13,217	
1966	74,797	2,618	77,415	455,055	12,865	724	13,589	34,270	455,055	34,270	489,325	15,927	
1967	119,196	4,172	123,367	578,422	10,621	1,199	11,820	46,090	578,422	46,090	624,512	20,245	
1968	131,055	4,587	135,642	714,064	13,737	1,613	15,350	61,440	714,064	61,440	775,504	24,992	
1969	116,073	4,063	120,136	834,200	18,793	2,150	20,943	82,383	834,200	82,383	916,583	29,197	
1970	72,081	2,523	74,604	908,803	24,548	2,883	27,431	109,814	908,803	109,814	1,018,617	31,808	$46
1971	58,349	2,042	60,391	969,195	21,990	3,843	25,833	135,647	969,148	135,647	1,104,795	33,920	249
1972	25,575	895	26,470	995,665				135,647	995,369	128,839	1,124,208	34,838	903
1973	22,325	781	23,106	1,018,771				135,647	1,017,573	122,160	1,139,733	35,615	2,077
1974	19,569	685	20,254	1,039,025				135,647	1,035,750	115,398	1,151,148	36,251	3,506
1975	10,049	352	10,401	1,049,426				135,647	1,042,645	109,621	1,152,266	36,493	4,704
1976	2,675	94	2,769	1,052,194				135,647	1,040,710	104,641	1,145,351	36,425	5,784
1977	18,075	633	18,708	1,070,902				135,647	1,053,634	100,385	1,154,019	36,877	7,446
1978	49,107	1,719	50,826	1,121,728				135,647	1,097,014	97,320	1,194,334	38,395	9,310
1979	56,069	1,962	58,031	1,179,759				135,647	1,145,735	95,454	1,241,189	40,101	11,057
1980	69,459	2,431	71,890	1,251,649				135,647	1,206,568	94,535	1,301,103	42,230	12,327
1981	74,461	2,606	77,067	1,328,716				135,647	1,271,308	93,942	1,365,250	44,496	13,472
1982	38,991	1,365	40,356	1,369,072				135,647	1,298,192	93,269	1,391,461	45,437	14,257
1983	18,109	634	18,743	1,387,815				135,647	1,302,678	91,161	1,393,839	45,594	15,029
1984	16,725	585	17,310	1,405,125				135,647	1,304,959	89,110	1,394,069	45,674	15,795
1985	16,014	560	16,574	1,421,700				135,647	1,305,739	87,094	1,392,833	45,701	16,470
1986	18,664	653	19,317	1,441,017				135,647	1,308,586	85,004	1,393,590	45,800	17,080
1987	12,720	445	13,165	1,454,182				135,647	1,304,671	82,726	1,387,397	45,663	17,899
1988	10,419	365	10,784	1,464,966				135,647	1,297,556	80,489	1,378,045	45,414	19,126
1989	35,201	1,232	36,433	1,501,399				135,647	1,314,863	78,693	1,393,556	46,020	20,482
1990	66,749	2,336	69,085	1,570,484				135,647	1,363,466	77,242	1,440,708	47,721	22,049
1991	39,999	1,400	41,399	1,611,883				135,647	1,382,816	76,063	1,458,879	48,399	23,732
1992	13,920	487	14,407	1,626,290				135,647	1,373,490	75,439	1,448,929	48,072	25,040
1993	12,379	433	12,812	1,639,103				135,647	1,361,262	75,159	1,436,421	47,644	26,138
1994	14,649	513	15,162	1,654,264				135,647	1,350,285	74,999	1,425,284	47,280	27,258
1995	15,248	534	15,782	1,670,046				135,647	1,338,809	74,917	1,413,726	46,858	28,408
1996	12,453	436	12,889	1,682,935				135,647	1,323,290	74,908	1,398,198	46,315	29,631
1997	9,943	348	10,291	1,693,226		121	121	135,768	1,303,950	75,029	1,378,979	45,638	30,824
1998	7,679	269	7,948	1,701,174		203	203	135,971	1,281,074	75,232	1,356,306	44,838	32,030
1999	7,168	251	7,419	1,708,592		277	277	136,248	1,256,463	75,509	1,331,971	43,976	33,582
2000	20,698	724	21,422	1,730,015		661	661	136,909	1,244,303	76,170	1,320,475	43,551	35,574
2001	41,565	1,455	43,020	1,773,035		1,337	1,337	138,246	1,251,748	77,507	1,329,256	43,811	37,309
2002	20,502	718	21,220	1,794,254		1,545	1,545	139,791	1,235,659	79,052	1,314,712	43,248	38,785
2003	7,249	254	7,503	1,801,757		1,608	1,608	141,399	1,204,376	80,660	1,285,036	42,153	40,294
2004	8,269	289	8,558	1,810,315		1,759	1,759	143,158	1,172,640	82,419	1,255,059	41,042	41,884
2005	7,248	254	7,502	1,817,817		1,933	1,933	145,091	1,138,258	84,352	1,222,610	39,839	43,537
2006	3,119	109	3,228	1,821,045		2,132	2,132	147,223	1,097,949	86,484	1,184,433	38,428	45,213
2007	9,912	347	10,259	1,831,304		2,332	2,332	149,555	1,062,995	88,816	1,151,811	37,205	46,917
2008	13,683	479	14,162	1,845,466		2,459	2,459	152,014	1,030,240	91,275	1,121,515	36,058	48,653
2009	7,040	246	7,286	1,852,752		2,530	2,530	154,544	988,873	93,805	1,082,678	34,611	50,444
2010	120	4	124	1,852,877		2,652	2,652	157,196	938,554	96,457	1,035,011	32,849	52,279
2011				1,852,877		2,811	2,811	180,007	886,275	99,268	985,543	31,020	53,822
2012	4,129	145	4,274	1,857,150		2,625	2,625	162,632	836,727	101,893	938,620	29,285	53,403
2013	8,269	289	8,558	1,865,709		380	380	163,012	791,882	102,273	894,155	27,716	50,838
2014	4,129	145	4,274	1,869,982					745,317	98,168	843,485	26,086	47,347
2015									697,970	88,615	786,585	24,429	44,836
2016									653,134	76,817	729,951	22,860	42,819
2017									610,315	65,962	676,277	21,361	38,662
2018									571,654	50,303	621,957	20,008	33,831
2019									537,823	28,851	566,674	18,824	29,475
2020									508,348	1,712	510,060	17,792	27,015
2021									481,333	0	481,333	16,847	25,132
2022									456,200		456,200	15,967	24,823
2023									431,377		431,377	15,098	24,711
2024									406,666		406,666	14,233	24,678
2025									381,988		381,988	13,370	25,055
2026									356,933		356,933	12,493	25,802
2027									331,131		331,131	11,590	25,829
2028									305,302		305,302	10,686	24,353
2029									280,948		280,948	9,833	22,488
2030									258,460		258,460	0,046	19,909
2031									238,552		238,552	8,349	16,997
2032									221,555		221,555	7,754	15,702
2033									205,853		205,853	7,205	15,374
2034									190,479		190,479	6,667	15,101
2035									175,378		175,378	6,138	14,854
2036									160,525		160,525	5,618	14,469
2037									146,056		146,056	5,112	14,359
2038									131,697		131,697	4,609	14,356
2039									117,341		117,341	4,107	13,153
2040									104,188		104,188	3,647	10,378
2041									93,810		93,810	3,283	8,803
2042									85,007		85,007	2,975	8,436
2043									76,571		76,571	2,680	8,131
2044									68,439		68,439	2,395	7,706
2045									60,733		60,733	2,126	7,237
2046									53,496		53,496	1,872	6,887
2047									46,610		46,610	1,631	6,646
2048									39,964		39,964	1,399	6,506
2049									33,458		33,458	1,171	6,386
2050									27,072		27,072	948	5,607
2051									21,465		21,465	751	3,789
2052									17,676		17,676	619	2,927
2053									14,749		14,749	516	2,679
2054									12,070		12,070	422	2,372
2055									9,699		9,699	339	2,103
2056									7,595		7,595	266	2,026
2057									5,570		5,570	194	1,617
2058									3,953		3,953	138	1,010
2059									2,943		2,943	103	704
2060									2,239		2,239	78	723
2061									1,516		1,516	52	748
2062									768		768	26	575
2063									193		193	7	193
2064									0		0	0	0
Totals	$1,807,000	$63,000	$1,870,000		$123,000	$40,000	$163,000					$2,287,000	$1,870,000

* *Values reflect "steam-drive and feedback" operation.*

TABLE 29—FINANCIAL ANALYSIS OF AQUEDUCT SYSTEM "B" * (values in thousands)—Continued

(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)
Annual expense					Revenue received from service areas			Difference between revenue and annual expense	Application of excess revenue toward repayment of deficit			Value of invested revenue	Year
Debt service	Annual operating cost												
Subtotal	Net pumping cost	Oper. main. replacements, gen. expenses	Subtotal	Total	For debt service	For operating expenses	Total		To interest	To principal	Total		
$138				$138				$—138					1960
732				732				—732					1961
2,841				2,641				—2,641					1962
6,021		$26	$26	6,047				—6,047					1963
10,036		26	26	10,062				—10,062					1964
13,217	$42	688	730	13,947	$2,256	$171	$2,427	—11,520					1965
15,927	139	2,646	2,785	18,712	7,200	881	8,081	—10,631					1966
20,245	285	2,712	2,997	23,242	8,430	1,103	9,533	—13,709					1967
24,992	393	2,740	3,133	28,125	9,370	1,211	10,581	—17,544					1968
29,197	500	4,766	5,266	34,463	9,973	2,095	12,068	—22,395					1969
31,855	456	7,113	7,569	39,424	10,110	2,245	12,355	—27,069					1970
34,169	2,505	7,550	10,055	44,224	46,003	9,610	55,813	11,589	$4,748	$6,808	$11,556		1971
35,741	3,849	8,277	12,126	47,867	47,104	11,848	58,952	11,085	4,509	6,679	11,188		1972
37,692	5,199	9,077	14,276	51,968	48,907	14,100	63,007	11,039	4,276	6,762	11,038		1973
39,757	6,557	9,316	15,873	55,630	49,761	15,696	65,457	9,827	4,039	5,777	9,816		1974
41,196	7,907	9,759	17,666	58,862	50,200	17,478	67,678	8,616	3,837	4,980	8,817		1975
42,209	9,257	9,796	19,053	61,262	50,316	18,866	69,182	7,920	3,662	4,256	7,918		1976
44,323	10,609	9,840	20,449	64,771	51,089	20,260	71,349	6,578	3,513	3,065	6,578		1977
47,706	11,962	9,840	21,802	69,508	53,200	21,614	74,814	5,306	3,406	1,866	5,272		1978
51,158	13,310	10,944	24,254	75,412	55,640	24,032	79,672	4,260	3,341	919	4,260		1979
54,556	14,661	11,064	25,725	80,281	58,682	25,503	84,185	3,904	3,309	593	3,902		1980
57,968	15,716	11,288	27,004	84,972	61,929	26,780	88,709	3,737	3,288	673	3,961		1981
59,694	18,343	12,767	31,110	90,803	65,065	31,110	96,175	5,372	3,264	2,108	5,372		1982
60,623	19,680	13,755	33,435	94,058	65,865	33,435	99,300	5,242	3,191	2,051	5,242		1983
61,468	21,061	14,252	35,313	96,781	66,602	35,314	101,916	5,135	3,119	2,016	5,135		1984
62,171	22,442	14,560	37,002	99,174	67,309	37,002	104,311	5,138	3,048	2,090	5,138		1985
62,880	23,824	14,681	38,505	101,385	68,133	38,505	106,638	5,253	2,975	2,278	5,253		1986
63,562	25,216	16,680	41,896	105,458	68,694	41,896	110,590	5,132	2,895	2,237	5,132		1987
64,541	26,598	16,680	43,278	107,818	69,154	43,277	112,431	4,613	2,817	1,796	4,613		1988
66,502	27,980	17,233	45,213	111,715	70,707	45,214	115,920	4,205	2,754	1,451	4,205		1989
69,771	29,362	17,602	46,964	116,734	73,652	46,963	120,615	3,881	2,702	1,179	3,881		1990
72,131	30,671	18,485	49,156	121,287	75,417	49,156	124,573	3,286	2,662	624	3,286		1991
73,113	31,981	18,485	50,466	123,579	76,032	50,466	126,498	2,919	2,639	280	2,919		1992
73,783	33,159	19,708	52,867	126,650	76,574	52,867	129,441	2,791	2,631	160	2,791		1993
74,518	34,466	19,708	54,174	128,692	77,224	54,174	131,398	2,706	2,624	82	2,706		1994
75,266	35,770	20,862	56,632	131,899	77,897	56,633	134,530	2,631	2,622	9	2,631		1995
75,946	37,075	20,862	57,937	133,883	78,446	57,937	136,383	2,500	2,500		2,500		1996
76,462	38,379	21,037	59,416	135,878	76,885	59,416	138,301	2,423	2,423		2,423		1997
76,868	39,592	21,087	60,679	137,546	79,223	60,678	139,901	2,355	2,355		2,355		1998
77,558	40,758	21,477	62,235	139,793	79,540	62,235	141,775	1,982	1,982		1,982		1999
79,125	41,925	21,477	63,402	142,527	80,453	63,402	143,855	1,328	1,328		1,328		2000
81,120	42,828	21,477	64,305	145,425	82,288	64,305	146,593	1,168	1,168		1,168		2001
82,033	43,367	22,650	66,017	148,050	83,192	66,017	149,209	1,158	1,158		1,158		2002
82,448	44,266	23,395	67,661	150,109	83,512	67,661	151,173	1,064	1,064		1,064		2003
82,928	45,182	23,395	68,557	151,483	83,877	68,557	152,434	951	951		951		2004
83,378	48,060	23,794	89,854	153,229	84,197	69,853	154,050	821	821		821		2005
83,641	46,957	23,794	70,751	154,392	84,335	70,751	155,086	894	694		894		2006
84,122	47,855	24,548	72,403	156,525	84,772	72,403	157,175	650	650		650		2007
84,712	48,753	24,548	73,301	158,012	85,376	73,300	158,676	664	664		664		2008
85,054	49,650	25,022	74,872	159,727	85,886	74,673	160,359	632	632		632		2009
85,128	50,548	25,032	75,580	160,708	85,692	75,580	161,272	564	564		564		2010
84,842	51,159	25,032	76,191	161,032	85,692	76,191	161,883	850	850		850		2011
82,688	51,768	25,032	76,800	159,488	85,874	76,800	162,874	3,186	3,186		3,186		2012
78,554	52,379	25,032	77,411	155,965	86,239	77,410	163,649	7,885	3,580	4,105	7,685		2013
73,433	52,988	25,442	78,430	151,863	86,421	78,430	164,851	12,988	3,435	9,553	12,988		2014
69,265	53,598	25,442	79,040	148,306	84,165	79,040	163,206	14,900	3,102	11,798	14,900		2015
65,678	54,208	25,442	79,651	145,329	79,221	79,651	158,872	13,543	2,888	10,855	13,543		2016
60,023	54,819	25,442	80,261	140,283	77,990	80,281	158,251	17,968	2,309	15,659	17,968		2017
53,839	55,429	25,442	80,871	134,709	77,050	80,871	157,921	23,212	1,760	21,452	23,212		2018
48,299	58,038	25,442	81,481	129,779	76,447	81,481	157,928	28,149	1,010	27,139	28,149		2019
44,807	56,649	25,442	82,091	126,898	76,311	82,091	158,402	31,504	60	1,712	1,772	$29,732	2020
41,979	58,649	25,442	82,091	124,070	40,418	82,091	122,509	—1,581				29,212	2021
40,790	58,649	25,442	82,091	122,881	39,319	82,091	121,409	—1,472				28,762	2022
39,809	56,649	25,442	82,091	121,900	37,515	82,091	119,606	—2,294				27,475	2023
38,911	56,649	25,442	82,091	121,002	36,681	82,091	118,752	—2,250				28,187	2024
38,424	56,649	25,442	82,091	120,515	38,222	82,091	118,313	—2,202				24,901	2025
38,295	56,649	25,442	82,091	120,385	36,105	82,091	118,196	—2,189				23,584	2026
37,419	56,649	25,442	82,091	119,509	35,332	82,091	117,423	—2,088				22,323	2027
35,039	56,849	25,442	82,091	117,129	33,222	82,091	115,313	—1,817				21,287	2028
32,321	56,649	25,442	82,091	114,412	30,782	82,091	112,873	—1,539				20,493	2029
28,955	56,649	25,442	82,091	111,046	27,740	82,091	109,831	—1,215				19,996	2030
25,346	58,649	25,442	82,091	107,437	24,493	82,091	106,584	—853				19,842	2031
23,456	58,649	25,442	82,091	105,547	21,356	82,091	103,446	—2,100				18,437	2032
22,579	58,649	25,442	82,091	104,669	20,557	82,091	102,647	—2,022				17,060	2033
21,788	58,649	25,442	82,091	103,859	19,822	82,091	101,913	—1,946				15,711	2034
20,992	58,649	25,442	82,091	103,083	19,112	82,091	101,203	—1,880				14,381	2035
20,087	56,649	25,442	82,091	102,178	18,288	82,091	100,379	—1,799				13,086	2036
19,471	56,649	25,442	82,091	101,581	17,727	82,091	99,818	—1,744				11,800	2037
18,966	56,649	25,442	82,091	101,057	17,267	82,091	99,358	—1,699				10,514	2038
17,260	56,849	25,442	82,091	99,350	15,714	82,091	97,805	—1,546				9,336	2039
14,025	56,649	25,442	82,091	96,115	12,769	82,091	94,859	—1,258				8,406	2040
12,086	56,649	25,442	82,091	94,177	11,004	82,091	93,094	—1,082				7,618	2041
11,411	56,649	25,442	82,091	93,502	10,389	82,091	92,480	—1,022				6,863	2042
10,811	56,649	25,442	82,091	92,902	9,843	82,091	91,934	—968				6,135	2043
10,101	56,649	25,442	82,091	92,192	9,197	82,091	91,288	—904				5,448	2044
9,362	56,649	25,442	82,091	91,453	8,524	82,091	90,615	—838				4,799	2045
8,759	58,649	25,442	82,091	90,850	7,974	82,091	90,065	—785				4,182	2046
8,277	56,649	25,442	82,091	90,368	7,538	82,091	89,627	—741				3,787	2047
7,905	58,649	25,442	82,091	89,996	7,199	82,091	89,290	—706				3,008	2048
7,557	56,849	25,442	82,091	89,648	6,881	82,091	88,972	—676				2,437	2049
6,554	56,849	25,442	82,091	88,645	5,967	82,091	88,058	—587				1,935	2050
4,540	56,649	25,442	82,091	86,630	4,132	82,091	86,223	—407				1,596	2051
3,546	56,649	25,442	82,091	85,637	3,229	82,091	85,320	—317				1,335	2052
3,195	56,649	25,442	82,091	85,285	2,908	82,091	84,999	—288				1,095	2053
2,794	56,849	25,442	82,091	84,885	2,544	82,091	84,635	—250				884	2054
2,443	56,849	25,442	82,091	84,533	2,223	82,091	84,314	—219				696	2055
2,292	56,649	25,442	82,091	84,382	2,070	82,091	84,161	—221				499	2056
1,811	56,849	25,442	82,091	83,902	1,849	82,091	83,740	—162				354	2057
1,148	56,849	25,442	82,091	83,239	1,045	82,091	83,138	—103				264	2058
807	56,649	25,442	82,091	82,898	735	82,091	82,826	—72				201	2059
801	56,649	25,442	82,091	82,892	729	82,091	82,820	—72				138	2060
801	58,649	25,442	82,091	82,892	729	82,091	82,820	—72				69	2061
801	58,649	25,442	82,091	82,892	547	82,091	82,838	—54				17	2062
200	66,649	25,442	82,091	82,291	182	82,091	82,273	—18				0	2063
0	58,649	25,442	82,091	82,091	0	82,091	82,091	0					2064
$4,167,000	$4,179,000	$2,079,000	$6,258,000	$10,415,000	$4,321,000	$6,241,000	$10,562,000	$147,000	$123,000	$183,000	$286,000		

TABLE 30—FINANCIAL ANALYSIS OF AQUEDUCT SYSTEM "C" * (values in thousands)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	Capital requirements								Debt status			Annual expense	
	Construction				For deficit in annual revenue							Debt service	
Year	Construction cost	Interest during construction	Annual	Cumulative	Required for year	Interest	Annual	Cumulative	Construction	Deficit in annual revenue	Total	Interest	Principal
1960	$4,575	$160	$4,735	$4,735					$4,735		$4,735	$166	
1961	17,521	613	18,134	22,869	$166		$166	$166	22,869	$166	23,035	800	
1962	61,200	2,142	63,342	86,211	800	$6	806	972	86,211	972	87,183	3,017	
1963	113,500	3,973	117,473	203,684	3,043	34	3,077	4,049	203,684	4,049	207,733	7,129	
1964	166,162	5,816	171,978	375,662	7,710	142	7,852	11,901	375,662	11,901	387,563	13,148	
1965	174,467	6,106	180,573	558,235	13,866	417	14,283	26,184	556,235	26,184	582,419	19,468	
1966	116,034	4,061	120,095	676,330	19,638	916	20,554	46,738	676,330	46,738	723,068	23,872	
1967	115,612	4,046	119,858	795,988	19,259	1,636	20,895	67,633	795,988	67,633	863,621	27,860	
1968	122,898	4,294	126,992	922,981	22,323	2,367	24,690	92,323	922,981	92,323	1,015,304	32,304	
1969	79,898	2,796	82,694	1,005,875	27,178	3,231	30,409	122,732	1,005,675	122,732	1,128,407	35,199	
1970	41,990	1,470	43,460	1,049,135	29,936	4,296	34,232	156,964	1,049,135	156,964	1,206,099	36,720	$56
1971	36,714	1,285	37,999	1,087,134	26,796	5,494	32,290	189,254	1,087,078	189,254	1,276,332	38,048	272
1972	40,044	1,402	41,446	1,128,580				189,254	1,128,251	181,552	1,309,803	39,489	1,031
1973	50,575	1,770	52,345	1,180,925				189,254	1,179,565	173,662	1,353,227	41,285	2,457
1974	64,649	2,263	66,912	1,247,836				189,254	1,244,020	166,605	1,410,625	43,541	4,577
1975	79,360	2,778	82,138	1,329,974				189,254	1,321,581	160,827	1,482,408	46,255	6,872
1976	74,274	2,600	76,874	1,408,848				189,254	1,391,582	154,994	1,546,576	48,705	8,533
1977	66,204	2,317	68,521	1,475,369				189,254	1,451,570	149,873	1,601,443	50,805	10,247
1978	46,895	1,641	48,536	1,523,905				189,254	1,489,859	145,532	1,635,391	52,145	12,108
1979	43,598	1,526	45,124	1,569,029				189,254	1,522,875	142,200	1,665,075	53,301	13,510
1980	72,099	2,523	74,822	1,643,651				189,254	1,583,988	139,417	1,723,405	55,440	14,497
1981	81,939	2,868	84,807	1,728,458				189,254	1,654,298	136,512	1,790,810	57,900	15,453
1982	39,650	1,388	41,038	1,769,496				189,254	1,679,882	133,159	1,813,041	58,796	16,485
1983	10,939	383	11,322	1,780,818				189,254	1,674,719	128,614	1,803,333	58,615	17,681
1984	21,684	759	22,443	1,803,261				189,254	1,679,482	124,443	1,803,925	58,782	19,091
1985	20,630	722	21,352	1,824,613				189,254	1,681,743	120,747	1,802,490	58,861	20,730
1986	16,432	575	17,007	1,841,620				189,254	1,678,020	117,729	1,795,749	58,731	22,365
1987	9,189	322	9,511	1,851,131				189,254	1,665,165	115,386	1,780,551	58,281	23,958
1988	5,380	188	5,568	1,856,699				189,254	1,646,775	113,697	1,760,472	57,637	25,371
1989	34,181	1,196	35,377	1,892,076				189,254	1,656,781	112,481	1,769,262	57,987	26,793
1990	70,040	2,451	72,491	1,964,568				189,254	1,702,480	111,487	1,813,967	59,587	28,613
1991	41,531	1,454	42,985	2,007,552				189,254	1,716,852	110,787	1,827,639	60,090	30,617
1992	13,090	458	13,548	2,021,100				189,254	1,699,783	110,738	1,810,520	59,492	32,174
1993	12,060	422	12,482	2,033,582		331	331	189,585	1,680,090	111,069	1,791,159	58,803	33,434
1994	14,910	522	15,432	2,049,014		381	381	189,966	1,662,088	111,450	1,773,538	58,173	34,870
1995	13,049	457	13,506	2,062,520		542	542	190,508	1,640,723	111,992	1,752,715	57,425	36,343
1996	8,100	284	8,384	2,070,904		710	710	191,218	1,612,764	112,702	1,725,466	56,447	37,816
1997	4,030	141	4,171	2,075,075		872	872	192,090	1,579,118	113,574	1,692,692	55,269	39,252
1998	2,050	72	2,122	2,077,196		983	983	193,073	1,541,988	114,557	1,656,545	53,970	40,692
1999	7,458	261	7,719	2,084,915		1,067	1,067	194,140	1,509,015	115,624	1,624,639	52,816	42,535
2000	5,366	188	5,554	2,090,469		1,464	1,464	195,604	1,472,034	117,088	1,589,122	51,521	44,881
2001	23,607	826	24,433	2,114,902		2,331	2,331	197,935	1,451,587	119,419	1,571,006	50,806	46,960
2002	37,470	1,311	38,711	2,153,684		2,734	2,734	200,669	1,443,408	122,153	1,565,561	50,519	48,764
2003	23,061	807	23,868	2,177,552		2,693	2,693	203,362	1,418,512	124,846	1,543,358	49,648	50,618
2004	5,800	196	5,796	2,183,348		2,753	2,753	206,115	1,373,690	127,599	1,501,289	48,079	52,572
2005	7,309	256	7,565	2,190,913		2,987	2,987	209,102	1,328,683	130,586	1,459,269	46,504	54,572
2006	5,919	207	6,126	2,197,039		3,195	3,195	212,297	1,280,237	133,781	1,414,018	44,808	56,581
2007	9,298	325	9,623	2,206,662		3,359	3,359	215,656	1,233,279	137,140	1,370,419	43,165	58,611
2008	9,850	345	10,195	2,216,857		3,454	3,454	219,110	1,184,863	140,594	1,325,457	41,470	60,687
2009	5,350	187	5,537	2,222,394		3,522	3,522	222,632	1,129,713	144,116	1,273,829	39,540	62,903
2010	280	10	290	2,222,684		3,694	3,694	226,326	1,067,100	147,810	1,214,910	37,348	64,948
2011				2,222,684		3,666	3,666	229,992	1,002,152	151,476	1,153,628	35,075	66,661
2012	3,720	130	3,850	2,226,534		3,234	3,234	233,226	939,341	154,710	1,094,051	32,877	66,487
2013	7,440	260	7,700	2,234,235		810	810	234,036	880,554	155,520	1,036,074	30,819	63,595
2014	3,700	130	3,830	2,238,064					820,788	151,080	971,868	28,728	57,837
2015									762,952	138,471	901,423	26,703	51,495
2016									711,457	119,373	830,830	24,901	47,746
2017									663,712	99,149	762,861	23,230	43,927
2018									619,784	73,996	693,780	21,692	39,638
2019									580,146	43,063	623,209	20,305	37,219
2020									542,927	7,830	550,757	19,002	36,490
2021									506,437	0	506,437	17,725	35,988
2022									470,449		470,449	16,466	35,352
2023									435,097		435,097	15,228	34,229
2024									400,868		400,868	14,030	32,339
2025									368,529		368,529	12,899	29,625
2026									338,904		338,904	11,862	27,062
2027									311,842		311,842	10,914	24,801
2028									287,041		287,041	10,046	23,396
2029									263,645		263,645	9,228	22,102
2030									241,544		241,544	8,454	19,381
2031									222,163		222,163	7,776	16,088
2032									206,076		206,076	7,213	14,729
2033									191,346		191,346	6,697	14,714
2034									176,632		176,632	6,162	14,179
2035									162,453		162,453	5,686	13,675
2036									148,778		148,778	5,207	13,357
2037									135,421		135,421	4,740	13,379
2038									122,042		122,042	4,271	13,587
2039									108,455		108,455	3,796	12,406
2040									96,049		96,049	3,362	9,445
2041									86,604		86,604	3,031	7,763
2042									78,841		78,841	2,759	7,400
2043									71,441		71,441	2,500	7,075
2044									64,366		64,366	2,253	6,600
2045									57,766		57,766	2,022	8,198
2046									51,567		51,567	1,805	6,023
2047									45,544		45,544	1,594	6,038
2048									39,506		39,506	1,383	6,150
2049									33,356		33,356	1,167	6,004
2050									27,352		27,352	957	5,954
2051									21,398		21,398	748	5,019
2052									16,379		16,379	573	3,378
2053									13,001		13,001	455	2,379
2054									10,622		10,622	371	2,191
2055									8,431		8,431	295	1,913
2056									6,518		6,518	228	1,693
2057									4,825		4,825	189	1,302
2058									3,523		3,523	123	870
2059									2,653		2,653	93	641
2060									2,012		2,012	70	650
2061									1,362		1,362	47	673
2062									689		689	24	516
2063									173		173	6	173
2064									0		0	0	0
Totals	$2,162,000	$76,000	$2,238,000		$171,000	$63,000	$234,000					$2,737,000	$2,238,000

* *Values reflect "steam-electric" and "steam-drive and feedback" operation.*

TABLE 30—FINANCIAL ANALYSIS OF AQUEDUCT SYSTEM "C" * (values in thousands)—Continued

(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)
Annual expense					Revenue received from service areas			Difference between revenue and annual expense	Application of excess revenue toward repayment of deficit			Value of invested revenue	Year
Debt service	Annual operating cost												
Subtotal	Net pumping cost	Oper. main. replacements, gen. expenses	Subtotal	Total	For debt service	For operating expenses	Total		To interest	To principal	Total		
$166				$166				$—166					1960
800				800				—800					1961
3,017				3,017				—3,017					1962
7,129		$26	$26	7,155				—7,155					1963
13,148		581	581	13,729				—13,729					1964
19,468	$34	864	898	20,366	$2,319	$180	$2,499	—17,867					1965
23,672	126	3,302	3,428	27,100	7,412	939	8,351	—18,749					1966
27,860	264	3,902	4,166	32,025	8,680	1,167	9,847	—22,178					1967
32,304	364	4,047	4,411	36,715	9,606	1,268	10,874	—25,841					1968
35,190	465	6,160	6,625	41,823	10,196	2,145	12,341	—29,482					1969
36,776	425	6,785	7,210	43,986	10,326	2,277	12,603	—31,383					1970
38,320	1,819	6,861	8,680	47,000	52,944	8,334	61,278	14,278	$6,624	$7,702	$14,326		1971
40,520	2,906	8,300	11,206	51,726	55,062	10,908	65,970	14,244	6,354	7,890	14,244		1972
43,741	4,000	8,300	12,300	56,041	57,178	12,002	69,180	13,139	6,078	7,057	13,135		1973
48,117	5,142	9,397	14,539	62,656	59,854	14,237	74,091	11,435	5,831	5,778	11,609		1974
53,128	6,950	10,044	16,994	70,122	64,718	16,869	81,587	11,469	5,629	5,833	11,462		1975
57,239	8,144	11,560	19,704	76,943	67,940	19,576	87,516	10,573	5,425	5,121	10,546		1976
61,052	9,338	12,177	21,515	82,567	70,807	21,360	92,167	9,600	5,246	4,341	9,587		1977
64,253	10,530	13,262	23,792	88,045	72,849	23,624	96,473	8,428	5,094	3,332	8,426		1978
66,810	11,724	13,399	25,123	91,933	74,759	24,953	99,712	7,779	4,977	2,783	7,760		1979
69,936	12,917	14,085	27,002	96,938	77,913	26,813	104,726	7,788	4,880	2,905	7,785		1980
73,354	13,887	14,271	28,158	101,511	81,487	27,966	109,453	7,942	4,780	3,353	8,133		1981
75,280	16,459	15,869	32,328	107,609	84,485	32,328	116,813	9,204	4,660	4,545	9,205		1982
76,296	17,805	16,881	34,686	110,982	84,968	34,686	119,654	8,672	4,501	4,171	8,672		1983
77,873	19,194	16,881	36,075	113,947	85,924	36,075	121,999	8,052	4,356	3,696	8,052		1984
79,591	20,583	17,720	38,303	117,895	86,836	38,303	125,139	7,244	4,226	3,018	7,244		1985
81,096	21,973	17,840	39,813	120,909	87,560	39,813	127,373	6,464	4,121	2,343	6,464		1986
82,239	23,372	19,772	43,144	125,383	87,966	43,144	131,110	5,727	4,038	1,689	5,727		1987
83,008	24,762	19,772	44,534	127,542	88,203	44,534	132,737	5,195	3,979	1,216	5,195		1988
84,780	26,147	19,967	46,114	130,894	89,714	46,114	135,825	4,931	3,937	994	4,931		1989
88,200	27,542	19,967	47,509	135,709	92,802	47,509	140,311	4,602	3,902	700	4,602		1990
90,707	28,835	21,438	50,273	140,980	94,634	50,273	144,907	3,927	3,878	49	3,927		1991
91,667	30,128	21,438	51,566	143,232	95,211	51,566	146,777	3,545	3,545		3,545		1992
92,238	31,290	22,642	53,932	146,170	95,744	53,932	149,676	3,506	3,506		3,506		1993
93,043	32,578	22,642	55,220	148,263	96,402	55,220	151,622	3,359	3,359		3,359		1994
93,768	33,865	23,874	57,739	151,507	96,978	57,739	154,717	3,210	3,210		3,210		1995
94,263	35,152	23,874	59,026	153,289	97,335	59,026	156,361	3,072	3,072		3,072		1996
94,521	36,441	24,274	60,715	155,236	97,513	60,715	158,228	2,992	2,992		2,992		1997
94,662	37,635	24,274	61,909	156,570	97,603	61,909	159,512	2,942	2,942		2,942		1998
95,350	38,783	24,274	63,057	158,407	97,933	63,057	160,990	2,583	2,583		2,583		1999
96,402	39,933	24,427	64,360	160,762	98,169	64,360	162,529	1,767	1,767		1,767		2000
97,765	40,819	24,427	65,246	163,011	99,211	65,246	164,457	1,446	1,446		1,446		2001
99,283	41,336	24,562	65,898	165,181	100,865	65,898	166,763	1,582	1,582		1,582		2002
100,266	42,216	26,385	68,601	168,867	101,882	68,601	170,483	1,616	1,616		1,616		2003
100,651	43,097	26,385	69,482	170,133	102,130	69,482	171,612	1,479	1,479		1,479		2004
101,076	43,977	26,655	70,632	171,708	102,452	70,632	173,084	1,376	1,376		1,376		2005
101,390	44,858	26,655	71,513	172,902	102,712	71,513	174,225	1,323	1,323		1,323		2006
101,776	45,739	27,513	73,252	175,027	103,122	73,252	176,374	1,346	1,346		1,346		2007
102,158	46,619	27,519	74,138	176,296	103,567	74,138	177,695	1,399	1,399		1,399		2008
102,443	47,500	27,869	75,369	177,812	103,793	75,369	179,162	1,350	1,350		1,350		2009
102,297	48,381	27,888	76,269	178,565	103,805	76,269	180,074	1,508	1,508		1,508		2010
101,737	48,972	27,888	76,860	178,596	103,805	76,860	180,665	2,068	2,068		2,068		2011
99,364	49,563	27,888	77,451	176,815	103,969	77,451	181,420	4,605	4,605		4,605		2012
94,415	50,154	27,888	78,042	172,457	104,298	78,042	182,340	9,883	5,443	4,440	9,883		2013
86,564	50,745	28,268	79,013	165,577	104,461	79,013	183,474	17,897	5,288	12,609	17,897		2014
78,198	51,336	28,268	79,604	157,802	102,142	79,604	181,746	23,944	4,846	19,098	23,944		2015
72,647	51,927	28,268	80,195	152,842	97,050	80,195	177,245	24,402	4,178	20,224	24,402		2016
67,157	52,518	28,268	80,786	147,943	95,780	80,786	176,566	28,623	3,470	25,153	28,623		2017
61,331	53,110	28,268	81,378	142,709	94,854	81,378	176,232	33,523	2,590	30,933	33,523		2018
57,524	53,701	28,268	81,969	139,493	94,264	81,969	176,233	36,740	1,507	35,233	36,740		2019
55,492	54,292	28,268	82,560	138,052	94,135	82,560	176,695	38,643	274	7,830	8,104	$30,539	2020
53,713	54,292	28,268	82,560	136,273	51,517	82,560	134,077	—2,196				29,412	2021
51,818	54,292	28,268	82,560	134,378	49,399	82,560	131,959	—2,419				28,022	2022
49,458	54,292	28,268	82,560	132,018	47,283	82,560	129,843	—2,175				26,828	2023
46,370	54,292	28,268	82,560	128,930	44,607	82,560	127,167	—1,763				26,004	2024
42,523	54,292	28,268	82,560	125,083	39,742	82,560	122,302	—2,781				24,133	2025
38,924	54,292	28,268	82,560	121,484	36,521	82,560	119,081	—2,403				22,575	2026
35,715	54,292	28,268	82,560	118,275	33,654	82,560	116,214	—2,061				21,304	2027
33,442	54,292	28,268	82,560	116,002	31,612	82,560	114,172	—1,830				20,219	2028
31,329	54,292	28,268	82,560	113,889	29,702	82,560	112,262	—1,627				19,300	2029
27,835	54,292	28,268	82,560	110,395	26,548	82,560	109,108	—1,287				18,688	2030
23,863	54,292	28,268	82,560	106,423	22,975	82,560	105,535	—888				18,455	2031
21,942	54,292	28,268	82,560	104,502	19,977	82,560	102,537	—1,965				17,136	2032
21,412	54,292	28,268	82,560	103,972	19,494	82,560	102,054	—1,918				15,817	2033
20,361	54,292	28,268	82,560	102,921	18,537	82,560	101,097	—1,824				14,547	2034
19,361	54,292	28,268	82,560	101,921	17,627	82,560	100,187	—1,734				13,322	2035
18,564	54,292	28,268	82,560	101,124	16,902	82,560	99,462	—1,662				12,126	2036
18,119	54,292	28,268	82,560	100,679	16,496	82,560	99,056	—1,623				10,928	2037
17,858	54,292	28,268	82,560	100,418	16,259	82,560	98,819	—1,599				9,711	2038
16,202	54,292	28,268	82,560	98,762	14,751	82,560	97,311	—1,451				8,600	2039
12,807	54,292	28,268	82,560	95,367	11,660	82,560	94,220	—1,147				7,754	2040
10,794	54,292	28,268	82,560	93,354	9,828	82,560	92,388	—966				7,059	2041
10,160	54,292	28,268	82,560	92,720	9,250	82,560	91,810	—910				6,396	2042
9,575	54,292	28,268	82,560	92,135	8,718	82,560	91,278	—857				5,763	2043
8,853	54,292	28,268	82,560	91,413	8,060	82,560	90,620	—793				5,172	2044
8,220	54,292	28,268	82,560	90,780	7,484	82,560	90,044	—736				4,617	2045
7,828	54,292	28,268	82,560	90,388	7,127	82,560	89,687	—701				4,078	2046
7,632	54,292	28,268	82,560	90,192	6,949	82,560	89,509	—683				3,537	2047
7,533	54,292	28,268	82,560	90,093	6,858	82,560	89,418	—675				2,986	2048
7,172	54,292	28,268	82,560	89,732	6,529	82,560	89,089	—643				2,448	2049
6,911	54,292	28,268	82,560	89,471	6,292	82,560	88,852	—619				1,914	2050
5,767	54,292	28,268	82,560	88,327	5,251	82,560	87,811	—516				1,465	2051
3,951	54,292	28,268	82,560	86,511	3,598	82,560	86,158	—354				1,163	2052
2,834	54,292	28,268	82,560	85,394	2,581	82,560	85,141	—254				949	2053
2,562	54,292	28,268	82,560	85,122	2,333	82,560	84,893	—229				754	2054
2,208	54,292	28,268	82,560	84,768	2,010	82,560	84,570	—198				582	2055
1,921	54,292	28,268	82,560	84,481	1,749	82,560	84,309	—172				430	2056
1,470	54,292	28,268	82,560	84,030	1,339	82,560	83,899	—131				314	2057
993	54,292	28,268	82,560	83,553	904	82,560	83,464	—89				236	2058
734	54,292	28,268	82,560	83,294	668	82,560	83,228	—66				179	2059
720	54,292	28,268	82,560	83,280	656	82,560	83,216	—64				121	2060
720	54,292	28,268	82,560	83,280	656	82,560	83,216	—64				61	2061
540	54,292	28,268	82,560	83,100	492	82,560	83,052	—48				15	2062
179	54,292	28,268	82,560	82,739	163	82,560	82,723	—16				0	2063
0	54,292	28,268	82,560	82,560	0	82,560	82,560	0					2064
$4,975,000	$3,981,000	$2,337,000	$6,318,000	$11,293,000	$5,223,000	$6,296,000	$11,519,000	$226,000	$178,000	$234,000	$412,000		

TABLE 31

SUMMARY OF FINANCIAL ANALYSES OF ALTERNATIVE AQUEDUCT SYSTEMS[a, b, c]

Service area	Aqueduct System								
	"A"			"B"			"C"		
	Allocated capital cost, in millions of dollars	Equivalent annual costs[d]		Allocated capital cost, in millions of dollars	Equivalent annual costs[d]		Allocated capital cost, in millions of dollars	Equivalent annual costs[d]	
		In millions of dollars	In dollars per acre-foot		In millions of dollars	In dollars per acre-foot		In millions of dollars	In dollars per acre-foot
Delta to Avenal Gap	$109.0	$5.5	$12	$109.0	$5.5	$12	$109.0	$5.5	$12
Kern County									
Upper Antelope Plain	52.1	2.6	16	59.2	3.0	19	55.2	2.8	18
Avenal Gap to Pumping Plant In-III	84.2	4.4	11	78.9	4.2	10	80.1	4.3	11
Pumping Plant In-III to Pumping Plant In-IV	86.9	4.4	19	74.5	3.7	16	77.6	3.8	16
Pumping Plant In-IV to Pumping Plant In-VI	20.5	1.1	35	16.9	0.9	24	17.6	0.9	25
San Luis Obispo	10.4	0.4	27	20.5	0.7	51	11.7	0.5	34
Santa Barbara	48.1	1.9	28	78.8	2.7	49	57.3	2.5	38
Ventura County	114.0	3.7	55	81.6	3.4	50	140.3	6.3	80
Antelope-Mojave	89.8	5.0	56	56.2	3.4	38	58.0	3.3	38
Whitewater-Coachella	45.2	2.2	77	29.9	1.5	52	30.9	1.5	50
Southern California									
Coastal Plain and Coastal San Diego County	1,700.5	57.0	51	1,201.3	48.9	44	1,524.7	58.0	52
Totals	$2,360.7	$88.2	[e]$33	$1,806.8	$77.9	[e]$29	$2,162.4	$88.4	[e]$33

[a] Values reflect "steam-electric" or "steam-drive and feedback" operation.
[b] Does not include estimated Federal expenditure of about $100,000 in the San Luis Unit.
[c] Reflects cost of main aqueduct only; does not include local conveyance and distribution facilities.
[d] Reflects a one dollar per acre-foot cost of water in the Delta.
[e] Weighted average.

TABLE 32

COMPARISON OF AQUEDUCT SYSTEMS "B" AND "C" WITH ALTERNATIVE OPERATIONAL SCHEMES[a]

Aqueduct system	Off-peak electric and feedback			Steam-electric or steam-drive and feedback		
	Capital cost in millions of dollars	Equivalent annual costs		Capital cost in millions of dollars	Equivalent annual costs	
		in millions of dollars	In dollars per acre-foot		In millions of dollars	In dollars per acre-foot
"B"	$1,523	$59	$27	$1,298	$51	$23
"C"	1,872	66	30	1,653	61	28

[a] Values reflect costs south of Avenal Gap only.

Net Benefits. Determination of net benefits or benefits in excess of costs provides a measure of the increase in economic value produced by successively larger projects and is also useful in comparing alternative locations of project facilities.

Net Benefit-Investment Ratio. This relationship expresses a measure of return on the investment and is useful in comparing alternative locations of project facilities of the same size, but like the benefit-cost ratio does not fully evaluate the worth of increasing the size of a given project.

Unit Cost of Water. Determination of the unit cost of water, giving consideration to all costs associated in delivering the supply to the ultimate consumer, is useful in comparing alternative locations of project facilities of the same size and providing comparable water service. However, application of this criterion alone is not feasible if comparable water service is not provided either with respect to system location or capacity.

Each of the foregoing relationships was developed as an aid in aqueduct system evaluation and selection. Since each system would provide essentially equivalent water service, the relationships reflect the difference in cost of accomplishing this service.

In addition, certain other economic relationships were developed for purposes of comparing the alternative aqueduct systems.

The question of the high pump lift on the inland aqueduct route has been a subject of controversy for several years. Comparisons were therefore made of the systems with respect to net fuel consumption for pumping, using several assumed costs of fuel oil. Also prepared were comparisons of costs of the alternative systems on a "perpetual life" basis, i.e., capitalization of all costs including recurring annual costs in perpetuity.

Benefits

Estimates of the value of benefits that would be derived from service of surplus northern California water in the southern California area were made for both irrigated agriculture and municipal and industrial uses. The values so derived are for primary benefits although it is recognized that secondary and intangible benefits do result from projects of this nature and in some instances could be of a substantial magnitude. However, in the interest of conservatism, only primary benefits were estimated, which results in possible understatement of the project's accomplishments.

Irrigated Agriculture. The measure of primary benefits to lands which would be irrigated with surplus northern California water was the difference between net returns from farming operations with and without the availability of this water. The net return from farming operations, as used herein, is defined as the difference between gross income and all farm expenses, except water costs and either land rental or interest on capital invested in the land.

Tables 33 and 34 set forth by aqueduct systems for the period of analysis the value of the average primary unit irrigation benefits that would be derived from the availability and use of surplus northern California water in each service area.

This summary of benefits indicates that the greatest unit benefit to irrigated agriculture would occur in the Southern California Coastal Plain and Coastal San Diego County Service Area, with the least unit benefit occurring in portions of the Kern County Service Area. This reflects the difference in the value of crops grown in the two areas.

It will also be noted that unit benefits in certain service areas would be the greatest for the aqueduct systems delivering the least amounts of water and at the highest unit costs. This results from the elimination of lower value crops from water service.

In addition to the foregoing benefits, in those areas where irrigated agriculture is now supported by ground water overdraft with resultant progressive declines in ground water elevations, qualitative consideration was also given to the "rescue" effects of northern California water on sustaining the then existing economy and the incomes dependent thereon. The analysis of these rescue effects was limited to such agricultural areas as the Oxnard Plain of Ventura County, the Maricopa-Wheeler Ridge area in Kern County, and the Santa Maria Valley of Santa Barbara County. With the introduction of imported water, these areas would be rescued from the loss of economic development because of either recession of the water table to uneconomic pumping depths, or by sea-water intrusion in coastal areas.

Although benefits to agriculture in these rescue areas were not assessed quantitatively, it is apparent that the actual benefit of importing surplus northern California water thereto would be greater than shown.

TABLE 33

ESTIMATED AVERAGE PRIMARY UNIT BENEFITS FOR IRRIGATED AGRICULTURE FOR AQUEDUCT SYSTEMS "A" AND "C"

(In dollars per acre-foot)

Service area	1965	1970	1980	1990	2000	2010	2020 to 2065
Delta to Avenal Gap	$35	$35	$35	$35	$35	$35	$35
Kern County							
Upper Antelope Plain	50	50	50	50	50	50	50
Avenal Gap to Pumping Plant In-III	45	45	45	45	45	45	45
Pumping Plant In-III to Pumping Plant In-IV	60	60	60	60	60	60	60
Pumping Plant In-IV to Pumping Plant In-VI	69	69	69	69	69	69	69
San Luis Obispo	----	58	58	60	59	53	54
Santa Barbara	----	74	74	77	88	103	104
Ventura County	----	104	104	103	104	104	----
Antelope-Mojave	----	----	----	----	----	----	----
Whitewater-Coachella	----	----	----	----	----	----	----
Southern California Coastal Plain and Coastal San Diego County	----	147	147	150	150	150	144

TABLE 34

ESTIMATED AVERAGE PRIMARY UNIT BENEFITS FOR IRRIGATED AGRICULTURE FOR AQUEDUCT SYSTEM "B"

(In dollars per acre-foot)

Service area	1965	1970	1980	1990	2000	2010	2020 to 2065
Delta to Avenal Gap	$35	$35	$35	$35	$35	$35	$35
Kern County							
Upper Antelope Plain	50	50	50	50	50	50	50
Avenal Gap to Pumping Plant In-III	45	45	45	45	45	45	45
Pumping Plant In-III to Pumping Plant In-IV	60	60	60	60	60	60	60
Pumping Plant In-IV to Pumping Plant In-VI	69	69	69	69	69	69	69
San Luis Obispo	----	64	64	62	59	53	54
Santa Barbara	----	77	77	79	89	111	114
Ventura County	----	104	104	103	104	104	----
Antelope-Mojave	----	----	----	----	----	----	----
Whitewater-Coachella	----	----	----	----	----	----	----
Southern California Coastal Plain and Coastal San Diego County	----	147	147	150	150	150	144

Municipal and Industrial. It is recognized that the benefits derived from delivery of supplemental water to a metropolitan area, which thereby permits future growth of that area or sustains an existing economy, are extremely great and substantially in excess of the benefits that would be obtained from water service to irrigated agriculture. With respect to the southern portion of the State, it is certain that, without the introduction of surplus northern California water, the growth of this area necessarily would be severely inhibited; and it is probable that economic loss to the existing development would finally be experienced. Even though these conditions are recognized, a quantitative determination of municipal and industrial benefits is difficult to make with any degree of exactness.

An evaluation of primary benefits to municipal and industrial entities through the introduction of surplus northern California water into the southern California area in the manner described for irrigated agriculture was deemed impracticable. It would require prognostication, for many years in the future, of economic values resulting from increased income, increases in land values, etc., which it will be recognized would have little reliability.

The measure of municipal and industrial benefits selected was the estimated cost of water from the least costly alternative source. By this method, alternative sources of water supply which could be considered must (1) be practicable, (2) provide water at a cost within the ability of water users to pay, and (3) be capable of supplying an equivalent amount of water to that available from northern California. In Chapter II, possible alternative sources of water supply to southern California were discussed. It was concluded that there is no practical alternative, which is competitive in cost and of comparable magnitude, to surplus northern California water.

For purposes of the analyses, a unit value for the primary municipal and industrial benefit of $150 per acre-foot was selected. This represents a cost somewhat less than the presently estimated minimum future cost of demineralizing ocean water. It is believed that could ocean water be converted for beneficial use at this cost, it would be within most municipal and industrial users' payment capacity.

This value was used for determining the municipal and industrial benefits in the coastal counties of San Luis Obispo, Santa Barbara and Ventura; in the southern California coastal plain and coastal San Diego County; and in the Antelope-Mojave and Whitewater-Coachella Service Areas. For the San Joaquin Valley and in particular the metropolitan area of Bakersfield, inasmuch as no practicable alternative exists for municipal and industrial water supply in this area, a primary benefit was assumed that was equal to the maximum irrigated agricultural benefit, or $69 per acre-foot. It was assumed that the benefit would be measured at the point of delivery from the local distribution facilities, as outlined in Chapter VI, for each service area. This differs from the estimates for irrigated agriculture, where the benefit at the point of delivery to the ultimate consumer was derived.

Costs

The costs utilized in the benefit-cost analyses are all costs associated in delivering water to the service areas including both those of the main aqueduct facilities as well as the primary local conveyance and distribution facilities. In the case of irrigated agriculture, the secondary facilities required to deliver water to the farmer's headgate are also included since, as stated, the benefit was measured at this point.

In addition to the capital costs of the facilities, all computed interest charges and costs of operation, maintenance, replacement, and general expense for the main aqueduct system, and for the conveyance and distribution systems within the service areas, as set forth in Chapter VI, were utilized. A cost of $1.00 per acre-foot for water in the Delta was utilized for the purposes of these analyses. For municipal and industrial water supplies, the estimated unit costs of treatment, as set forth in Chapter III, were included.

System "A"

Presented in Table 35 are the summary results of the economic analyses of Aqueduct System "A", with the "steam-electric and feedback" scheme of operation. It may be noted in this table that not only does the entire system exhibit economic justification in that benefits derived exceed costs, but also service to each area is demonstrated to be economically justified for the same reason.

The capitalized value in perpetuity of all costs of Aqueduct System "A", including those associated with local conveyance and distribution would be 3,816 million dollars.

Equivalent annual fuel oil consumption for this system south of Avenal Gap, including that consumed in local conveyance and distribution facilities, would be 8.03 million barrels or about 2.33 barrels per acre-foot.

System "B"

Presented in Table 36 are the summary results of the economic analyses of Aqueduct System "B", with the "steam-drive and feedback" scheme of operation. As in System "A", not only does the entire system exhibit economic justification in that benefits derived exceed costs, but also service to each area is demonstrated to be economically justified.

The capitalized value in perpetuity of all costs of Aqueduct System "B", including those associated with local conveyance and distribution would be 3,236 million dollars.

TABLE 35

SUMMARY OF THE ECONOMIC ANALYSES OF AQUEDUCT SYSTEM "A" [a]

(In millions of dollars)

Service area	Present worth of costs							Present worth of primary benefits			Benefit-cost ratio	Benefits in excess of costs (net benefits)	Net benefit-investment ratio	Total unit cost of water in service area [b]
	Main aqueduct			Local conveyance facilities			Total							
	Capital investment costs	Operating costs	Subtotal	Capital investment costs	Operating costs	Subtotal		Irrigated agri-culture	Municipal and industrial	Total				
Delta to Avenal Gap [c]	$98.0	$54.5	$152.5	$107.3	$28.0	$135.3	$287.8	$469.8	----	$469.8	1.63	$182.0	0.89	$22
Kern County														
Upper Antelope Plain	40.8	30.3	71.1	29.6	30.4	60.0	131.1	225.5	----	225.5	1.72	94.4	1.34	29
Avenal Gap to Pumping Plant In-III	79.9	43.2	123.1	35.0	12.4	47.4	170.5	498.9	----	498.9	2.93	328.4	2.86	16
Pumping Plant In-III to Pumping Plant In-IV	76.4	46.0	122.4	28.8	61.3	90.1	212.5	205.1	$220.6	425.7	2.00	213.2	2.03	[d]32
Pumping Plant In-IV to Pumping Plant In-VI	16.8	14.7	31.5	4.5	2.4	6.9	38.4	63.4	----	63.4	1.65	25.0	1.17	42
Subtotals	$213.9	$134.2	$348.1	$97.9	$106.5	$204.4	$552.5	$992.9	$220.6	$1,213.5	2.20	$661.0	2.12	----
San Luis Obispo	7.3	4.4	11.7	5.4	3.6	9.0	20.7	12.0	33.6	45.6	2.20	24.9	1.96	48
Santa Barbara	33.1	19.4	52.5	13.4	16.5	29.9	82.4	78.5	143.8	222.3	2.70	139.9	3.01	44
Ventura County	74.0	29.6	103.6	2.0	12.1	14.1	117.7	18.2	255.5	273.7	2.33	156.0	2.05	63
Subtotals	$114.4	$53.4	$167.8	$20.8	$32.2	$53.0	$220.8	$108.7	$432.9	$541.6	2.45	$320.8	2.37	----
Antelope-Mojave	67.9	70.3	138.2	21.9	18.9	40.8	179.0	----	370.9	370.9	2.07	191.9	2.14	73
Whitewater-Coachella	33.8	27.7	61.5	22.2	11.8	34.0	95.5	----	121.4	121.4	1.27	25.9	0.46	120
Southern California Coastal Plain and Coastal San Diego County	1,061.0	521.8	1,582.8	428.9	367.0	795.9	2,378.7	419.0	4,198.0	4,617.0	1.94	2,238.3	1.50	77
Totals for system	$1,589.0	$861.9	$2,450.9	$699.0	$564.4	$1,263.4	$3,714.3	$1,990.4	$5,343.8	$7,334.2	1.97	$3,619.9	1.58	[e]50

[a] Values reflect "steam-electric and feedback" operation.
[b] In dollars per acre-foot, including a one dollar per acre-foot cost in the Delta.
[c] Does not include estimated Federal expenditures of about $100,000,000 in facilities for the San Luis service area.
[d] Average cost of water to agriculture is $28 per acre-foot; urban water costs would be higher because of longer conveyance facilities and filtration costs.
[e] Weighted average.

TABLE 36

SUMMARY OF THE ECONOMIC ANALYSIS OF AQUEDUCT SYSTEM "B" [a]

(In millions of dollars)

Service area	Present worth of costs							Present worth of primary benefits			Benefit-cost ratio	Benefits in excess of costs (net benefits)	Net benefit-investment ratio	Total unit cost of water in service area [b]
	Main aqueduct			Local conveyance facilitiea			Total							
	Capital investment costs	Operating costs	Subtotal	Capital investment costs	Operating costs	Subtotal		Irrigated agri-culture	Municipal and industrial	Total				
Delta to Avenal Gap [c]	$98.0	$54.5	$152.5	$107.3	$28.0	$135.3	$287.8	$469.8	----	$469.8	1.63	$182.0	0.89	$22
Kern County														
Upper Antelope Plain	48.0	35.8	83.8	29.6	30.4	60.0	143.8	225.5	----	225.5	1.57	81.7	1.05	32
Avenal Gap to Pumping Plant In-III	75.3	42.5	117.8	35.0	12.4	47.4	165.2	516.7	----	516.7	3.13	351.5	3.19	15
Pumping Plant In-III to Pumping Plant In-IV	63.4	39.9	103.3	28.8	61.3	90.1	193.4	206.9	$220.6	427.5	2.21	234.1	2.54	[d]29
Pumping Plant In-IV to Pumping Plant In-VI	12.2	11.8	24.0	4.5	2.4	6.9	30.9	67.8	----	67.8	2.19	36.9	2.21	31
Subtotals	$198.9	$130.0	$328.9	$97.9	$106.5	$204.4	$533.3	$1,016.9	$220.6	$1,237.5	2.32	$704.2	2.37	----
San Luis Obispo	14.5	5.7	20.2	5.2	3.3	8.5	28.7	10.2	33.6	43.8	1.53	15.1	0.77	73
Santa Barbara	54.6	19.6	74.2	25.5	22.4	47.9	122.1	50.1	144.0	194.1	1.59	72.0	0.90	81
Ventura County	56.2	37.7	93.9	26.2	13.4	39.6	133.5	18.2	255.4	273.6	2.05	140.1	1.70	71
Subtotals	$125.3	$63.0	$188.3	$56.9	$39.1	$96.0	$284.3	$78.5	$433.0	$511.5	1.80	$227.2	1.25	----
Antelope-Mojave	36.5	58.4	94.9	19.4	18.4	37.8	132.7	----	373.2	373.2	2.81	240.5	4.30	53
Whitewater-Coachella	18.6	23.1	41.7	16.1	6.4	22.5	64.2	----	121.4	121.4	1.89	57.2	1.65	79
Southern California Coastal Plain and Coastal San Diego County	748.3	611.6	1,359.9	217.4	257.6	475.0	1,834.9	419.0	4,198.0	4,617.0	2.52	2,782.1	2.88	60
Totals for system	$1,255.6	$940.6	$2,166.2	$515.0	$456.0	$971.0	$3,137.2	$1,984.2	$5,346.2	$7,330.4	2.34	$4,193.2	2.41	[e]42

[a] Values reflect "steam-drive and feedback" operation.

[b] In dollars per acre-foot, including a one dollar per acre-foot cost in the Delta.

[c] Does not include estimated Federal expenditures of about $100,000,000 in facilities for the San Luis service area.

[d] Average cost of water to agriculture is $26 per acre-foot; urban water costs would be higher because of longer conveyance facilities and filtration costs.

[e] Weighted average.

Equivalent annual fuel oil consumption for this system south of Avenal Gap, including that consumed in local conveyance and distribution facilities, would be 9.35 million barrels or about 2.71 barrels per acre-foot.

System "C"

Presented in Table 37 are the summary results of the economic analyses of Aqueduct System "C", with the "steam-electric" and "steam-drive and feedback" schemes of operation. As in Systems "A" and "B", the entire system exhibits economic justification as well as service to each area.

The capitalized value in perpetuity of all costs of Aqueduct System "C", including those associated with local conveyance and distribution would be 3,498 million dollars.

Equivalent annual fuel oil consumption for this system south of Avenal Gap, including that consumed in local conveyance and distribution systems, would be 8.67 million barrels or about 2.51 barrels per acre-foot.

FINANCIAL AND ECONOMIC COMPARISON OF ALTERNATIVE AQUEDUCT SYSTEMS

From the foregoing financial and economic analyses of alternative aqueduct systems, their relative costs and accomplishments can be compared. Under the criteria of evaluation employed, each of the systems has been demonstrated to be financially feasible and economically justified. Further, it has been shown earlier in this report that each of these systems would also be feasible of construction from a physical standpoint. Summarized in Table 38, for comparative purposes, are the various financial and economic considerations bearing upon the selection of the optimum aqueduct system from among these alternatives. Certain of these factors are discussed in the ensuing paragraphs.

Water Service

All three systems would provide nearly equivalent water service but, as shown in Table 38, at differing costs in the various service areas. With the construction of System "C", there would be a delay in water service to the desert area as compared to the other two systems. System "A" would delay introduction of the better quality northern California water into the Upper Santa Ana Valley and coastal San Diego County and, as has been demonstrated, would cause a substantial economic burden in these areas with possible destruction of the utility of ground water basins in the Upper Santa Ana Valley.

Systems "A" and "C", which would convey water to the southern California coastal plain via a coastal route, would thereby deliver water at a lesser cost to San Luis Obispo and Santa Barbara Service Areas than System "B". This condition is reflected in somewhat greater deliveries of water to these service areas under the former two systems. This additional water delivery would be used on agricultural lands which do not now exhibit sufficient payment capacity to have an economic demand for water delivered under System "B".

Conversely, a more rapid build-up in water demand is postulated in the San Joaquin Valley under System "B" than under System "A" and, to some extent, System "C" because of the difference in estimated costs of water.

Costs

System "B" would have a lesser total capital cost and cost of initial sequence of construction than either of the other two systems. Further, the total average annual cost, including costs of local conveyance and distribution facilities, would be less for System "B" than for either of the other two.

A similar relationship exists with respect to the unit cost of water. The over-all unit cost of water under System "B", either delivered at the aqueduct or within the service areas, would be less than for Systems "A" and "C". It has been shown earlier in this chapter that the foregoing relationship would exist whether an operational scheme employing a concept of purchased energy for pumping or one employing a scheme independent of utility participation were adopted. Thus it may be concluded that aqueduct system selection is independent of operational scheme employed.

Further, it will be noted that the total capitalized value of all costs in perpetuity, for the main aqueduct and local conveyance and distribution facilities, including recurring annual costs for pumping, would be greater for Systems "A" and "C" than for System "B".

Economic Relationships

As shown in Table 38, System "B" exhibits the highest benefit-cost and net benefit-investment ratios.

Although Systems "A" and "C" would produce slightly greater total benefits than System "B" because of service of greater amounts of irrigation water in San Luis Obispo and Santa Barbara Service Areas, the net benefits or benefits in excess of costs would be greatest for Aqueduct System "B". However, as shown in the table, the average cost of producing one dollar of benefits greater than those produced in System "B" would be 144 dollars in System "A" and 34 dollars in System "C". It is therefore considered that the increments in water deliveries provided by Systems "A" and "C" would not be economically justified.

Fuel Consumption

Equivalent annual fuel consumption for facilities south of Avenal Gap is shown to be 8.03 million barrels for System "A", 9.35 million barrels for System

TABLE 37

SUMMARY OF THE ECONOMIC ANALYSES OF AQUEDUCT SYSTEM "C"[a]

(In millions of dollars)

Service area	Present worth of costs							Present worth of primary benefits			Benefit-cost ratio	Benefits in excess of costs (net benefits)	Net benefit-investment ratio	Total unit cost of water in service area[b]
	Main aqueduct			Local conveyance facilities										
	Capital investment costs	Operating costs	Subtotal	Capital investment costs	Operating costs	Subtotal	Total	Irrigated agri-culture	Municipal and industrial	Total				
Delta to Avenal Gap[c]	$98.0	$54.5	$152.5	$107.3	$28.0	$135.3	$287.8	$469.8	----	$469.8	1.63	$182.0	0.89	$22
Kern County														
Upper Antelope Plain	45.2	33.3	78.5	29.6	30.4	60.0	138.5	225.5	----	225.5	1.63	87.0	1.16	31
Avenal Gap to Pumping Plant In-III	76.3	42.5	118.8	35.0	12.3	47.3	166.1	507.5	----	507.5	3.06	341.4	3.07	15
Pumping Plant In-III to Pumping Plant In-IV	65.5	41.0	106.5	28.8	61.3	90.1	196.6	206.9	$220.6	427.5	2.17	230.9	2.45	[d]30
Pumping Plant In-IV to Pumping Plant In-VI	12.3	11.6	23.9	4.5	2.4	6.9	30.8	66.0	----	66.0	2.14	35.2	2.10	32
Subtotals	$199.3	$128.4	$327.7	$97.9	$106.4	$204.3	$532.0	$1,005.9	$220.6	$1,226.5	2.31	$694.5	2.34	----
San Luis Obispo	9.3	5.4	14.7	5.4	3.6	9.0	23.7	12.0	33.6	45.6	1.92	21.9	1.49	$55
Santa Barbara	45.6	22.6	68.2	13.4	16.5	29.9	98.1	78.5	143.8	222.3	2.27	124.2	2.11	54
Ventura County	108.8	37.4	146.2	2.0	12.1	14.1	160.3	18.2	255.5	273.7	1.71	113.4	1.02	87
Subtotals	$163.7	$65.4	$229.1	$20.8	$32.2	$53.0	$282.1	$108.7	$432.9	$541.6	1.92	$259.5	1.41	----
Antelope-Mojave	34.7	56.4	91.1	18.6	17.8	36.4	127.5	----	361.4	361.4	2.83	233.9	4.39	$53
Whitewater-Coachella	17.7	22.8	40.5	16.1	6.4	22.5	63.0	----	121.4	121.4	1.93	58.4	1.73	78
Southern California Coastal Plain and Coastal San Diego County	985.5	627.5	1,613.0	231.3	262.4	493.7	2,106.7	419.0	4,198.0	4,617.0	2.19	2,510.3	2.06	68
Totals for System	$1,498.9	$955.0	$2,453.9	$492.0	$453.2	$945.2	$3,399.1	$2,003.4	$5,334.3	$7,337.7	2.16	$3,938.6	1.98	[e]$45

[a] Values reflect "steam-electric" and "steam-drive and feedback" operation.
[b] In dollars per acre-foot, including a one dollar per acre-foot cost in the Delta.
[c] Does not include estimated Federal expenditures of about $100,000,000 in facilities for the San Luis service area.
[d] Average cost of water to agriculture is $26 per acre-foot; urban water costs would be higher because of longer conveyance facilities and filtration costs.
[e] Weighted average.

TABLE 38

SUMMARY ECONOMIC COMPARISON OF ALTERNATIVE AQUEDUCT SYSTEMS [a]

Item	System "A"	System "B"	System "C"
Capital cost of main aqueduct in millions of dollars	$2,361	$1,807	$2,162
Capital cost of units for initial delivery to Southern California in millions of dollars	$1,298	$ 927	$1,031
Capital cost of local conveyance and distribution facilities in millions of dollars	$1,220	$ 745	$ 703
Total equivalent annual cost in millions of dollars—including local conveyance and distribution facilities [b]	$ 134	$ 113	$ 122
Capitalized value of all costs in perpetuity in millions of dollars [b]	$3,816	$3,236	$3,498
Average unit cost of water at main aqueduct in dollars per acre-foot [b, c]	$ 33	$ 29	$ 33
Average unit cost of water in service area in dollars per acre-foot [b, c]	$ 50	$ 42	$ 45
Total direct benefits in millions of dollars	$7,334	$7,330	$7,338
Benefit-cost ratio	1.97	2.34	2.16
Net benefits in millions of dollars	$3,620	$4,193	$3,939
Net benefit-investment ratio	1.58	2.41	1.98
Average cost of producing one dollar of incremental benefit over $7,330 million in System "B" in dollars	$ 144	$ ----	$ 34
Equivalent annual fuel consumption in million barrels of oil per year [d]	8.03	9.35	8.67
Barrels per acre-foot of water [d]	2.33	2.71	2.51

[a] Values in table do not include estimated Federal expenditures of about $100,000,000 in facilities for the San Luis service area.

[b] Reflects a one dollar per acre-foot cost in the Delta.

[c] Based upon derived "equivalent annual cost" of water.

[d] Based upon "steam-drive and feedback" or "steam-electric" operational schemes for main aqueduct south of Avenal Gap and purchased power for local distribution facilities.

''B''; and 8.67 million barrels for System ''C'', when operated under ''steam-electric'' and ''steam-drive and feedback'' schemes. These values also include the fuel consumption of local conveyance and distribution facilities. As shown in Chapter V, fuel oil consumption under year 2020 conditions would be about 14 per cent less for System ''A'' than for System ''B''. System ''C'' under these conditions would use about 5 per cent less fuel than System ''B''.

The cost relationships among the aqueduct systems cited in a previous section were based on an estimate of $2.50 per barrel of fuel oil for pumping. An analysis was made to estimate the relative variation in unit cost of water delivered south of Avenal Gap with various assumed prices of fuel oil. Figure 14 graphically presents the results of this analysis. It is shown by this figure that even were the cost of energy for pumping to rise to much higher levels than are foreseen at this time, the unit cost of water from System ''B'' would remain substantially less than from Systems ''A'' and ''C''.

Summary

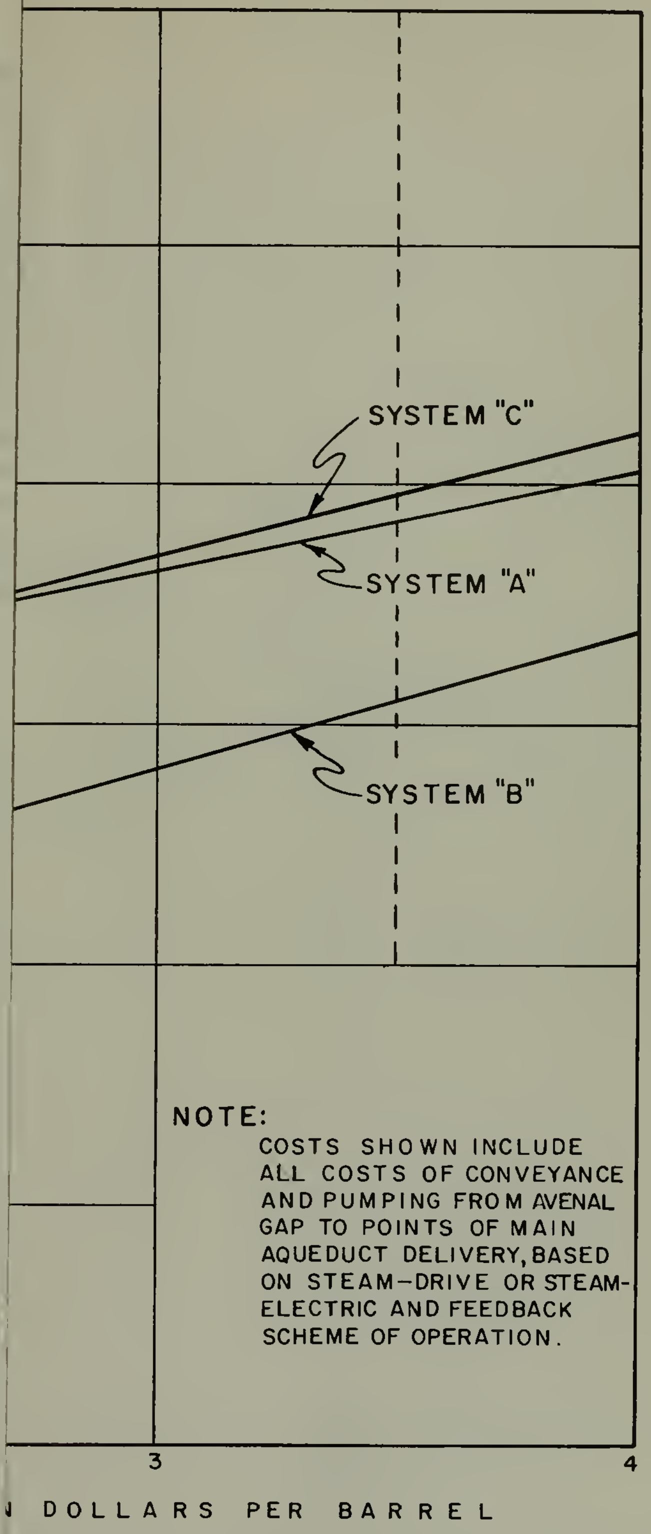
From the analyses presented in this chapter and preceding chapters of this report, it was determined that Aqueduct System ''B'', as compared to Systems ''A'' and ''C'', would provide water to the ultimate consumer in the southern California area at a minimum over-all cost, and, through its construction, would produce the greatest net economic benefit in the area. Further, it was found that the unit cost of water at the main aqueduct would be less under Aqueduct System ''B'' than under the other two, either with an operational scheme employing the concept of power utility participation or with one which is independent of such participation.

It was found that Aqueduct System ''B'' is financially feasible with respect to recovery of incurred costs under the criteria employed. It is also economically justified in that estimated benefits produced by its construction would substantially exceed the cost thereof, giving consideration to the time value of money with respect to both benefits and costs.

Aqueduct System ''B'' is feasible of construction from a physical standpoint. It is readily adapted to several methods of operation with respect to pumping and power recovery, and also to the utilization of other sources and types of energy for pumping.

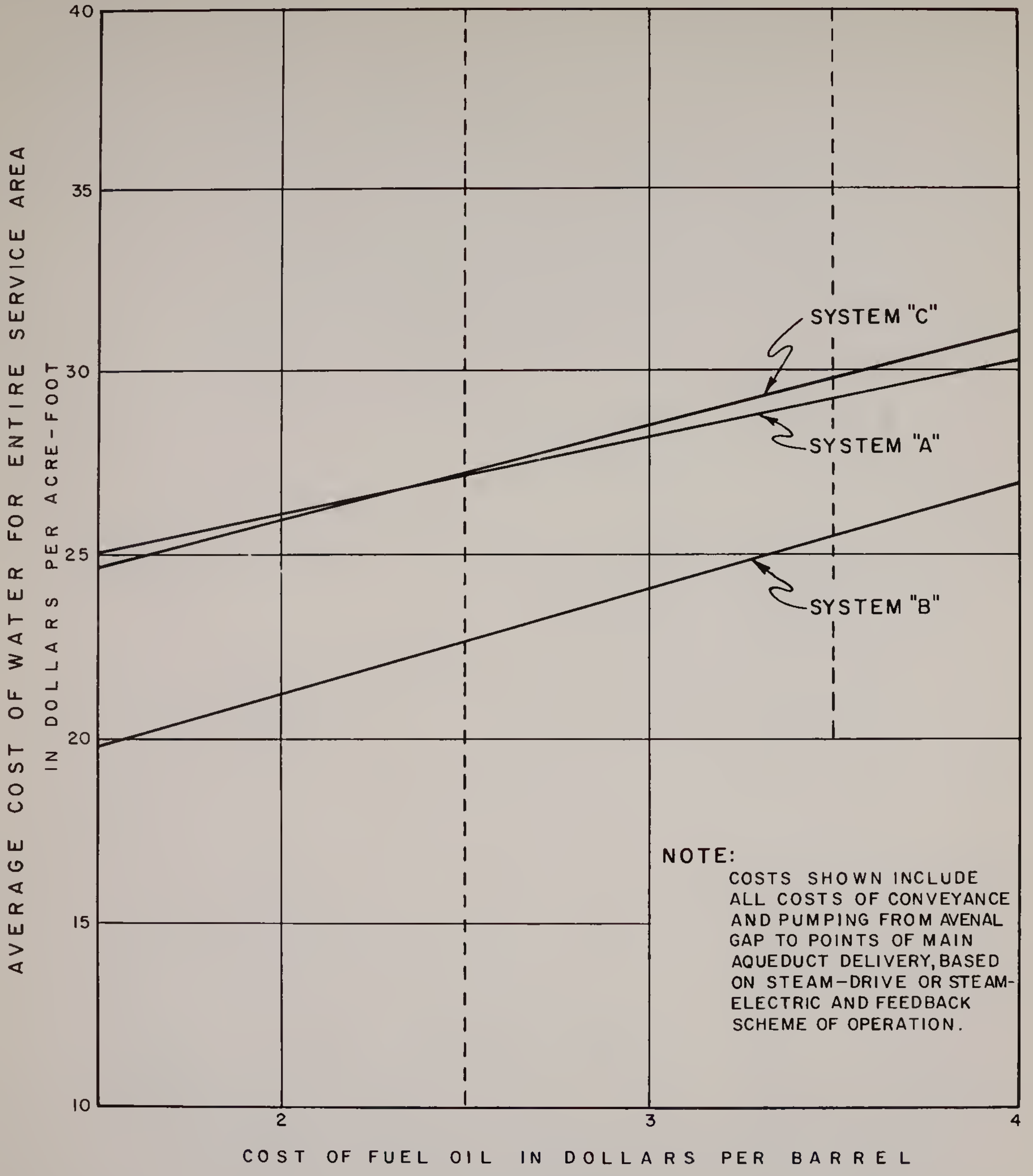
On the basis of the foregoing, Aqueduct System ''B'' is considered the optimum system for the delivery of surplus northern California water to the southern California area.

FIGURE 14



NOTE:
COSTS SHOWN INCLUDE ALL COSTS OF CONVEYANCE AND PUMPING FROM AVENAL GAP TO POINTS OF MAIN AQUEDUCT DELIVERY, BASED ON STEAM-DRIVE OR STEAM-ELECTRIC AND FEEDBACK SCHEME OF OPERATION.

OIL AND AVERAGE COST OF WATER
SOUTH OF AVENAL GAP



NOTE:
COSTS SHOWN INCLUDE ALL COSTS OF CONVEYANCE AND PUMPING FROM AVENAL GAP TO POINTS OF MAIN AQUEDUCT DELIVERY, BASED ON STEAM-DRIVE OR STEAM-ELECTRIC AND FEEDBACK SCHEME OF OPERATION.

RELATIONSHIP BETWEEN COST OF FUEL OIL AND AVERAGE COST OF WATER FOR AQUEDUCT SYSTEMS SOUTH OF AVENAL GAP

CHAPTER VIII

THE OPTIMUM AQUEDUCT SYSTEM

The financial and economic analyses presented in Chapter VII resulted in the conclusion that Aqueduct System "B" was the optimum system among possible alternatives for the delivery of surplus northern California water to the San Joaquin Valley, the coastal counties of San Luis Obispo and Santa Barbara, and to the area south of the Tehachapi Mountains. This system, together with other Delta export projects and upstream development projects, is depicted on Plate 19, entitled "The Optimum Aqueduct System and Other Features of the California Water Development Program".

This chapter presents a recapitulation of the physical facilities, construction schedule, costs and accomplishments of Aqueduct System "B".

AQUEDUCT FACILITIES

The San Joaquin Valley-Southern California Aqueduct System, incorporating selected System "B", will consist of a large canal leading south from the Delta along the west side of the San Joaquin Valley past the proposed San Luis Reservoir to Avenal Gap. A "Coastal Aqueduct" from Avenal Gap will extend west and then south through San Luis Obispo County to the Santa Maria Valley of Santa Barbara County. An "Inland Aqueduct" will continue along the west side of the San Joaquin Valley from Avenal Gap through Kern County and across the Tehachapi Mountains, where it will divide into a "West Branch" leading to the San Fernando Valley in Los Angeles County and an "East Branch" to the proposed Perris Reservoir in Riverside County. The total length of aqueduct facilities from the Delta to the three termini will be 638 miles. This aqueduct system, under a 55-year program of staged construction, will eventually deliver in excess of eight million acre-feet of water annually to agricultural lands and the metropolitan areas of the water deficient San Joaquin Valley and southern part of the State.

The location and nature of facilities described herein may be expected to be modified in detail by subsequent engineering studies. However, such modifications would not alter the conclusions of this investigation and report.

Delta to Avenal Gap

The 195 miles of aqueduct leading from the Delta to Avenal Gap will be principally in large canal. The aqueduct will divert from the Delta at sea level through Pumping Plant I and will extend south to San Luis Creek where Pumping Plant II will lift the water into San Luis Reservoir and/or into the canal leading south to Avenal Gap.

The Aqueduct between the Delta and San Luis Reservoir will be completed as soon after 1965 as possible in order to build up storage in San Luis Reservoir and thereby provide for conveyance of sufficient quantities of water to meet increasing demands on the aqueduct system. Canal sections in this reach would have top widths of about 145 feet and depths of flow of about 30 feet for discharges of about 13,000 second-feet. Until the completion of this reach of aqueduct, water from the Delta will be conveyed through the existing Delta-Mendota Canal, utilizing the off-season capacity thereof under a proposed contractual arrangement with the United States.

The canal leading southward from San Luis Reservoir to Kettleman City, under a proposed joint venture with the United States, will be completed in time to provide initial water deliveries by 1965 to western Fresno County, including the Federal Government's proposed service area therein, to Kings and Tulare Counties and to Kern County to the south.

For purposes of this bulletin, it was assumed that the Federal Government's expenditure in the foregoing works would amount to $100,000,000.

Coastal Aqueduct

The Coastal Aqueduct from Avenal Gap to its terminus will be 131 miles in length. About 78 miles will be in canal, 46 miles in siphon and penstock and about 7 miles in tunnel. The Coastal Aqueduct eventually will divert 581,000 acre-feet of water annually from the large canal in the San Joaquin Valley, at about elevation 325 feet. The aqueduct will proceed westward through Pumping Plants C-3, C-4, and C-5, to an elevation of about 1,230 feet and then will enter a five-mile tunnel through the Polonio Pass area. The Polonio Pass Tunnel will have an inside diameter of 7½ feet with a capacity of 294 second-feet. The aqueduct will continue westward across the Upper Salinas Valley alternately in canal and double-barreled pipe-siphon to enter a two-mile tunnel through Cuesta Pass. Canal reaches will have top widths of up to 30 feet, while siphon barrels will be from 66 to 75 inches in diameter. A short distance beyond the south portal of the Cuesta Pass Tunnel the hydraulic grade line will be lowered about 500 feet through the San Luis Obispo Power Development and the aqueduct will continue southerly, largely in canal, to a terminus in

Santa Maria Valley at elevation 405 feet. The pumping lift from the Delta to the terminus of this aqueduct in Santa Maria Valley will be about 1,300 feet less the head recovered through the 500-foot power drop.

Conveyance and distribution in the Santa Barbara Service Area will be accomplished by facilities, constructed by local agencies, extending southerly from the Santa Maria Terminus.

Work on the aqueduct will be started as soon as possible and completed to provide for initial water deliveries in San Luis Obispo and Santa Barbara Service Areas and to the Upper Antelope Plain in Kern County by 1971.

Inland Aqueduct

The 120 miles of Inland Aqueduct between Avenal Gap and the southerly end of the crossing of the Tehachapi Mountains will comprise about 105 miles of canal, 6 miles of tunnel, and 9 miles of siphon, and miscellaneous conveyance works. This reach of aqueduct will have a maximum capacity of 9,700 second-feet near Avenal Gap. Canal sections will have depths of up to 28 feet and top widths of up to 130 feet. The Tehachapi Tunnels will have a diameter of 21.5 feet, with a discharge capacity of about 4,800 second-feet.

The aqueduct will continue southward from Avenal Gap, at an initial elevation of about 325 feet, along the west side of the San Joaquin Valley to Buena Vista Lake, where Pumping Plant In-III will lift the water to about elevation 500 feet, thence eastward to Pumping Plants In-IV and In-V at Wheeler Ridge. At these plants the water will be lifted to elevation 1,245 feet and the aqueduct will follow along the southerly end of the San Joaquin Valley to a point about one mile east of Pastoria Creek, where Pumping Plant In-VI will lift the water to elevation 3,415 feet. At the end of the discharge lines of Pumping Plant In-VI, the water will enter the Tehachapi Tunnels and connecting siphons totaling about seven miles in length and terminating in the Antelope Valley. At the south portal of the Tehachapi Tunnels, the Inland Aqueduct will divide into the West and East Branches.

Work on the Inland Aqueduct south of Avenal Gap will be started immediately in order to begin water deliveries to Kern County by 1965. Pumping Plant In-VI and tunnels through the Tehachapi Mountains will be scheduled for completion to meet water deliveries through the West Branch of the aqueduct by 1971.

West Branch. The West Branch of the Inland Aqueduct will extend about 50 miles southerly from the Tehachapi Tunnels to the San Fernando Valley. It will comprise about 18 miles of siphon and penstock, 14 miles of tunnel, and the balance in canal section and reservoirs. Siphons will consist of two barrels, having diameters of up to 13 feet. Penstocks will be constructed in three stages and will have diameters of up to 9.5 feet. Tunnels will have diameters of up to 17 feet. The maximum capacity of aqueduct in this reach will be about 2,100 second-feet.

The aqueduct will continue from a small afterbay at water surface elevation 3,348 feet at the south portal of the Tehachapi Tunnels, southward across the west end of the Antelope Valley, through a forebay in the vicinity of Liebre Mountain, and through Castaic Power Plant No. 1 into Beartrap Reservoir. This power plant will have an operating head of about 824 feet, and will discharge to a water surface elevation of 2,486 feet in the reservoir. The aqueduct will continue through a series of siphons and tunnels to Castaic Power Plant No. 2, with an operating head of about 1,010 feet, which will discharge into Castaic Reservoir with maximum water surface elevation of 1,417 feet. From Castaic Reservoir the aqueduct will continue southward to a terminus at elevation 1,218 feet at the north end of the San Fernando Valley near Balboa Boulevard. The pumping lift from the Delta to Balboa Terminus will be about 3,500 feet, less the head recovered through about 1,800 feet of power drop.

Work on the West Branch will be scheduled to begin by 1965 to permit completion to Balboa Terminus and initiation of water deliveries for Ventura County and the southern California coastal plain by 1971.

East Branch. The 142-mile long East Branch will have about 93 miles of canal, about 44 miles of siphon, discharge line, and penstock, 4 miles of tunnel and the remainder in reservoir. Canal reaches will have a maximum top width of 82 feet and depths of about 17 feet. Siphon sections will be constructed in either two or three stages, with each barrel having diameters varying from 11 to 14 feet. The tunnel through the San Bernardino Mountains will be about 17 feet in diameter. This reach of aqueduct will have a discharge capacity varying from about 1,800 to 3,200 second-feet.

The East Branch will enter a siphon and penstock from the afterbay at the south portal of the Tehachapi Tunnels leading to Cottonwood Power Plant with a tailrace elevation of 3,013 feet. A canal will continue from the power plant along the southerly side of Antelope Valley eastward to the community of Pearblossom, where Pumping Plant In-VII will raise the hydraulic grade line elevation to about 3,500 feet. The aqueduct will continue eastward to Cedar Springs Reservoir on the West Fork of the Mojave River at the base of the San Bernardino Mountains. This reservoir will have a maximum water surface elevation of 3,455 feet. A four-mile tunnel through the San Bernardino Mountains will lead from Cedar Springs Reservoir to the Devil Canyon Power Development consisting of two drops with a final tailrace elevation of 1,734 feet. From the tailrace of the Devil Canyon Power Development, the aqueduct will continue in siphon across the Upper Santa Ana Valley to Perris Reservoir in Riverside County, which will have a maximum water surface elevation of 1,592 feet. The pumping lift from the Delta to Perris Reservoir will be about 4,100 feet, less the head recovered from power drops totaling about 2,000 feet.

The canal from the Tehachapi Tunnels to Little Rock Creek near Pearblossom will be started about 1968 and completed by 1971 to initiate water deliveries at that time to the Antelope Valley. Subsequently, the aqueduct from Little Rock Creek to Perris Reservoir will be completed and water deliveries made to the Mojave River area and Whitewater-Coachella Service Area as well as to the southern California coastal plain and coastal San Diego County by 1982. Should earlier demands for surplus northern California water develop in the latter areas, the construction timetable for completion of the East Branch could be advanced about five years to about 1977.

SYSTEM OPERATION

Controlled releases of water into the Sacramento-San Joaquin Delta from upstream storage, as well as naturally occurring flood flows, will be diverted from the Delta to be conveyed southward to the 2,100,000 acre-foot capacity San Luis Reservoir. Until about year 1970, the conveyance of water between the Delta and San Luis Reservoir, as stated, will be by means of the off-season capacity of the existing Delta-Mendota Canal, under a proposed contractual agreement with the United States. Water from the Delta either will be regulated in San Luis Reservoir or conveyed directly to service areas beyond this facility. Water deliveries, primarily for irrigation purposes, in western Fresno, Kings, Tulare and Kern Counties will be on a monthly service area demand schedule.

The Coastal Aqueduct will operate on a continuous flow basis throughout its length, with the exception of the reach between Avenal Gap and Pumping Plant C-5, which will be sized to deliver water on a monthly demand schedule to the Upper Antelope Plain portion of Kern County. Continuous water deliveries will be made to San Luis Obispo and Santa Barbara Counties. Coordinated ground water pumping or use of locally-constructed surface storage within these latter two areas will have the effect of regulating aqueduct flow to demand schedules.

Flow in the West Branch of the Inland Aqueduct delivered at Balboa Terminus will be regulated by Castaic Reservoir to the primarily monthly urban demand schedule of the southern California coastal plain area. Castaic Reservoir will be built to a storage capacity of 150,000 acre-feet. In addition emergency storage will be provided above Castaic Reservoir in the 56,000 acre-foot Beartrap Reservoir. Water for Ventura County will be released from Castaic Reservoir on a continuous flow basis to be conveyed to Balboa Terminus and thence to local regulatory storage at Conejo Reservoir.

The East Branch of the Inland Aqueduct will deliver water for the Antelope-Mojave and Whitewater-Coachella Service Areas on a continuous flow basis with regulation to be effected in the service areas. Cedar Springs Reservoir with a capacity of 216,000 acre-feet, will permit deliveries to the coastal plain area en route to Perris Reservoir to be made on a monthly demand schedule. Perris Reservoir, with a total storage capacity of 148,000 acre-feet, also will be operated to regulate deliveries to a monthly demand schedule in portions of the southern California coastal plain. Water supplies will be delivered to the Colorado River Aqueduct on this schedule, but flows transported through a connection to the Second San Diego Aqueduct will be on a continuous flow basis to be regulated in local storage facilities.

A total of 285,000 acre-feet of emergency storage, sufficient to provide continuity of deliveries for more than three weeks' time under 2020 conditions of demand, will be distributed among Beartrap, Castaic, Cedar Springs, and Perris Reservoirs, and in existing and future reservoir facilities of local water supply agencies.

Several pumping and power recovery schemes for the aqueduct system were investigated and found to be feasible from an engineering standpoint. The relative merits of each of these schemes, employing varying concepts of purchase and/or sale of electric energy or operation independent of electrical utility connections and combinations of these concepts, will be more fully investigated and definite selection made during final design.

For facilities south of Avenal Gap the "steam-drive and feedback" scheme of operation was employed herein for the purposes of financial and economic analyses. Analyses were also made employing the "off-peak electric and feedback" scheme of operation.

With either of the foregoing operational schemes, Pumping Plants I and II were considered to be operated continuously using steam-electric generation and electric motor drive. Under the "steam-drive and feedback" scheme, Pumping Plants In-III, In-IV, In-V, In-VII, C-3, C-4, and C-5, would be operated continuously using electric motor drive with energy supplied by feedback from power recovery plants supplemented by steam-electric generation. Pumping Plant In-VI would also be operated continuously, with the main pumps driven by direct-connected steam turbines.

The "off-peak electric and feedback" scheme, for facilities south of Avenal Gap, would employ electric motor drive on all pumping plants for both Coastal and Inland Aqueducts. Power recovery plants on the Inland Aqueduct would be oversized to permit peaking operation. The recovered power would be transmitted to pumping plants in the San Joaquin Valley and at Pearblossom. San Luis Obispo Power Development on the Coastal Aqueduct would be operated continuously because of the lack of suitable regulatory forebay and afterbay sites. Continuous power from this plant would be fed into the transmission lines connecting all of the plants. Off-peak power would be purchased from power utilities to supplement the recovered peaking and continuous flow power to drive all of the pumping plants. Since the recovered power would be insufficient to sustain continuous pumping during on-peak hours, pumping plants in the San Joaquin Valley would be oversized for greater rates of discharge during off-peak hours.

Set forth in the following tabulation is the installed capacity that would be required at the various pumping and power recovery plants for the system, under conditions of water demand of year 2020, using the "steam-drive and feedback" operational scheme:

Pumping plant	*Installed capacity in megawatts*
I	300
II	360
In-III	126
In-IV	105
In-V	273
In-VI	1,050
In-VII	156
C-3	34
C-4	28
C-5	11
Total	2,443

Power recovery plant	*Installed capacity in megawatts*
Castaic No. 1	97
Castaic No. 2	119
Cottonwood	76
Devil Canyon No. 1	232
Devil Canyon No. 2	127
San Luis Obispo	9
Total	660

Under the foregoing scheme, the average annual equivalent fuel oil consumption required to deliver up to eight million acre-feet of water annually through the main aqueduct system, over the period from 1970 to 2020, would be 14 million barrels. This amount of fuel oil was found to constitute only a small fraction of present crude oil production in California.

LOCAL CONVEYANCE AND DISTRIBUTION

Water service from the main aqueduct system will require local construction of conveyance and distribution facilities within each service area. For urban uses, treatment including filtration and chlorination will be required.

The Coastal Aqueduct will serve Upper Antelope Plain in the San Joaquin Valley and San Luis Obispo and Santa Barbara Counties. Service to Upper Antelope Plain will require two main laterals extending south, parallel to but at a higher elevation than the main inland aqueduct. Laterals from the Coastal Aqueduct will serve the Upper Salinas Valley and the coastal portions of San Luis Obispo County. Santa Barbara County will be served by a local main conveyance facility extending from Santa Maria Terminus of the main aqueduct to Cachuma Reservoir, together with laterals therefrom in the northern portion of the county. East and west laterals extending from the south portal of the existing Tecolote Tunnel will serve the coastal area of Santa Barbara County south of the Santa Ynez Mountains.

The Inland Aqueduct will serve the remainder of Kern County and the area south of the Tehachapi Mountains. Turnouts from the main aqueduct in the San Joaquin Valley will deliver water into local irrigation distribution systems both above and below the aqueduct. A lateral canal about 40 miles in length will also be required to serve water for urban purposes in the Bakersfield area.

From the Balboa Terminus of the West Branch of the Inland Aqueduct, a main feeder 26 miles in length will be required to serve Ventura County and adjacent areas in westerly Los Angeles County. In addition, conveyance facilities will have to be constructed from Balboa Terminus to connect with existing facilities of the Metropolitan Water District and other local water service agencies.

Service to the Antelope-Mojave Service Area from the East Branch will be by laterals extending northerly into the desert area. The Whitewater-Coachella Service Area will be served by a lateral, largely in canal, extending from the East Branch near Hesperia through Lucerne, Yucca, and Morongo Valleys to a power development site above Desert Hot Springs.

From the tailrace of the Devil Canyon Power Development and from Perris Reservoir, local conveyance facilities will be required to serve existing facilities in the Upper Santa Ana Valley and to connect with the existing Colorado River Aqueduct facilities. Also, from Perris Reservoir, a lateral about 15 miles in length will be required to connect with the Second San Diego Aqueduct near San Jacinto.

AQUEDUCT SYSTEM COSTS

The estimated capital costs of construction of this optimum aqueduct system are summarized following:

	*Capital costs**
Delta to San Luis Reservoir	$314,000,000
San Luis Reservoir	112,000,000
San Luis Reservoir to Avenal Gap	184,000,000
Coastal Aqueduct	
Avenal Gap to Santa Maria River	111,000,000
Inland Aqueduct	
Avenal Gap to South Portal of Tehachapi Tunnels	505,000,000
West Branch to Balboa Terminus	224,000,000
East Branch to Perris Reservoir	458,000,000
Total	$1,908,000,000

* Capital costs include estimated Federal investment of about $100,000,000 in facilities for the San Luis service area.

Set forth in Table 39 is a year by year schedule of expenditures for construction of the system facilities according to the sequence described previously. The initial State expenditures for construction through the year 1971 will be about $936,000,000 under the assumption of an estimated initial Federal expenditure of $90,000,000 in the joint construction of San Luis

TABLE 39

SCHEDULE OF CAPITAL EXPENDITURES FOR COMPLETION OF AQUEDUCT SYSTEM "B" FOR THE "STEAM-DRIVE AND FEEDBACK" OPERATIONAL SCHEME[a]

(In millions of dollars)

Aqueduct reaches and appurtenant features	Years[b]																		Total capital cost
	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972[c]	1973 to 1980	1981 to 1990	1991 to 2000	2001 to 2010	2011 to 2014[d]	
Delta to Avenal Gap																			
Aqueduct-Delta to San Luis Reservoir	$1	$1	$1	----	----	----	$11	$25	$28	$17	$7	----	----	----	----	----	----	----	$91
Pumping Plants 1, II and Steam Plants[e]	----	----	----	$10	$10	$9	----	16	15	15	----	$2	$2	$17	$46	$30	$22	----	194
San Luis Reservoir and Appurtenances	1	1	3	9	17	13	10	8	8	----	----	----	----	----	----	----	----	----	70
Aqueduct-San Luis Reservoir to Avenal Gap	1	13	32	42	44	22	----	----	----	----	----	----	----	----	----	----	----	----	154
Coastal Aqueduct																			
Pumping and Power Plants[e]	----	----	----	----	----	----	----	1	1	2	1	----	----	4	4	3	1	----	17
Steam Plants	----	----	----	----	----	----	----	1	1	2	1	----	----	----	4	----	----	----	9
Aqueduct—Canal, Siphon and Miscellaneous	----	----	----	1	2	4	7	7	8	9	7	3	----	----	----	17	----	----	65
Polonio and Cuesta Tunnels	----	----	----	----	----	4	4	3	4	3	1	----	----	----	----	----	----	----	19
Reservoirs	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	1
Inland Aqueduct																			
Avenal Gap to South Portal Tehachapi Tunnels																			
Aqueduct-Avenal Gap to Pumping Plant In-VI	1	1	16	26	24	15	3	----	----	----	----	----	----	1	1	1	1	----	90
Pumping Plants In-III, In-IV, and In-V[e]	----	----	----	1	2	3	----	1	2	1	----	2	3	15	21	13	16	$4	84
Steam Plant	----	----	----	3	3	3	----	----	----	----	----	----	----	----	10	----	----	----	19
Pumping Plant In-VI[e]	----	----	----	----	----	----	----	5	10	9	5	5	9	36	51	49	43	11	233
Tehachapi Tunnels and Connecting Siphons	----	----	----	----	10	12	30	19	1	1	----	----	----	2	2	1	1	----	79
West Branch																			
Aqueduct—Tehachapi Mountains to Balboa	----	----	----	----	----	2	3	6	1	4	13	15	3	26	----	----	----	----	73
Castaic Power Plants[e]	----	----	----	----	----	----	----	2	5	4	3	2	4	13	----	----	----	----	33
Tunnels	----	----	----	----	----	----	3	14	21	19	9	9	----	----	----	----	----	----	75
Beartrap Reservoir	----	----	----	----	----	----	----	9	8	----	----	----	----	----	----	----	----	----	17
Castaic Reservoir	----	----	----	----	1	----	----	----	6	12	7	----	----	----	----	----	----	----	26
East Branch																			
Aqueduct—Tehachapi Mountains to Little Rock Creek	----	----	----	----	----	----	----	1	8	16	19	21	3	----	5	4	5	----	82
Cottonwood Power Plant[e]	----	----	----	----	----	----	----	----	----	----	----	----	----	1	5	2	3	----	11
Aqueduct—Little Rock Creek to Cedar Springs Reservoir	----	----	----	----	----	----	1	----	1	----	----	----	----	40	8	5	7	----	62
Pumping Plant In-VII[e]	----	----	----	----	----	----	----	----	----	----	----	----	----	1	9	7	6	2	25
Devil Canyon Power Plants[e]	----	----	----	----	----	----	----	----	----	----	----	----	----	7	34	9	14	----	64
Cedar Springs Reservoir	----	----	----	----	----	----	----	1	----	1	----	----	----	20	7	----	----	----	29
San Bernardino Tunnel	----	----	----	----	----	----	----	----	----	----	----	----	----	31	6	----	----	----	37
Aqueduct—Devil Canyon to Perris Reservoir	----	----	----	----	----	----	1	----	1	----	----	----	----	28	68	14	----	----	112
Perris Reservoir	----	----	----	----	----	----	1	1	1	1	----	----	----	8	24	----	----	----	36
Total Capital Costs	$4	$16	$52	$92	$113	$88	$74	$120	$130	$116	$73	$59	$24	$250	$305	$155	$119	$17	$1,807

[a] Does not include estimated Federal expenditure of about $100,000,000 in reach extending from Delta to Avenal Gap.
[b] Fiscal years ending June 30.
[c] Initial stage of aqueduct system completed in year 1971-72.
[d] Final stage aqueduct system completed by year 2014.
[e] All penstock costs are included in plant costs.

Reservoir and the aqueduct south from this point to Kettleman City. This sequence of construction will permit deliveries of water to the San Joaquin Valley, San Luis Obispo and Santa Barbara Counties, the Antelope Valley and to the southern California coastal plain and Ventura County.

Equivalent annual costs of capital recovery and interest at 3½ per cent, operation and maintenance, replacement, general expense, and energy for pumping over the economic life of the entire aqueduct system will be about $78,000,000.

FINANCIAL FEASIBILITY AND ECONOMIC JUSTIFICATION

Financial analyses made for the main aqueduct system as a whole and for units thereof enabled determination of the equivalent annual cost of water at the main aqueduct for each considered service area. Separate computations were made to determine the cost of water delivered within each service area. Included in these costs was a value of one dollar per acre-foot representing the estimated cost of water in the Delta. It is to be emphasized that these costs are not to be construed as suggested prices for water, but rather cost values developed for purposes of this report.

The estimated costs so derived are set forth in the following tabulation for service areas south of Avenal Gap:

	Equivalent annual cost per acre-foot of water	
Service area	*Delivered at main aqueduct*	*Delivered within service area*
Kern County		
Upper Antelope Plain	$19	$32
Avenal Gap to Pumping Plant In-III	10	15
Pumping Plant In-III to Pumping Plant In-IV	16	29
Pumping Plant In-IV to Pumping Plant In-VI	24	31
San Luis Obispo	51	73
Santa Barbara	49	81
Ventura County	50	71
Antelope-Mojave	38	53
Whitewater-Coachella	52	79
Southern California Coastal Plain and Coastal San Diego County	44	60

With respect to the area between Pumping Plants In-III and In-IV, the cost within the service area for agricultural water was estimated to be 26 dollars per acre-foot and for urban water, 33 dollars per acre-foot. This difference in cost results from differences in length of conveyance facilities and the necessity of treating the urban water.

Since water deliveries from the aqueduct system were adjusted to the rates of growth of economic demand for water that were estimated would occur at the foregoing costs, and since it was further estimated that full recovery of invested capital with interest would be achieved from the service areas over the postulated period of 50 years for each stage of aqueduct construction, the aqueduct system from this standpoint is considered financially feasible.

Economic analyses showed that over the assumed economic life of project facilities of 105 years, the estimated ratio of primary benefits to all costs, including those of local conveyance and distribution systems, would be 2.34 to 1. In the analyses, both benefits and costs were discounted to common time at an annual rate of 3½ per cent. Further, the net benefit-investment ratio was estimated to be about 2.4 to 1. It was therefore concluded that the San Joaquin Valley-Southern California Aqueduct System will have a high degree of economic justification. Economic analyses for units of the system yielded similar results.

SYSTEM ACCOMPLISHMENTS

This optimum aqueduct system is planned eventually to convey over 8 million acre-feet per year southward from the Delta, of which about 5.5 million acre-feet per year will be transported to the southern California area south of Avenal Gap. This aqueduct system will support anticipated economic expansion of unprecedented proportions in its service area, the implications of which will be felt throughout the State and nation. By year 2020, water delivered by this system south of Avenal Gap will, to a substantial degree, support an estimated population of over 28 million, and an irrigated area of about 1,200,000 acres. A summary of water deliveries over time to service areas south of Avenal Gap is presented in Table 40.

TABLE 40

SUMMARY OF WATER DELIVERIES FROM AQUEDUCT SYSTEM "B" TO SERVICE AREAS SOUTH OF AVENAL GAP

(In thousands of acre-feet)

Year	Service areas							
	Kern County	San Luis Obispo	Santa Barbara	Ventura County	Antelope-Mojave	Whitewater-Coachella	Southern California Coastal Plain and Coastal San Diego County	Total
1965	13	----	----	----	----	----	----	13
1970	146	----	----	----	----	----	----	146
1980	823	4	47	41	75	----	864	1,854
1990	1,409	17	66	55	142	35	1,513	3,237
2000	1,606	26	85	115	175	55	2,160	4,222
2010	1,700	34	118	168	195	90	2,635	4,940
2020	1,785	52	159	236	208	100	2,955	5,495

Kern County Service Area

Water deliveries to the western and southern parts of Kern County from the aqueduct system, beginning about year 1965 and increasing to about 1.8 million acre-feet by year 2020, will make possible an increase of over 450,000 acres of irrigated lands during this period. Aqueduct deliveries will prevent eventual abandonment of irrigation on as much as 50,000 acres of presently irrigated lands, which would result from continued overdraft. The aqueduct will also provide sufficient water to meet the increased water demand of a population in the Bakersfield area of up to one million people by year 2020, along with increased urban development in the western part of the county, particularly around the City of Taft.

San Luis Obispo Service Area

Planned water deliveries through the Coastal Aqueduct to the San Luis Obispo Service Area will provide the additional water supplies necessary to meet the full urban growth postulated therein. It was estimated that the service area's population will increase 10 times or to about 700,000 by year 2020. Most of the area's limited supply of high quality land that enjoys favorable climatic conditions will be fully utilized either for urban purposes or for production of relatively high value crops. By 2020, it was estimated that irrigated land will have increased from 18,000 acres at present to 38,000 acres.

Santa Barbara Service Area

The activities at Vandenberg Air Force Base have accelerated population growth in the Santa Barbara Service Area, which is expected to continue in the future. The Coastal Aqueduct will supply the supplemental water needed to sustain this anticipated development and provide for continued growth. Increases in urban area will act to limit agricultural expansion since some of the best agricultural lands in the service area are also those lands with the highest potential for becoming urbanized.

The water delivered by the Coastal Aqueduct will permit the projected full development of all irrigable or habitable lands south of the Santa Ynez Mountains by the year 2020. In the balance of the service area, it was estimated that only the better lands which are capable of growing high value crops would utilize northern California water. By 2020, it was estimated that the population of Santa Barbara County will have increased to 915,000, and that in excess of 90,000 acres will be under irrigation.

Ventura County Service Area

Ventura County Service Area is expected to exhibit a continuing urbanization at the expense of agricultural lands. The recent increase of 200 per cent in manufacturing employment, from years 1949 to 1957, portends the pattern of future developments in this county.

The delivery of imported water to Ventura County, commencing in 1971 from the West Branch of the Inland Aqueduct, will alleviate the serious ground water overdrafts occurring in the Oxnard Plain and within the Calleguas Municipal Water District, as well as provide for further expansion of population in these areas. It was estimated that use of northern California water by agriculture will be limited to high value crops, and then probably only if this water is commingled with water from existing sources.

It was estimated that by year 2020 the population of the county will have reached 1,700,000 and at that time about 50,000 acres will be under irrigation, largely in small suburban holdings.

Antelope-Mojave Service Area

The availability of large expanses of vacant land in this area located near the Los Angeles metropolitan area was a prime factor in the projection of a population therein of about two and one-half million people by year 2020. The East Branch of the Inland Aqueduct will provide sufficient water to support this projected population. The derived cost of water delivered in the service area appears generally to be too high to be utilized for the type of agriculture climatically adapted to the Antelope-Mojave Service Area. It is expected that irrigated agriculture in this area will decline as a result of urban encroachment combined with high water costs resulting from continued lowering of ground water levels, particularly in Antelope Valley.

Whitewater-Coachella Service Area

The availability of water from the East Branch of the Inland Aqueduct will enable continuation of the recent rapid population growth of the desert communities to the year 2020. By that time, the population of this area is expected to reach nearly 600,000. It is anticipated that the economy of this area will remain a predominantly residential and resort type, with continuation of irrigated agriculture projected for the lands served with water from the Coachella Branch of the All-American Canal. As in the Antelope-Mojave Service Area, it is believed that irrigated agriculture could not develop with water costs of the magnitude estimated.

Southern California Coastal Plain and Coastal San Diego County Service Area

This service area comprises one of the most highly developed regions of the State. Recent growth therein has been spectacular as indicated by a 350 per cent increase in manufacturing employment over an eight-year period in Orange County, and substantial gains in the economy of other parts of the area.

Colorado River water is available throughout much of this area, but it was estimated that demands on this source of water will exceed supplies by about 1970. Economic stalemate or retrogression thereafter will be prevented through importation of northern California water as planned in the aqueduct system. Further, this system will prevent the probable loss of the utility of ground water basins of the Upper Santa Ana Valley with attendant heavy financial burdens, and will provide nearly equivalent mineral qualities of imported water supplies throughout the entire service area by deliveries of northern California water through the East and West Branches of the Inland Aqueduct.

Use of northern California water of up to about three million acre-feet annually will permit the population of this service area to grow to about 21 million by year 2020, at which time the area would be essentially fully developed. This projected future population is about one and one-half times that of the entire State at the present time. It is anticipated that urban expansion will result in encroachment on agricultural lands, and that a gradual reduction of irrigated agricultural land will be experienced.

CHAPTER IX

CONCLUSIONS

The principal conclusions of this investigation of alternative aqueduct systems to transport and deliver surplus water from northern California to the water-deficient areas of southern California, which include that portion of Kern County in the San Joaquin Valley, San Luis Obispo County, Santa Barbara County, Ventura County, Orange County, the Antelope Valley-Mojave River area, the Whitewater-Coachella area, and the coastal portions of Los Angeles, San Bernardino, Riverside, and San Diego Counties, are presented:

1. The phenomenal growth of population and industry experienced in recent years in southern California is expected to continue and provision must be made for an adequate supply of water therefor.

2. The only feasible source of additional supplemental water for these water deficient areas is the surplus water that can be developed in and exported from northern California, over and above the needs of the watersheds of origin.

3. Additional supplemental water will be required to sustain the economic development of the southern California area after 1970. By that date, only eleven years away, the water needs of expanding population, industry and agriculture will have fully utilized the entire claimed right of The Metropolitan Water District of Southern California in and to waters of the Colorado River, amounting to 1,212,000 acre-feet per year. Northern California water is needed now in the San Joaquin Valley and in other portions of the southern California area.

4. The annual supply of 1,800,000 acre-feet of water originally considered for delivery to the area south of the Tehachapi Mountains and the 840,000 acre-feet of water originally considered for Kern County, in the report entitled "Program for Financing and Constructing the Feather River Project", dated February, 1955, will be fully utilized within 20 years after first deliveries of northern California water are made to these areas.

5. Based upon the latest projections of population and economic growth in the considered portions of the southern California area, it is estimated that the economic demands for supplemental water to be imported from northern California will amount to about five and one-half million acre-feet annually by year 2020.

6. Since south of Avenal Gap neither a "coastal" nor an "inland" aqueduct route, separately, can physically or economically serve all areas of need wherein an economic demand for northern California water will exist, an aqueduct system comprising elements of both of these routes must be constructed.

7. The aqueduct system must be so planned and constructed as to deliver the requisite quantities of supplemental water in the several areas which will have a demand therefor, in time to meet those demands. This will require a more extensive aqueduct system of greater capacities than heretofore envisioned.

8. In planning for the importation of supplemental water, particular attention must be given to the necessity of providing a supply of high quality water to the Upper Santa Ana Valley and coastal San Diego County in order to avoid large economic losses in these areas.

9. The aqueduct system which can serve forecast demands for surplus northern California water most economically will include an aqueduct from the Delta along the west side of the San Joaquin Valley to Avenal Gap, a coastal aqueduct from Avenal Gap to Santa Maria Valley, an inland aqueduct from Avenal Gap south through Kern County and across the Tehachapi Mountains, with a west branch to San Fernando Valley and an east branch along the Antelope Valley through the San Bernardino Mountains to Perris reservoir site in Riverside County.

10. This system, designated Aqueduct System "B" in this report, has been determined to be the best system for delivering water from northern California to the Coastal Counties, the San Joaquin Valley and southern California. The system is feasible of construction and operation from an engineering standpoint; is economically justified, having a ratio of primary benefits produced to costs incured of 2.34; and is financially feasible from the standpoint of recovery of the incurred costs.

11. This optimum aqueduct system is adaptable to staged construction over a 55-year period consistent with the build-up of economic demand for water therefrom.

12. The aqueduct system will eventually deliver about about five and one-half million acre-feet of water annually to the San Joaquin Valley south of Avenal Gap, the coastal counties, and the area south

of the Tehachapi Mountains under the following schedule:

Year	*Delivery in acre-feet*
1965	13,000
1970	146,000
1980	1,854,000
1990	3,237,000
2000	4,222,000
2010	4,940,000
2020	5,495,000

13. The aqueduct system must be constructed in time to provide initial deliveries of water to lands in San Joaquin Valley between San Luis Reservoir and Avenal Gap and in Kern County by 1965, through the Coastal Aqueduct to San Luis Obispo and Santa Barbara Counties by 1971, through the West Branch of the Inland Aqueduct to the southern California coastal plain and Ventura County by 1971, and through the first sequence of construction of the East Branch of the Inland Aqueduct to the Antelope Valley by 1971.

14. The second sequence of construction will include the extension of the East Branch of the Inland Aqueduct from Little Rock Creek in the Antelope Valley to Perris Reservoir in Riverside County, with completion scheduled for 1982 to serve the Mojave River and Whitewater-Coachella areas and provide additional water supplies, needed by that time from both quantity and quality standpoints, to the southern California coastal plain and coastal San Diego County.

15. The second sequence of construction could be completed by 1977 if economic demands for water from the system developed earlier than estimated herein.

16. The optimum aqueduct system is physically adaptable to several feasible methods of pumping and power recovery, from which a single definite selection will be made at a later time after further engineering and economic study. Pending further study, none of the operational schemes evaluated or referred to in this bulletin should be considered as adopted features of the San Joaquin Valley-Southern California Aqueduct System.

17. Satisfaction of forecast economic demands for surplus northern California water which will be delivered by this aqueduct system requires an immediate start on acquisition of lands and on design and construction of facilities throughout the system.

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SOUTHERN CALIFORNIA DISTRICT

FEATHER RIVER AND DELTA
DIVERSION PROJECTS

INVESTIGATION OF ALTERNATIVE
AQUEDUCT SYSTEMS TO SERVE SOUTHERN CALIFORNIA

WATER SERVICE AREAS AND ORGANIZED WATER AGENCIES IN SOUTHERN CALIFORNIA AREA

1959

NOTES

1. SANTA BARBARA COUNTY WATER AGENCY AND SAN LUIS OBISPO COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT INCLUDE ALL AREA WITHIN THEIR RESPECTIVE COUNTIES
2. BAKERSFIELD METROPOLITAN AREA PHYSICALLY WITHIN THE AVENAL GAP TO PP In-III SUBUNIT OF THE KERN COUNTY SERVICE AREA IS CONSIDERED PART OF THE PP In-III TO PP In-IV SUBUNIT

PLATE 3

LEGEND

PUMPING PLANT

POWER PLANT

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

FEATHER RIVER AND DELTA
DIVERSION PROJECTS

◆

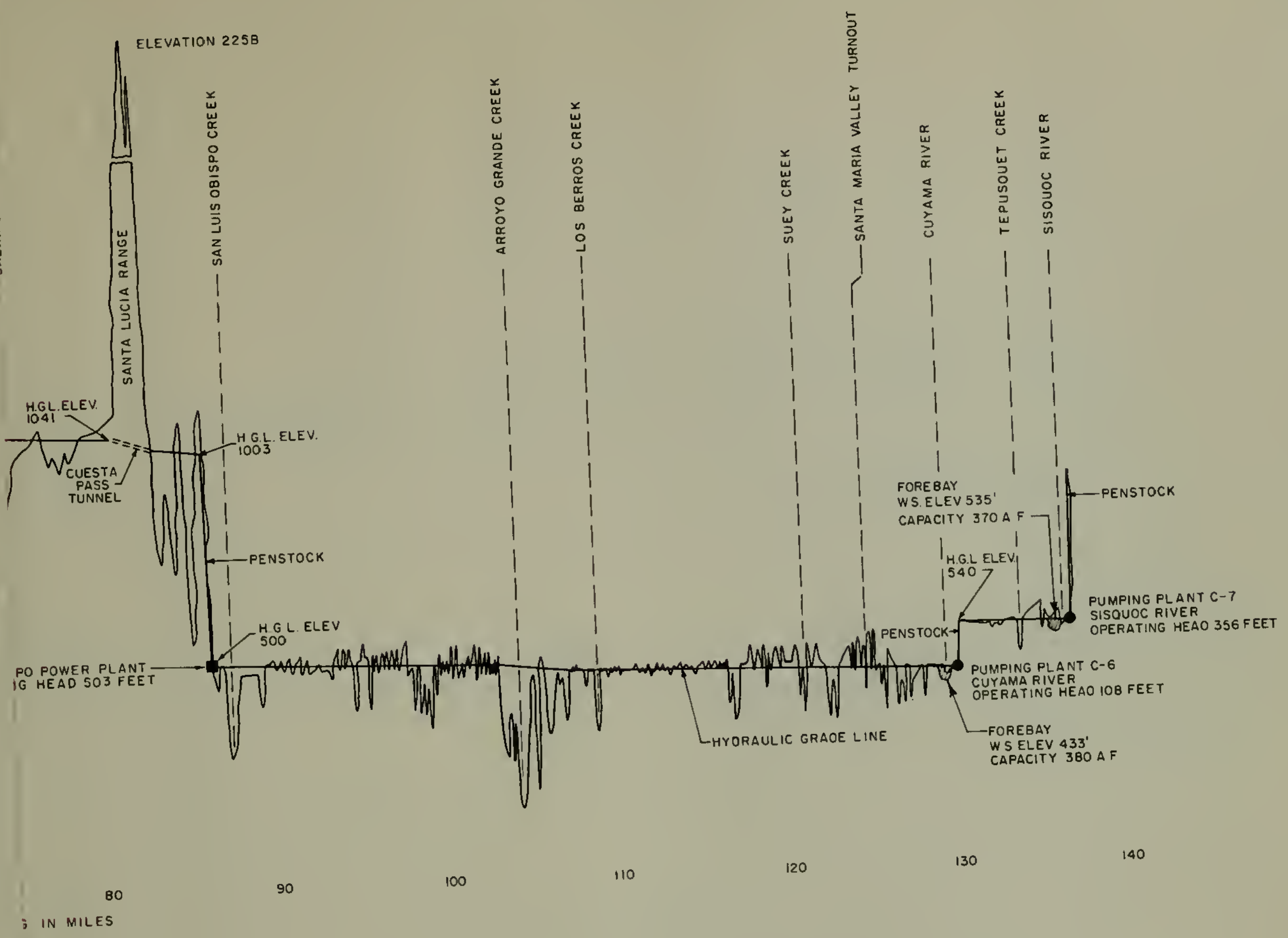
INVESTIGATION OF ALTERNATIVE
AQUEDUCT SYSTEMS TO SERVE SOUTHERN CALIFORNIA

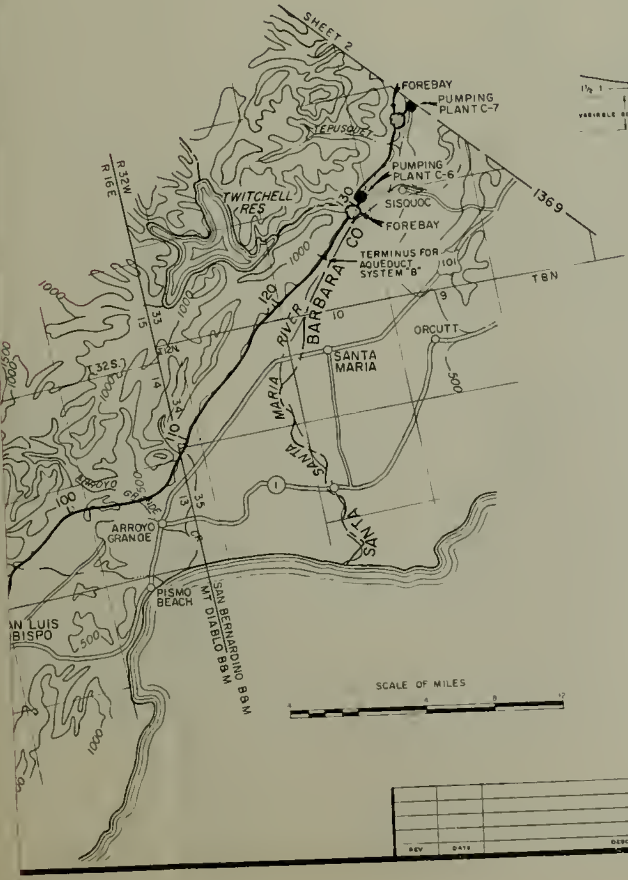
◆

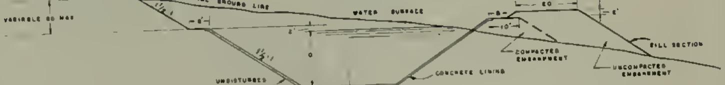
GENERAL LOCATIONS OF INVESTIGATED AQUEDUCT ALIGNMENTS

1959

SCALE OF MILES







TYPICAL CANAL SECTION
NOT TO SCALE

TYPICAL CANAL DIMENSIONS AND HYDRAULIC PROPERTIES							
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28 0	18 18	1004 81	4 47	4496	10 75	014	0000747

NOTE:
DATA SHOWN ARE FOR AQUEDUCT SYSTEM "A" WITH "STEAM DRIVE AND FEED BACK" OPERATION DESIGNED TO DIVERT 3,790,000 ACRE FEET ANNUALLY THROUGH PUMPING PLANT C-3 FACILITIES OF AQUEDUCT SYSTEM "C" WOULD BE SIMILAR BUT DESIGNED TO DIVERT 1,795,000 ACRE FEET ANNUALLY AQUEDUCT SYSTEM "B" WOULD TERMINATE IN THE SANTA MARIA VALLEY.

REV	DATE	DESCRIPTION	SUB	APP'D

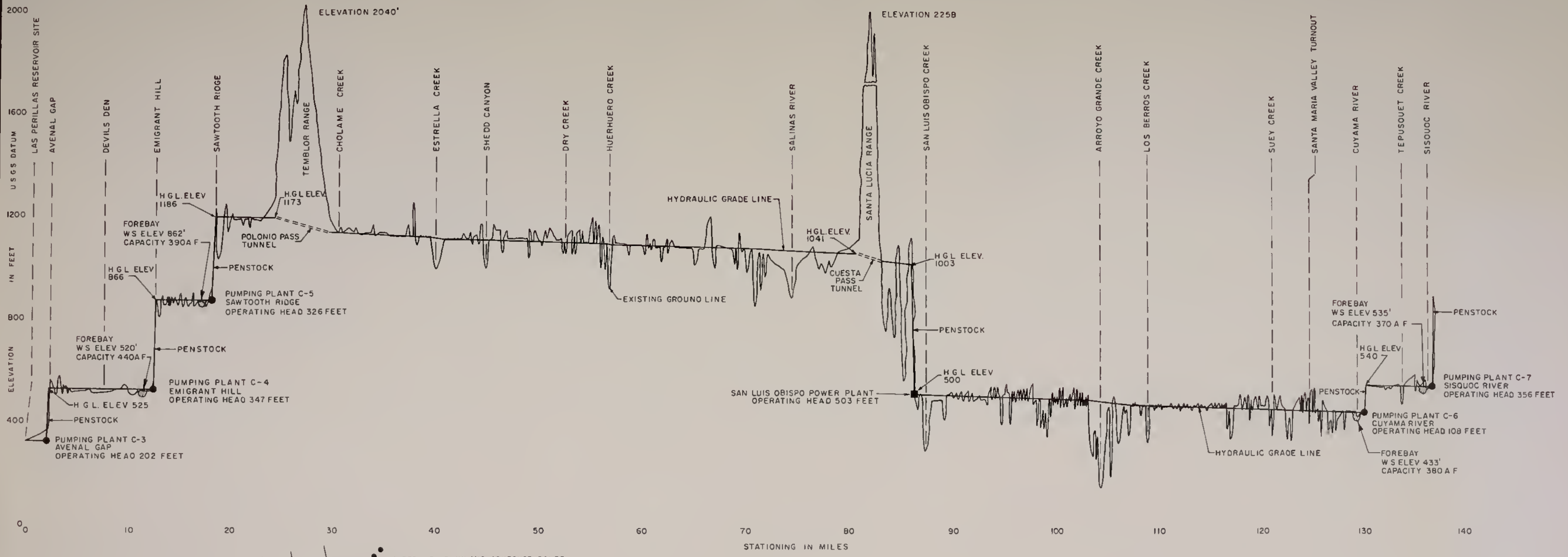
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

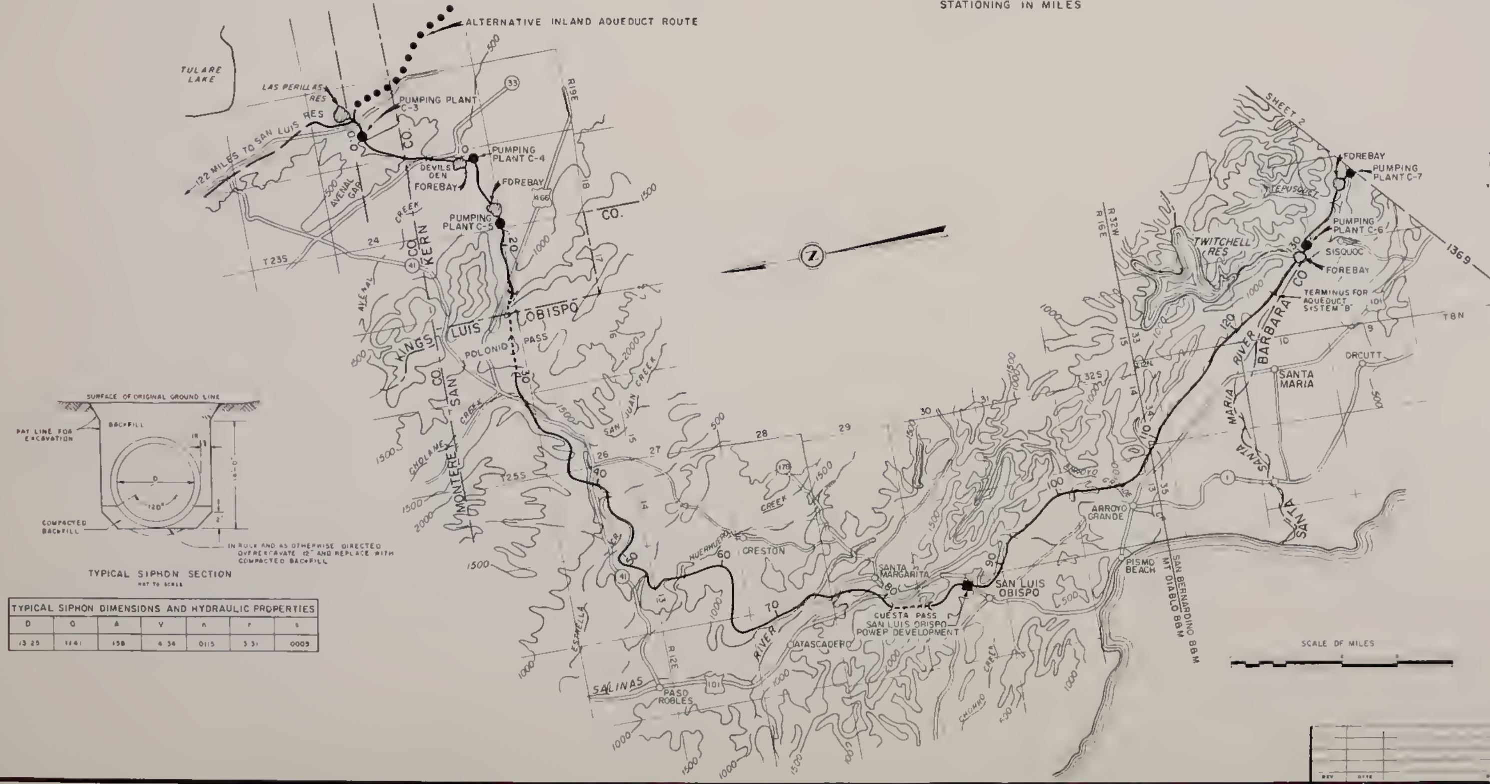
PROJECT FEATHER RIVER AND DELTA DIVERSION
FEATURE SAN JOAQUIN VALLEY-SOUTHERN CALIFORNIA AQUEDUCT

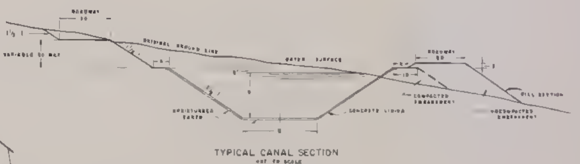
ALTERNATIVE COASTAL AQUEDUCT
PLAN AND PROFILE
MILE 0.0 TO 136.9

DESIGNED M H
DRAWN H Z
CHECKED J A
SUBMITTED P HOOD PLANNING E JACKSON DESIGN
RECOMMENDED SUPERVISING HYDRAULIC ENGINEER
APPROVAL RECOMMENDED R M Edmonston PRINCIPAL HYDRAULIC ENGINEER
APPROVED: DATE
Max Bookman 2/16/59
DISTRICT ENGINEER
DRAWING No
FILE No

SHEET 1 OF 2







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28 0	18 19	1004 41	4 47	4455	10 75	014	0000747

NOTE:
DATA SHOWN ARE FOR AQUEDUCT SYSTEM "A" WITH "STEAM DRIVE AND FEED BACK" OPERATION DESIGNED TO DIVERT 3,790,000 ACRE FEET ANNUALLY THROUGH PUMPING PLANT C-3
FACILITIES OF AQUEDUCT SYSTEM "C" WOULD BE SIMILAR BUT DESIGNED TO DIVERT 1,795,000 ACRE FEET ANNUALLY
AQUEDUCT SYSTEM "B" WOULD TERMINATE IN THE SANTA MARIA VALLEY

TYPICAL SIPHON SECTION
NOT TO SCALE

TYPICAL SIPHON DIMENSIONS AND HYDRAULIC PROPERTIES						
D	Q	A	V	n	r	s
13 25	1141	138	4 34	0115	3 31	0003

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

PROJECT FEATHER RIVER AND DELTA DIVERSION
FEATURE SAN JOAQUIN VALLEY-SOUTHERN CALIFORNIA AQUEDUCT

ALTERNATIVE COASTAL AQUEDUCT
PLAN AND PROFILE
MILE 0.0 TO 136.9

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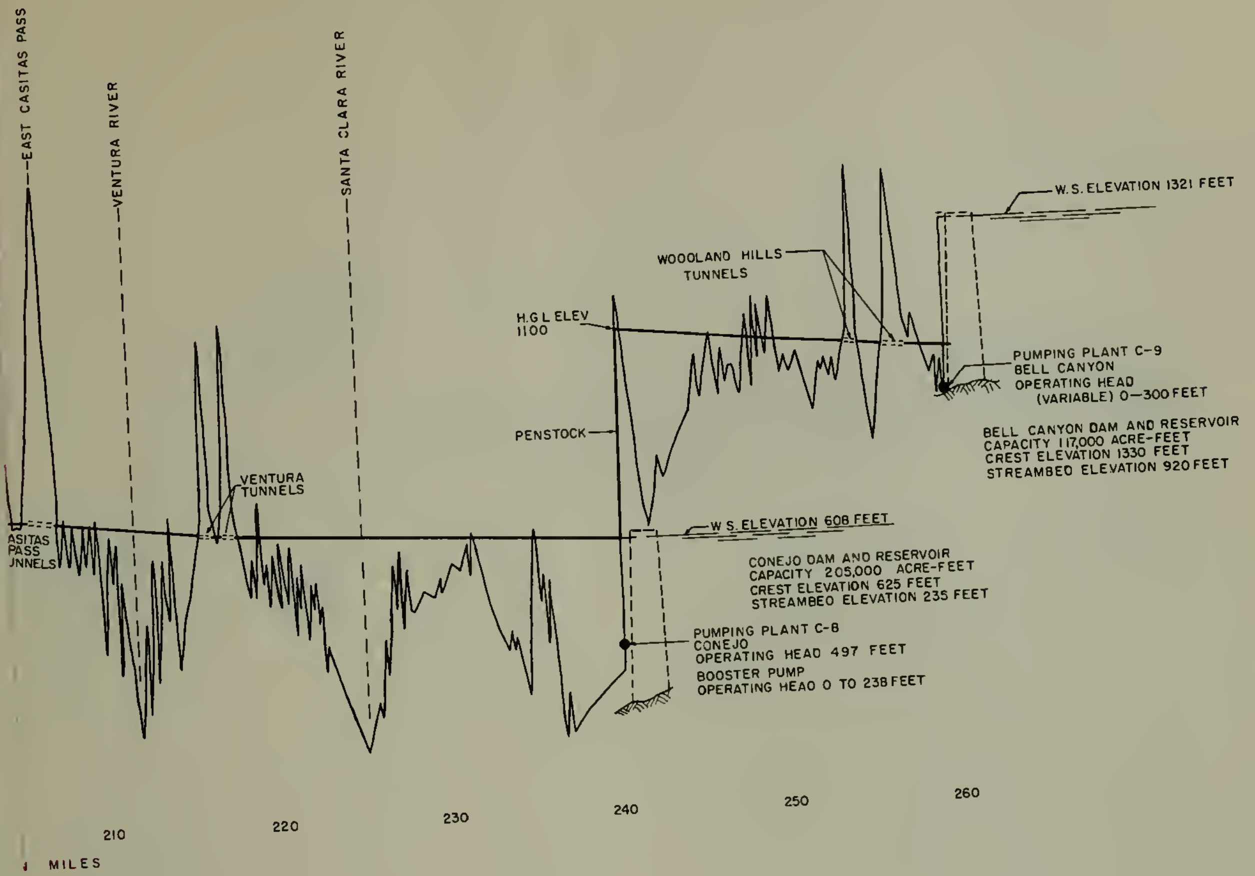

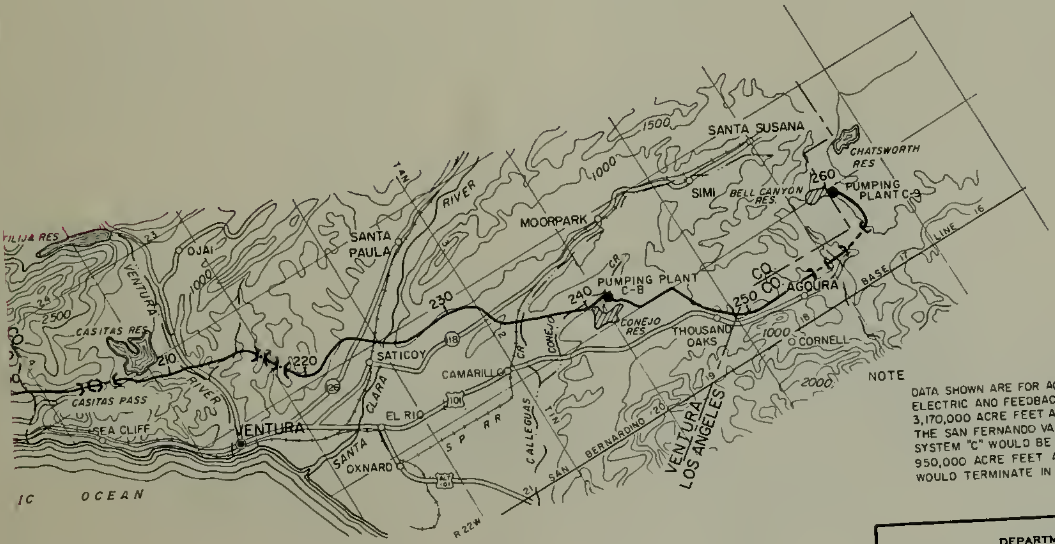

NOTE

DATA SHOWN ARE FOR AQUEDUCT SYSTEM "A" WITH "STEAM ELECTRIC AND FEEDBACK" OPERATION DESIGNED TO DELIVER 3,170,000 ACRE FEET ANNUALLY TO CONEJO RESERVOIR OR THE SAN FERNANDO VALLEY. FACILITIES OF AQUEDUCT SYSTEM "C" WOULD BE SIMILAR BUT DESIGNED TO DELIVER 950,000 ACRE FEET ANNUALLY. AQUEDUCT SYSTEM "B" WOULD TERMINATE IN THE SANTA MARIA VALLEY.

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

PROJECT FEATHER RIVER AND DELTA DIVERSION
FEATURE SAN JOAQUIN VALLEY-SOUTHERN CALIFORNIA AQUEDUCT

ALTERNATIVE COASTAL AQUEDUCT
PLAN AND PROFILE
MILE 136.9 TO 260.0

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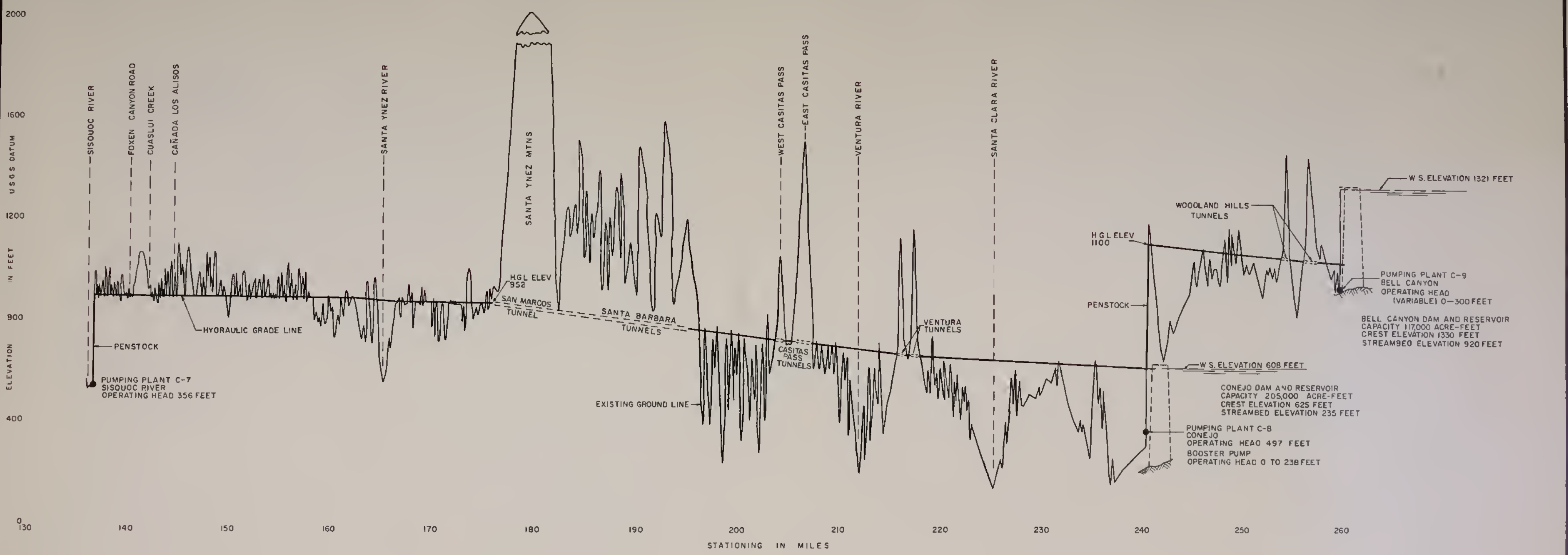
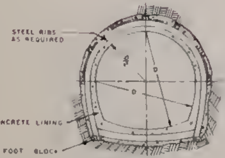
DRAWN H Z.	RECOMMENDED: SUPERVISING HYDRAULIC ENGINEER	DRAWING NO / FILE NO
CHECKED J A.	APPROVAL RECOMMENDED R. M. Edmonston PRINCIPAL HYDRAULIC ENGINEER	

REV	DATE	DESCRIPTION	SUB	APP'D

SHEET 2 OF





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NOT TO SCALE

TYPICAL TUNNEL DIMENSIONS AND HYDRAULIC PROPERTIES						
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NOTE

DATA SHOWN ARE FOR AQUEDUCT SYSTEM "A" WITH "STEAM ELECTRIC AND FEEDBACK" OPERATION DESIGNED TO DELIVER 3,170,000 ACRE FEET ANNUALLY TO CONEJO RESERVOIR OR THE SAN FERNANDO VALLEY. FACILITIES OF AQUEDUCT SYSTEM "C" WOULD BE SIMILAR BUT DESIGNED TO DELIVER 950,000 ACRE FEET ANNUALLY. AQUEDUCT SYSTEM "B" WOULD TERMINATE IN THE SANTA MARIA VALLEY.

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FEATURE SAN JOAQUIN VALLEY-SOUTHERN CALIFORNIA AQUEDUCT

ALTERNATIVE COASTAL AQUEDUCT
PLAN AND PROFILE
MILE 136.9 TO 260.0

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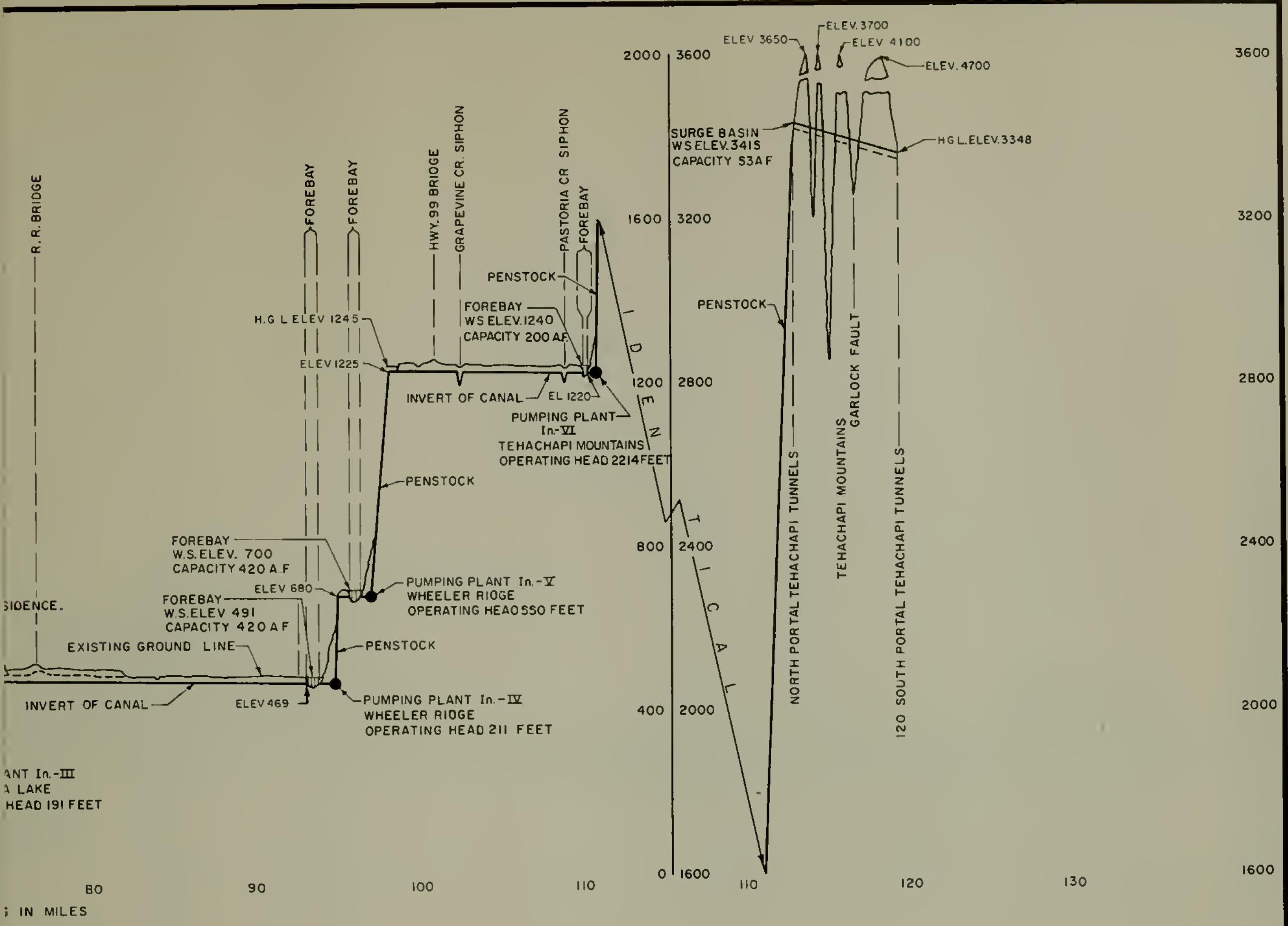

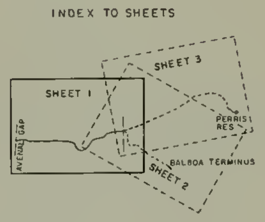
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NOTE

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PROJECT FEATHER RIVER AND DELTA DIVERSION
FEATURE SAN JOAQUIN VALLEY-SOUTHERN CALIFORNIA AQUEDUCT
ALTERNATIVE INLAND AQUEDUCT
PLAN AND PROFILE
MILE 0.0 TO 120

DESIGNED	SUBMITTED	APPROVED:	DATE:
D. S	S GOULD PLANNING E. JACKSON DESIGN		
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CHECKED J P	APPROVAL RECOMMENDED R M Edmonston PRINCIPAL HYDRAULIC ENGINEER	DRAWING No	FILE No

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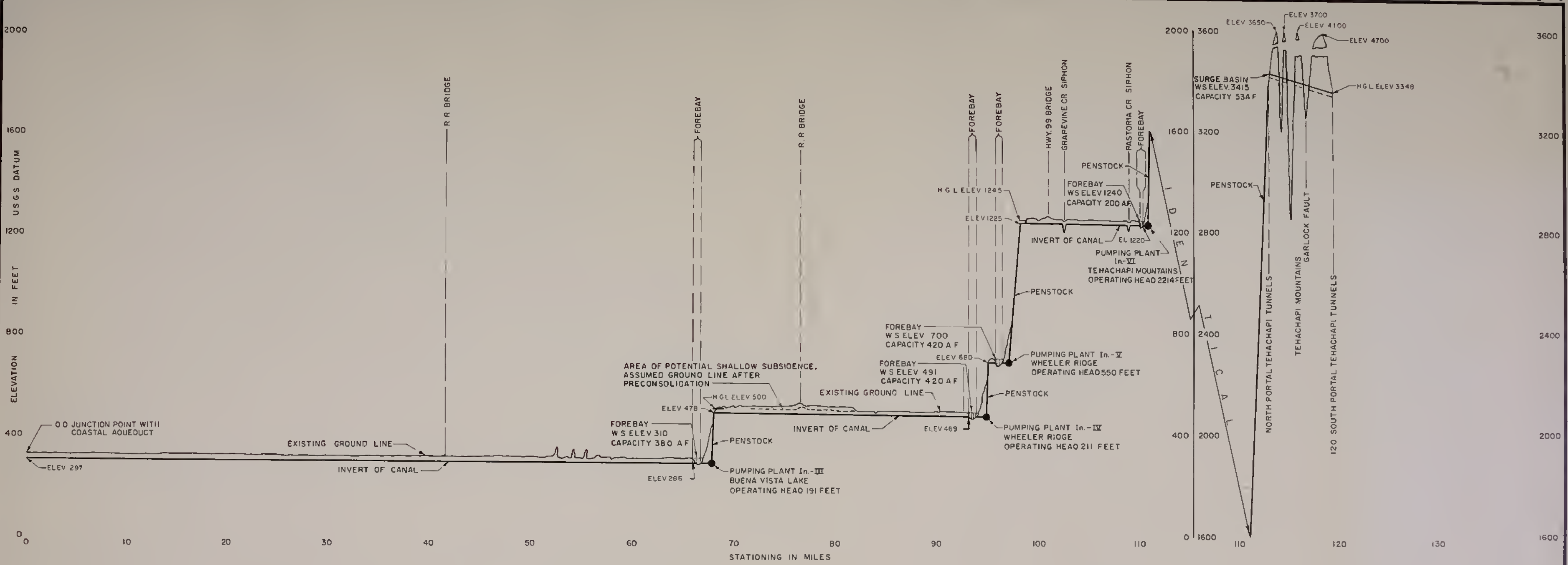

TYPICAL CANAL SECTION

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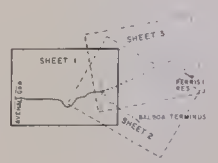

NOTE

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SCALE OF MILES

TYPICAL CANAL DIMENSIONS AND HYDRAULIC PROPERTIES

b	D	A	V	Q	r	n	s
42.00	27.35	2271	4.26	9667	18.15	.014	0.00004
14.65	12.30	458	3.59	1636	7.24	.014	0.00008

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FEATURE SAN JOAQUIN VALLEY–SOUTHERN CALIFORNIA AQUEDUCT
ALTERNATIVE INLAND AQUEDUCT
PLAN AND PROFILE
MILE 0.0 TO 120

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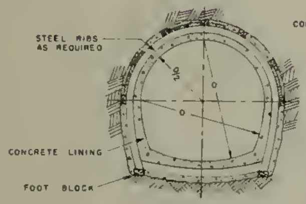
SHEET 1 OF 3

GROUND LINE

LEV 1215

A TERMINUS

180
IN MILES



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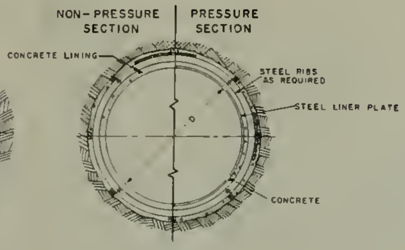

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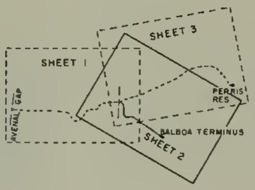

NOTE

DATA SHOWN ARE FOR AQUEDUCT SYSTEM "B" DESIGNED TO DELIVER 1,185,000 ACRE FEET ANNUALLY THROUGH THE CASTAIC POWER DEVELOPMENT WITH "STEAM DRIVE AND FEEDBACK" OPERATION THE REACH OF AQUEDUCT SHOWN ON THIS SHEET IS NOT INCLUDED IN AQUEDUCT SYSTEMS "A" AND "C"

TYPICAL TUNNEL DIMENSIONS AND HYDRAULIC PROPERTIES

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22 00	4833	380	12 8	014	5 50	00147	CIRCULAR
14 60	1636	167	9 8	0115	3 65	00102	PRESSURE
15 70	1636	204	8 0	014	3 98	00090	HORSESHOE

REV	DATE	DESCRIPTION	SUB	APP'D

STATE OF CALIFORNIA
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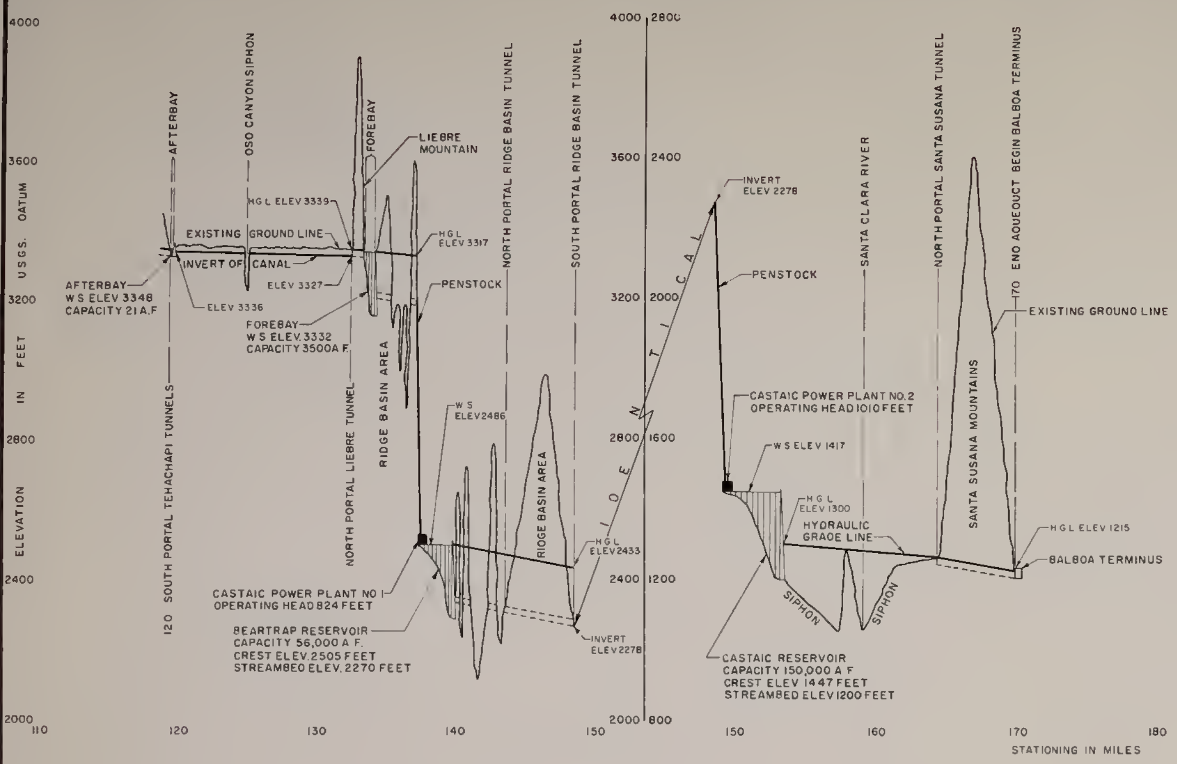
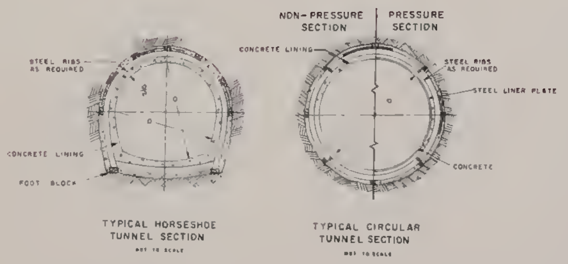
PROJECT FEATHER RIVER AND DELTA DIVERSION
FEATURE SAN JOAQUIN VALLEY-SOUTHERN CALIFORNIA AQUEDUCT
ALTERNATIVE INLAND AQUEDUCT
PLAN AND PROFILE
MILE 120 TO 170

DESIGNED: T B	SUBMITTED: S.GOULD PLANNING E.JACKSON DESIGN	APPROVED: DATE:
DRAWN: P B	RECOMMENDED: Lucas Meyers SUPERVISING HYDRAULIC ENGINEER	Max Bookman 2/16/59 DISTRICT ENGINEER
CHECKED: J P	APPROVAL RECOMMENDED: R M Edmonston PRINCIPAL HYDRAULIC ENGINEER	DRAWING No FILE No

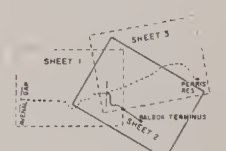




TYPICAL HORSESHOE TUNNEL SECTION
NOT TO SCALE

TYPICAL CIRCULAR TUNNEL SECTION
NOT TO SCALE

INDEX TO SHEETS



NOTE

DATA SHOWN ARE FOR AQUEDUCT SYSTEM "B" DESIGNED TO DELIVER 1,185,000 ACRE FEET ANNUALLY THROUGH THE CASTAIC POWER DEVELOPMENT WITH "STEAM DRIVE AND FEEDBACK" OPERATION. THE REACH OF AQUEDUCT SHOWN ON THIS SHEET IS NOT INCLUDED IN AQUEDUCT SYSTEMS "A" AND "C"

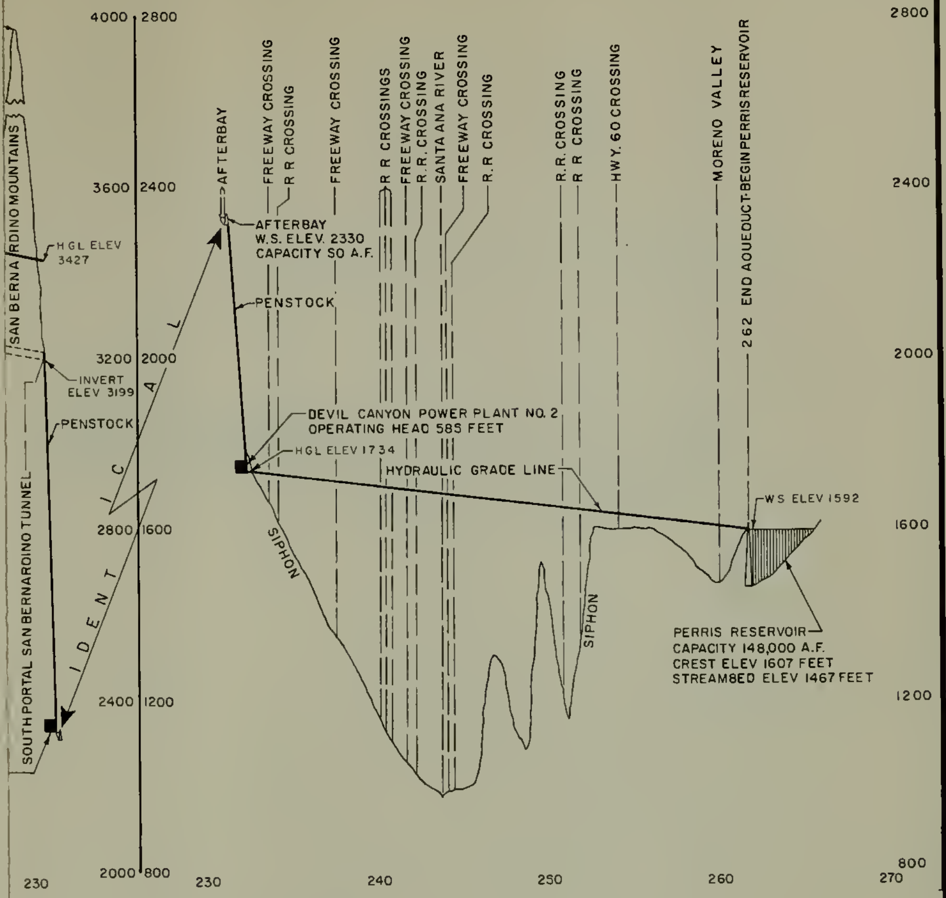
TYPICAL TUNNEL DIMENSIONS AND HYDRAULIC PROPERTIES

D	Q	A	V	n	i	s	SECTION
21 50	4855	383	12 8	.014	5 48	00147	HORSESHOE
22 00	4835	380	12 8	014	5 50	00147	CIRCULAR
14 60	1636	167	9 8	0115	5 85	00102	PRESSURE
15 70	1636	204	8 0	014	5 98	00050	HORSESHOE

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

PROJECT FEATHER RIVER AND DELTA DIVERSION
FEATURE SAN JOAQUIN VALLEY-SOUTHERN CALIFORNIA AQUEDUCT
ALTERNATIVE INLAND AQUEDUCT
PLAN AND PROFILE
MILE 120 TO 170

DESIGNED	SUBMITTED	APPROVED	DATE
T B	S. GOULD E JACKSON		
DRAWN P B	RECOMMENDED	Max Bookman	2/10/59
CHECKED J P	APPROVAL RECOMMENDED R M Edmonston	DRAWING No	FILE No



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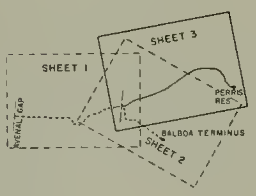
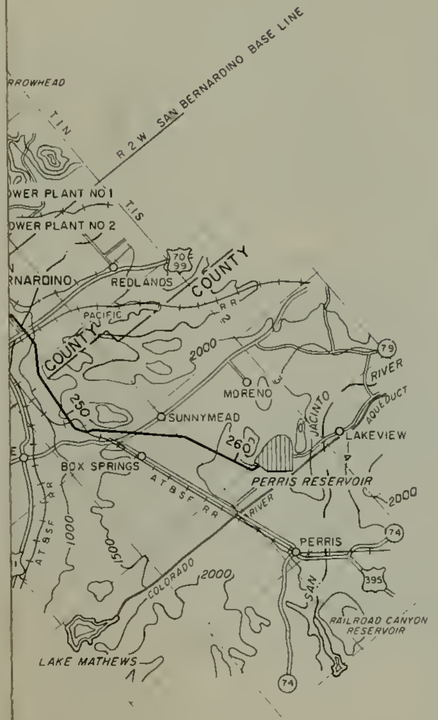




NOTE

DATA SHOWN ARE FOR AQUEDUCT SYSTEMS "B" AND "C" DESIGNED TO DELIVER 1,995,000 ACRE-FEET ANNUALLY THROUGH THE DEVIL CANYON POWER DEVELOPMENT WITH "STEAM DRIVE AND FEEDBACK" OPERATION. AQUEDUCT SYSTEM "A" WOULD TERMINATE AT LITTLE ROCK CREEK AT MILE 172 AND HAVE A DIFFERENT OPERATING HEAD AT COTTONWOOD POWER PLANT AS WELL AS CANAL INVERT ELEVATIONS ADJUSTED FOR SMALLER DESIGN CAPACITY

DATE	DESCRIPTION	SUB	APP'D

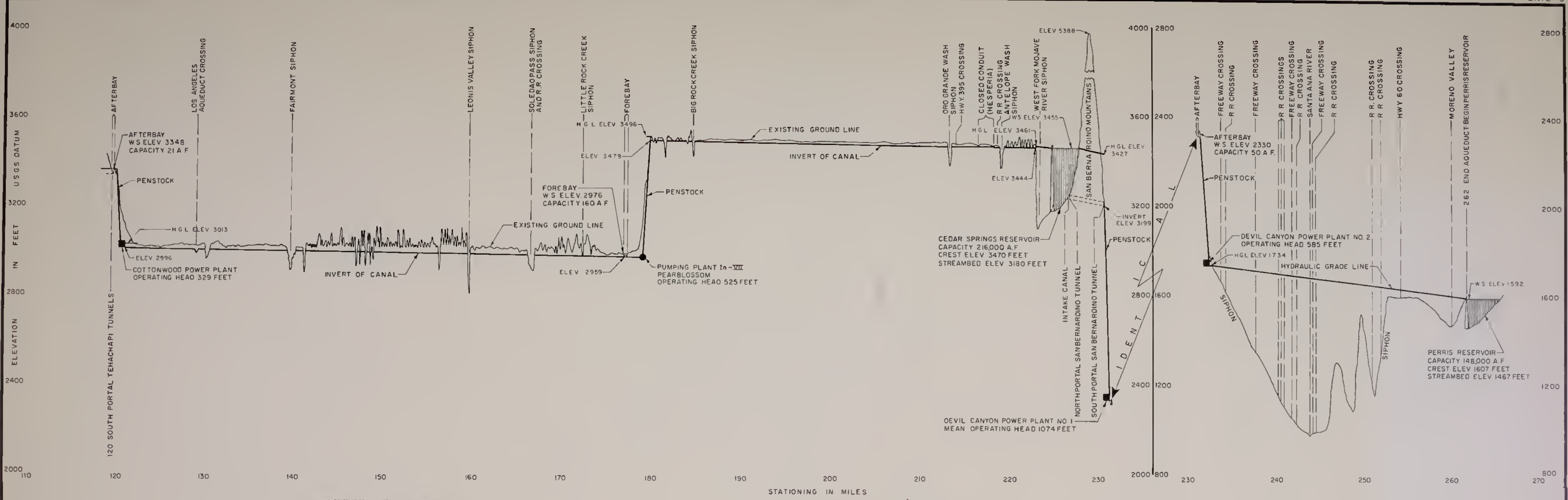
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

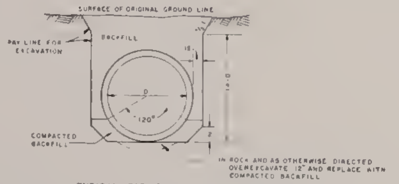
PROJECT FEATHER RIVER AND DELTA DIVERSION
FEATURE SAN JOAQUIN VALLEY-SOUTHERN CALIFORNIA AQUEDUCT

ALTERNATIVE INLAND AQUEDUCT
PLAN AND PROFILE
MILE 120 TO 262

DESIGNED: H H
DRAWN: P B
CHECKED: J P
SUBMITTED: S GOULD, PLANNING; E. JACKSON, DESIGN
RECOMMENDED: SUPERVISING HYDRAULIC ENGINEER
APPROVAL RECOMMENDED: R M. Edmonston, PRINCIPAL HYDRAULIC ENGINEER
APPROVED: Max Bookman, DISTRICT ENGINEER
DATE. 2/16/59
DRAWING NO
FILE NO

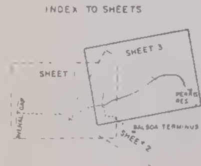
PLATE 6





TYPICAL SIPHON SECTION
NOT TO SCALE

TYPICAL SIPHON DIMENSIONS AND HYDRAULIC PROPERTIES						
Q	D	n	A	V	r	s
1266	15.67	.0115	193	6.56	3.92	.000415
915	15.30	.0115	184	4.97	3.83	.000462



INDEX TO SHEETS

NOTE

DATA SHOWN ARE FOR AQUEDUCT SYSTEMS "B" AND "C" DESIGNED TO DELIVER 1,995,000 ACRE-FEET ANNUALLY THROUGH THE DEVIL CANYON POWER DEVELOPMENT WITH "STEAM DRIVE AND FEEDBACK" OPERATION. AQUEDUCT SYSTEM "A" WOULD TERMINATE AT LITTLE ROCK CREEK AT MILE 172 AND HAVE A DIFFERENT OPERATING HEAD AT COTTONWOOD POWER PLANT AS WELL AS CANAL INVERT ELEVATIONS ADJUSTED FOR SMALLER DESIGN CAPACITY

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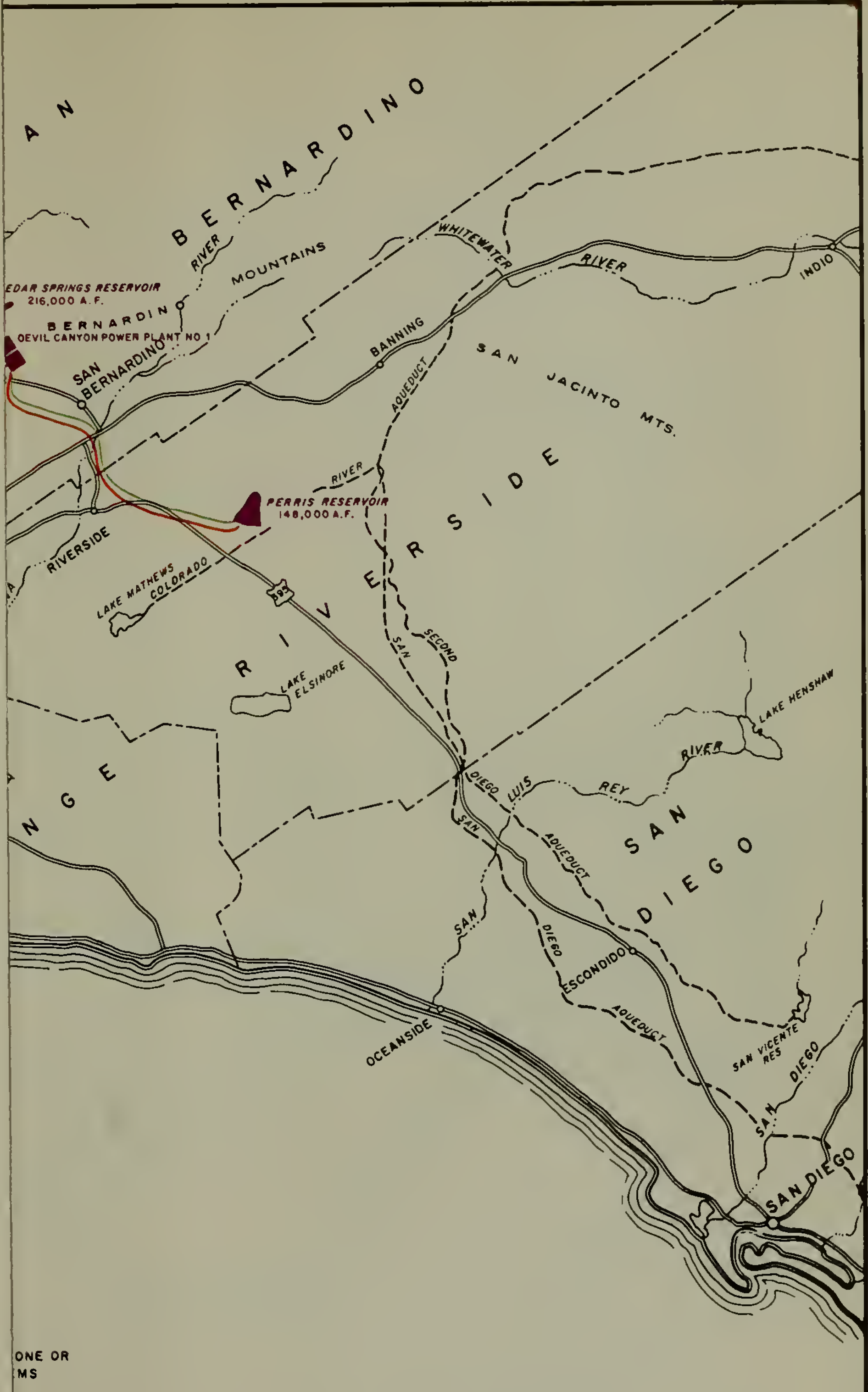
SOUTHERN CALIFORNIA DISTRICT

PROJECT FEATHER RIVER AND DELTA DIVERSION
FEATURE SAN JOAQUIN VALLEY-SOUTHERN CALIFORNIA AQUEDUCT
ALTERNATIVE INLAND AQUEDUCT
PLAN AND PROFILE
MILE 120 TO 262

DESIGNED N H	SUBMITTED S GOULD E JACKSON	APPROVED	DATE
DRAWN P B	RECOMMENDED		2-6-57
CHECKED J P	APPROVAL RECOMMENDED R M. Edmonston	DRAWING No.	FILE No.

SHEET 3 OF 3

PLATE 7



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

FEATHER RIVER AND DELTA
DIVERSION PROJECTS

◆

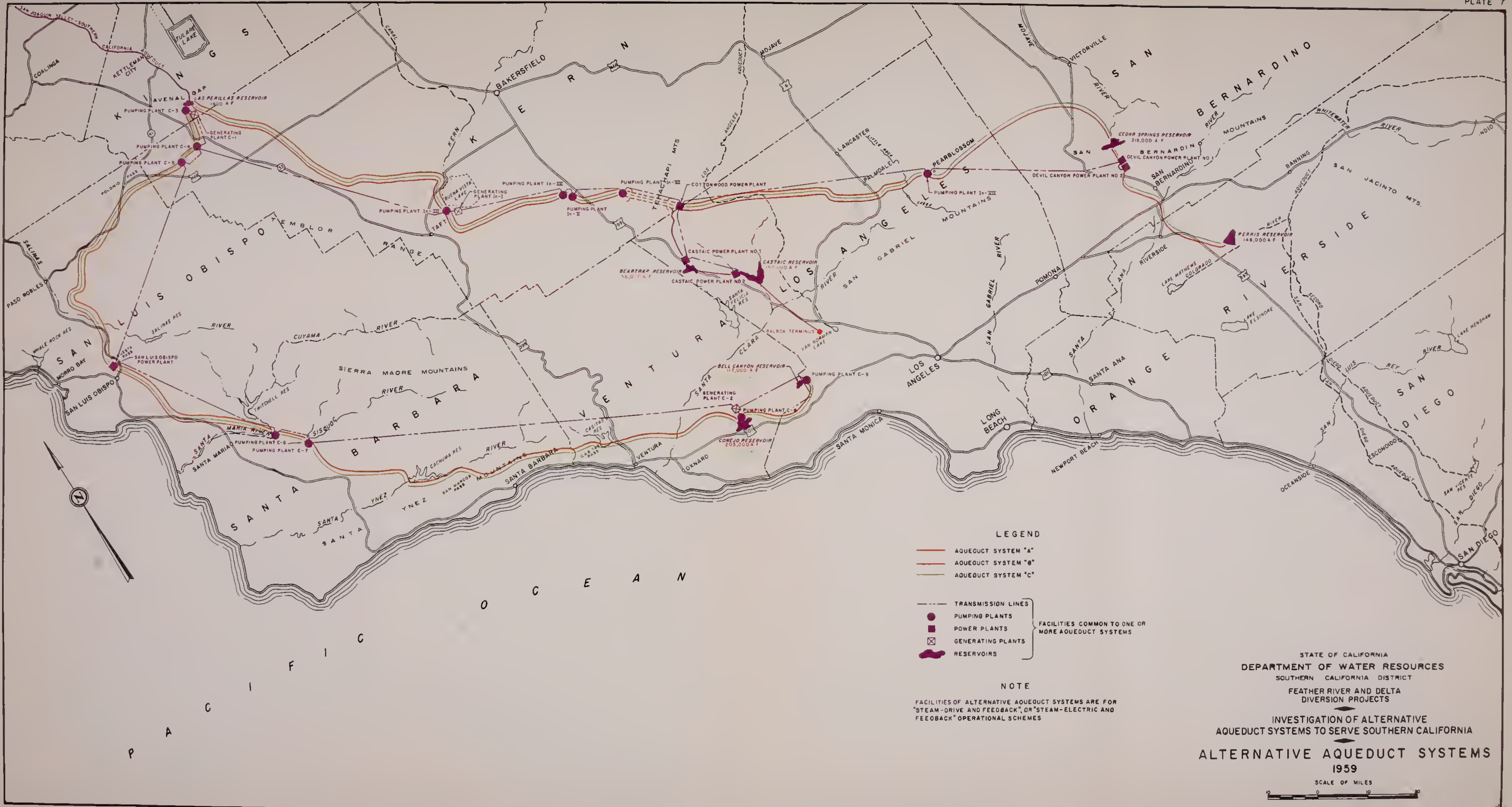
INVESTIGATION OF ALTERNATIVE
AQUEDUCT SYSTEMS TO SERVE SOUTHERN CALIFORNIA

◆

ALTERNATIVE AQUEDUCT SYSTEMS
1959

SCALE OF MILES
10 0 10 20

PLATE 7



NOTE

FACILITIES OF ALTERNATIVE AQUEDUCT SYSTEMS ARE FOR "STEAM-DRIVE AND FEEDBACK", OR "STEAM-ELECTRIC AND FEEDBACK" OPERATIONAL SCHEMES

STATE OF CALIFORNIA
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FEATHER RIVER AND DELTA
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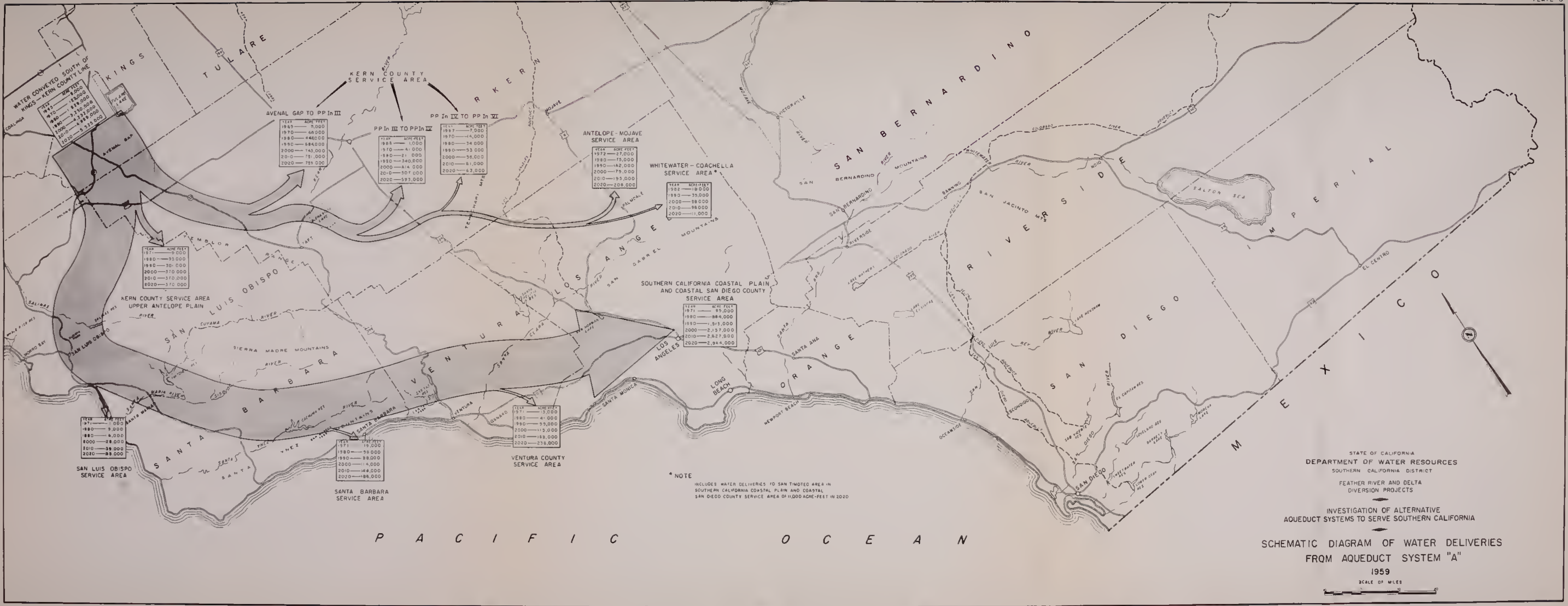
INVESTIGATION OF ALTERNATIVE
AQUEDUCT SYSTEMS TO SERVE SOUTHERN CALIFORNIA

◆

ALTERNATIVE AQUEDUCT SYSTEMS

1959



WATER CONVEYED SOUTH OF KINGS—KERN COUNTY LINE

YEAR	ACRE-FEET
1965	8,000
1970	123,000
1980	1,820,000
1990	3,230,000
2000	4,232,000
2010	4,988,000
2020	5,325,000

KERN COUNTY SERVICE AREA

AVENAL GAP TO PP In III

YEAR	ACRE-FEET
1965	5,000
1970	68,000
1980	448,000
1990	684,000
2000	745,000
2010	751,000
2020	759,000

PP In III TO PP In IV

YEAR	ACRE-FEET
1968	1,000
1970	41,000
1980	21 000
1990	340,000
2000	414,000
2010	507,000
2020	593,000

PP In IV TO PP In VI

YEAR	ACRE-FEET
1967	7,000
1970	14,000
1980	34,000
1990	53,000
2000	58,000
2010	61,000
2020	63,000

ANTELOPE-MOJAVE SERVICE AREA

YEAR	ACRE-FEET
1972	27,000
1980	75,000
1990	142,000
2000	175,000
2010	195,000
2020	208,000

WHITEWATER—COACHELLA SERVICE AREA*

YEAR	ACRE-FEET
1982	19,000
1990	35,000
2000	58,000
2010	98,000
2020	111,000

KERN COUNTY SERVICE AREA UPPER ANTELOPE PLAIN

YEAR	ACRE-FEET
1971	9,000
1980	93,000
1990	301,000
2000	370,000
2010	370,000
2020	370,000

SOUTHERN CALIFORNIA COASTAL PLAIN AND COASTAL SAN DIEGO COUNTY SERVICE AREA

YEAR	ACRE-FEET
1971	85,000
1980	884,000
1990	1,513,000
2000	2,137,000
2010	2,627,000
2020	2,944,000

SAN LUIS OBISPO SERVICE AREA

YEAR	ACRE-FEET
1971	1,000
1980	3,000
1990	6,000
2000	20,000
2010	39,000
2020	89,000

SANTA BARBARA SERVICE AREA

YEAR	ACRE-FEET
1971	19,000
1980	58,000
1990	88,000
2000	114,000
2010	146,000
2020	186,000

VENTURA COUNTY SERVICE AREA

YEAR	ACRE-FEET
1971	15,000
1980	41,000
1990	93,000
2000	113,000
2010	168,000
2020	238,000

* NOTE

INCLUDES WATER DELIVERIES TO SAN TIMOTEO AREA IN SOUTHERN CALIFORNIA COASTAL PLAIN AND COASTAL SAN DIEGO COUNTY SERVICE AREA OF 11,000 ACRE-FEET IN 2020

STATE OF CALIFORNIA
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SCHEMATIC DIAGRAM OF WATER DELIVERIES FROM AQUEDUCT SYSTEM "A"

1959

SCALE OF MILES

PLATE 9

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RTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

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INVESTIGATION OF ALTERNATIVE
YSTEMS TO SERVE SOUTHERN CALIFORNIA

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DIAGRAM OF WATER DELIVERIES
M AQUEDUCT SYSTEM "B"
1959

SCALE OF MILES
0 10 20

PLATE 9

WATER CONVEYED SOUTH OF KINGS—KERN COUNTY LINE

YEAR	ACRE FEET
1965	13,000
1970	46,000
1980	854,000
1990	3,237,000
2000	4,222,000
2010	4,940,000
2020	5,495,000

KERN COUNTY SERVICE AREA

AVENAL GAP TO PP In III

YEAR	ACRE FEET
1963	13 000
1970	66 000
1980	476 000
1990	705 000
2000	759 000
2010	759 000
2020	759 000

PP In III TO PP In IV

YEAR	ACRE FEET
1966	11,000
1970	42,000
1980	213 000
1990	342,000
2000	416 000
2010	508,000
2020	593,000

PP In IV TO PP In VI

YEAR	ACRE FEET
1967	8 000
1970	16 000
1980	39 000
1990	98,000
2000	61,000
2010	63,000
2020	63 000

ANTELOPE—MOJAVE SERVICE AREA

YEAR	ACRE FEET
1971	21 000
1980	75 000
1990	142,000
2000	175 000
2010	195 000
2020	208,000

WHITEWATER—COACHELLA SERVICE AREA

YEAR	ACRE FEET
1982	18,000
1990	35 000
2000	55,000
2010	90,000
2020	100,000

YEAR	ACRE FEET
1982	70,000
1990	565 000
2000	1 212 000
2010	1 687 000
2020	2,007,000

KERN COUNTY SERVICE AREA UPPER ANTELOPE PLAIN

YEAR	ACRE FEET
1971	9 000
1980	95 000
1990	-30 000
2000	370 000
2010	370 000
2020	370 000

SAN LUIS OBISPO SERVICE AREA

YEAR	ACRE FEET
1971	1 000
1980	4 000
1990	17,000
2000	26 000
2010	34 000
2020	52,000

SANTA BARBARA SERVICE AREA

YEAR	ACRE FEET
1971	18 000
1980	67,000
1990	66 000
2000	85 000
2010	118 000
2020	159 000

VENTURA COUNTY SERVICE AREA

YEAR	ACRE FEET
1971	13,000
1980	41,000
1990	55,000
2000	115 000
2010	168 000
2020	236,000

SOUTHERN CALIFORNIA COASTAL PLAIN AND COASTAL SAN DIEGO COUNTY SERVICE AREA

YEAR	ACRE FEET
1971	95,000
1980	864,000
1990	946 000
2000	968 000
2010	948 000
2020	948 000

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INVESTIGATION OF ALTERNATIVE
AQUEDUCT SYSTEMS TO SERVE SOUTHERN CALIFORNIA

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SCHEMATIC DIAGRAM OF WATER DELIVERIES FROM AQUEDUCT SYSTEM "B"

1959

PLATE 10

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DEPARTMENT OF WATER RESOURCES
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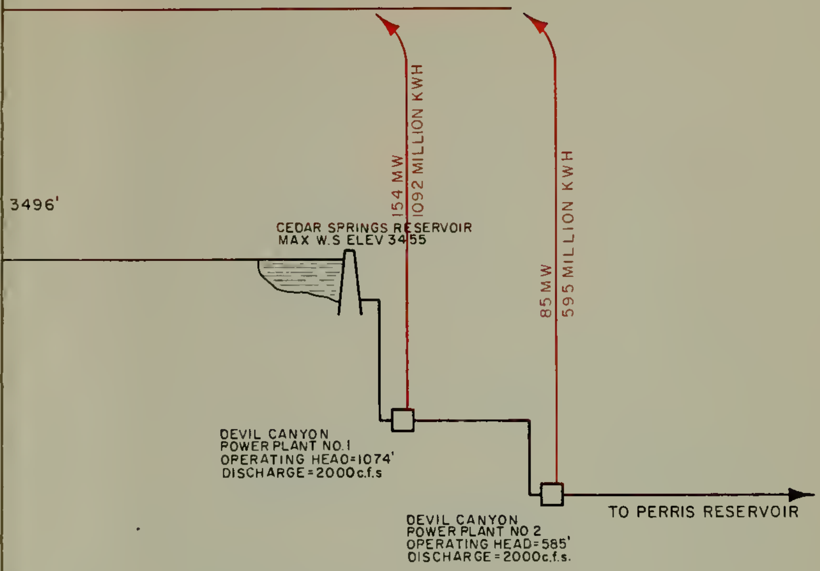
INVESTIGATION OF ALTERNATIVE
AQUEDUCT SYSTEMS TO SERVE SOUTHERN CALIFORNIA

◆

SCHEMATIC DIAGRAM OF WATER DELIVERIES FROM AQUEDUCT SYSTEM "C"

1959



ENERGY BALANCE

NS OF KILOWATT-HOURS PER YEAR

ELECTRICAL ENERGY FROM GENERATING PLANTS	
COTTONWOOD	401
CASTAIC NO. 1	740
CASTAIC NO 2	910
DEVIL CANYON NO 1	1092
DEVIL CANYON NO. 2	595
SAN LUIS OBISPO	41
TOTAL HYDRO	3779
PLUS STEAM	324
TOTAL	4103

ED ARE FOR FACILITIES SOUTH OF AVENAL GAP ONLY

STATE OF CALIFORNIA
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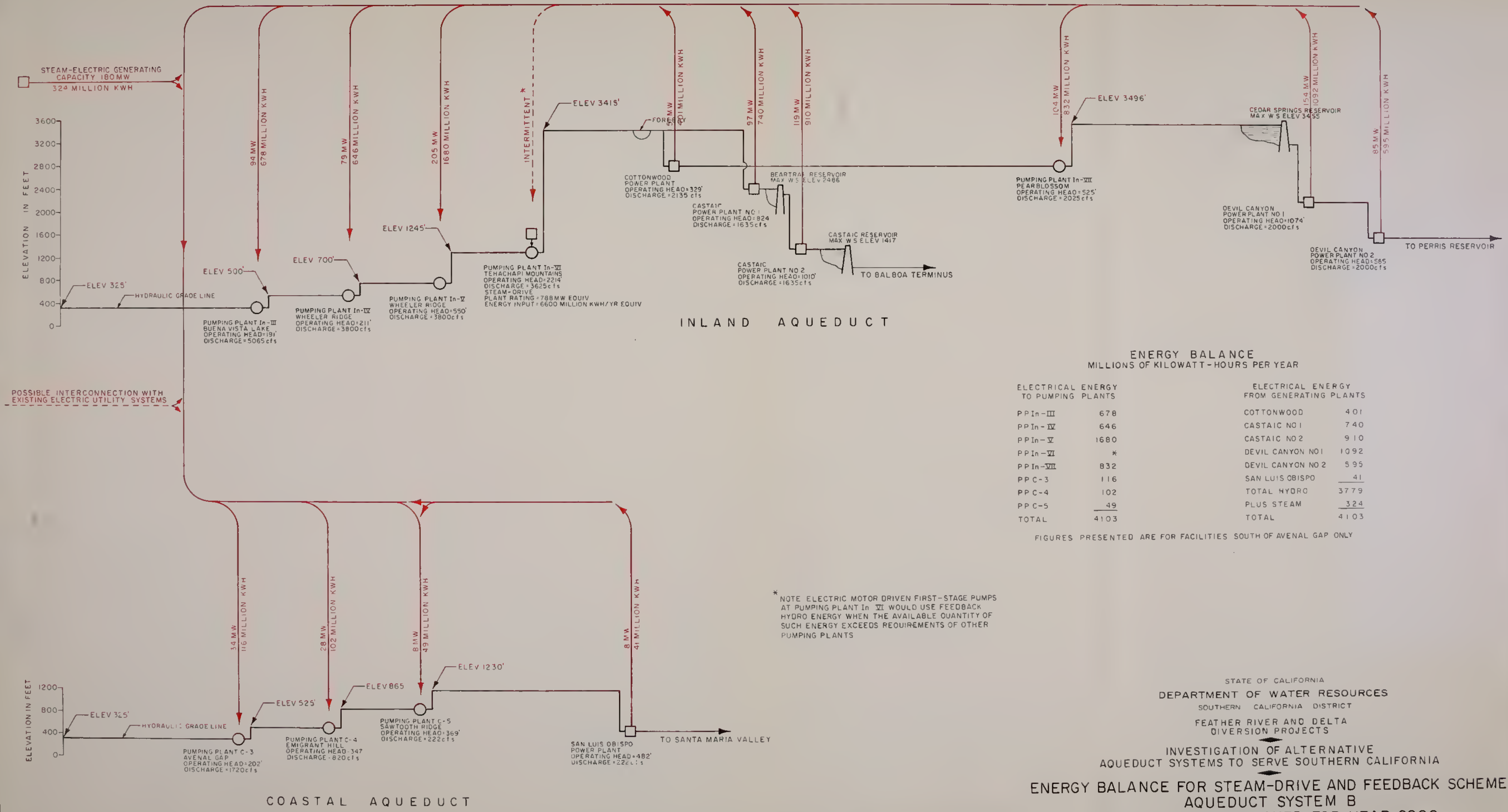
INVESTIGATION OF ALTERNATIVE
EDUCT SYSTEMS TO SERVE SOUTHERN CALIFORNIA

LANCE FOR STEAM-DRIVE AND FEEDBACK SCHEME
AQUEDUCT SYSTEM B
NDITIONS ESTIMATED FOR YEAR 2000

1959

PLATE II



ENERGY BALANCE

MILLIONS OF KILOWATT-HOURS PER YEAR

ELECTRICAL ENERGY TO PUMPING PLANTS		ELECTRICAL ENERGY FROM GENERATING PLANTS	
P P In-III	678	COTTONWOOD	401
P P In-IV	646	CASTAIC NO 1	740
P P In-V	1680	CASTAIC NO 2	910
P P In-VI	*	DEVIL CANYON NO 1	1092
P P In-VII	832	DEVIL CANYON NO 2	595
P P C-3	116	SAN LUIS OBISPO	41
P P C-4	102	TOTAL HYDRO	3779
P P C-5	49	PLUS STEAM	324
TOTAL	4103	TOTAL	4103

FIGURES PRESENTED ARE FOR FACILITIES SOUTH OF AVENAL GAP ONLY

* NOTE ELECTRIC MOTOR DRIVEN FIRST-STAGE PUMPS AT PUMPING PLANT In VI WOULD USE FEEDBACK HYDRO ENERGY WHEN THE AVAILABLE QUANTITY OF SUCH ENERGY EXCEEDS REQUIREMENTS OF OTHER PUMPING PLANTS

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INVESTIGATION OF ALTERNATIVE
AQUEDUCT SYSTEMS TO SERVE SOUTHERN CALIFORNIA

ENERGY BALANCE FOR STEAM-DRIVE AND FEEDBACK SCHEME
AQUEDUCT SYSTEM B
CONDITIONS ESTIMATED FOR YEAR 2000

1959

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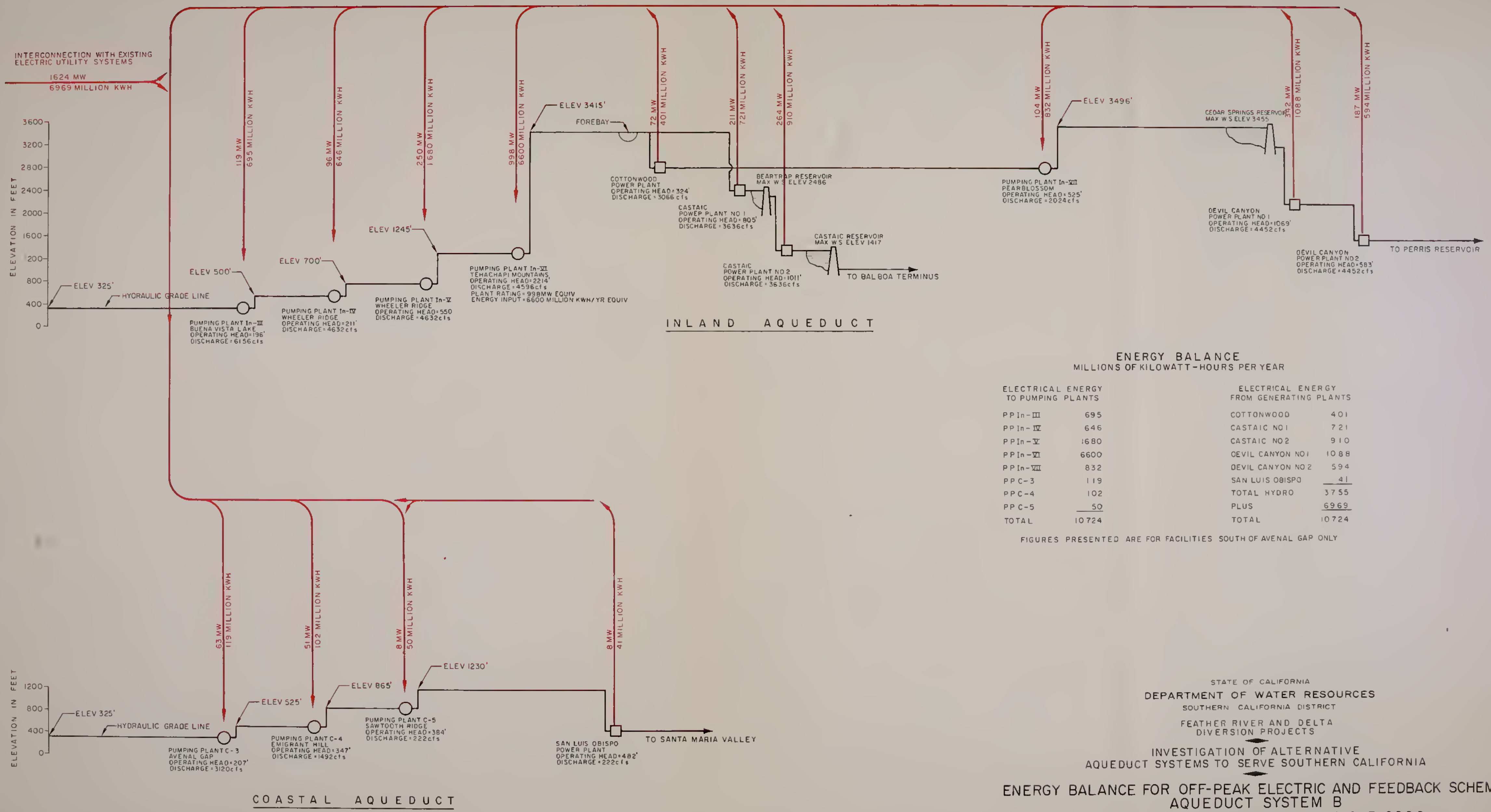
PLATE 12



ENERGY BALANCE

MILLIONS OF KILOWATT-HOURS PER YEAR

ELECTRICAL ENERGY TO PUMPING PLANTS		ELECTRICAL ENERGY FROM GENERATING PLANTS	
PP In-III	695	COTTONWOOD	401
PP In-IV	646	CASTAIC NO 1	721
PP In-V	1680	CASTAIC NO 2	910
PP In-VI	6600	DEVIL CANYON NO 1	1088
PP In-VII	832	DEVIL CANYON NO 2	594
PP C-3	119	SAN LUIS OBISPO	41
PP C-4	102	TOTAL HYDRO	3755
PP C-5	50	PLUS	6969
TOTAL	10724	TOTAL	10724

FIGURES PRESENTED ARE FOR FACILITIES SOUTH OF AVENAL GAP ONLY

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INVESTIGATION OF ALTERNATIVE
AQUEDUCT SYSTEMS TO SERVE SOUTHERN CALIFORNIA

◆

ENERGY BALANCE FOR OFF-PEAK ELECTRIC AND FEEDBACK SCHEME
AQUEDUCT SYSTEM B
CONDITIONS ESTIMATED FOR YEAR 2000

1959


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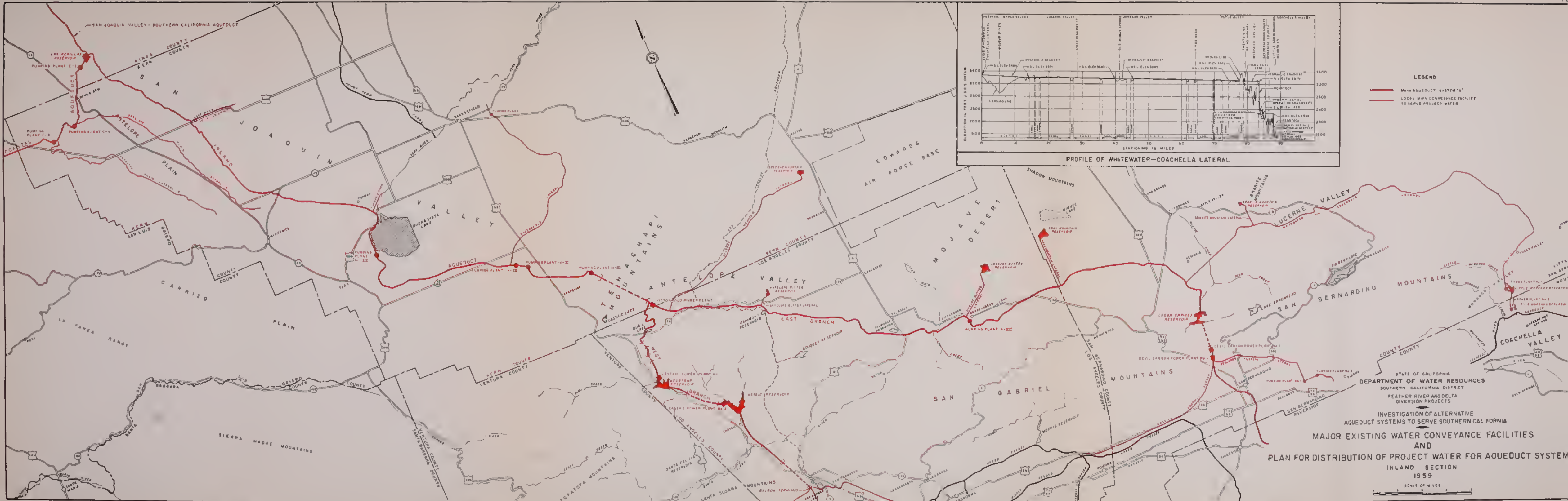

LEGEND

MAIN AQUEDUCT SYSTEM "B"

LOCAL MAIN CONVEYANCE FACILITY TO SERVE PROJECT WATER

STATE OF CALIFORNIA
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INVESTIGATION OF ALTERNATIVE
AQUEDUCT SYSTEMS TO SERVE SOUTHERN CALIFORNIA

◆

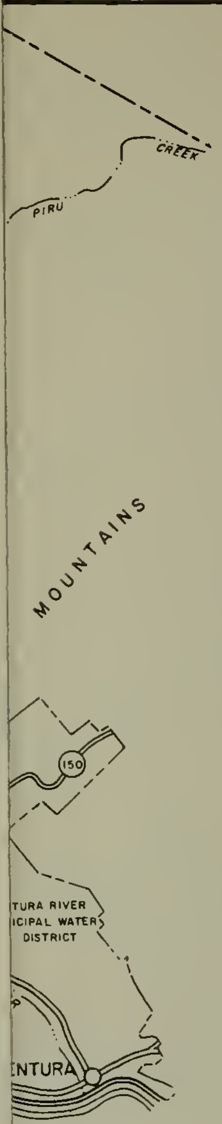
MAJOR EXISTING WATER CONVEYANCE FACILITIES AND PLAN FOR DISTRIBUTION OF PROJECT WATER FOR AQUEDUCT SYSTEM

INLAND SECTION

1959

SCALE OF MILES

PLATE 14



LEGEND

MAJOR EXISTING CONVEYANCE FACILITY.

MAIN AQUEDUCT, SYSTEM "B".

LOCAL MAIN CONVEYANCE FACILITY
TO SERVE PROJECT WATER.

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INVESTIGATION OF ALTERNATIVE
UEDUCT SYSTEMS TO SERVE SOUTHERN CALIFORNIA

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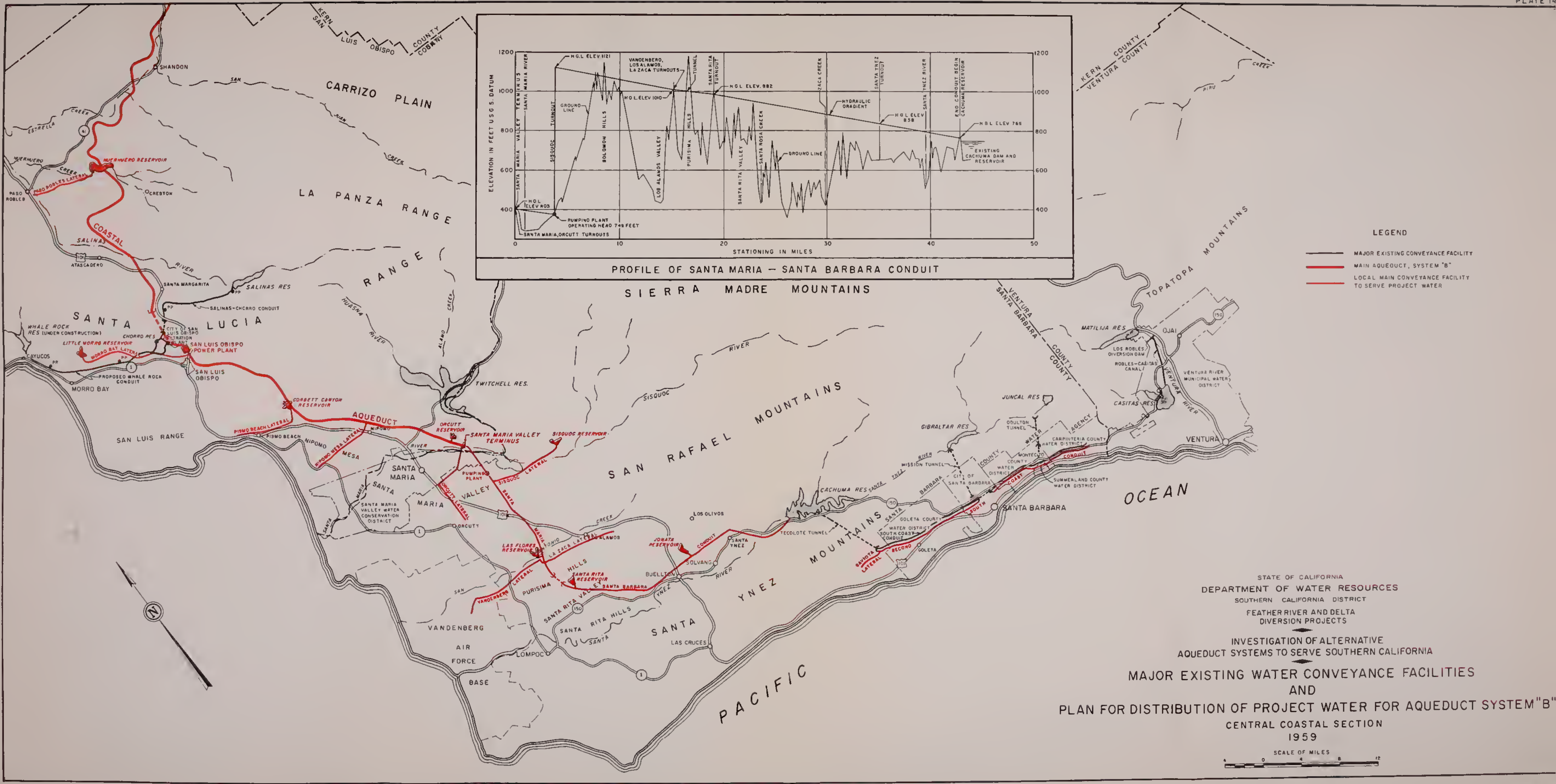
XISTING WATER CONVEYANCE FACILITIES
AND
TION OF PROJECT WATER FOR AQUEDUCT SYSTEM "B"
CENTRAL COASTAL SECTION
1959

SCALE OF MILES
4 0 4 8 12

PLATE 14



PROFILE OF SANTA MARIA — SANTA BARBARA CONDUIT

LEGEND

▬	MAJOR EXISTING CONVEYANCE FACILITY
🟥	MAIN AQUEDUCT, SYSTEM "B"
🟥	LOCAL MAIN CONVEYANCE FACILITY TO SERVE PROJECT WATER

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INVESTIGATION OF ALTERNATIVE
AQUEDUCT SYSTEMS TO SERVE SOUTHERN CALIFORNIA

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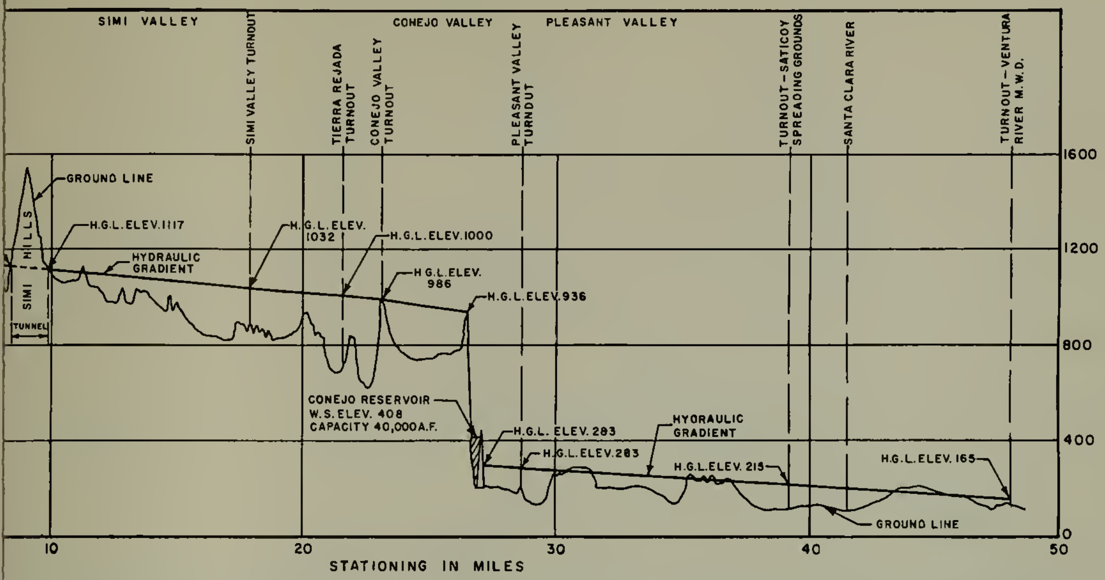
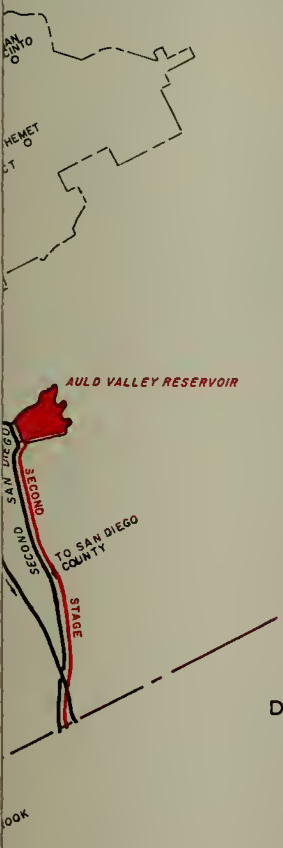
MAJOR EXISTING WATER CONVEYANCE FACILITIES AND PLAN FOR DISTRIBUTION OF PROJECT WATER FOR AQUEDUCT SYSTEM "B"

CENTRAL COASTAL SECTION
1959

SCALE OF MILES
4 0 4 8 12



NTURA COUNTY FEEDER—SATICOY-VENTURA LATERAL AND VENTURA EXTENSION



LEGEND

━━ ← 100 c.f.s.	METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA OR SAN DIEGO COUNTY WATER AUTHORITY—EXISTING CONVEYANCE FACILITY, NOMINAL CONVEYANCE CAPACITY, AND DIRECTION OF FLOW UNDER NORMAL OPERATION.
- - - - - - - - -	CITY OF LOS ANGELES—MAJOR EXISTING CONVEYANCE FACILITY.
──	WATER SERVICE AGENCIES OUTSIDE METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA—MAJOR EXISTING CONVEYANCE FACILITY.
🟥	MAIN AQUEDUCT, SYSTEM "B".
🟥	LOCAL MAIN CONVEYANCE FACILITY TO SERVE PROJECT WATER.

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INVESTIGATION OF ALTERNATIVE
AQUEDUCT SYSTEMS TO SERVE SOUTHERN CALIFORNIA

◆

MAJOR EXISTING WATER CONVEYANCE FACILITIES
AND
FOR DISTRIBUTION OF PROJECT WATER FOR AQUEDUCT SYSTEM "B"

SOUTH COASTAL SECTION
1959

SCALE OF MILES
4 0 4 8 12

PROFILE OF VENTURA COUNTY FEEDER—SATICOY-VENTURA LATERAL AND VENTURA EXTENSION

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INVESTIGATION OF ALTERNATIVE
AQUEDUCT SYSTEMS TO SERVE SOUTHERN CALIFORNIA

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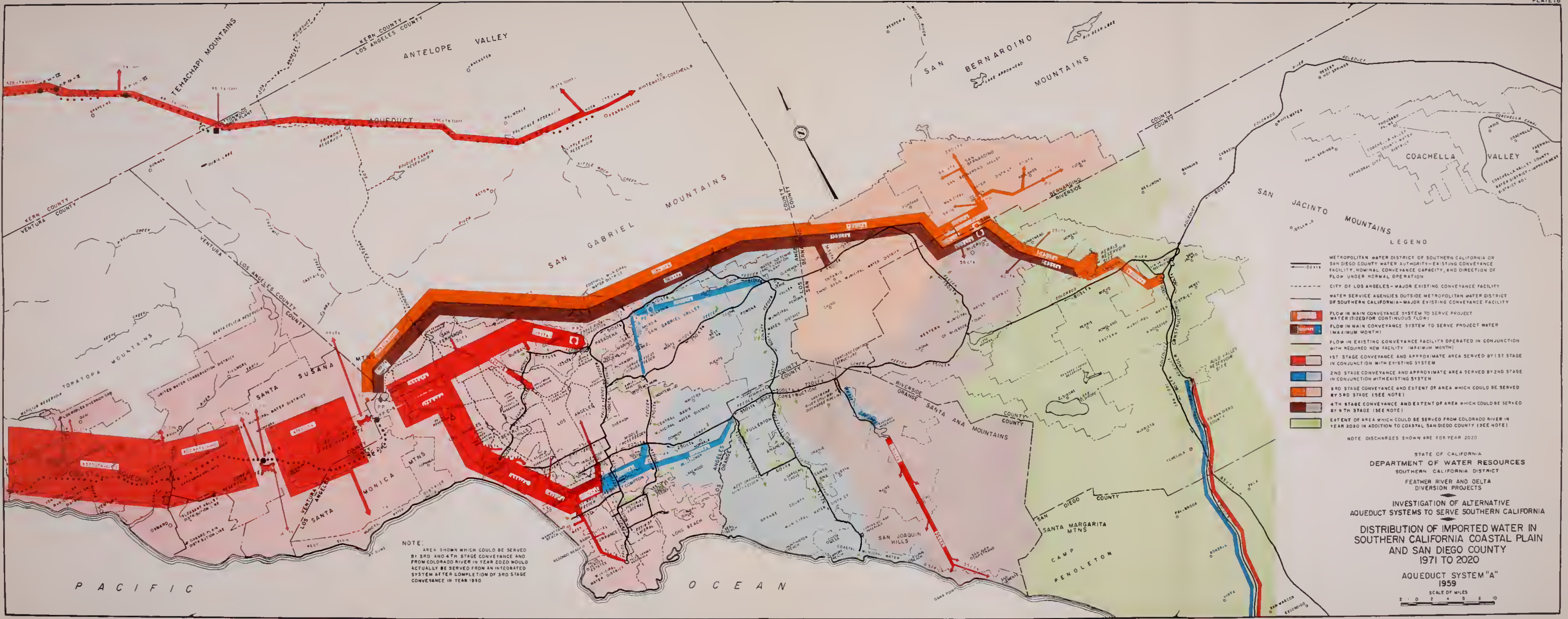
MAJOR EXISTING WATER CONVEYANCE FACILITIES AND PLAN FOR DISTRIBUTION OF PROJECT WATER FOR AQUEDUCT SYSTEM "B"

SOUTH COASTAL SECTION
1959

SCALE OF MILES

PLATE 16



NOTE:
AREA SHOWN WHICH COULD BE SERVED BY 3RD AND 4TH STAGE CONVEYANCE AND FROM COLORADO RIVER IN YEAR 2020 WOULD ACTUALLY BE SERVED FROM AN INTEGRATED SYSTEM AFTER COMPLETION OF 3RD STAGE CONVEYANCE IN YEAR 1990

LEGEND

METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA OR SAN DIEGO COUNTY WATER AUTHORITY—EXISTING CONVEYANCE FACILITY, NOMINAL CONVEYANCE CAPACITY, AND DIRECTION OF FLOW UNDER NORMAL OPERATION

CITY OF LOS ANGELES—MAJOR EXISTING CONVEYANCE FACILITY

WATER SERVICE AGENCIES OUTSIDE METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA—MAJOR EXISTING CONVEYANCE FACILITY

FLOW IN MAIN CONVEYANCE SYSTEM TO SERVE PROJECT WATER (SIZED FOR CONTINUOUS FLOW)

FLOW IN MAIN CONVEYANCE SYSTEM TO SERVE PROJECT WATER (MAXIMUM MONTH)

FLOW IN EXISTING CONVEYANCE FACILITY OPERATED IN CONJUNCTION WITH REQUIRED NEW FACILITY (MAXIMUM MONTH)

1ST STAGE CONVEYANCE AND APPROXIMATE AREA SERVED BY 1ST STAGE IN CONJUNCTION WITH EXISTING SYSTEM

2ND STAGE CONVEYANCE AND APPROXIMATE AREA SERVED BY 2ND STAGE IN CONJUNCTION WITH EXISTING SYSTEM

3RD STAGE CONVEYANCE AND EXTENT OF AREA WHICH COULD BE SERVED BY 3RD STAGE (SEE NOTE)

4TH STAGE CONVEYANCE AND EXTENT OF AREA WHICH COULD BE SERVED BY 4TH STAGE (SEE NOTE)

EXTENT OF AREA WHICH COULD BE SERVED FROM COLORADO RIVER IN YEAR 2020 IN ADDITION TO COASTAL SAN DIEGO COUNTY (SEE NOTE)

NOTE DISCHARGES SHOWN ARE FOR YEAR 2020

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

FEATHER RIVER AND DELTA
DIVERSION PROJECTS

◆

INVESTIGATION OF ALTERNATIVE
AQUEDUCT SYSTEMS TO SERVE SOUTHERN CALIFORNIA

◆

DISTRIBUTION OF IMPORTED WATER IN SOUTHERN CALIFORNIA COASTAL PLAIN AND SAN DIEGO COUNTY 1971 TO 2020

AQUEDUCT SYSTEM "A"
1959

SCALE OF MILES
2 1 0 2 4 6 8 10

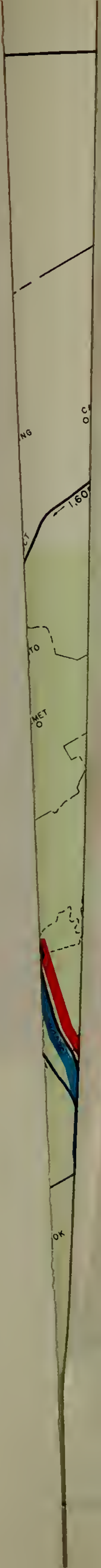

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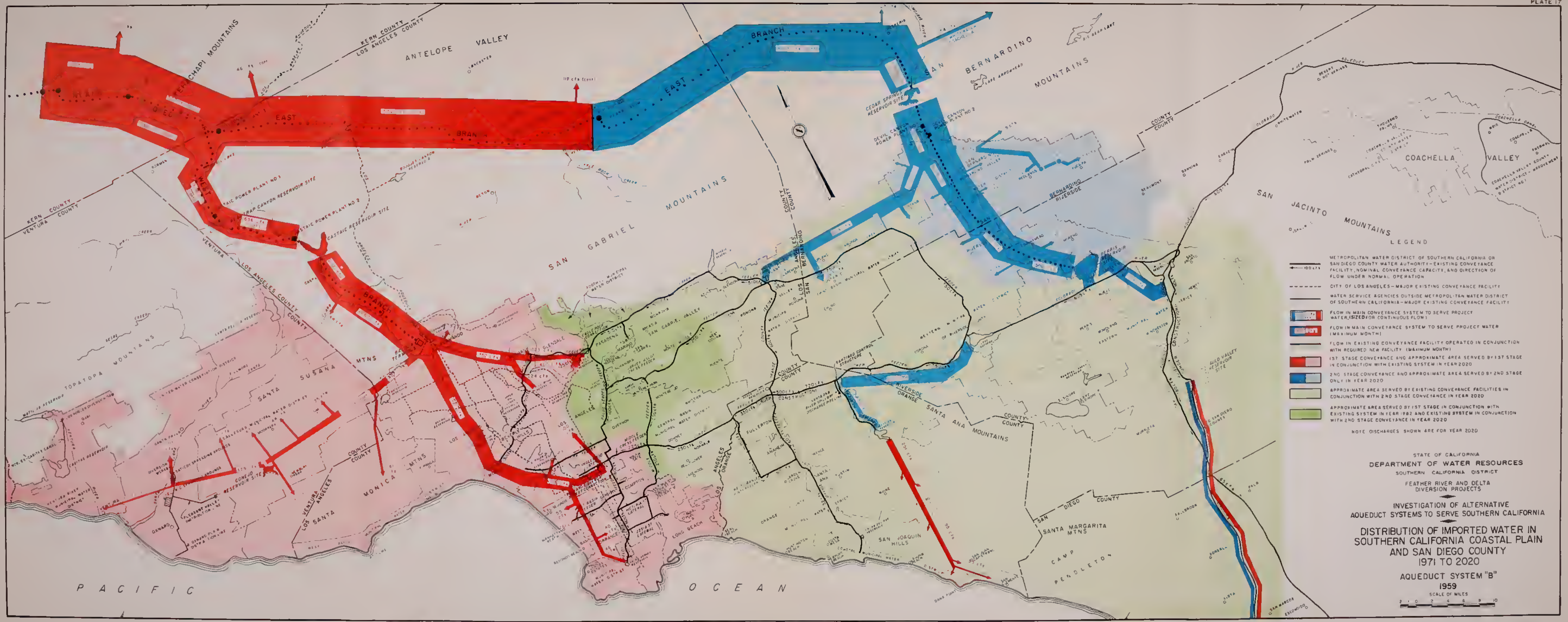
PLATE 17



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

FEATHER RIVER AND DELTA
DIVERSION PROJECTS

◆

INVESTIGATION OF ALTERNATIVE
AQUEDUCT SYSTEMS TO SERVE SOUTHERN CALIFORNIA

◆

DISTRIBUTION OF IMPORTED WATER IN SOUTHERN CALIFORNIA COASTAL PLAIN AND SAN DIEGO COUNTY 1971 TO 2020

AQUEDUCT SYSTEM "B"

1959

LEGEND

← 100 c.f.s.	METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA OR SAN DIEGO COUNTY WATER AUTHORITY—EXISTING CONVEYANCE FACILITY, NOMINAL CONVEYANCE CAPACITY, AND DIRECTION OF FLOW UNDER NORMAL OPERATION.
- - - - - -	CITY OF LOS ANGELES—MAJOR EXISTING CONVEYANCE FACILITY.
——	WATER SERVICE AGENCIES OUTSIDE METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA—MAJOR EXISTING CONVEYANCE FACILITY.
1000 c.f.s. (Cont.)	FLOW IN MAIN CONVEYANCE SYSTEM TO SERVE PROJECT WATER (SIZED FOR CONTINUOUS FLOW)
1000 c.f.s.	FLOW IN MAIN CONVEYANCE SYSTEM TO SERVE PROJECT WATER. (MAXIMUM MONTH)
← 100 c.f.s.	FLOW IN EXISTING CONVEYANCE FACILITY OPERATED IN CONJUNCTION WITH REQUIRED NEW FACILITY. (MAXIMUM MONTH).
🟥▨	1ST. STAGE CONVEYANCE AND APPROXIMATE AREA SERVED BY 1 ST. STAGE IN CONJUNCTION WITH EXISTING SYSTEM IN YEAR 2020.
🟦☐	2 ND. STAGE CONVEYANCE AND APPROXIMATE AREA SERVED BY 2ND. STAGE ONLY IN YEAR 2020.
🟩	APPROXIMATE AREA SERVED BY EXISTING CONVEYANCE FACILITIES IN CONJUNCTION WITH 2 ND. STAGE CONVEYANCE IN YEAR 2020.
🟩	APPROXIMATE AREA SERVED BY 1ST. STAGE IN CONJUNCTION WITH EXISTING SYSTEM IN YEAR 1982 AND EXISTING SYSTEM IN CONJUNCTION WITH 2 ND. STAGE CONVEYANCE IN YEAR 2020.

NOTE: DISCHARGES SHOWN ARE FOR YEAR 2020

STATE OF CALIFORNIA
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SOUTHERN CALIFORNIA DISTRICT

FEATHER RIVER AND DELTA
DIVERSION PROJECTS

◆

INVESTIGATION OF ALTERNATIVE
AQUEDUCT SYSTEMS TO SERVE SOUTHERN CALIFORNIA

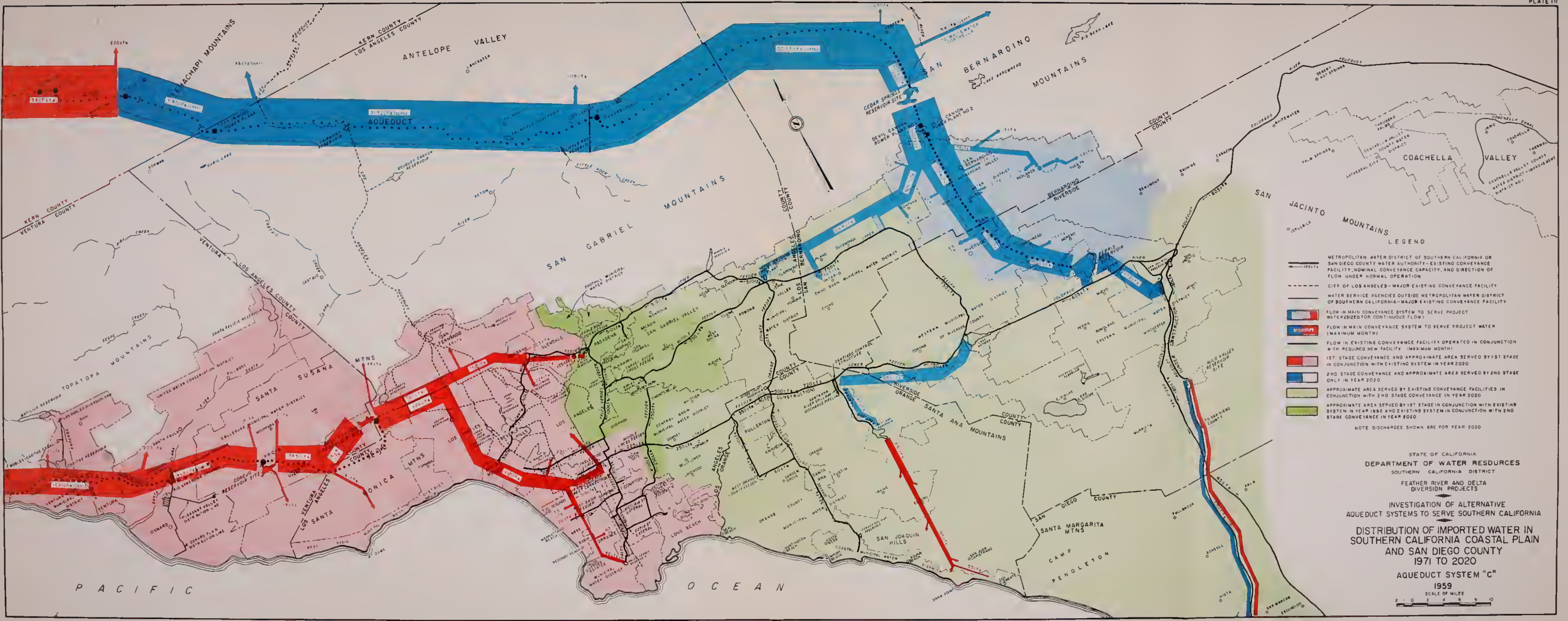
◆

DISTRIBUTION OF IMPORTED WATER IN SOUTHERN CALIFORNIA COASTAL PLAIN AND SAN DIEGO COUNTY 1971 TO 2020

AQUEDUCT SYSTEM "C"

1959

SCALE OF MILES
2 1 0 2 4 6 8 10



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN CALIFORNIA DISTRICT

FEATHER RIVER AND DELTA
DIVERSION PROJECTS

INVESTIGATION OF ALTERNATIVE
AQUEDUCT SYSTEMS TO SERVE SOUTHERN CALIFORNIA

DISTRIBUTION OF IMPORTED WATER IN SOUTHERN CALIFORNIA COASTAL PLAIN AND SAN DIEGO COUNTY 1971 TO 2020

AQUEDUCT SYSTEM "C"

1959