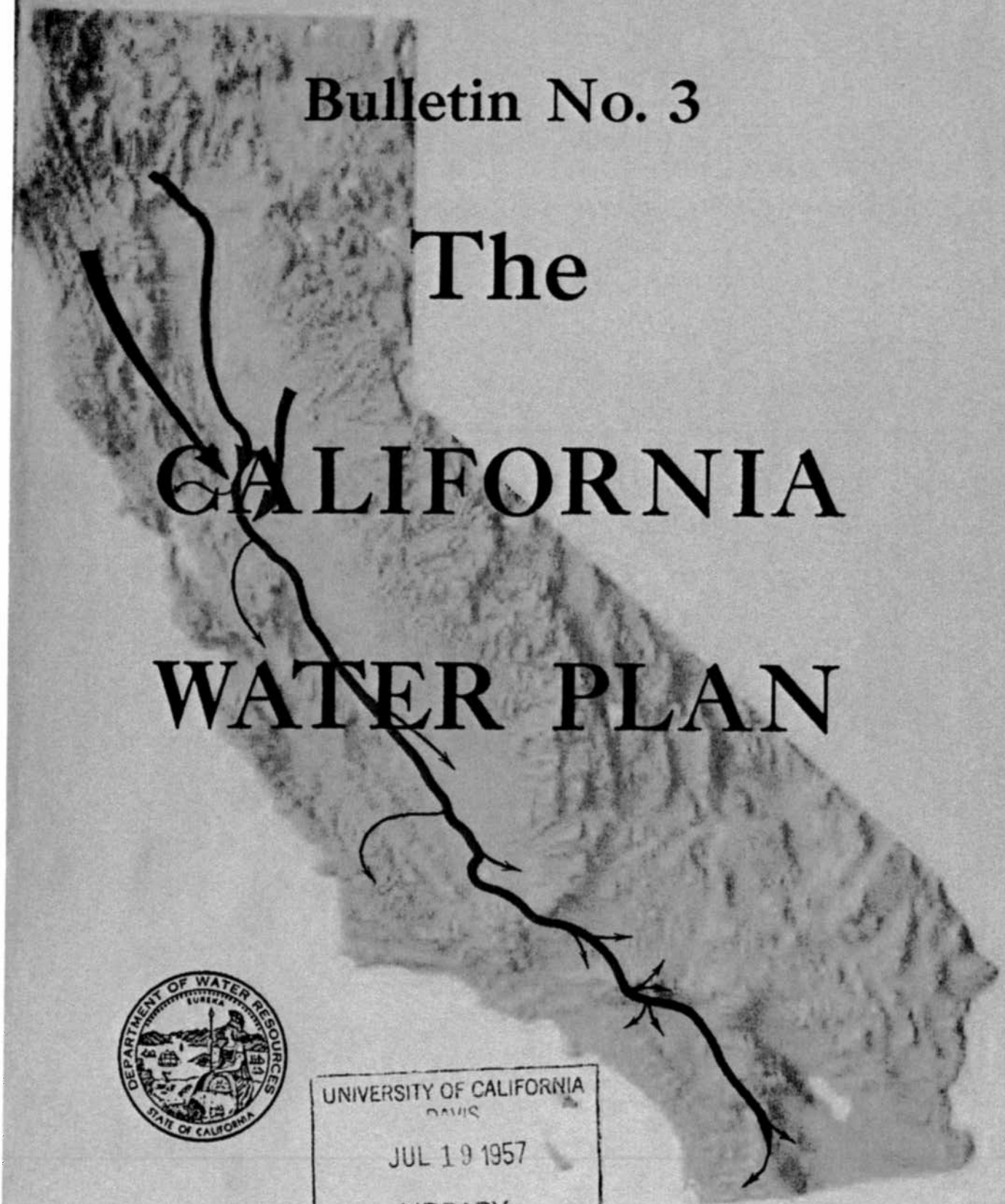
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

Bulletin No. 3

The CALIFORNIA WATER PLAN



GOODWIN J. KNIGHT
Governor

May, 1957

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Director of Water Resources

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FOREWORD

California is presently faced with problems of a highly critical nature—the need for further control, protection, conservation, and distribution of her most vital resource—water. While these problems are not new, having been existent ever since the advent of the first white settlers, never before have they reached such widespread and serious proportions. Their critical nature stems not only from the unprecented recent growth of population, industry, and agriculture in a semiarid state, but also from the consequences of a long period during which the construction of water conservation works has not kept pace with the increased need for additional water. Unless corrective action is taken—and taken immediately—the consequences may be disastrous.

What are the principal water problems faeing the people of California? The most recently and tragically demonstrated problem—the floods of December, 1955—is still vivid in the memory of all. Taking the lives of 64 persons, destroying and damaging homes, farms, businesses, and utilities to the tangible toll of $200,000,000, with great additional intangible losses to the general economy, the streams of northern and central California went on a rampage unparalled in recent history.

Not so speetaeular, but nonetheless signifieant, and constantly evident, is the problem of water deficieney in many areas of the State. A critieal need for supplemental water supply now exists in many areas, including: Alameda, Santa Clara, and San Benito Counties; the east, west, and south portions of the San Joaquin Valley; Antelope Valley; Santa Maria Valley and Ventura County. The ground water basins in these areas are being pumped to the point of dangerous overdraft whieh threatens their welfare. There have been, for many years, severe overdrafts on the ground water basins in the South Coastal Area in Los Angeles, Orange, San Bernardino, and Riverside Counties. An acute need for additional water exists in San Diego County, which will be temporarily alleviated by the construction of an additional aqueduet to convey presently surplus Colorado River water, as now authorized by The Metropolitan Water District of Southern California and the San Diego County Water Authority. The supply which can be made available to the South Coastal Area under rights to Colorado River waters, while not now fully utilized, will be fully committed and used by about 1970. By 1975, or possibly much earlier, all of southern California will need more water. Moreover, many of the mountainous areas, such as the Upper Feather River Basin and portions of the North Coastal Area, need water development works, not only for municipal and irrigation water but also to maintain stream flow for preservation of fish and wildlife, and to enhance the recreational potential, an important economie asset.

The urgeney of California's water problems can best be illustrated by eiting the example of the recent rapid growth of the State. In 1940, just before the beginning of World War II, California had a population of about 6,900,000. By 1950 this population had increased to about 10,600,000, and by 1955 it had increased an additional 23 per cent to more than 13,000,000. In 1957 the population reached 14,000,000. Coincidentally, the use of water per eapita has increased significantly and will continue to grow. In 1950 the estimated seasonal shortage of developed water in California was about 2,700,000 acre-feet, largely representing an overdraft on ground water storage. By 1955, water requirements had increased an additional 3,000,000 acre-feet per season. Allowing for the yield from new construction during the intervening period and for increase in the delivery of constructed works to their full potential wherever possible, the deficit aggregated nearly 4,000,000 acre-feet per year. Although the bulk of this supplemental water is needed for irrigation purposes, substantial quantities are required for urban and domestic uses.

Based upon reasonable forecasts of growth of the State during the next decade, it is indicated that the net shortage of developed water supply could amount to more than 10,000,000 acre-feet per season by 1965, taking into aceount inereasing importations and deliveries from presently developed water sources.

The need for solution of the present and future water problems of California is clear. It is also clear from a study of the past history of water development in the State that the future growth of California will now depend upon a coordinated state-wide program for water development. The authorized Feather River Project, the first truly state-wide project, will be the first major step in this direction. However, even if the project were constructed and in operation today and serving all areas of water deficieney, it would barely overcome the deficieneies of the present. In other words, the large water supply to be gained from the Feather River Project is fully needed today. Furthermore, unless we assume that the population remains at present levels, one or more additional projects of comparable size should be rapidly planned for construction in the near future. This fact should be cause for concern, for there is no reason to believe that our phenomenal recent rate of growth will slow down now or in the near future. The responsibility of

immediate initiation of a state-wide water development planning and construction program is particularly acute because of the often-demonstrated time lag between the planning stage and the financing and construction stage of any large-scale project.

The State Legislature in 1947 authorized comprehensive state-wide investigations and studies, which have culminated, after 10 years of intensive effort, in "The California Water Plan," a master plan to guide and coordinate the planning and construction by all agencies of works required for the control, protection, conservation, and distribution of California's water resources for the benefit of all areas of the State and for all beneficial purposes.

What does "The California Water Plan" purport to do?

1. It evaluates the water supply available to California and describes the places and characteristics of its occurrence.

2. It estimates the water requirements, both present and future, for all purposes for each area of the State, as best as can be foreseen now.

3. It points out (a) the watersheds where present estimates indicate surplus waters exist over and above the future needs for local development, and gives an estimate of such surplus, and (b) the areas of deficiency and the estimated deficiency for each such area.

4. It outlines existing and prospective water problems in each area of the State.

5. It describes the beneficial uses to which the remaining unappropriated waters of the State should be put for maximum benefit to the people of all areas of the State.

6. It suggests the manner in which the waters of the State should be distributed for the benefit and use of all areas.

7. It proposes objectives toward which future development of the water resources of the State should be directed in all areas of the State, and suggests broad patterns for guidance toward these objectives.

8. It defines these objectives in terms of potential physcial accomplishments, which may be used to measure the merits of projects proposed for construction by any agency.

9. Finally, it demonstrates that the waters available to the State of California, including the State's rights in and to the waters of the Colorado River, are not only adequate for full future development of the land and other resources of the State, but also that physical accomplishment of these objectives is possible.

The California Water Plan must be implemented by a state-wide program for the construction of projects needed to control and supply water wherever and whenever the need arises and as projects are found feasible. Physical works for the control, protection, development, and use of water do not pertain solely to the so-called "areas of deficiency." There are few areas which do not now or will not require physical works for the development of water resources. The job is a big one, and will require the combined efforts of the Federal Government, the State Government, and local agencies, as well as private entities and individuals, with the State logically taking a leading role in administration and coordination as well as financing and construction.

The Feather River Project, the initial unit of The California Water Plan, must be started immediately, and other projects must follow in the near future. The California Water Plan, a coordinated master plan, should be accepted as the general framework or pattern for future water development in the State. Finally, and this cannot be emphasized too strongly, solution of the water problems of California lies in the construction of physical works—not alone in laws and reservations of water, however necessary these may be as steps in the process.

SYNOPSIS

This is the final of a series of three bulletins setting forth the results of the State-wide Water Resources Investigation, which has been in progress for the past 10 years under provisions of Chapter 1541, Statutes of 1947. This investigation entailed a three-fold program of study to evaluate the water resources of California, to determine present and probable ultimate water requirements, and to formulate plans for the orderly development of the State's water resources to meet its ultimate water requirements. Funds to meet the cost of the investigation were provided by the cited statute and subsequent budgetary acts of the Legislature.

The first phase of the State-wide Water Resources Investigation comprised an inventory of data on sources, quantities, and characteristics of water in California. The results are available in State Water Resources Board Bulletin No. 1, "Water Resources of California," published in 1951. This bulletin comprises a concise compilation of data on precipitation, runoff of streams, flood flows and frequencies, and quality of water throughout the State.

The second phase dealt with present and ultimate requirements for water. The associated report, State Water Resources Board Bulletin No. 2, "Water Utilization and Requirements of California," was published in 1955. This study comprised determinations of the present use of water throughout the State for all consumptive purposes, and forecasts of ultimate water requirements based in general on the capabilities of the land to support further balanced development.

The final phase of the State-wide Water Resources Investigation is presented herein as "The California Water Plan." Bulletin No. 3 describes a comprehensive master plan for the control, protection, conservation, distribution, and utilization of the waters of California, to meet present and future needs for all beneficial uses and purposes in all areas of the State to the maximum feasible extent. The Plan is designed to include or supplement rather than to supersede existing water resource development works, and does not interfere with existing rights to the use of water.

The objective in the formulation of The California Water Plan has been to provide a logical, engineering basis for future administration of the water resources of the State and for coordination of the efforts of all entities engaged in the construction and operation of water development projects, to the end that maximum benefit to all areas and peoples of the State may ultimately be achieved.

The California Water Plan includes local works to meet local needs in all portions of the State. It also includes the California Aqueduct System, an unprecedented system of major works to redistribute excess waters from northern areas of surplus to areas of deficiency throughout the State. The Plan gives consideration to water conservation and reclamation; to flood control and flood protection; to the use of water for agricultural, domestic, municipal, and industrial purposes; to hydroelectric power development; to salinity control and protection of the quality of fresh waters; to navigation; to drainage; and to the interests of fish, wildlife, and recreation. It contemplates the conjunctive operation of surface and ground water reservoirs, which operation will be essential to regulation of the large amounts of water ultimately to be involved.

The very magnitude of the task involved in formulation of The California Water Plan was such that detailed surveys and studies, and economic and financial analyses, could not be undertaken in this initial phase of investigation. At this stage of its development, therefore, the Plan must be regarded as no more than a broad and flexible pattern into which future definite projects may be integrated in an orderly fashion. As additional data and experience are gained, as technology advances, and as future conditions change in manners that cannot be foreseen today, The California Water Plan will be substantially altered and improved. However, the basic concept of the Plan as a master plan to meet the ultimate requirements for water at some unspecified but distant time in the future, when the land and other resources of California have essentially reached a state of complete development, will remain unchanged.

Voluminous data and information have been compiled and assembled in connection with preparation of The California Water Plan. It is realized that the need of the general public, on the one hand, is for a summary report with a minimum of technical detail but containing all of the information essential to an adequate understanding of the Plan. The need of engineering and other professional people, on the other hand, is for more detailed technical information which would be of minor interest to the general public. Therefore, publication has been set up to meet these separate needs—Bulletin No. 3 itself to meet the general need and the several appendixes to Bulletin No. 3 to meet the engineering and other technical needs.

CHAPTER I

INTRODUCTION

Today, the future agricultural, urban, and industrial growth of California hinges on a highly important decision, which is well within the power of the people to make. We can move forward with a thriving economy by pursuing a vigorous and progressive water development planning and construction program; or we can allow our economy to stagnate, perhaps even retrogress, by adopting a complacent attitude and leaving each district, community, agency, or other entity to secure its own water supply as best it can with small regard to the needs of others. The choice of these alternatives is clear. The need for coordinated planning on a state-wide basis has long been realized. Comprehensive plans have been formulated and reported upon in the past, and noteworthy accomplishments have been achieved by local enterprise and private and public agencies. But despite the great water development projects constructed in the past, California's water problems continue to grow day by day.

The construction of highways, schools, hospitals, and other public works has greatly accelerated since the end of World War II. However, to supply its necessary water, California is relying for the most part on works which were designed to meet the needs as anticipated 20 to 30 years ago. These facts are now becoming known and more generally understood by the people. It is apparent to most that the continued growth and prosperity of California is dependent upon prompt and substantial efforts by the responsible local governmental agencies, the State, and the Federal Government to ensure that the planning and construction of water development projects keeps pace with the growing needs for water.

The population of California has continued to grow at a phenomenal rate, and irrigated agriculture and industrial activity have increased proportionately. This recent rapid expansion of the economy has occurred largely in areas of inherent water deficiency, thus intensifying the problem in those areas. While in most instances the increases in water requirements are physically being met, they are provided for by drawing on diminishing ground water reserves in order to meet the deficiency. Such perennial overdraft has been increasing rapidly in recent years and has resulted in accelerated lowering of ground water levels in many parts of the State.

Effects of these overdrafts are presently manifested in the intrusion of sea water into the principal pumping aquifers of a number of coastal ground water basins, and the threat of such intrusion into others. Certain inland ground water basins have experienced degradation in quality of their fresh waters by mixture with underlying entrapped connate brines (i.e., salt water entrapped when the formation was deposited) or other waters of undesirable mineral quality. Furthermore, overdraft conditions may result in an accumulation of excess minerals or salts in a ground water basin, which in a period of time may degrade the water quality beyond acceptable limits. Thus, it is evident that continuing overdrafts will not only drastically reduce the reserves in storage, with possible exhaustion in some cases, but in many instances will irreparably damage the immensely valuable ground water reservoirs unless supplemental water supplies are developed.

While experiencing problems of water deficiency on the one hand, California is presently faced with the anomaly of other problems of the exact opposite nature—that of periodic floods which result in major damage and loss of life. Ironically, in many cases the same areas suffering deficiency in water supplies are besieged with winter floods when the water, so urgently needed for the economy, wastes to the ocean, accomplishing nothing but damage and grief. Historically, agricultural and urban development has occurred largely in valleys and on plains inherently subject to flooding. With the intensification of agriculture and expansion of urban and industrial areas, future flood problems will become more severe unless remedial action is taken.

Concurrently with the expanding population and increasing irrigation and industrial development in the valleys and metropolitan areas of the State, there has been increasing pressure for enhancement of fish and wildlife resources and for the provision of adequate recreational opportunities, particularly in the hill and mountainous areas. If these needs are to be adequately met, provision must be made therefor in future water development through development of water areas and live streams.

The magnitude of the foregoing water problems may be better appreciated by referring to Plate 1, entitled "Present Water Problems." The 1947 Legislature, recognizing these problems and appreciating the role of water in the future of the State, directed that the water resources and present and future water requirements of California be studied and evaluated, and that plans be formulated for the orderly development of the State's water resources to meet its ultimate water requirements. This directive initiated the "State-wide Water Resources Investigation," which

of California through a comparison of the water resources and water requirements as determined during the first two phases of the State-wide Water Resources Investigation, and corollary problems. Chapter III, "Water Development Planning," presents a brief historical account of water resource planning and development in California up to the present time, discusses the urgent need for comprehensive coordinated planning and development on a state-wide basis, and outlines the considerations necessary to the formulation of plans to accomplish the solution of California's water problems. Chapter IV, "The California Water Plan," describes the physical features and accomplishments of works, both local and state-wide, which would meet the basic objectives heretofore described. Chapter V, "Implementation of The California Water Plan," discusses various considerations, such as legal, economic, financial, and engineering, and others which are vital to the physical implementation of The California Water Plan. Chapter VI, "Summary, Conclusions, and Recommendations," summarizes the bulletin, and presents the conclusions resulting from the State-wide Water Resources Investigation and the recommendations based upon the conclusions.

Appendix A to this bulletin presents a more detailed engineering report on The California Water Plan. It describes both local and interbasin transfer projects on an individual basis, with accompanying tabulations of physical features and capital costs. It also discusses, in some detail, the accomplishments of The California Water Plan and the considerations upon which the operation of the plan will be contingent.

There will be published separately, and at later dates, additional appendixes which will elaborate on certain specific phases of The California Water Plan, and on considerations and premises on which the Plan was based. The basic assumptions, criteria, and procedures employed in formulating the Plan are presented in Appendix B. General geology of the State, geologic conditions affecting the location and design of engineering works, and ground water geology are described in Appendix C. Appendix D outlines the utilization of ground water storage capacity under The California Water Plan, particularly with regard to conjunctive operation of surface and underground reservoirs. Factors involved in maintenance of water quality are treated in Appendix E.

The effects of The California Water Plan on fish and wildlife are presented in Appendix F, as are the potentialities for enhancement of recreational facilities. Flood problems and existing project works are described in Appendix G, and flood control accomplishments of The California Water Plan are discussed. Economic and financial aspects of The California Water Plan are discussed in Appendix H. Water rights and attendant legal considerations and their implications with respect to The California Water Plan are presented in Appendix I.

In the State-wide Water Resources Investigation, due cognizance has been taken of all possibilities for augmenting the State's water supplies. The potentialities of sea-water conversion, waste-water reclamation, artificial increase of precipitation, and watershed management are discussed and evaluated in Appendix J. Future power sources and energy requirements as related to The California Water Plan are considered in Appendix K, which discusses the development of power requirements and future load characteristics, and the adaptability of atomic energy and its influence upon the development of hydroelectric energy.

graphic areas are delineated on Plate 3, entitled "Major Hydrographic Areas and Planning Groups."

Ground Water

The extensive ground water basins of California provide natural regulation for runoff from tributary drainage areas and for precipitation directly on overlying lands. Some 250 ground water basins having valley floor areas of about 5 square miles or larger have been identified in California. A large part of the surface runoff from tributary mountain and foothill watersheds that would otherwise waste to the ocean is retained in these basins and conserved for later utilization. In effect, these ground water reservoirs provide a means for natural regulation of stream flow in much the same manner as is accomplished by surface reservoirs.

Sufficient data on the ground water basins of California are available to permit an estimate of gross storage capacity within certain depth limits for 211 valley floor areas. The areas for which such storage capacities were estimated comprise 96 per cent of the total valley floor area of all basins of the State. The depth limits vary from basin to basin, but the average weighted interval is approximately 185 feet, or generally between the depths of about 15 and 200 feet. The gross storage capacity within this depth interval is about 450,000,000 acre-feet. The Central Valley alone contains over 130,000,000 acre-feet of this total in approximately the same depth interval.

Only a portion of the gross storage capacity is usable storage, largely because of the presence of saline water or other waters of deleterious mineral quality. These waters either limit the depth to which ground water levels may be lowered or, in many areas, preclude the use of ground water. Enough information is presently at hand to estimate the usable storage capacity for only 80 ground water basins, comprising 43 per cent of the total valley floor area of the State. In the Central Valley, usable capacity in the depth interval from 15 to 200 feet aggregates about 100,000,000 acre-feet.

More than half the water presently consumptively used in California comes from underground sources. Many of these ground water basins have been intensively developed. In the San Joaquin Valley and parts of southern California particularly, the ready availability of ground water has been primarily responsible for supporting rapid expansion of agriculture and industry far beyond the firm capabilities of water resource developments. This has been accomplished by utilizing the vast reserves of water stored in these underground reservoirs, in many cases at rates greatly exceeding their replenishment. Presently available data concerning ground water are far less comprehensive than for surface water resources. Much more study will be necessary to evaluate reasonably accurately the capability of ground water resources of the State.

WATER REQUIREMENTS

Under the State-wide Water Resources Investigation all lands in the State have been classified as to their suitability for development under probable ultimate conditions. Determinations have also been made of the location, nature, and extent of present water service areas, and appropriate factors for the various types of water use have been evaluated. Estimates of present and probable ultimate water requirements developed from these data, and published in State Water Resources Board Bulletin No. 2, have been generally accepted as a measure of water requirements for the formulation of The California Water Plan. However, modifications have been made where the need for such has been indicated by further study. These estimates, modified where necessary, are summarized in this section.

In 1950, the year adopted as "present" in Bulletin No. 2, a gross area of about 7,300,000 acres was under irrigation in California. The actual area irrigated, or net area, was about 6,900,000 acres. A gross area of about 20,000,000 acres is classified as suitable for irrigated agriculture, of which an estimated 16,200,000 acres could be irrigated in any one season under ultimate conditions of development. In 1950, approximately 1,100,000 acres were devoted to urban, suburban, and industrial types of land use. It is estimated that urban, suburban, and industrial water service areas will ultimately occupy about 3,600,000 acres.

For the most part, the remaining lands of California include only scattered water service areas, largely in mountainous and desert regions and in national forests and monuments, public beaches and parks, private recreational areas, wildfowl refuges, and military reservations. It is expected that even under ultimate development the majority of these lands will be only sparsely settled and will have only very minor requirements for water service. About 180,000 acres of such remaining lands actually receive water service at the present time. It is assumed that all of the approximately 77,300,000 acres of such lands ultimately will be served with water in the minor amounts sufficient for their needs.

Table 2 summarizes data relative to present and ultimate water service areas in the seven major hydrographic areas of California, classified by broad land usage groupings. The potential water service areas under The California Water Plan, consisting of all lands included in the irrigated and urban-suburban-industrial categories, are delineated on Plate 4, entitled "Present and Ultimate Areas of Intensive Water Service."

ments are found south of the same line. This geographic disparity is clearly indicated in Table 4, which shows a comparison of the water supply with the present and ultimate water requirement for each major hydrographic area of the State, expressed as percentages of the respective totals for the State.

In addition to the unequal areal distribution of California's water resources and requirements, its water problems are further intensified by the sporadic nature of the occurrence of runoff, both within the season and from year to year. The greater part of the runoff occurs during the winter and spring months when the demand for water is the least. Fortunately, a considerable portion of the runoff of most major inland mountain streams is detained in snowfields of the Sierra Nevada until the late spring and early summer snowmelt period. However, this natural regulation is not by any means sufficient to provide for the large demands in the summer and fall.

Although seasonal fluctuation of runoff is a serious problem, because its regulation requires a considerable amount of storage, it is the fluctuation of stream flow from year to year that presents the most difficult problem of regulation. California is subject to extended wet and dry periods. As previously stated, the State suffered a severe drought in the late 1920's and early 1930's, one of many in the past, during which the runoff of streams throughout the State for a 10-year period averaged only 69 per cent of the long-time mean. These periodic droughts have superimposed on the need for storage for normal seasonal regulation the need for provision of extremely large amounts of reservoir storage capacity for necessary cyclic regulation of water supply. A severe drought, superimposed upon present deficiencies in water supply development, could create widespread havoc and even economic disaster throughout California. Furthermore, there is no reason to believe that drought conditions in the future may not be more intense and of longer duration than those of the short recorded past.

All other water problems of California basically result from the primary problem of geographical maldistribution and seasonal and cyclic fluctuation of the water resources of the State, and are briefly discussed herein as problems of water deficiency, both surface and underground, floods, and impairment of water quality.

Problem of Water Deficiency

Because of the characteristic semiarid climate, nearly all areas of the State experience a natural surface water deficiency during the summer and fall months when rainfall is negligible and runoff is meager. This seasonal deficiency is often greatly intensified and prolonged by the extremely variable occurrence of California's water resources from year to year, whereby rainfall and resultant runoff is subnormal for varying periods of years. To add to the natural problems of seasonal and cyclic deficiency, the water resources are not geographically distributed in conformity with the requirements. This has necessitated a high degree of development of available resources in the central and southern parts of the State.

Works have been constructed by numerous entities for regulation of stream flow and conveyance to areas of use, and the water thus delivered has allowed extensive agricultural activity on fertile lands which formerly supported only hay, grain, and native grasses. Many fertile areas of potential productivity, however, are not close enough to surface supplies to allow their development within the limited means of some local agencies.

Further, during periods when runoff is deficient over a series of years, those agencies and individuals depending on facilities adequate only for seasonal regulation are faced with the necessity of cutback in their economy. Occasionally, agricultural develop-

TABLE 4

DISTRIBUTION OF WATER RESOURCES AND REQUIREMENTS

Area number on Plate 3	Hydrographic area	Natural stream flow, in per cent of total for State	Requirement for water, in per cent of total for State		Requirement for additionally developed water, in acre-feet	
			Present*	Ultimate	Present*	Ultimate
1	North Coastal	40.8	2.4	4.0	13,000	1,564,000
2	San Francisco Bay	1.7	3.4	6.9	42,000	**2,257,000
3	Central Coastal	3.5	3.0	4.4	65,000	1,681,000
4	South Coastal	1.7	9.1	10.9	370,000	**3,027,000
5A	Sacramento River Basin	31.6	18.1	14.5	124,000	3,732,000
5B, C	San Joaquin-Tulare Lake Basin (including Sacramento-San Joaquin Delta)	15.9	44.5	31.9	1,661,000	9,427,000
	Operation of Salinity Control Barrier	0.0	0.0	1.7	0	876,000
6	Lahontan	4.5	3.6	13.2	279,000	6,148,000
7	Colorado Desert	0.3	15.9	12.5	0	**2,181,000
	TOTALS	100.0	100.0	100.0	2,554,000	30,893,000

* Present requirements determined as of 1950.
** Assumes imports to full extent of claimed water rights.

ments—and urban developments as well—have overextended their economy during wet periods with extremely critical results during following periods of drought.

Surface diversions and interbasin transfers have done much in the past to develop the economy of the State and are the great potential of the future. However, it may be categorically stated that the degree of economic development which is enjoyed today would not have been possible without the utilization of ground water. The availability of what appeared to be an unlimited supply of ground water has been a great boon to this development. It has been necessary only to put down a well and utilize water from a vast underground reservoir at relatively small cost; expensive conservation and transmission systems have been unnecessary and distribution facilities minimized. Extensive areas overlying natural ground water basins have been developed to a high level of productivity. By utilization of a ground water source, many municipalities in the central and southern parts of the State have also experienced expansion which otherwise would have been impossible.

However, the high level of economic development in many areas of the State has been achieved at the expense of overdraft conditions on the underlying ground water basins, wherein the extraction has exceeded the replenishment. In many of these areas the overdraft is continuing—in fact increasing—generally with no active measures being taken to correct the serious problem. How long these conditions of overdraft, or "mining" of ground water resources, can continue without drastic and far-reaching detrimental consequences is a matter of serious concern. If the underground sources of water are allowed to be completely depleted and no other sources of supply are developed in the interim, the economy of the State will not just stand at the current level, but must of necessity regress to one supportable largely by surface developments. Surface water sources are meager in the central and southern areas of the State where the water requirements are the greatest. The calamity of economic depression attendant on the excessive depletion of ground water reservoirs would not be limited to those agricultural areas overlying the reservoirs. Just as the whole State now enjoys the benefits of an expanding economy, so would the whole State—north as well as south—feel the possible catastrophic effects of the destruction of ground water basins by continued overdraft.

Overdraft conditions presently exist in several of the major and in many of the minor ground water basins in the State. The most serious overdraft in terms of magnitude is manifested in the San Joaquin-Tulare Lake Basin where the present (1955) draft exceeds the mean seasonal replenishment by some 2,500,000 acre-feet. Conditions are particularly acute along the west and south sides of the basin. Overdraft conditions are also serious in the Antelope Valley, presently approximating 175,000 acre-feet per season. The overdraft on the coastal plain of Los Angeles, Orange, Santa Barbara, and Ventura Counties is estimated at 400,000 acre-feet per season. In addition to these areas of critical overdraft, substantial overdrafts are being experienced in portions of the Sacramento Valley, in the Santa Clara, Salinas, and Santa Maria Valleys in central California, and the Santa Clara River Valley in southern California. Twenty-four smaller ground water basins are also known to be overdrawn.

The present (1955) deficiency in developed water supply, both surface and underground, aggregates some 4,000,000 acre-feet per season on a state-wide basis, largely representing an overdraft on ground water supplies. It is forecast that, if California is to attain her full economic potential, additional water supplies amounting to some 31,000,000 acre-feet per season must ultimately be developed to meet consumptive requirements plus irrecoverable losses. On certain streams additional water will have to be developed for stream flow maintenance for fish, wildlife, and recreational purposes, and for maintenance of water quality.

Problem of Floods

It is ironical that the very forces which man now attempts to control to prevent flood damage have formed the flat fertile valleys which attracted him originally. Agricultural enterprise, with the resultant urban and industrial economy, has been developed almost entirely upon the fertile natural flood plains and basins and alluvial fans of active streams.

The great Central Valley is itself an evolvement of many centuries of periodic flooding of the Sacramento and San Joaquin Rivers and their tributaries. It also is the major example in California of the results of recent intensive improvements encroaching upon flood plains. During the flood of December, 1955, great havoc was wrought throughout this area, which includes that particular area of disaster in and about Yuba City. Protective works were generally designed for the economy existent prior to World War II. When the levees of the Feather River were breached, 38 lives were lost and some 100,000 acres flooded, including Yuba City. It should be noted that this tragic loss of lives and destruction of property would have been prevented had Oroville Dam and Reservoir been in operation in conjunction with existing downstream flood control works.

The combined effect of flood runoff of Central Valley streams and coincident extremely high tides during the 1955 flood, produced critical conditions in the Sacramento-San Joaquin Delta. Consisting as it does of a maze of reclaimed islands and separating chan-

Problems of Recreation, Fish, and Wildlife

The need for more and better opportunities for wholesome outdoor recreation in California is rapidly expanding, due to the impact of a growing population, increased awareness by the people of the joys and benefits of such activity, and increased time and opportunity available to them for such pursuits. Accessible water areas and flowing streams well stocked with fish constitute an important aspect of the public desire for recreational opportunities. Satisfaction of that desire to the maximum feasible extent is a problem inherent in the development of California's water resources. That development will provide several hundred new reservoirs with many thousands of acres of water area, and will make possible releases of water in hundreds of miles of natural streams for improvement of fish and wildlife habitat. Enhancement of fish and wildlife resources and development of the recreational potential will provide important economic assets to many areas in California, particularly in the mountains and foothills. Provisions of facilities and opportunities for such use by the public therefore becomes an important objective in further water development.

Problem of Drainage

An ever-present problem in irrigated agriculture is the necessity of providing adequate drainage. Extensive drainage systems may be necessary to maintain soil productivity. Leaching and drainage have made possible the reclamation and use of large areas formerly considered valueless. Adequate drainage and proper disposal of saline drain waters may be an important factor in maintenance of ground water quality.

At the present time, the most serious unsolved drainage problem in California is in the west side of the San Joaquin Valley. It is considered probable that full solution will require a master drainage channel extending from Buena Vista Lake in Kern County to Suisun Bay.

Drainage must be considered an integral and indispensable part of the development and utilization of water resources. Adequate provision must be made therefor in the total program.

Problem of Full Use of Available Storage Capacity

A highly important problem which must be continually kept in mind in the further development of California's water resources involves the proper use of available storage capacity, both surface and underground. With respect to surface storage development, the most economical dam and reservoir sites have already been developed, leaving the less desirable projects available for future construction. Remaining combinations of good dam sites with surface reservoir sites of adequate capacity are rare, particularly in the areas in which export waters must be developed. With regard to ground water, it has been demonstrated in many areas of the State that the ground water basins, once considered a source of virtually inexhaustible supply, must be carefully managed in order to ensure their continued usability.

Because of the limited remaining surface storage capacity susceptible of development and the many purposes and uses to which the developed water must be put, it is highly important and urgently necessary that the available storage capacity be used wisely and for maximum benefit. This can be accomplished only by achieving the optimum development at each site selected for construction, which necessitates provision for the full development of the water production capabilities of the watershed and, in many instances, operation of the reservoir to meet the needs of several purposes, such as irrigation, urban, and industrial uses; flood control; power generation; recreation; fish and wildlife; and protection of water quality.

Failure to develop a site to its full potential through construction of a single-purpose project where a multipurpose project is necessary and justified initially in the public interest, or initial construction such as to preclude later full development, would result in the extravagant waste of the site.

Of paramount importance among the advantages inherent in multipurpose planning and development are economy and conservation of project sites. With respect to economy, it is generally cheaper to provide for several water uses in a single project than to build several single-purpose projects. Conservation of project sites is necessary because the scarcity of favorable dam sites dictates the fullest practicable development of the potential of each site.

In view of California's continuing growth in population and water demand, practices which result in the wasting of surface storage opportunities by inadequate development, without regard to future requirements for other purposes, should no longer be permitted on any stream in the State. These criteria should apply wherever storage is contemplated by the State or any other agency. In those cases where initial construction to optimum size of reservoir is currently infeasible, then provisions for future raising of the dam to full height should be incorporated in the original construction.

Careful management of California's underground storage capacity will be required not only in areas where increased use of ground water resources is expected, but also for preservation of the present level of use in those basins which are experiencing or are threatened with overdraft and deterioration of water quality. In other words, unless an effective management program is implemented in the near future, involving the maintenance of water quality and the limiting of pumping extractions within safe yield rates, the utility of the State's ground water basins cannot be perpetually maintained.

doned gravel pits to supplement natural percolation. The recharge capability of these percolation works is commonly increased by detention of excess runoff in upstream reservoirs and the control of releases to rates within the percolation capacity of the works.

Notable achievements in artificial recharge have been accomplished by the Los Angeles County Flood Control District, the Orange County Flood Control District, United Water Conservation District in Ventura County, San Bernardino County Flood Control District, Santa Clara Valley Water Conservation District, and Kern County Land Company, among others.

COMPREHENSIVE COORDINATED PLANNING AT STATE-WIDE LEVEL

A great deal of progress has been made so far in the development of California's water resources. No one can refute the fact that the initiative and resourcefulness of local agencies in planning and constructing water development projects has been largely responsible for the present highly developed level of economy throughout the State. The assistance of the Federal Government has been most helpful. However, the growth of the State, made possible by the progressive development of water supplies, has constantly created new water problems, each of which has become successively more difficult of solution. All too often, limited planning for the future has resulted in construction of works sufficient only to meet the needs of the present, as growth throughout the State has continued at rates exceeding even the most optimistic forecasts.

The great water development projects conceived and constructed in the past, notable as they are and vital to the State's development as they have been, represent comparatively localized planning when considered from the state-wide standpoint. Even the Central Valley Project, a revolutionary plan when conceived and a phenomenal development as it is being constructed, is limited in its scope and benefits to a comparatively small part of the State as a whole, notably portions of the Sacramento Valley, the Sacramento-San Joaquin Delta, and of the San Joaquin Valley. It is but a magnification of what some 100 irrigation and reclamation districts have done on their own initiative with local financing. Without such local projects constructed in the past, however, California for the most part would still be a semiarid wasteland.

Because of the dictates of economics, which governs water development as well as all other engineering projects, the cheapest and easiest-to-develop water projects have always been selected first for construction. Naturally, local water supplies were developed first. Development of water from distant sources and conveyance through lengthy and costly aqueducts have been resorted to only after available local supplies have become insufficient. The same principle of economics has prevailed in the selection of alternative sources of imported water supplies. Thus, we are now faced with the inevitable consequences: future water development in California must involve "leftover" local projects and costly major import projects which are generally beyond the means of all but a very few local agencies.

Today, there is increasingly severe competition between areas and between uses for the remaining available water resources. In some streams there is no remaining unappropriated water available for the further development of areas which should logically be served therefrom. As previously mentioned, several of the major ground water basins are seriously overdrawn.

In view of this and of the previously discussed wide disparity between the occurrence of the State's water resources and needs, both as to time and place, it is apparent that the era of piecemeal water development planning and construction virtually has reached an end. Future development of the State's water resources must rely, to a constantly increasing extent, on coordinated, comprehensive planning on a state-wide level if the needs of all areas and all uses are to be met in the most effective and economical manner. The need for such planning is continually becoming more evident as undeveloped local water resources diminish and development of supplemental supplies becomes more complex, while water requirements increase in unprecedented proportions.

The purpose of such coordinated, state-wide planning must be to establish a framework into which all future water development projects, both local and state-wide, can be integrated, and which will serve as a guide to ensure optimum development and utilization of available water resources, with due consideration to the varying interests and uses involved. This is the objective of The California Water Plan. It will serve as the engineering basis for proper administration in the public interest of the State's water resources by the various agencies involved. It will provide the means for badly-needed coordination in further planning and in the construction and operation of water projects among the manifold entities, federal, state, local, and private, engaged in water control and development in California.

A continuing, coordinated, state-wide, planning program, implemented progressively by the construction of projects as necessary and justified, is the only means by which the logical, orderly, and economic development of California's water resources can be assured to the degree necessary to meet the ultimate requirements for all uses. The construction of projects to accomplish the objectives of the planning program will undoubtedly require the combined efforts of the Federal Government, the State Government,

and local entities, but the State logically must take a leading role, since much of the development that will be needed is outside the scope of federal interest and beyond the capabilities of local entities. Further, the magnitude of the job to be done will require the financial support of all agencies involved.

PLANNING FOR DEVELOPMENT OF CALIFORNIA'S WATER

Solution of California's water problems will not be fully accomplished until the water resources are captured and controlled at their source, transported to areas of need, and reregulated to the demand schedules prevailing in the particular areas served in amounts sufficient to meet the ultimate requirements for all beneficial uses. The indicated solution will involve the redistribution of water supplies for use in local areas, and the transfer on a state-wide basis of water from northern areas of abundance to central and southern areas of deficiency. Thus, the planning of projects necessary for achievement of the required degree of water resource development to meet the ultimate requirements involves three primary considerations, each of which presents difficult but not insurmountable obstacles. As presented herein, these considerations concern the development of a solution of ultimate problems, but do not cover the many phases of interim uses and transfers of water that would inevitably occur during the step-by-step implementation of the ultimate plan.

Capture and Control of Water

The first consideration—capture and control of the water at its source—involves the planning of large surface storage reservoirs and substantial ground water storage to regulate the inherent seasonal and cyclic fluctuation of stream flow to a more or less uniform seasonal supply, for conveyance to areas of use both local and distant. Actually it is the variation of runoff from year to year, rather than that within the season, that imposes the large storage requirements, as sufficient storage must be available to capture surplus water during wet periods to carry through subsequent extended drought periods. Were it not for the variable or cyclic occurrence of the water resources, the storage requirement would be greatly reduced. The enormous storage requirement, as subsequently developed in this bulletin, probably could be met by surface storage alone on the north coast streams. However, full cyclic regulation of the flow of the Sacramento Valley streams would necessitate not only full development of all available surface storage opportunities but also conjunctive operation of the large underground reservoirs in the Sacramento and San Joaquin Valleys. Some 30 per cent of the developed runoff of the Sacramento Valley would need to be regulated by underground storage. This in turn would require the provision of conveyance canals adequate in capacity to transport this secondary water, of irregular occurrence and variable flow characteristics, to the areas of recharge of the underground storage basins.

Conveyance to Areas of Need

The second consideration—the conveyance of water over long distances to areas of need—involves large conduits which must pass over or through either or both the Coast Range and Tehachapi Mountains, and which would extend practically from the northern to the southern borders of the State. Economic and geologic considerations dictate the design of such conduits generally for continuous year-round conveyance of a uniform quantity of water, in order to minimize the size of tunnels, pumping plants, canals, siphons, and other conveyance facilities. In certain cases, however, pumping plants and conduits would be designed for larger capacities to enable the use of lower cost off-peak power. Moreover, conveyance of the variable seasonal secondary water from the Sacramento Valley to the San Joaquin Valley would necessitate the design of certain conduits to the maximum rather than the average seasonal flows. Even at their minimum possible size wherever possible, conveyance facilities required for interbasin transfer of water under ultimate conditions would be without precedent in magnitude and scope.

Reregulation in Areas of Use

Finally, the third consideration— the reregulation of delivered water to the monthly demand schedule prevailing in the areas of use—involves the planning of terminal storage reservoirs to regulate the largely uniform deliveries to the varying monthly demands for the various uses in the areas served. Because the bulk of the water would be delivered to most areas on a uniform seasonal basis, the required terminal storage facilities would be relatively small. However, in areas such as the San Joaquin Valley, where a portion of the supplemental water would be delivered on a variable basis from year to year, final regulation would be accomplished by use of ground water storage to a very large extent.

Development and Use of Water

In addition to the foregoing considerations of development, conveyance, and reregulation of water, planning for the ultimate solution of California's water problems also requires the consideration of other physical problems brought about by the development and use of water. Those problems associated with the development of water involve the operation of reservoirs for the several beneficial, although somewhat incompatible, purposes of providing municipal, irrigation, and industrial supplies; flood control; fish and

wildlife; recreation; navigation; and power generation. Problems associated with the use of water involve the consideration of protection of water quality and provision for adequate drainage. Means of financing, although involving problems vital to the effectuation of the vast system of works necessary to the solution of California's water problems, are beyond the scope of planning considerations presented herein.

Certain basic legal concepts are inherent in the planning considerations necessary to the solution of California's water problems. Minimum possible interference with vested water rights is a major objective. However, some instances of conflict with vested rights are inevitable in a plan of such magnitude. In those instances of interference and to the extent vested rights might be adversely affected, the interference would have to be adjusted either by agreement, purchase, or condemnation. Exchanges of water, where necessary or desirable, would be accomplished by mutual agreement among the parties affected, including the State and Federal Government where pertinent. With respect to the protection of areas of origin of water and the areas of deficiency for which new water supplies must be made available, it is assumed that the legislation necessary to provide that protection would be enacted prior to its need. Similarly, with regard to ground water operations, it is assumed that necessary legislation would establish the policy and the authority which would enable the operation of ground water basins to the degree required under ultimate conditions, prior to the time such operation becomes necessary. Many other legal problems are certain to arise as the water resources are developed. For the purposes of this report it is assumed that they will be solved as the need arises.

Development of Water. As previously stated, problems associated with the development of water involve the operation of reservoirs for the somewhat incompatible purposes of providing municipal, irrigation, and industrial supplies; flood control; fish and wildlife; recreation; navigation; and power generation. This statement refers to the problem of resolving the inherent conflict in the allocation of limited available reservoir storage to each of those purposes. As an example, operation for flood control sometimes requires the use of storage that might otherwise be used for conservation. Operation for power generation similarly may encroach upon conservation storage, because of the required minimum storage for maintenance of power head. Moreover, the schedule of power releases is not in phase with the schedule of releases for irrigation purposes, although a large portion of the conservation releases also accomplishes the dual purpose of power generation. Operation of reservoirs for water supply, flood control, and power generation is not readily amenable to recreational use of the reservoir area because of the extreme and sometimes rapid fluctuations of water levels. Furthermore, reservoir releases for downstream fishery enhancement may adversely affect the conservation yield for other purposes. Conversely, any major storage structure would affect anadromous fish by blocking their passage to upstream spawning areas, necessitating the provision of adequate facilities for maintaining the fisheries resources. To minimize the effects of these conflicts and thus achieve the maximum degree of conservation consistent with the manifold benefits desired, carefully coordinated operation of multipurpose reservoirs is mandatory.

All of the foregoing purposes of water development are vitally necessary and must be fully considered in planning for the solution of the State's water problems. Such planning involves consideration of certain reservoirs to be operated solely for flood control, other reservoirs to be operated solely for fish and wildlife and recreational purposes, and certain reservoirs to be operated primarily for power generation. However, most major reservoirs would be operated for all of these and other beneficial purposes.

1. *Flood Control.* It should be pointed out that, in addition to planned operation for flood control, a measure of incidental flood protection would be derived from operation of any storage reservoir. However, storage capacity sufficient to contain all flood waters would require extremely large and expensive reservoirs. Generally, it is not feasible to attain complete conservation and flood control by storage alone. Improvement of downstream channels in combination with upstream storage reservoirs will probably provide the most economic solution to the important problem of flood control in California. Flood control has in the past and will continue to be largely a joint endeavor between the United States, the State, and local public interests.

2. *Recreation, Fish, and Wildlife.* Outdoor recreation and fish and wildlife conservation are essential considerations in planning for water resource development. When reservoir storage is contemplated on streams with recreation potential, sufficient reservoir releases must be planned to maintain favorable downstream conditions for recreational pursuits and propagation of fish life. Planning of major dams which would block passage of migratory fishes to their ancestral spawning grounds requires the concurrent planning of fish ladders, substitute fish hatcheries, or spawning ground, or development of other streams solely for fish life as compensatory measures. Planning for recreational purposes also involves the contemplated operation of reservoirs dedicated solely to the improvement of summer stream flow conditions in popular recreational areas where such flows are presently deficient.

consisting largely of protection of the channel and fish habitat from scouring flood flows.

No developments are contemplated above Bridgeport Valley on the East Walker River. However, a hydroelectric generating plant, utilizing the available head between Bridgeport Dam and the state line, of 3,200-kilowatt capacity, could develop 39,700,000 kilowatt-hours of electrical energy per year. Bridgeport Valley forms an excellent potential ground water unit. Bridgeport Reservoir, at the lower end of the valley, has caused high ground water elevations under the town of Bridgeport. Use of the ground water basin might tend to lower such existing water levels. Both the United States Bureau of Reclamation and the Walker River Irrigation District have investigated the possibility of raising Bridgeport Dam. A project of that nature should include works necessary to protect the town of Bridgeport from further damage by high ground water levels.

Mono-Owens Group. The Mono-Owens Group comprises the Mono Lake, Adobe Valley, and Owens River areas in the central part of the State, adjacent to the California-Nevada boundary. The westerly boundary of the group lies along the crest of the Sierra Nevada. The gross area of this group in California is about 4,112 square miles, of which about 184 square miles are valley and mesa lands. Mt. Whitney, the highest peak in the continental United States, rising 14,500 feet above sea level, is the outstanding topographic feature.

Mono Lake is a perennial lake with a surface area of about 88 square miles, at an elevation of 6,400 feet above sea level. The lake waters are highly saline and unsuitable for general use. Many small reservoirs and lakes in the upper reaches of Rush, Leevining, Parker, Walker, and Mill Creeks afford excellent opportunities for fishing and recreation. Grant Lake on Rush Creek, and Walker and Sardine Lakes on Walker Creek are owned by the City of Los Angeles and are operated to facilitate the exportation of water to Los Angeles. Several reservoirs in Mono Lake Basin, used primarily for hydroelectric power production, are owned and operated by the California Electric Power Company. The several small reservoirs in the basin have an aggregate storage capacity of about 90,000 acre-feet.

The Owens River rises in volcanic formations to the north of Owens Valley, flowing across the broad upland meadows of Long Valley. The river then drops steeply through the Owens River Gorge, arriving at the head of Owens Valley at an elevation of about 4,400 feet. The fall through the gorge has been utilized for the production of hydroelectric energy. From the mouth of the gorge, the river follows a meandering course through the valley, finally terminating in Owens Lake. Exportation of water to the City of Los Angeles has reduced the inflow to the lake, and a brine processing industry now conducts extensive operations on the lake bed.

The many lakes and small reservoirs in the Mono-Owens Group provide excellent and much-needed recreational opportunities. In addition to the existing facilities for fishing and camping, the organization and provisioning of groups formed for fishing and hunting is a major activity. Much of the present economy of the group is based upon these recreational aspects, factors which are expected to be of increasing importance to the area. Long Valley Reservoir, also known as Lake Crowley, is a very important recreational asset to the Mono-Owens Group.

Long Valley, Tinemaha, and Haiwee Reservoirs regulate the runoff of the Owens River and the imported waters from Mono Lake Basin. The City of Los Angeles purchased some 300,000 acres of lands in Owens-Mono Basin to obtain water rights for its project. The city now leases lands under agreements which contemplate applying water to varying acreages of these lands, depending upon the availability of water in excess of the carrying capacity of the Los Angeles Aqueduct, which now delivers 320,000 acre-feet per annum, approximately its full capacity.

No plans have been prepared for further local development in the Mono-Owens Group as the City of Los Angeles claims rights to the use of most of the waters of these basins. It is expected, however, that some agricultural development on the more favorable lands will occur in the future, utilizing water presently wasted by phreatophyte infestation. Importation of additional water would be extremely difficult and costly. Every effort must be made to preserve and enhance the fish and wildlife resources of the area and to expand the recreational opportunities.

Mojave Group. The Mojave Group comprises Death Valley, the Mojave River Basin, and Antelope Valley. The group is located in the southern part of the Lahontan Area and is bounded on the west and south by the crest of the Sierra Nevada and other drainage divides separating the Lahontan and Colorado Desert Areas. The group contains a total of about 22,700 square miles, of which 6,800 square miles are valley and mesa lands. Death Valley National Monument, an outstanding vacation land, is located in this group and is bordered on the west by the imposing Panamint Range.

The Mojave Group is unique because all drainage is internal, the streams terminating in dry lakes, or sinks, which are subject to inundation in the occasional periods of exceptionally high runoff. The principal streams in the group, all of which are comparatively minor, are the Mojave River, draining the northerly slopes of the San Bernardino Mountains, Big and Little Rock Creeks in Antelope Valley, and the Amargosa River, draining Death Valley.

Tremendous expansion has taken place in the desert areas during the past few years. Camp Irwin and the Naval Ordnance Test Station at Inyokern are located in the Mojave Group. The recent acceleration of activities of these and other military installations has caused a major influx of population into adjacent urban areas. Antelope Valley has experienced some agricultural expansion during the last decade, but the principal development has been due to expansion of industry with the accompanying commercial development to support the urban growth. In the Palmdale and Lancaster areas, the advent of military and related aircraft industrial installations has resulted in a great increase in population. Major industries in the Mojave Group are the manufacture of portland cement, the production of crops by irrigated agriculture, and the operation and maintenance of railroad plant and equipment. Commercial development has expanded rapidly, due to the growth of population and the increased tourist trade that is being experienced in this group.

Water quality problems are inextricably connected with the development of the native water resources of the Mojave Group and the provision of additional imported supplies. Poor-quality ground water is presently found in many of the individual ground water basins. The existence of borax mines is indicative of present and future problems associated with excessive boron content of otherwise usable water supplies. It is anticipated that other problems will develop as the expansion of economic activity occasions the further development of ground water resources.

Future development of available ground water storage capacity, involving the utilization of large quantities of imported water supplies, would require adequate control over the maintenance of salt balance. This is a serious and aggravated problem under conditions of internal drainage such as are found in the Mojave Group, where all drainage water remains in the immediate vicinity of the primary supply. Salt balance in the usable ground water reservoirs must be maintained by providing facilities to export, or transfer, from the underground basins as great a quantity of salts as is added in the processes of use and re-use.

Flood problems in this group are those principally connected with the Mojave River. Occasional floods on this stream have in the past caused extensive damage in the valley areas. In 1956 the Corps of Engineers, U. S. Army, investigated the problem of floods, and recommended construction of a flood control reservoir on the West Fork of the Mojave River.

In common with most other arid areas, the Mojave Group is subject to cloudbursts, which cause flash floods, during which a large volume of water is discharged down a normally dry stream bed. Floods of this type have caused considerable damage in localized areas, but are so erratic in time and place as usually to make infeasible the provision of adequate safeguards against the prospective flood damage.

The irrigated area in the Mojave Group amounted to about 99,000 acres in 1950. The water supplies required to support this agricultural development, together with necessary urban and suburban requirements, have been principally secured by development of available underground water supplies.

In Antelope Valley, the Little Rock Creek and Palmdale Irrigation Districts have developed available surface supplies originating in the San Bernardino Mountains. In addition to the development of surface supplies, ground water has been extensively developed to supply most of the 74,000 acres presently under irrigation in 1950. As a consequence, an annual overdraft of about 160,000 acre-feet existed at that time; the ground water resources were overdrawn prior to 1946, at least. As a result, ground water levels now (1957) average 176 feet below ground surface. It has been estimated that, under 1950 conditions, the water requirements for the then existing development in Antelope Valley amounted to about 226,000 acre-feet per season. It is estimated that the probable ultimate habitable water service area in Antelope Valley would total about 725,000 acres, of which about 610,000 acres would be irrigated, or approximately eight times the 1949-50 area of irrigated lands. The estimated probable ultimate mean seasonal water requirement is about 1,520,000 acre-feet, of which 1,490,000 acre-feet might be used for irrigated agriculture. Since the native water supply amounts to only about 66,000 acre-feet, it is apparent that, for all practical purposes, the water supplies necessary to support the potential economic development of this area would have to be imported through the facilities of the California Aqueduct System.

It is estimated that the yield available from native water supplies in the Mojave Group is about 200,000 acre-feet per season, including about 135,000 acre-feet from the Mojave River and 66,000 acre-feet from watersheds tributary to Antelope Valley. Although the Amargosa River, draining Death Valley, contributes an unknown amount to the water supply of the area, its effect, in relation to the magnitude of the estimated requirement, is believed to be small.

The objectives of The California Water Plan for the Mojave Group would be met by the importation of about 4,835,000 acre-feet of supplemental water supplies per season from areas of surplus in California through the facilities of the California Aqueduct System, and the transmission and distribution of such water supplies to local agencies throughout the area. It is contemplated that water would be supplied on a constant-flow basis, and that reregulation to the monthly demand schedule prevailing in the service areas would be accomplished by utilization of avail-

le ground water storage. The flow in excess of requirements during the winter months would be placed underground storage, and, during periods when e demand for water would be greater than the delered flow, supplemental water supplies would be mped from the underground reservoirs and distbuted through the existing system.

It is pointed out that the cost of importing water this area would be high because of the elevations d distances involved. This cost might well be beyond the repayment capacity of irrigated agriculture der current economic conditions. On the other hand, is believed that urban communities, military activies, and industrial developments could bear these sts. The feasibility of providing adequate water supies for the Mojave Group in the near future, at st, will be largely dependent upon the probable fure trend of economic development, whether it be incipally urban and industrial or agricultural. The partment of Water Resources is currently (1957) ving further and intensive study to the matter.

A unit of the California Aqueduct System would ter the Lahontan Area at the Antelope Afterbay. is described hereafter under the heading "Buena sta-Cedar Springs Aqueduct." It would traverse e area along the southerly edge of Antelope Valley d leave the area at Mojave Junction, from whence would proceed into the South Coastal Area. Diversn of necessary water supplies for the Mojave Group uld be made as required at various points along the e of the California Aqueduct route.

Summary of Lahontan Area. Objectives of the lifornia Water Plan in the Lahontan Area would met by further development of local water reurces, supplemented with imported water delivered rough facilities of the California Aqueduct System the southerly portion of the area. Deficiencies in deloped water supplies to support the existing munici- al and agricultural development in the area have creased rapidly in the past few years, particularly the Mojave Group. The population in the Lahontan ea was about 126,000 in 1955, with much of the crease since 1950 occurring in the southerly portion the area.

Local water resources in the Lassen Group are inufficient to provide for the water requirements of is group. Projects contemplated herein, while augenting the present development, would not suffice meet the probable ultimate requirements. However, ovision of imported water supplies to this area is t considered feasible of accomplishment due to its mote geographical location and the difficulties attndant on exporting required water supplies from urces of the Central Valley.

In the Alpine Group the yield from local works uld accrue largely to the benefit of lands lying in e State of Nevada. Contemplated works could provide water supplies adequate to meet the estimated ultimate requirements in this group. However, the considerations involved in the distribution of waters of an interstate stream will probably govern the amount of water which could be made available for the ultimate development of the lands in the California portion of the stream system. Projects included in The California Water Plan, together with existing works in this area, would provide a high degree of conservation of surface water resources, developing a yield of about 310,000 acre-feet of water per season. This yield would be additional to the yield from Bridgeport Reservoir on the Walker River and the proposed Watasheamu Reservoir on the East Carson River. In contrast, the estimated probable water requirements of lands in California included in this group are about 144,000 acre-feet per season.

The possible yield from development of local water supplies in the Mojave Group is estimated to be about 200,000 acre-feet of water per season. Required supplemental water supplies in this group would be largely provided from imported water delivered through the facilities of the California Aqueduct System. This would be accomplished principally through the use of ground water storage in conjunction with supplemental water supplies amounting to 4,835,000 acre-feet per season, which would ultimately be imported into the group through the California Aqueduct System, if determined to be feasible, and be distributed by local water service agencies.

The future growth of California will necessitate a considerable increase in the development of recreational areas and facilities. Water development must provide specific features for the enhancement of the sport fishery and the wildlife of California. The recreational aspect of anticipated water development is of outstanding importance in the Lahontan Area, particularly in the Lassen, Alpine, and Mono-Owens Groups. This region of the State has many almost unparalleled advantages for recreational development. Much of the present economic development is based upon supplying the recreational needs of California's population, and it is expected that this activity will increase at a rapid rate in the future.

The general features and costs of the local development works contemplated as features of The California Water Plan in the Lahontan Area are presented in Table 15. The location and layouts of all these facilities are delineated on Sheets 4, 6, and 9 of Plate 5.

Colorado Desert Area

The Colorado Desert Area comprises all lands draining directly into the Colorado River, together with a number of centrally drained desert basins without outlet. The area includes a total of 19,400 square miles, of which about one-half consists of valley and mesa lands. The climate of the area is arid.

TABLE 15

SUMMARY OF WORKS TO MEET WATER REQUIREMENTS IN LAHONTAN AREA

(These works show future development possibilities. They are not project proposals.)

Dam and reservoir	Stream	Dam: Location, MDB&M, and sheet of Plate 5 on which shown	Dam: Type	Dam: Height, in feet	Normal pool elevation, in feet	Storage capacity, in acre-feet: Gross	Storage capacity, in acre-feet: Active	Seasonal yield, in acre-feet	Purpose	Place of water use	Capital cost[a]
Lassen Group											
Devils Corral	Susan River	Sec. 5, T29N, R11E 4	E	189	4,737	30,000	29,500	31,000	I	Honey Lake area	4,649,000
Long Valley	Long Valley Creek	Sec. 10, T23N, R17E 6	E	104	4,700	20,000	19,100	8,000	I	Long Valley	827,000
Pete's Valley	Willow Creek	Sec. 1, T30N, R13E 4	E	133	4,543	22,000	19,800	20,000	I,R	Willow Creek-Honey Lake area	1,404,000
Eagle Lake Dike	Eagle Lake	Sec. 16, 17, T32N, R11E 4	E,R	30	5,102	83,000	83,000				848,000
Alpine Group											
Stampede[b]	Little Truckee River	Sec. 20, 21, 29, T19N, R17E 6	E	207	5,932	175,000	174,000	120,000	I,P,F,R	Little Truckee-Prosser Creek area	6,375,000
Hope Valley	West Carson River	Sec. 25, T11N, R18E 9	E	176	7,166	100,000	95,000	55,000	I,P,F,R	Carson Valley-Diamond Valley	5,101,000
Silver King	East Carson River	Sec. 2, T8N, R21E	E	75	6,430	8,000	7,900	7,900	F,R	East Carson River area	465,000
Leavitt Meadows	West Walker River	Sec. 27, T6N, R22E 9	E	103	7,183	20,000	19,200	127,000	I,P,F,R	Antelope Valley	1,106,000
Pickle Meadows	West Walker River	Sec. 18, T6N, R23E 9	R	173	6,833	125,000	124,000		I,P,F,R	Antelope Valley	7,867,000
Mono-Owens Group	(no local works)										
Mojave Group	(no local works)										
Totals						583,000	571,500				$28,642,000

Power plants and conduits	Location, MDB&M, and sheet of Plate 5 on which shown	Average head, in feet	Installed capacity, in kilowatts	Average annual energy generation, in kilowatt-hours	Length of conduit, in miles: Canal	Tunnel	Pipe	Total	Capital cost[a]
Lassen Group									
Diversion conduits					5.0			5.0	Included in cost of dams
Alpine Group									
Union Mills	Sec. 8, T17N, R17E 6	500	10,000	36,200,000	5.7	3.8	0.4	9.9	$5,960,000
New Farad	Sec. 12, T18N, R17E 6	425	14,000	66,400,000	2.9	4.4		7.3	7,640,000
Calvada[b]	Sec. 31, T19N, R18E 6	890	20,000	81,000,000		4.5		4.5	8,792,000
Woodfords	Sec. 1, T10N, R19E 9	1,100	10,300	47,200,000		4.1		4.1	4,932,000
Paynesville	Sec. 17, T11N, R20E 9	952	6,500	24,400,000		6.1		6.1	1,160,000
Pickle Meadows	Sec. 25, T6N, R22E 9	300	5,000	18,600,000			1.1	1.1	805,000
Antelope Valley	Sec. 28, T8N, R23E 9	1,184	25,000	116,600,000		8.9	1.0	9.9	14,279,000
Bridgeport	Sec. 31, T7N, R20E 9	500	8,200	39,800,000	8.5		0.3	8.8	2,073,000
Diversion conduits					14.7	0.3		15.0	731,000
Totals			99,000	430,200,000	36.8	32.1	2.8	71.7	$46,372,000

Symbols of Type of Dam
E—Earthfill
R—Rockfill

Symbols of Purpose
I—Irrigation
P—Power
F—Enhancement of fish environment
R—Recreation

[a] At 1955 price levels.
[b] Stampede-Calvada Project under construction by U. S. Bureau of Reclamation, with Stampede Reservoir storage capacity of 125,000 acre-feet.

This aqueduct would convey about 825,000 acre-feet per season, of which 368,000 acre-feet would be delivered to the South Coastal Area and 457,000 acre-feet would be conveyed to the Colorado Desert Area.

TABLE 28

SUMMARY OF CAPITAL COSTS, SOUTHERN CALIFORNIA DIVISION, CALIFORNIA AQUEDUCT SYSTEM

Item	Capital cost*
Buena Vista-Cedar Springs Aqueduct	
Feather River Project Aqueduct	$251,470,000
Pumping Plant No. III	13,060,000
Pumping Plant No. IV	16,790,000
Pumping Plant No. V	31,560,000
Pumping Plant No. VI	74,410,000
Quail Lake Reservoir	500,000
Cedar Springs Forebay	4,870,000
Upper Aqueduct	593,820,000
Pumping Plant No. 4	79,640,000
Pumping Plant No. 5	123,400,000
Pumping Plant No. 6	406,000,000
Pumping Plant No. 7	11,290,000
Buena Vista Forebay	6,940,000
Antelope Afterbay	10,330,000
Antelope-Mojave Aqueduct System	410,000,000
Subtotal	$2,034,080,000
San Fernando-Ventura Aqueduct	
Conduit	$142,570,000
Liebre Gulch Power Plant	17,720,000
Liebre Gulch Reservoir	3,130,000
Castaic Creek Power Plant	23,590,000
Castaic Creek Reservoir	18,740,000
Conejo Reservoir	5,030,000
Subtotal	$210,780,000
Devil Canyon Power Development	
Conduit	$87,161,000
San Bernardino Power Plant	41,320,000
Arrowhead Springs Afterbay	16,500,000
Subtotal	$144,981,000
Chino-San Gabriel Aqueduct	
Conduit	$16,153,000
Second San Diego Aqueduct	
Conduit	$63,700,000
Keys Canyon Reservoir	5,701,000
Enlarged Lower Otay Reservoir	3,045,000
Subtotal	$72,446,000
Barona Aqueduct	
Conduit	$178,934,000
Barona Reservoir	2,156,000
Subtotal	$181,090,000
San Diego High-Line Aqueduct (Feather River Project)	
Conduit	$230,880,000
Santa Ysabel Pumping Plant	1,450,000
Santa Ysabel Reservoir	7,230,000
Whitewater Aqueduct	
Conduit	5,140,000
Banning Power Plant	920,000
Hathaway Power Plant	440,000
Cabazon Power Plant	1,000,000
Whitewater Power Plant	330,000
San Felipe Aqueduct	
Conduit	21,800,000
San Felipe Dam and Reservoir	970,000
San Felipe Power Plant	1,440,000
Narrows Power Plant	1,690,000
Kane Springs Power Plant	570,000
Subtotal	$273,860,000
Total	$2,933,390,000

* At 1955 price levels.

Deliveries to high lands in the upper Santa Ana and San Jacinto Valleys, to the San Gorgonio Pass area and desert lands to the east, and to high lands in Riverside and San Diego Counties, would be made directly from the aqueduct. Near Lake Henshaw, a diversion by tunnel on a continuous flow basis would be made to the Borrego Valley area. About 85,000 acre-feet of water per season would also be provided from the San Diego High-Line Aqueduct to Barona Reservoir by the Barona High-Line Interconnection for use on lower-lying lands.

The general features and capital costs of the California Aqueduct System in the Southern California Division are presented in Tables 27 and 28. The location of these facilities are delineated on Sheets 16, 17, 20, 21, 22, 24, 25, and 26 of Plate 5.

UTILIZATION OF GROUND WATER STORAGE

Inherent in the concept of development, and vitally necessary to the successful implementation and operation of The California Water Plan, is the availability of adequate facilities for storage, regulation and transportation of the developed water supplies. Transportation facilities would consist of the major local and transbasin conduits, and the California Aqueduct System. Because of the many possible alternative means of accomplishing the transfer of water from areas of surplus to areas of deficiency, both on a local and on a state-wide scale, the problem of water transportation, from an engineering point of view, is not likely to present insurmountable difficulties in the implementation of The California Water Plan.

There are, on the other hand, no alternative means of developing the physical storage space required to provide the necessary control and regulation of the large volumes of water over long climatic cycles. Early in the studies concerning The California Water Plan it became apparent that such control and regulation cannot be accomplished by surface storage alone, within foreseen economic limits. It was therefore necessary to examine in detail the feasibility of utilizing the natural storage capacity available in underground basins in order to supplement the available surface storage. Based on such examination there is every indication that storage capacity, adequate by a relatively safe margin, exists in California's major underground basins to enable the necessary regulation, and that such regulation is physically possible under conservative assumptions.

Under The California Water Plan, sufficient reservoir storage capacity would be necessary in regions of water surplus to so regulate water supplies that they may be exported at a nearly uniform rate, thereby reducing the sizes of transport conduits. Similar

addition to further conservation of local water resources, reservoir storage space would be necessary in e areas of water deficiency to provide reregulation imported water, since such a rate of water delivery es not correspond to the demand rates. Adequate rface reservoir storage capacity was found to be ailable in the North Coastal Area to accomplish the quired regulation. However, in the Sacramento and an Joaquin-Tulare Lake Basins and in the Lahontan, olorado Desert, and South Coastal Areas, the large olumes of required storage could not be provided tirely in surface reservoirs.

In the case of the Sacramento River, San Joaquin iver, and Tulare Lake Basins, studies of the relaon which would exist between historical inflow and timated ultimate water requirements indicate that maximum of approximately 53,000,000 acre-feet of relic storage capacity would be required to regulate e water supply so that water demands could be et as they occur, without shortages. It is further dicated that foothill storage reservoirs could be ecomically constructed in the basins to an aggregate gulatory capacity of about 22,000,000 acre-feet. nsequently, the additional 31,000,000 acre-feet of quired storage space necessarily would be provided rough utilization of ground water basins. Estimates the storage capacity existing in the alluvium of e Central Valley, made by the United States Geogical Survey and the Department of Water Reurces, indicate that some 133,000,000 acre-feet of oss storage capacity is available within 200 feet of e land surface. Taking into consideration areas of estionable water quality and areas where rates of charge and extraction might present problems, it indicated that the usable storage capacity might nount to about 98,000,000 acre-feet.

se of Ground Water Storage

For the most part, the total storage capacity which available in the alluvial valley fills is the sum of e volumes of the innumerable small pore spaces, voids, that exist around the particles comprising e alluvial fill. Not all of this volume, however, is able; in clays and fine silts, the interparticle spaces e too minute to permit sufficient rates of water ovement. Moreover, not all of the water stored in e interstices of the alluvium will drain out as the ter table drops. Primarily, the larger pore spaces und in sand and gravel strata and deposits prode the usable underground storage space. Even in ese larger interstices, the movement of ground ter is so slow that rates of placing surface water storage, flow within the ground water basin itself, d rates of extracting water from storage by means wells are prime problems in the utilization of the rage capacity of a ground water basin.

In addition to the physical problems, economic and ter quality criteria must be considered fully in estimating usable ground water storage capacity and in selecting water supply sources. For each water use and for each source of supply there is an economic limit to the price which could be paid for the supply. Thus, there is a limiting depth from which ground water could be obtained economically. This economic depth, of course, varies with the use of the water. Profitable agricultural endeavors in certain areas of the State are now obtaining water from depths in excess of 600 feet. However, under The California Water Plan pumping depths of such magnitude are not envisaged.

If parts of the alluvium contain water of unsuable quality, or if soluble minerals exist within the subsurface basin which would degrade water placed in storage, these volumes of the alluvium cannot be considered as usable for water storage. In time, such zones or areas might be flushed of their degradants and become usable. However, since sufficient information is not now available concerning these processes, such areas are presently classed as unusable. In those areas where the upper fresh ground waters are underlain by connate saline water or where the possibility of sea-water intrusion exists, the draft on the usable ground water must be controlled, as to both rate and total annual amount, to the extent necessary to maintain the quality of those waters at acceptable levels. Operators of a ground water basin must exercise constant care to assure that usable storage space is not rendered unusable by an accumulation of damaging concentrations of undesirable minerals. This can be accomplished by controlling the quality of water placed in storage; by adjusting the relative use of surface and ground water throughout the basin; by controlling the rate, amount, and areal pattern of extractions; and by providing requisite drainage or outflow from the basin to maintain salt balance. The California Water Plan envisions the maintenance of the utility of ground water basins in perpetuity.

Surface reservoirs and subsurface basins are similar in that they each have replenishment and discharge characteristics. Surface reservoirs will store water as fast as the inlet channels permit, and may be designed to discharge at any rate. In the case of ground water basins, however, the recharge or replenishment capacities are not so completely subject to artificial control. At the same time, they constitute primary factors in determining the utility of the basin. Under natural conditions water enters the ground by infiltration from direct precipitation and by percolation from streams and ponds. Under artificial development, additional important means of recharge, namely, canal seepage, deep percolation of unconsumed applied irrigation water, return flow from cesspools and the like, become effective, as well as does artificial recharge by spreading and other means. In addition, an area lying at higher elevations that receives an abundance of surface water may serve as a source of replenishment

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to a lower-lying area by providing subsurface flow to the lower area.

The significance of the problem of ground water recharge rates is apparent when a comparison is made between the short duration and large volume of flood flows, or even the usual peaks of seasonal runoff, and the low rates at which stream percolation occurs. Furthermore, this problem is exaggerated where surface reservoirs capture all but the larger flows, thus reducing the ground water recharge period to a relatively few days of peak discharge. In addition, there are many instances where the natural recharge opportunity is so limited that additional capacity must be developed artificially. Artificial recharge may take the form of stream channel modification to increase the wetted stream bed area; construction of spreading ponds or ditches, recharge wells, and shafts; and operation of the irrigation canal system during the nonirrigation season to effect recharge during the period when canals and ditches normally would not be full. Such operation would provide additional opportunity for seepage from the surface distribution system.

Artificial recharge operations should be so located with respect to the geologic structure of the ground water basin as to achieve the most efficient utilization of the storage capacity and of the transmissibility of the aquifers. In selecting a location, consideration must likewise be given to the surface soil texture and subsurface structure in order to obtain the best percolation rates. Artificial recharge works may involve considerable areas of land, with consequent cost and possible interference with other potential land uses. There are other problems involved which necessitate careful consideration, including: construction and maintenance of diversion works from streams; control of silting; maintenance of percolation rates; and prevention of nuisance and protection of the public health through adequate mosquito control and other measures.

Storage of water underground through artificial recharge has been widely practiced in California since 1895. Much information and data are available both from actual operating experience and from controlled research, but further study and evaluation are needed. It is emphasized that thorough knowledge of the physical characteristics and geologic structure of a ground water basin is a prerequisite to successful artificial recharging operations therein.

Deep percolation of unconsumed applied irrigation water is an important means of ground water recharge. Drainage problems frequently develop in areas receiving abundant supplies of surface water, and the possibility that such problems may arise must be considered in planning the utilization of ground water basins. Such problems, however, can be prevented by controlled pumping of water from the ground water basin so as to maintain a lowered water table. The water thus pumped could be discharged from the area as drainage water, or could be utilized to irrigate adjacent or overlying lands, thus reducing the amount of the required surface supply. For example, if only the water requirement necessary to satisfy consumptive uses were imported to an area, and surface and ground water service areas were properly balanced, the amount of water entering ground water storage would be equal to the amount leaving ground water storage and water levels would not fluctuate appreciably from season to season, thereby preventing serious drainage problems. However, with such constant recharge and constant discharge, no cyclic regulation would be provided, and the underground basin would be ineffective in providing beneficial regulation of water supplies over long-time climatic cycles. Problems of salt accumulation in the ground water would undoubtedly arise.

On the other hand, if the entire service area were supplied with surface water to the maximum extent possible during wet periods and the ground water drawn upon to a much greater degree during dry periods, the ground water basin operated in conjunction with surface reservoirs could serve to regulate the available water supply over long-time climatic cycles.

Under the concept of planned utilization, the ground water in storage would be deliberately drawn down for beneficial use either on overlying lands or by export during dry periods, thus creating greater storage space to be refilled with excess runoff during ensuing wet periods under a carefully planned and managed program. The operation of available surface and ground water storage reservoirs would be so coordinated as to achieve the maximum feasible degree of conservation. This method of operation has been used in the studies for the Central Valley which are described subsequently.

In some regions, such as the South Coastal Area, where the runoff is extremely erratic both in season and from year to year, with dry periods of several years' duration, and where surface storage is very limited, the ground water basins must be relied upon for long-time cyclic storage. Under such circumstances, surface reservoirs are often used primarily to regulate the runoff to the extent necessary to enable the storage of the water underground through artificial recharge operations. It is anticipated that this practice will become increasingly prevalent in the more arid portions of the State in order to obtain the maximum practicable conservation of local water resources.

Under conditions of full development and planned utilization of ground water resources, the rate, the amount, and the areal pattern of extractions must be carefully planned and controlled if most efficient use is to be made of a basin. These withdrawal factors must be properly related to: the geologic structure

h areally and vertically, of the basin; the areas greatest potential usable storage capacity; the rces and areas of recharge; the transmissibility l permeability of the aquifers; the areas of water ; the possibility of water-logging in the lower por- s of the basin; and the necessity of controlling surface outflow and effluent seepage from the in. Here again it is obvious that full knowledge the characteristics of the ground water basin is rerequisite.

Certain legal and financial problems involved in planned utilization of ground water basins are ussed in Chapter V.

Conjunctive Operation in the Central Valley

The coordinated operation of surface reservoirs h underground storage basins in the manner de- bed, to produce the desired yield at minimum cost, ermed "conjunctive operation." Several trial op- tion studies were made for assumed conditions of imate development in the Central Valley. In these dies, the costs of operation with various combina- ns of surface reservoir release schedules and sur- e water transport capacities were compared with costs of required ground water pumping, in order determine the most economical, or optimum, bal- e between the two. The method of operation thus ected, and described in part herein, is presented as the only method which would serve the pur- e, but rather to illustrate in a general manner that required conservation results could be attained.

The conjunctive operation of the entire Central ley would not involve completely untried and un- ved principles, but, before being put into prac- would require much additional study and in- tigation, particularly as to geologic conditions and nomics. The only new aspects would be the valley- e application of the operation and, to a certain nt, the flexibility in serving irrigated areas from h surface and ground water sources. However, in operation herein described, provision was made service to portions of the valley entirely from er surface sources or from ground water, where ographic, geologic, and ground water quality con- erations dictate. Recharge to the ground water ins would occur mainly from deep percolation of unconsumed surface application of water for ir- tion and from seepage from unlined canals and ribution systems. In localized areas where normal und water recharge is limited, artificial methods ld be employed.

For studies of conjunctive operation, the Central ley was separated into four parts: the Sacramento ley, the Delta-Mendota Area, the San Joaquin ley-West Side Area, and the San Joaquin Valley- st Side Area. The location of the four areas, and major foothill storage reservoirs that were utilized in the studies, are depicted schematically on Plate 7, entitled "Conjunctively Operated Storage in the Central Valley."

The period chosen for detailed study of conjunctive operation of foothill and ground water reservoirs in the Central Valley was the 10-year period 1926-27 through 1935-36. This period includes the 6-year critical drought period, 1928-29 through 1933-34. In addition, water supply conditions prior to the 10-year period were such that the ground water reservoir could be considered to be full at the beginning of the period if conjunctive operation had been practiced on a long-term basis. Assuming an available water supply equivalent to the 10-year operation period, and assuming conditions of ultimate water demand, the operation study demonstrated that it would be possible to provide not only the ultimate water requirements for the entire Central Valley but also to provide a seasonal export to other areas of the State in excess of 1,700,000 acre-feet of water from the Sacramento Valley. Moreover, studies indicated that the ground water basins would again fill to the levels existing at the beginning of the 10-year period. A summary of results of the operation study is given in Table 29.

Several of the values given in Table 29 merit comment. For instance, the studies indicate that under the method of operation discussed herein, only 32 per cent of the usable ground water storage capacity within 200 feet of the ground surface would be required to accomplish the necessary cyclic regulation. Furthermore, since the selected 10-year period includes the most critical years during the 50-year mean period 1897-98 through 1946-47, from a water supply standpoint, it follows that the indicated maximum depths to ground water may occur about once in 50 years.

Under conjunctive operation, ground water pumping units would be distributed more uniformly over the underground basins, in comparison to the present over-concentration of wells in regions that derive their entire supply from underground sources. Furthermore, through use of an integrated surface distribution system, wells could be operated on a more continuous basis, thus reducing the number of installations required, and also reducing the unit costs of pumping by savings in stand-by charges.

In summary, utilization of the ground water storage capacity of the Central Valley is essential to the full ultimate development of the water resources of the State. There is economically available about 98,000,000 acre-feet of usable ground water storage capacity in the Central Valley, of which only 31,000,000 acre-feet would be required in the operation of The California Water Plan. In order to utilize effectively this subsurface reservoir, its conjunctive operation with the foothill surface reservoirs of the Central Valley would be required. A possible means of ob-

TABLE 29

SUMMARY OF RESULTS OF CONJUNCTIVE OPERATION OF SURFACE RESERVOIRS AND GROUND WATER BASIN OF THE CENTRAL VALLEY UNDER CONDITIONS OF ULTIMATE WATER REQUIREMENTS DURING THE CRITICAL OPERATION PERIOD 1926-27 THROUGH 1935-36

Item	Main subdivisions				Total Central Valley
	Sacramento Valley	Delta-Mendota Area	San Joaquin Valley		
			West Side Area	East Side Area	
...able foothill reservoir storage capacity, in millions of acre-feet	13.8	.....	2.1	6.5	22.4
...ired ground water storage capacity, in millions of acre-feet	4.0	6.8	6.4	13.7	30.9
...ated usable ground water storage capacity within 200 feet of land surface, in millions ...acre-feet	27.7	10.9	15.3	43.8	97.7
...on of usable ground water storage required, in per cent	14	62	42	31	32
...on of gross local water demand satified by ground water, in per cent, in:					
Dry season	80	74	53	68	67
Wet season	30	31	35	14	25
Average season	60	38	38	42	45
...mum gross seasonal recharge of ground water basin, in millions of acre-feet	7.2	1.3	2.8	5.0	16.3
...uum seasonal depletion of ground water in storage, in millions of acre-feet	3.1	1.3	1.1	3.1	8.6
...mum installed ground water pumping capacity, in millions of gallons per minute	6.2	2.3	2.5	7.5	18.5
...ximate number of pumping plants required	6,000	3,250	2,500	7,500	19,250
...ge depth to ground water, in feet from ground surface	25	60	40	30	30
...uum mean depth to ground water, in feet	50	130	90	70	70

...ining much of the recharge capacity necessary to ...rate the ground water basins of the Central Val... would be to have sufficient distribution capacity ...enable, on occasion, the service of about 75 per ...t of the area from surface supplies. Thus, the ...page from canals and deep percolation of uncon...ed applied irrigation water, plus certain artificial ...harge works, would recharge the underground ...ns so that they would be filled and be available ...heavy draft during drought periods.

...tudies of conjunctive operation indicate that in ...t areas where considerable present development ...ts, the average depth to ground water would be ... than at present and, in areas where little ground ...er development has occurred, the depths to ground ...er would be reasonable.

...s pointed out, there are actually no new principles ...olved in the operations just described. Further...e, there is every indication that the required ...und water storage capacity is available and that ... required recharge rates could be obtained. A ...ewhat similar method of operation is being prac...d at the present time in parts of the Tulare Lake ...in, notably in the service areas of the Kaweah, ...e, and Kern Rivers. The Raymond Basin area in ...thern California has been operated since 1945 on ... a planned basis.

...ased upon present knowledge and the assumptions ... have been made regarding available water sup...s and ultimate water requirements, it is indicated ...t it will be necessary to operate the underground ...ns in coordination with foothill reservoirs in ...ewhat the manner which has been described. ...thermore, there is every reason to believe that such operation could develop by local initiative and under local control to a considerable degree, although region-wide guidance in planning and control in operation would be necessary for most effective results. The legal problems involved in conjunctive operation are discussed in Chapter V.

SUMMARY OF THE CALIFORNIA WATER PLAN

There has been described in this chapter a vast system of integrated works, both local and interbasin, which serves to demonstrate that the objectives of The California Water Plan are physically possible of accomplishment within the limits of available water resources. While it is acknowledged that ultimate development of the land and other resources of the State may be achieved by works differing in many respects from those described herein, certain basic factors will remain essentially the same, regardless of the actual works ultimately selected for construction. Among these factors are: the probable ultimate water deficiency in the central and southern parts of the State; the ultimate surplus in the North Coastal Area and the Sacramento River Basin; the total storage requirement for the necessary regulation and control of water; and the approximate lengths and sizes of major aqueducts required to equalize geographically the water resources and the ultimate water requirements in California. In view of these factors, and of the inherent limitations of any plan for the indefinite future, it is considered that the works summarized in this section are as realistic as can now be foreseen.

CHAPTER V

IMPLEMENTATION OF THE CALIFORNIA WATER PLAN

ere have been discussed and described so far in bulletin the water problems of California and a system of physical works which could accomplish objectives of The California Water Plan. Briefly, Plan has as its objectives the full satisfaction of ent and future water requirements for all bene- purposes and uses in all parts of the State to maximum practicable extent. It has been pointed that development and operation of facilities ccomplish these objectives would bring about ad- nal engineering problems which must be con- ed and reconciled.

his chapter discusses certain considerations which basic to implementation of The California Water P, and without which the Plan could never be tuated. These considerations, which are essentially nonengineering nature but which govern all engi- ing considerations, are described under the gen- heading "Prerequisites to Implementation of California Water Plan." In addition, this chap- discusses various other considerations which, ough not essential to the implementation of the P, could exert a considerable effect on its scope accomplishments. These are discussed herein r the heading "Other Considerations Affecting California Water Plan."

PREREQUISITES TO IMPLEMENTATION OF THE CALIFORNIA WATER PLAN

ransformation of a system of physical works, such hose described in Chapter IV, from a plan to a ty, will require careful study and evaluation of and economic problems. Legal problems which be reconciled involve the inadequacy of present for accomplishment of comprehensive coor- ted water resource development, and the require- ts for amendment thereof or addition thereto. Eco- ic problems involve determinations of the need specific water development projects, benefits as ared to costs, and appropriate means of finance. Finally, and this cannot be emphasized too gly, the solution of engineering, legal, and eco- ic problems would be of little avail toward actual ementation of The California Water Plan with- a high degree of cooperation and close coordina- of efforts of all agencies and individuals at the , state, and federal levels.

Legal Considerations

State-wide coordinated development of California's water resources, as contemplated under The California Water Plan, will necessarily pose many legal problems. Such problems relate to inadequacies and uncertainties of present statutes; the required procedure for acquisition of water rights in furtherance of the coordinated plan; the nature and extent of vested rights to use of surface and ground water; the extent of unavoidable interference with any such rights and the methods by which such rights may be compensated or otherwise adjusted in order to permit full operation of the Plan; preferential rights of areas in which water originates; effectiveness of contract rights in assuring areas of deficiency of a dependable water supply; and relations between the State and other agencies.

No attempt is made in this discussion to consider all legal problems that might arise. As might be expected, many of the legal questions connected with such a vast undertaking have not been resolved by the courts and the Legislature, and many of the questions which may arise cannot now even be anticipated. It has been necessary, therefore, in many cases merely to identify the problem and to limit the discussion to problems having the most general application and interest.

As previously stated, The California Water Plan is designed to include and supplement, rather than to supersede, existing water resource developments, and incorporates certain of the planned works now proposed or authorized for construction by public and private agencies and individuals. Agencies of the State and Federal Governments and water users' organizations may all construct and operate features of the Plan. The legal considerations vary considerably with the agency involved, but generally they fall within the same framework of law.

Water Rights. Any agency constructing or operating a unit of The California Water Plan would have to acquire or adjust water rights. If the operating agency were not the user, it would acquire and hold water rights for the benefit of the actual users. To the extent that unused water not now subject to vested rights would be made available by construction of storage and diversion facilities, the law pertaining to acquisition of rights to the use of unappropriated water would be applicable. Where necessary, vested

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rights might be acquired either by agreement or condemnation.

1. *Appropriative Rights.* The Legislature has established procedures for the appropriation of surplus water. Water flowing in a natural channel not already subject to appropriative or riparian rights is public water of the State and subject to appropriation in accordance with the provisions of the Water Code (Water Code § 1201). However, the statutory provisions relate only to surface water in a stream, lake, or other body of water, and to subterranean streams flowing through known and definite channels (Water Code § 1200).

The foregoing requirements are applicable to state agencies, as well as to private corporations, organizations, and individuals, and to the United States. There is no provision for withdrawing water from appropriation; a priority may be preserved, however, by filing an application to appropriate unappropriated water and following the procedures prescribed by law.

The Department of Water Resources is authorized by the provisions of Part 2, Division 6 of the Water Code, to file applications to appropriate water which "in its judgment is or may be required in the development and completion of the whole or any part of a general or coordinated plan looking toward the development, utilization or conservation of the water resources of the State . . ." (Water Code § 10500). Such applications are, in general, subject to the requirements and rules which govern applications by others, except that the Legislature has provided from time to time that they are not subject to the statutory requirements relating to diligence.

A number of applications have been filed since 1927 pursuant to the foregoing authorization. Provision has been made by the Legislature for assignment of or release from priority under any such applications when the release or assignment is for a "development not in conflict with such general or coordinated plan" (Water Code § 10504). The assignee of any such application is subject to the requirements of diligence provided in Part 2 of Division 2 of the Water Code. A number of these applications have been assigned, including some to the United States as operator of the Central Valley Project.

The foregoing procedure, whereby the Department of Water Resources may file applications to appropriate unappropriated water for general or coordinated plans of development, is the only presently authorized method whereby rights to the use of unappropriated water may be preserved in furtherance of planning by the State.

The California Water Plan involves utilization of much of the remaining surpluses in California streams. As the Plan is carried forward, consideration must be given to the filing of additional applications to appropriate the water covered by it, or in the alternative, to some other method of insuring orderly development and maximum beneficial use of this resource.

2. *Acquisition of Existing Rights.* The California Water Plan is designed to minimize interference with vested water rights, but a few instances of conflict with senior rights would be inevitable in a plan of such magnitude. Water rights are property within the meaning of the rule that private property may not be taken or damaged for public use without payment of just compensation. This means that to the extent vested water rights might be adversely affected by operation of The California Water Plan, they must be acquired either by agreement, purchase, or condemnation.

Some theoretical problems arise in connection with the purchase or condemnation of riparian rights, but in practice if all the riparian owners adversely affected are compensated or otherwise satisfied, there is no one to complain. One who acquires an appropriative water right may change the point of diversion and the place and purpose of use to conform with his project, provided other lawful users are not injured thereby. Permission to make such changes with respect to appropriations initiated under provisions of the Water Code must be secured from the State Water Rights Board in accordance with the provisions of Sections 1700 through 1705 of the Water Code.

The power of eminent domain may be exercised in favor of a public use of water. The State Constitution provides that the use of all water appropriated for sale, rental, or distribution is a public use and subject to the regulation and control of the State, in the manner prescribed by law (Constitution, Article 14, Section 1).

The power of eminent domain may be exercised by the State or Federal Governments directly through their immediate officers or agents, or the power may be exercised by public agencies, private corporations, and individuals when delegated by statute. If water rights are damaged without compensation having been made, the owner may file an action in inverse condemnation to recover compensation.

3. *Exchange of Water.* It is probable that full operation of The California Water Plan would require exchanges of water between watersheds in some instances in order to achieve the most effective and economical distribution to areas of need. An exchange of existing supplies for water imported from another source has previously been effected by agreement between the United States, as operator of the Central Valley Project, and certain water users in the San Joaquin Valley. Of course, there is no legal obstacle to such agreements, and it is contemplated that any exchange necessary would be effected under negotiated agreements. Whether an exchange could be imposed in the absence of agreement and, if so, upon

hat conditions and under what circumstances under esent law, is open to question. Although it is ated in negative terms, the Department of Water sources may be authorized to effect exchanges of ter in the Central Valley Project by Section 11463 the Water Code. This section provides that in the nstruction and operation of the project no exchange the water of any watershed or areas for the water any other watershed or area may be made unless e water requirements of the watershed or area in hich the exchange is made are at all times met and tisfied to the same extent as though the exchange d not been made, and no right to the use of water all be gained or lost by reason of any such exchange. comparable provision in present law would govern its of The California Water Plan not included in e Central Valley Project. Further consideration ust be given to the problem as water development California proceeds.

4. *Rights of Areas of Origin and Areas of Deficiency.* For purposes of analysis, the so-called ounty of origin" problem may be divided into two rts: first, the problems with respect to the *areas of igin;* and, second, those with respect to the *areas deficiency.* As these terms are generally used, the incipal areas of origin occur in the northern portion the State above the latitude of Sacramento. In se northern California areas water occurs in excess the ultimate requirements of the areas, and the rplus could be exported and used in other portions the State without detriment to the areas of surplus. ere are, however, localized areas within the areas of gin which may be correctly termed areas of deficiency, due to either their geographic location or the ne of the occurrence of water.

The areas of deficiency include, generally speaking, e areas south of the latitude of Sacramento including the San Joaquin Valley, the San Francisco Bay ea, the Central Coastal Area, the desert areas, and uthern California.

The county of origin problem had its beginning out 30 years ago when plans for the Central Valley oject were being developed. Insofar as the areas of gin are concerned, the problem is one of insuring e reservation of adequate water for their future development. It is generally recognized that efficient ilization of the State's water resources requires servations now for the future needs of mountain d foothill areas. Unless this is done, difficult exange of water or expensive pumping installations ght become necessary when these needs develop. ith respect to the areas of deficiency, the problem one of having reasonable assurance of a dependable ter supply. The problem is basically physical in ture, having been created by unequal distribution of e State's water supplies, both as to time and place of currence. A full solution will require not only changes in the existing law, but, more importantly, the construction of physical works to meet the water needs in all areas of the State as such needs arise. With the ever-increasing competition among areas and uses for available water resources, a solution must be reached now. The solution to the problem must be state-wide in scope and must stem from attack of the whole problem rather than of the individual problems created by any specific project. It must be workable and must permit continued development of the State's water resources.

The only legal protection now afforded the counties or areas of origin for water for their future development is contained in Section 10505 and Sections 11460 through 11463 of the Water Code. As previously noted, the Department of Water Resources is authorized to file applications to appropriate water which is necessary for the coordinated development of the State's water resources. Applications have been filed by the State in furtherance of state plans. Some of these state filings have been assigned to the United States to be used as a basis for water rights in connection with the Central Valley Project, and others have been or are in the process of being assigned for various other projects. However, under the so-called "county of origin" law, the department is expressly prohibited from assigning or releasing the priority under any such application when, in its judgment, the effect would be to deprive the county in which the water originates of any such water necessary for its development (Water Code § 10505). Consequently, several of the assignments that have been executed contain conditions either reserving a specific amount of water for future use in the counties of origin, or making a reservation in terms of the law. To the extent, therefore, that a unit of The California Water Plan must depend upon a State application for necessary water rights, under present law, only water in excess of that necessary for development of the counties of origin would be availabe for use elsewhere.

The "county of origin" law under Section 10505 of the Water Code has the following marked limitations:

1. Section 10505 is applicable only where State filings have been made under Section 10500 of the Water Code, and can be effective only where an assignment or release of these filings is made. The streams upon which there are no State filings are not included under the so-called "county of origin" law as set forth in Section 10505.

2. The exemption from the ordinary legal requirements of diligence under State applications filed pursuant to Section 10500 of the Water Code is subject to renewal periodically by the Legislature. Should the Legislature fail to renew this exemption from diligence, the protection afforded to the counties of origin thereunder would probably be lost. The current ex-

tension of exemption from diligence expires on September 30, 1959.

3. There is the further problem as to how water reserved under State filings which have been assigned would be made available to users within the county of origin. There is some question at the present time as to whether any reservations for areas of origin would be effective as against anyone other than the assignee of State filings.

Under Water Code Sections 11460 through 11463, commonly referred to as the "watershed protection law," it is provided that, in the operation of the Central Valley Project, water may not be transported from a watershed in which it originates to other areas if it would deprive that watershed or areas adjacent thereto of water necessary for their future development. These sections of the code are limited in their applicability to the Central Valley Project, and present very serious problems for the operator of that project, since it is entirely conceivable under these sections that the substantial quantities of water developed under the Central Valley Project, and contracted for by numerous water users' organizations in the San Joaquin Valley, could be recalled for use in the watersheds of origin or areas immediately adjacent thereto. With such uncertainties, it is extremely difficult for the State or the Federal Government to plan intelligently or to operate the facilities of the Central Valley Project.

In addition to the cited problems, the question has been raised as to whether the existing county of origin and watershed protection statutes are in accordance with Article 14, Section 3, of the California Constitution.

As indicated by the foregoing discussion, there are now no constitutional guarantees for either the areas of origin or the areas of deficiency. The present statutes, insofar as the areas of origin are concerned, in some instances afford no protection and in other instances the protection is uncertain. The uncertainty created by the existing law makes any protection afforded to the areas of deficiency indefinite to the point where it is impossible to determine with certainty the quantities of water to be made available from certain projects for a specific service area on a continuing basis. This uncertainty with respect to the operation of any project has been of grave concern not only to the State but also to the Federal Government, and to local agencies attempting to construct water projects of their own.

In summary, the present statutes afford only limited and decidedly uncertain protection to the areas of origin with respect to reservation of adequate water for the future development of those areas. Water rights adverse to the future needs of the areas of origin continue to become vested. These areas now have no assurance that they will receive any assistance in the future in the construction of needed water development projects. They cannot depend upon unregulated stream flow for their future water supplies; conservation works must be constructed to regulate and conserve the natural stream flow. The present statutes create serious problems and uncertainties in the planning and operation of projects; these difficulties affect not only the State, but also the Federal Government and local agencies.

The areas of deficiency which may obtain water supplies under contract with the State as the operator of an export project now have no positive assurance that they will continue to receive a right to a dependable water supply under those contracts. Furthermore, some concern has been expressed that under the principles of a recent California court decision [*Mallon* v. *Long Beach*, 44 Cal. 2d. 199, 282 P. 2d. 481 (1955)], the State may, with complete immunity, abrogate its contracts with its political subdivisions.

It has become increasingly clear that the only final solution lies in the adoption of a proper constitutional amendment and of implementing legislative enactments. The solution must provide: (1) positive assurance to the areas of origin that adequate water will be reserved for their future development, (2) positive assurance to the areas of deficiency that when they contract with the State for water they can depend upon the right to that supply, (3) removal of the uncertainty inherent in existing statutes, and (4) an adequately financed, continuing program of water development to meet the needs for water in all areas of the State, as those needs arise and as projects to satisfy them are found to be feasible.

Power of Eminent Domain. The power of eminent domain is necessary in constructing water projects, not only for the acquisition of water rights but also for the acquisition of other real property. The Federal Government and most water users' organizations possess this power with few restrictions. The Department of Water Resources is specifically empowered to condemn property in the name of the State for construction and operation of the Central Valley Project, including the Feather River Project. (Water Code § 11575 et seq.) There are certain restrictions upon its power to condemn rights to water appropriated to public use prior to January 13, 1934, and to condemn appurtenant works which were dedicated to public use prior to July 1, 1933. Also, in the absence of agreement, the department may not take or destroy the line or plant of a common carrier railroad, public utility, or state agency, or the appurtenances thereof until new facilities of like character and equal usefulness have been provided. The department also has authority, without these restrictions, to condemn rights of way for flood control works (Water Code § 8304). It has not been granted authority, however, to condemn land and water rights for features of The California Water Plan not included in the Central

alley Project, nor has it been specifically authorized acquire excess lands or lands required for ture use.

Planned Utilization of Ground Water Basins. onservation of the State's water resources to the tent that ultimately may be necessary would require njunctive operation of surface and underground prage capacity and use of the underground storage otential as terminal storage, as well as full develop- ent of local ground water resources, under a care- lly planned and managed method of operation. The neral manner in which these objectives could be complished and some possible methods of operation e described in other sections of this report. Planned eration of ground water storage would result in mporary lowering of ground water levels during y periods, possibly lower than the levels that other- se would have occurred, until replenishment could effected during later periods of surplus water pply. Present statutory law (Water Code § 1242) cognizes the storing of water underground as a neficial use if such water is later applied to a bene- ial purpose.

Each owner of land which overlies a ground water sin has a right correlative with the similar right each other such owner, to the reasonable beneficial e of water upon his land from the common ground ater supply. This right is closely analogous to the parian right pertaining to surface streams, and is a sted property interest which cannot lawfully be ken or damaged without observing the requirements due process of law.

Although some cases look in that direction, it is t definitely settled that a particular entity could tain a right to place water imported from another urce into a ground water basin for purposes of prage, and to subsequently withdraw an equivalent antity of the resultant commingled water, even if ere were no material impairment of vested rights the use of the natural supply. Legal problems uld also be encountered if an attempt were made create storage space in a ground water basin by liberately lowering the water level, even though e withdrawn water were put to beneficial use. Pres- t law realistically recognizes that minor inconven- nce to existing rights caused by subsequent uses ay be unavoidable and is not actionable so long as is not unreasonable. Any substantial diminution of e available water supply or unreasonable interfer- ce with means of diversion, however, entitles ners of prior rights to appropriate relief either by junction or, where a public use has attached, to mpensation. Substantial lowering of ground water vels, with consequent material increase in pumping fts, would fall within one or the other of these rules, pending on the degree.

From the foregoing it is clear that major changes in the regimen of ground water basins must be accompanied or preceded by a determination of the rights of the water users. Such determination by the courts is the only method of control over the operation and management of a ground water basin which is possible under existing statutes. An efficient method of determining rights to the use of ground water should be available.

There are two procedures provided by present statutes whereby the State Water Rights Board may assist the courts in the adjudication of water rights. Only one of these procedures, notably the "court reference" procedure, can be applied to percolating ground water. Under the court reference procedure, any action for the determination of water rights may be referred by the court to the board. Another procedure, commonly referred to as a "statutory adjudication," is restricted to surface bodies of water and to subterranean streams flowing through known and definite channels. Under this procedure, all claimants to water from a stream system can be brought before the State Water Rights Board upon petition filed with the board and signed by one or more claimants to the waters involved; and upon the filing of the board's findings with the Superior Court, a judgment that is conclusive on all parties can be entered. A large number of the smaller stream systems, particularly in northern California, have been adjudicated under the statutory procedure. A number of ground water adjudications have been completed and others are in process under the court reference procedure. Conclusions relative to ground water adjudications which appear to be warranted by the considerable experience of the State Water Rights Board and the Department of Water Resources in this field are:

(a) The boundaries of ground water basins can be determined only after competent and thorough geologic and hydrologic investigations.

(b) The safe yield of a ground water basin is not a fixed quantity but varies with (among other factors) the state of development in the basin and in the watersheds tributary thereto. Accordingly, periodic redeterminations must be made of the allowable extractions of water from the basin if effective utilization of the ground water is to be achieved.

(c) It will invariably take a considerable period of time and substantial expense to obtain the data necessary to determine the safe yield of a ground water basin with reasonable accuracy, but without these data the basin cannot be operated properly.

(d) Because of the obscurities inherent in the occurrence of ground water and the multiplicity and variable nature of the factors affecting the safe yield of a ground water basin, measurement and collection of the basic data required for adjudica-

tion should be initiated long prior to the actual adjudication and carried on continuously, so that, when the need therefor arises, the information will be available for use.

(e) In many instances it would be difficult to establish that excessive extractions of water have resulted in irreparable damage to a basin. Some basins could be pumped substantially dry without irreparable damage resulting to such basins, for upon cessation of pumping, the basin would gradually refill with water of satisfactory quality by natural processes. On the other hand, where compaction and subsidence occurs, or in coastal ground water basins where sea-water intrusion occurs due to overdraft, or in other special cases, a finding of irreparable damage might be made.

A program should be adopted for continuing investigation of the ground water areas of the State, particularly those determined to be required for effective operation of The California Water Plan, supported by adequate appropriations. By this means, as and when it becomes necessary to adjudicate rights to the use of these ground water basins, to the extent the necessary data are available, the expense and delay of adjudication thereof would be minimized.

In 1955, Part 5 was added to Division 2 of the Water Code, providing a procedure for filing notices with the State Water Rights Board by every person who extracts ground water in excess of a certain minimum amount in the Counties of Riverside, San Bernardino, Los Angeles, Ventura, and Santa Barbara. Any person may request the board to investigate and determine the facts stated in a notice. The determination of the board is prima facie evidence of such facts in any action or proceeding in which they are material. By operation of this procedure, there will in time be accumulated much relevant information concerning rights to the use of ground water, which will be available if and when it becomes necessary to adjudicate such rights, and which will serve to minimize expense and delay in such adjudications.

In proceeding with The California Water Plan, consideration should be given to the adequacy of existing law and administrative procedures to accomplish its purposes. Over the course of time, it is believed that it will become necessary to adjudicate the rights to ground water in most of the underground basins in the State. Among other things, consideration should now be given to existing procedures for the collection of data concerning ground water, existing procedures to determine rights to its use, existing procedures for handling overdraft situations, and to the adequacy of present law to allow full utilization of ground water basins. The following modifications to the court reference and statutory adjudication procedures have been proposed in order to simplify, improve, and minimize the expense involved,[1] and careful consideration should be given to legislation to accomplish them.

(a) A practical lis pendens procedure should be supplied. This should apply to both the court reference and statutory procedures.

(b) The trial court should be authorized to refer any case involving the determination of water rights, surface or underground, at any time after filing of the complaint, to the State Water Rights Board, with direction to follow either the statutory adjudication procedure or the court reference procedure. This would supply a most desirable flexibility.

(c) The trial court should be authorized to impose, from time to time, trial distribution schedules. This also should apply to both procedures.

(d) The State Water Rights Board should be authorized to investigate and report upon all rights to the use of water, including ground water rights. This modification is necessary only in the statutory adjudication procedure.

(e) Provision should be added to the statutory adjudication procedure to the effect that initiation of a proceeding tolls the statute of limitations, and that, on motion of the Water Rights Board, an action to adjudicate the rights, in whole or in part, involved in any such proceeding, filed during the pendency thereof, shall be abated.

(f) The trial court should be authorized to impose a physical solution, either as recommended by the referee or as suggested by the parties, and to enter any other order as the interests of justice may require. This should apply to both procedures.

(g) In entering its judgment the trial court should retain broad jurisdiction, in accordance with the principles approved by the Supreme Court of California. This also should apply to both procedures.

In 1955 the Legislature enacted the Water Replenishment District Act as Division 18 of the Water Code. Although various other types of districts are authorized to replenish ground water, water replenishment districts organized under the provisions of this act would have the advantage of being authorized to levy assessments in proportion to water pumped from the underground. This is particularly important in making equitable assessments of those holding appropriative and prescriptive rights to use water on non-overlying land. These water users might not be adequately assessed on an ad valorem basis.

The organization of water replenishment districts is limited to the Counties of Santa Barbara, Ventura, Los Angeles, San Diego, Riverside, San Bernardino and Orange. As yet, no water replenishment district has been organized, so it cannot be said definitely

[1] Based on statement of Henry Holsinger, then Principal Attorney, Division of Water Resources (now Chairman, State Water Rights Board), before the Joint Legislative Interim Committee on Water Problems, December 14, 1954.

ether this will be an effective type of organization utilizing a ground water basin. If it should prove be so, consideration should be given to extending coverage of the Water Replenishment District to other areas of the State.

n 1953, The Orange County Water District Act ats. 1933, Ch. 924) was amended to give the dis-t similar assessment powers. The validity of these wers was sustained in *Orange County Water District* v. *Farnsworth*, 138 Cal. App. 2d. 518, 292 P. 2d. 9 (1956).

While it is not an immediate problem, it is evident t effective administration of the development and ization of ground water resources, either by the te or by local agencies, or by both, will become udatory as the stage of full water development is proached. When it becomes necessary to operate major ground water basins for import-export purs, as envisioned under The California Water Plan, requisite authority to do so must exist. Studies uld be initiated now as to the adequacy of existing utes to accomplish these ends, so that the necessary endments and additions thereto may be made at appropriate time. The following items are sug-ted for consideration in this connection:

1. A constitutional amendment to authorize and ccompanying statutes to set up procedures for a) the planned utilization of ground water basins or carry-over storage, and (b) adjustment of conflicts with existing rights either by delivery of ater or by cash compensation.

2. The requirement of permits and licenses for he appropriation of ground water.

3. Control and supervision of recharge of de-leted ground water basins.

o protect and maintain the quality of the State's und water resources, it is believed that minimum ndards of water well construction and adequate cedures for the maintenance and abandonment of ls should be enforced as necessary throughout the te. This cannot be done under existing state law; sideration should be given to the enactment of essary legislation at an early date.

Relationships With Other Agencies. 1. *Integration With Projects of Other Agencies.* Features of California Water Plan constructed and operated by the Department of Water Resources would of necessity be integrated with features already constructed and to be constructed by other agencies. This is particularly important in connection with projects operated by the Federal Government.

The Sacramento River and Delta channels will be used as a common water conveyance system by both the Central Valley Project and the Feather River Project. The San Luis Reservoir would also be utilized by both projects under current proposals. It is apparent that detailed operational agreements will be necessary for the integrated operation of these features, so as to avoid conflict and to obtain the highest degree of beneficial use of water in an efficient manner. Both the Central Valley Project and the Feather River Project rely in part on water right applications filed by the State on the same day. In general, use of natural stream flow by the two projects will be inextricably interrelated. Both projects require an agreement or determination as to the water available for their use—as between each other, and in relation to water users in the Sacramento-San Joaquin Stream System holding senior rights. There is no reason to believe that all of these problems cannot be solved by agreement if all of the parties approach them in good faith.

2. *The Federal Power Act.* The Federal Power Act authorizes the Federal Power Commission to issue preliminary permits and licenses for the purpose of investigating, constructing, operating, and maintaining project works "necessary or convenient for the development and improvement of navigation and for the development, transmission and utilization of power" in navigable waters of the United States or upon public lands and reservations of the United States (except national parks and monuments), or to utilize surplus water or water power from any government dam [41 Stat. 1063, 1065 (1920) as amended, 16 U.S.C. s. 797 (e) (1952 ed.)]. Construction, operation, or maintenance of any such project works by any person, state, or municipality without first securing a license from the Commission is unlawful. The act also contains provisions designed to accommodate state and federal law. Since the Federal Power Commission has authority over the planning and construction of certain hydroelectric projects within the states, conflicts may occur if the projects licensed by the commission differ from those approved by the state by the granting of necessary water rights. If conflicts should occur between federal power projects and The California Water Plan, they would have to be settled by the courts or by the Congress.

Water Development for Fish and Wildlife and for Recreational Use. In order to provide sufficient flowing water in a stream for fish and wildlife and for the enhancement of recreational aspects of a stream, it may be necessary to store water in headwater reservoirs to permit planned releases during low-water periods. The combined releases and natural flows would be planned for a desirable all-year regimen of flow in the interests of protection and enhancement of fish, wildlife, and recreation.

In order to accomplish the foregoing objectives, the planned stream flows should be protected against appropriations of water for other purposes. However, present law does not provide positive and reliable protection for such natural or unregulated flows in a

CHAPTER VI

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

In 1947, the California Legislature authorized the initiation of the State-Wide Water Resources Investigation to formulate a comprehensive master plan for the full control, conservation, protection, distribution, and utilization of all the State's water resources, both surface and underground, to meet the present and future needs for water for all beneficial purposes and uses in all areas of the State to the maximum practicable extent. As a result of intensive study, analysis of engineering and geologic data, and information made available during the planning phase of that investigation, and on the basis of estimates and assumptions discussed hereinbefore, the following summary, conclusions, and recommendations are presented.

SUMMARY

Problems

1. California's rapid and continuing population, agricultural, and industrial growth of recent years has given rise to unprecedented expansion in the needs for water for consumptive demands, comprising those for agricultural, industrial, and municipal purposes, and nonconsumptive uses, including those for flood control, hydroelectric power, recreation, and fish and wildlife. Corollary problems have developed, such as overdraft on ground water basins, intrusion of saline and other degraded waters into ground water basins, problems of control of mineral and organic quality of surface and underground waters, drainage, and related problems.

2. California's water problems result primarily from the unbalanced distribution of its water resources and water requirements. The major sources of water are in northern California where the waters of many streams now waste into the ocean virtually unused. The major urban areas and productive agricultural lands of California are in that portion of the State to the south in which occurs only 30 per cent of the total natural runoff. Great distances and rugged mountains separate source areas from areas of demand. About 70 per cent of the total stream flow occurs north of the latitude of Sacramento, but 77 per cent of the present use of water, and 80 per cent of the forecast ultimate use lie south of that line.

3. Water problems of California are further intensified by the large variations of runoff within the season and from year to year. Most of the runoff occurs during the winter and spring when the demand for water is least. Runoff is also subject to marked annual variations, with droughts of several years' duration characteristically being followed by one or more years of above-normal runoff. The periodic droughts impose the need for very large reservoir storage capacity for cyclic regulation, in addition to lesser storage requirements for seasonal regulation.

4. The largest problems of water deficiency occur in the San Joaquin Valley and southern areas of the State, the areas of greatest water demand. However, water deficiencies do occur in all areas throughout the State, especially in connection with seasonal unbalance of available water. In many instances, increasing water requirements have been provided for by drawing on the large but presently diminishing supplies available in ground water reservoirs. Withdrawals from ground water storage presently (1957) exceed mean annual replenishment by an estimated 4,000,000 acre-feet for the State as a whole, with resultant perennial lowering of ground water levels.

5. Periodic floods from rivers and streams throughout the State, in the valleys and flood plains where most of the 14,000,000 population live, have resulted in major damage and loss of life. Some of the flood problems have been solved. However, with the intensification and expansion of urban and industrial areas, many flood problems will become more severe until remedial action is taken. As land becomes more of a limiting factor in the ultimate development of the State, it will be increasingly important to prevent creation of blighted areas subject to recurring uncontrolled floods.

6. Deleterious effects on the quality of natural water supplies have resulted from deficiencies in surface and ground water development, from lack of drainage, and from improper disposal of wastes. Quality problems are common to nearly all other water problems. In several locations in the coastal plain, excessive draft has resulted in the intrusion of sea water into underground aquifers, thus impairing valuable sources of water supply. In many parts of the Central Valley, continuing ground water overdraft threatens quality degradation of fresh-water aquifers by upward movement of deep connate brines which were entrapped in underground basins in past geologic ages. In other areas, unfavorable salt balance is a practical certainty as the result of persistent overdraft conditions, unless additional water is imported and used. When more salt is brought into a basin than is carried out of it by the outgoing water, the salt balance is termed unfavorable. Another phase

of the water quality problem has resulted from inadequate treatment of sewage and industrial wastes and their disposal to streams and ground water basins, although this problem is rapidly being brought under control. Unless the quality of the State's water resources is maintained at proper levels, full satisfaction of California's ultimate water requirements will not be possible. Standards for the quality of water in relation to the beneficial uses thereof must be the subject of continuing study and should be changed when necessary in the light of further knowledge.

7. A serious problem associated with irrigated agriculture and stemming from it is the necessity for adequate drainage. Extensive drainage systems and proper disposal of drain waters of high mineral content are important factors in maintaining soil fertility and ground water quality.

8. Further extensive development of hydroelectric power is a necessary part of future water resource development. Full future satisfaction of water demands in all parts of the State will require mass movement of water over great distances and high mountains. This will ultimately require far more power than the presently undeveloped potential for hydroelectric power. Hydroelectric power now finds its greatest value in providing "peaking" energy (i.e., that portion of the daily load when, for a few hours, demands exceed the base demand) in combination with steam-generated power from fossil fuels, and would combine equally well with future atomic power generation. It is expected that the power market will absorb hydroelectric power output as rapidly as it can be made available. It is likewise believed that ample cheap "off-peak" energy will be available for pumping requirements.

9. Increasing demands have developed for enhancement of the fish and wildlife resources of the State, and for increasing the outdoor recreational opportunities associated with reservoir areas and live streams in valleys, hills, and mountains. These demands have increased at an accelerated rate, concurrently with the expanding population and urban and industrial development; their satisfaction is vital to the future welfare of California's citizens.

10. An additional problem in the further development of the water resources of California involves the optimum use of available ground water basins and potential surface storage reservoirs. Remaining combinations of satisfactory dam sites with reservoir storage sites of adequate capacity are relatively few, and must be utilized to the maximum practicable extent.

Concepts of The California Water Plan

1. The California Water Plan is a master plan to guide and coordinate the activities of all agencies in the planning, construction, and operation of works required for the control, development, protection, conservation, distribution, and utilization of California's water resources for the benefit of all areas of the State and for all beneficial purposes.

2. As such a master plan, The California Water Plan:

a. Evaluates the water supply available to California, and describes the places and characteristics of its occurrence;

b. Estimates the water requirements, both present and future, for all beneficial purposes for each area of the State, as those requirements can be foreseen;

c. Points out the watersheds where present estimates indicate surplus waters exist over and above future needs for local development, gives estimates of such surpluses, indicates the areas of deficiency, and gives the estimated deficiency for each such area;

d. Describes existing and prospective water problems in each area of the State;

e. Describes the uses to which the remaining unappropriated waters of the State should be put for maximum benefit to the people of all areas of the State;

f. Suggests the means by which the waters of the State could be distributed for the benefit and use of all the people in all areas;

g. Proposes objectives toward which future development of the water resources should be directed in all areas of the State, and suggests broad patterns for guidance toward these objectives;

h. Defines these objectives in terms of potential physical accomplishments which may be used to measure the merits of projects proposed for construction by any agency; and

i. Demonstrates that the waters available to California, including the State's rights in and to the waters of the Colorado River, are not only adequate for full future development of the land and other resources, but also that physical accomplishment of these objectives is possible.

3. The California Water Plan is conceived as:

a. A comprehensive plan which will meet the requirements for water at some unspecified but distant time in the future when the land and other resources of California have essentially reached a state of complete development; and

b. A flexible pattern, susceptible of orderly development by logical progressive stages as the growing demands of the State may dictate, into which future definite projects may be integrated in an orderly fashion, and which may be substantially altered and improved in accordance with advances in technology and changes in conditions which cannot be fully foreseen today.

4. The California Water Plan is designed to include or supplement, rather than to supersede, exist-