UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

APPRAISAL REPORT
CENTRAL ARIZONA PROJECT

REGION 3

BOULDER CITY, NEVADA

JANUARY 1962

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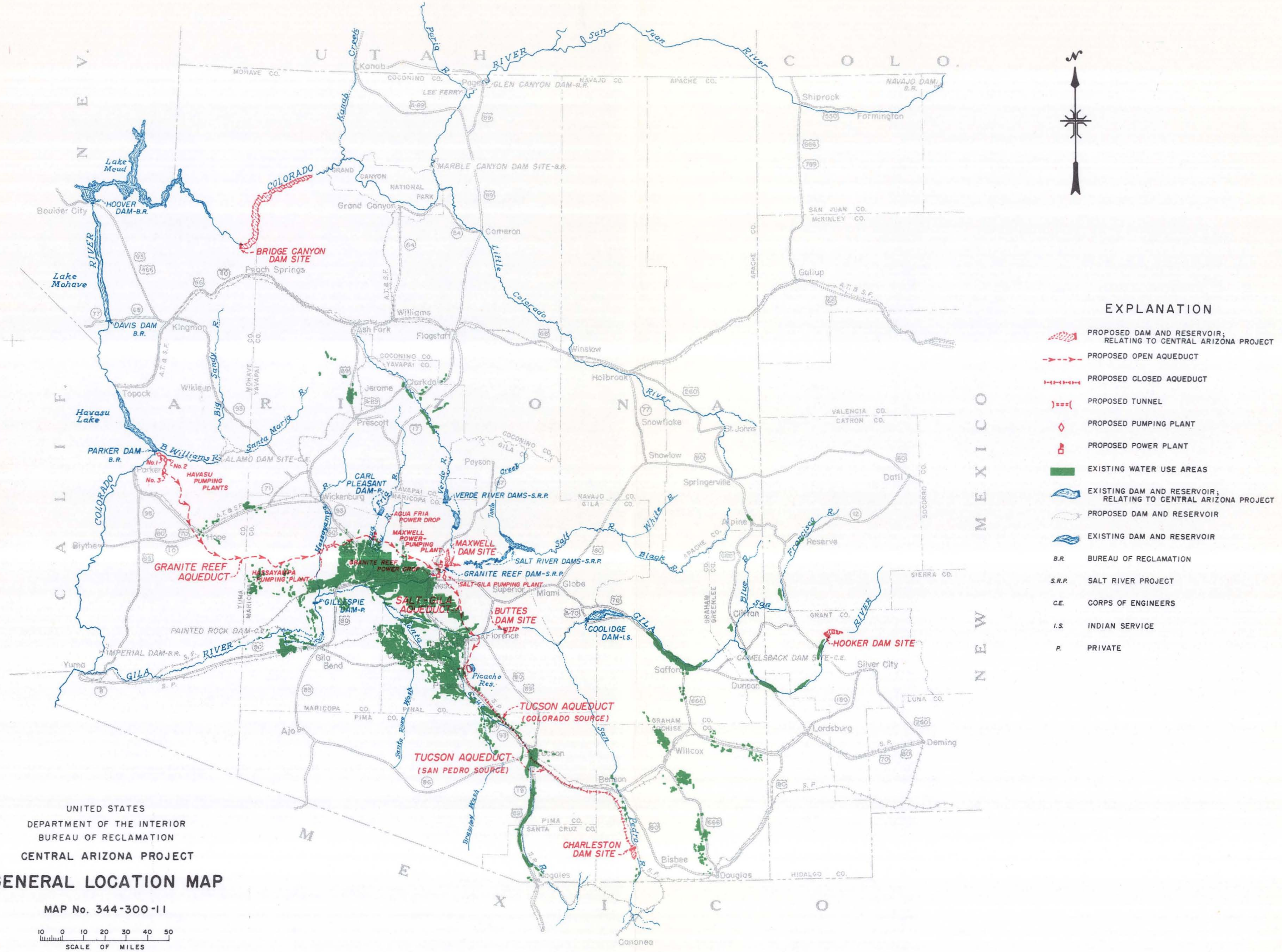
PLATE I



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CENTRAL ARIZONA PROJECT

GENERAL LOCATION MAP

MAP No. 344-300-11

10 0 10 20 30 40 50
SCALE OF MILES

NOVEMBER 1961

GPO 983510

SYNOPSIS

The following report presents an up-to-date appraisal and re-evaluation of the Bureau of Reclamation's project planning report on the Central Arizona Project, dated December 1947. The 1947 report was published in House Document No. 136, 81st Congress, 1st Session.

The Bureau of Reclamation's original report presented a comprehensive plan for importation of water from the Colorado River formulated to provide the best solution to the then existing water supply problems of the Gila River Basin in central Arizona and western New Mexico. The report was approved by the Secretary of the Interior in February 1948, and hearings on bills to authorize the project were held in the Senate and House of Representatives in 1949. Authorization bills passed the Senate in the years 1950 and 1951, but hearings were indefinitely postponed by the House Committee on Interior and Insular Affairs in 1951. Failure of the Central Arizona Project bill to be approved by the House Committee was attributed to a controversy of many years' standing between the States of Arizona and California over the division and use of Colorado River water.

In the summer of 1952, the State of Arizona initiated an interstate suit in the Supreme Court of the United States against California and others to confirm its title to Colorado River water. As a result of this litigation, the Bureau of Reclamation suspended work on the Central Arizona Project pending settlement of the suit. Litigation between the States has continued since 1952 and, on December 5, 1960, the Special Master for the case submitted to the Supreme Court his report and recommended decree.

Since the original Central Arizona Project report was issued, Arizona has experienced the greatest rate of population growth in the Nation. The State's water supply problems and needs resulting from this unprecedented postwar growth and development have become so critical that Arizona officials deemed it essential to re-examine and update costs for the Central Arizona Project prior to the time that a decree is issued by the Supreme Court in order that current information on the project would be available to the Congress as soon as possible after a decree is issued. Toward this end, an emergency appropriation by the Arizona Legislature in March 1961 provided $100,000 for the Bureau of Reclamation to appraise the Central Arizona Project plan in the light of present conditions. An additional $30,000 was subsequently contributed by the New Mexico Interstate Stream Commission to finance the New Mexico portion of the project investigations and for other studies of the Gila River drainage system in New Mexico.

Work on updating the Central Arizona Project plan was undertaken by the Bureau of Reclamation in May 1961 under the terms of a contract between the United States and the Arizona Interstate Stream Commission. This contract and a subsequent contract with the New Mexico Interstate Stream Commission recognized that the quantity of water available to Arizona from the Colorado River will remain indeterminate until such time as a Supreme Court decree is issued. This appraisal report, therefore, is based on the assumption of water diversion of 1,200,000 acre-feet annually from the Colorado River. This is the same assumption used in the original report. The studies are not to be construed as anticipating the terms of a decree or any interlocutory order in the case of Arizona vs. California, now pending before the Supreme Court of the United States, or affecting any rights or claims to the use of waters of the Gila River under existing decrees.

Authority and Financing

The preparation of this report is authorized by the Federal Reclamation Laws (Act of June 17, 1902, 32 Stat. 388) and Acts amendatory thereof or supplementary thereto, and particularly the Act of March 4, 1921 (41 Stat. 1404). Costs for preparation of this report were paid from contributed funds provided by the States of Arizona and New Mexico under the terms of contracts between the United States and the Arizona and New Mexico Interstate Stream Commissions, dated April 24, 1961, and August 2, 1961, respectively.

Cooperation and Acknowledgments

Valuable assistance was provided by the Interstate Stream Commissions of Arizona and New Mexico, which furnished all funds for this appraisal. Various other agencies of the Departments of the Interior, Agriculture, Commerce, and the Army, as well as other public and private agencies in Arizona and New Mexico, provided valuable assistance and cooperation.

Present Conditions

Since 1951, when Congressional hearings were last held regarding the project, the population of the project area has approximately doubled and now totals over 1,000,000. New lands have been brought under cultivation in the project area, and lands formerly irrigated have been subdivided for urban developments. Official census reports show that the population of Phoenix grew from 106,818 in 1950 to 439,170 in 1960, and that in the same years the population of Tucson grew from 45,454 to 212,892. The municipal and industrial water supply needs of these and other cities in the project area have increased proportionately with the population growth, and the expanding needs are expected to accelerate rapidly in future years. Present projections indicate that the population of the area may be expected to double in the next 10 to 15 years. In addition, urban developments have encroached upon lands over which potential project canals were located and the cost for right-of-way across these lands has increased manyfold. The pumpage of ground water, which exceeded the natural recharge of the basin shown in the original report, has more than doubled to supply the expanding demands of the area, and ground-water levels have been declining at an accelerated rate. The needs for flood control, sediment control, recreation, and fish and wildlife enhancement have increased in magnitude and urgency in proportion to the general population growth of the area. Likewise, land values and crop returns have increased, with a resultant increase in potential benefits and payment capacity of the lands.

Purpose and Scope of Appraisal Report

The plan of development set forth in the original report on the Central Arizona Project was designed primarily to provide supplemental water for the stabilization of the existing agricultural economy of the project area. Except for a small quantity of water provided for the city of Tucson, all project water was to have been used for irrigation and related agricultural purposes.

The purpose of this report is to update and appraise the original Central Arizona Project plan in the light of present-day conditions and projected future needs. To accomplish this purpose, the appraisal report provides data on changed water uses and needs resulting from the unprecedented growth and expansion which have occurred in the area, together with projections of future conditions. The water supply available to the area from local surface and underground sources has been re-examined and reanalyzed on the basis of present conditions.

The report includes such modifications of the original plan as appear necessary to adapt the plan to the changing conditions. Most project works have been completely redesigned in accordance with recent engineering advancements, and project costs have been re-estimated at July 1961 price levels. Designs and estimates for Bridge Canyon Dam and Powerplant and Buttes Dam are of feasibility grade, and designs and estimates for all other project features are of reconnaissance grade. However, all project features have been actually located in the field or designed on the basis of up-to-date field data, and estimated costs are considered suitable for the purpose of appraising the project. Economic and financial evaluations have been based on current practices of the Bureau of Reclamation.

Detailed engineering and economic data and studies supporting this appraisal are on file in offices of the Bureau of Reclamation.

Plan of Development

The present studies confirm that the basic concepts of the project plan presented in the original report are sound and can be used to evaluate the existing conditions. However, the expansion of the populated area and improvements in engineering technology have required a revision in the location and design of some project features, as well as modification of project functions and operations.

All the basic project features included in the original plan have been retained, with the exception of those elements which have been accomplished by subsequent development or superseded by other improvements which serve the same function. Glen Canyon Dam and Reservoir, now under construction on the Colorado River, were not considered in the original report to be in operation prior to the proposed Bridge Canyon Dam and Reservoir. Because the sediment control functions of the previously proposed Bluff and Coconino Reservoirs will be largely accomplished by the Glen Canyon Dam and Reservoir, these facilities have been eliminated from the present plan. The enlargement of Horseshoe Dam on the Verde River and the Safford Valley improvements in the Gila River Basin have been accomplished, in part, by local water user construction programs. The only addition to the project works has been a 50-mile extension of the Salt-Gila Aqueduct designed to convey municipal and industrial water for the expanding demands of the city of Tucson.

The design and cost estimates for the Bridge Canyon Dam and Powerplant have been made in accordance with latest engineering technology, which has contributed to increasing the power benefits and reducing the costs of this feature. Wherever appropriate, new designs and cost estimates were prepared for the canal system and other project facilities, including pumping plants, powerplants, and their appurtenant works. The design and cost estimates for Hooker Dam and Reservoir on the Gila River and Charleston Dam and Reservoir on the San Pedro River were updated to July 1961 price levels.

The present plan of development provides for the conveyance and delivery of Colorado River water through the main project canal system, extending from Lake Havasu to its terminus at Tucson, Arizona. This plan eliminates the previously contemplated arrangement for exchanging Colorado River water for Salt River water, in which the exchanged Salt River water would have been delivered through the Salt-Gila Aqueduct. This major change in project formulation resulted in part from the necessity for relocating about 80 miles of the Granite Reef Aqueduct to a higher elevation around the metropolitan area of Phoenix, Arizona, to avoid urban developments which have encroached upon the original canal location through this area.

The geographically designated service units used in the original report have been abandoned in favor of hydrologic study areas which encompass the total land area affected by local water supplies and present uses, and are in need of an augmented water supply. These hydrologic study areas, having common surface- and ground-water supplies, have been adopted to demonstrate the need for Colorado River water which could be made available by direct diversions or exchange arrangements. The present plan contemplates the sale of Colorado River import water at a canalside delivery point on a cost-per-acre-foot basis. Arrangements would have to be made between upstream and downstream water users to effect the exchange of local supplies diverted at higher elevations for Colorado River water delivered to lower elevations through project canals. No attempt has been made in this report to delineate lands or areas to which specific quantities of water would be delivered. A complex and detailed study is necessary to make such a delineation and is considered beyond the scope of this report. Any proposed distribution of Colorado River water would be premature at this time, pending final settlement of the litigation.

The present plan contemplates that distribution systems to deliver project water to lands served would be constructed and financed by local water-using entities, or by the Bureau of Reclamation under separate repayment contracts utilizing funds which are not included in the repayment study of this report. The canalside water rate reflects the repayment capacity of the farmer to pay for water after all the costs of distribution are taken care of.

The various project functions served under the present plan are identical to those of the original plan, but the magnitude and relative importance of these functions have changed materially. Under the original plan, about one percent of the total water supply would have been delivered for municipal and industrial purposes, whereas, in the present study, approximately one-third of the assumed project water has been tentatively assigned to municipal and industrial uses. Water supply studies have recognized the need for conservation and use of the large quantities of useable return flow that will be available from the projected municipal and industrial water uses. Such return flows would have the effect of augmenting the potential water supply and increasing the overall efficiency of use. Full consideration has been given in the present plan to the multipurpose operation of all project reservoirs for flood control, recreation, fish and wildlife, and other purposes, in recognition of the increasing magnitude of potential flood damages and the greater need for aquatic recreation by the expanding population in this desert area.

Project Operations and Administration

Studies show that the present economy of the area is supported by essentially full utilization of the surface- and ground-water resources of the area. Present ground-water pumping is about 4,300,000 acre-feet annually, of which about 2,200,000 acre-feet represents an overdraft, or mining, of the ground-water basin. Further, these studies show that water levels are dropping progressively year by year and, unless positive measures are taken without delay, the present economy will suffer and the irrigated land will decrease before an additional water supply can be brought into the area.

The water supply assumed to be diverted from the Colorado River is 1,200,000 acre-feet per year, which is obviously not sufficient to offset the present ground-water overdraft. Whatever quantity of water that may be diverted from the Colorado River, the demand for such water will far exceed the supply. Present estimates of local service area water requirements and water availability are of reconnaissance nature, considering broad hydrologic basins as a basis for study. Within these broad basins are many variable conditions which affect the water requirements of individual water-using entities to varying degrees. The limited scope of this study does not permit a definition of each of the potential water user's problems and considerable study of these variables will be required.

No effort has been made to formulate plans for distribution or administration of the imported water supply. Existing and potential water-using agencies in the area have expressed a willingness and desire to contract for water service. The appraisal report is based on the assumption of water sales to be made at a canalside rate measured from turnout points along the main canal route. Contracting agencies would be responsible for distributing water supplies from the main canal to the point of use. Because deficient water supply conditions would continue to exist even after completion of the project, it is necessary that local interests make every effort to conserve the available supply. For this reason, it is essential that all water supplies be distributed in lined canals or underground pipe systems. Several water user organizations have lining programs in progress and others are planning such work in the near future. It is anticipated that the new systems required in areas now served exclusively from ground-water pumping will be of a similar nature. The conservation of water by the increased efficiency of operation and curbing of the nonbeneficial consumptive uses has been taken into consideration in the analysis of water supply under future project conditions.

Other matters of administration and operation which must be considered during later studies include the method of handling water exchanges to the upstream areas of Arizona and western New Mexico. These upstream areas are along streams which have been overappropriated, and offsetting present overdrafts and providing future development will be dependent upon water imported through the Central Arizona Project. In this connection, close coordination will be required with the Corps of Engineers and other agencies planning reservoir developments in these upper areas to explore possibilities for integrating these features into the Central Arizona Project. One such instance would be the utilization of storage which may be available in the proposed Camelsback Reservoir at the head of the Safford Valley.

This report does not evaluate the benefits provided to the operation of the Bridge Canyon Dam and Reservoir by regulation and storage provided by Glen Canyon Dam and Reservoir. Although the benefits are difficult to evaluate, the function of Glen Canyon Dam enhances the feasibility and operation of Bridge Canyon Dam and Reservoir.

The details of operation and administration of the Central Arizona Project are extremely complicated and will require comprehensive studies of the entire area to provide the data necessary to develop plans for full utilization of all available water. One aspect of this comprehensive water operation is the requirement for more effective control of the use of ground water in the area.

Estimated Costs and Benefits

The estimated construction cost of the Central Arizona Project is $967,220,000 exclusive of $4,109,000 investigation costs. The average annual operation, maintenance, and replacement costs are $7,052,000. The total estimated average annual benefits for a 100-year period of analysis are $86,750,000. The benefit-cost ratio for this period would be 2.5 to 1. For a 50-year period, the benefit-cost ratio would be 2.0 to 1.

The reimbursable Federal investment in the project could be paid out in a period of 50 years from revenues derived from the sale of water and electrical energy. For such a payout, irrigation water could be sold at canalside at an average of about $10.00 per acre-foot, and raw water for municipal and industrial purposes could be sold at canalside point of delivery to the municipality at an average of about $33.50 per acre-foot. The energy produced by project facilities over and above that required for project pumping, sold commercially at 6.0 mills per kwh, would repay costs allocated to power and its appropriate interest component. The cost of water would be within the ability of the water-using agencies to repay, and the cost of capacity and energy would be competitive with commercial rates in the area for the peaking-type power made available. The project, accordingly, would be economically justified and financially feasible, with an assumed annual diversion of 1,200,000 acre-feet of water from the Colorado River.

Concepts for Future Water Supply

This appraisal has clearly brought into focus the fact that the present economy of the Central Arizona Project area is being supported by an overdraft of the ground-water basin and that, without additional water, a substantial part of the presently developed lands will ultimately be forced out of production and the growth and development of the area retarded. The plan of development outlined in this report will provide but partial relief; therefore, it is essential that steps be taken to chart a long-range course of conservation and development that will allow the area to enjoy continued growth.

In considering long-range plans, it must be recognized that water shortages exist throughout Arizona and that many nonproject areas in the State hope to benefit through exchange agreements from the importation of water to central Arizona. It is further evident that water demands in all states of the Lower Colorado River Basin exceed the supply which can be made available from the Colorado River. The Lower Basin includes most of Arizona; the southern parts of California, Nevada, and Utah; and western New Mexico--the most dynamic growth areas in the Nation. The Central Arizona Project must be considered as a part of a basin-wide program to provide for the expanding water needs of this rapidly developing region.

The most urgent requirement leading toward conservation of the available water resources of the Lower Basin appears to be the provision of impervious linings or closed conduit systems for all irrigation canals and distribution systems. This report provides that all water conveyance facilities in the Central Arizona Project area will be so constructed. Concurrently, rehabilitation and betterment programs should be undertaken in all presently irrigated areas to provide similar facilities throughout the Lower Colorado River Basin. Waters conserved by these measures will aid in alleviating water shortages in all areas. Comprehensive conservation measures should include the salvage of water along the Colorado and Gila Rivers and many of their tributaries through the clearing of phreatophytic growth and channel rectification. More effective and efficient use of water supplies and return flows in irrigated areas, together with soil and moisture conservation programs on the watersheds, would contribute further to water savings.

About a decade ago, the Bureau made a reconnaissance appraisal of surplus water in the Pacific Northwest as a part of the United Western Investigations. The investigations suggested the possibility of bringing water into the Colorado River watershed by diversions from streams with future surplus flow. The inventory of water resources and future demands summarized in the reports of the Senate Select Committee reaffirmsthese findings.

In looking toward the future, it is evident that the needs of the Lower Colorado River Basin can be met only through concurrent accomplishment of water conservation measures described above, combined with a comprehensive water development plan such as that described in the United Western Investigations. Such comprehensive programs would involve the expenditure of many millions of dollars over a long period of years and, therefore, would require financial assistance.

These concepts for the future have been included in this appraisal report to emphasize:

1. That the Central Arizona Project plan presented herein is only a part of a more comprehensive basin-wide plan of water conservation and development required to sustain the existing economy and permit future growth of the entire Lower Colorado River Basin; and

2. That financial assistance from existing and potential hydroelectric power developments along the Lower Colorado River will be required to accomplish such long-range objectives as (a) the lining of the All-American and Coachella Canals; (b) the salvage of water along the Colorado and Gila Rivers through channel rectification and clearing of phreatophytes; (c) the importation of additional needed quantities of water, such as a United Western Program; and (d) the development of other potential projects in the Lower Colorado River Basin.

Summary and Conclusions

The hydrologic, engineering and economic studies made during this appraisal of the original Central Arizona Project report have forcibly brought to attention the following conditions, facts, and conclusions:

1. Since the original report on the Central Arizona Project was prepared, the population of the project area has approximately doubled and now totals over 1 million. Projections by responsible authorities indicate that this rate of population growth may be expected to continue.

2. The metropolitan areas of Phoenix and Tucson are now in need of a dependable supplemental supply of water for municipal and industrial uses and this need will continue to increase in the future.

3. Water uses in the area exceed the available safe annual supply, and present demands are being offset by an overdraft of the ground-water basins averaging about 2,200,000 acre-feet per year.

4. Unless additional water is made available to the project area, a substantial reduction in the presently developed lands in the area will occur and urban growth and development will be retarded.

5. The only practicable source of additional water at the present time is the Colorado River. The quantity of water which could be diverted annually to the project area is indeterminate pending settlement of litigation. The present appraisal is based on an assumed diversion of 1,200,000 acre-feet per year from the Colorado River. This is the same figure used in the original report. This assumption has been made for the purpose of analyzing the project under present conditions without intent to anticipate the terms of any decree or order in the case of Arizona vs. California now pending before the Supreme Court of the United States.

6. The overall plan described in this appraisal provides a favorable means of accomplishing the purposes of the project. This plan is based on average conditions throughout the project area, and further investigations will be required to provide detailed information on variations from these averages.

7. Colorado River water can be delivered by aqueduct from Lake Havasu above Parker Dam, serving areas below the aqueducts and the city of Tucson. Other needs at higher elevations can be served through water exchange agreements.

8. Present demands for supplemental irrigation and municipal and industrial water supplies exceed the quantity assumed for diversion from the

Colorado River; thus, a maximum effort is required by water users to conserve the local water supplies. Toward this end, present studies assume that, under project conditions, all present and future distribution systems in the area will be constructed or rehabilitated by local interests to provide impervious linings or pipe systems.

9. The demand for electric energy in the Lower Colorado River Basin power market area provides a ready outlet for all project power supplies in excess of project pumping needs.

10. The investigations carried out under this appraisal are adequate for the evaluation of project potentialities. No project features are of unprecedented size or of unusual engineering design. Plans and estimates of costs for the Bridge Canyon Dam and Powerplant and the Buttes Dam and service canal are of feasibility grade. Plans and estimates for all other features are of reconnaissance grade.

11. The plan of development described in this appraisal is formulated to be operated in accordance with Reclamation law and predicated on the concept of a high Bridge Canyon Dam. Under these conditions the project appears to have economic justification and financial feasibility. The benefit-cost ratio on a 100-year period of analysis is estimated to be 2.5 to 1. The cost of water is estimated to be within the payment ability of water users, and the cost of commercial power would be competitive with alternative sources. The payout schedule indicates that reimbursable Federal costs could be paid out in 50 years from water sales and power revenues.

12. Subsequently in this report the effect of a high Bridge Canyon Dam on Grand Canyon National Park and the potential need for a highway bridge and road are described. If, for any reason, Bridge Canyon Dam is not built to the proposed height or if the cost of the highway bridge and road is determined

to be a reimbursable item of the project, financial assistance will be required from some other source in order to pay out the reimbursable costs of the plan presented in this report.

13. The existing demands for additional water to meet the needs of the Central Arizona Project area make it imperative that construction of the Central Arizona Project be initiated as soon as possible.

14. The coordination of hydrologic operations with growing water needs and increasing use of sewage effluent and other return flows offer opportunities for future cooperative planning and action.

15. Previously reported flood control plans need to be reanalyzed to facilitate possible water exchanges which are essential to comprehensive basin development.

16. Within New Mexico, possibilities for land and water development are present which require more extensive analysis.

17. River and stream channels used for water transport are basically canals and, when used as such, their efficiency should ideally approach that of constructed channels. Additional studies should be made leading to the development of feasible plans to accomplish this objective.

18. Benefits of national and state significance would accrue from added facilities which are not necessary for project construction and operation. One such item of major importance would be a bridge and road extending northward from the Bridge Canyon damsite through the Lake Mead National Recreation Area, which would improve interstate travel between Arizona, Nevada, and Utah. Further consideration should be given to such facilities during later investigation.

19. Power revenues accruing after amortization of the portion of the project costs allocated to power could be pooled with surplus revenues from

existing and potential power developments along the Lower Colorado River to assist in financing water conservation developments in the Lower Colorado River Basin.

CENTRAL ARIZONA PROJECT

APPRAISAL REPORT

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CHAPTER I

THE AREA =

ITS PROBLEMS

AND

NEEDS

CHAPTER I - THE AREA--ITS PROBLEMS AND NEEDS

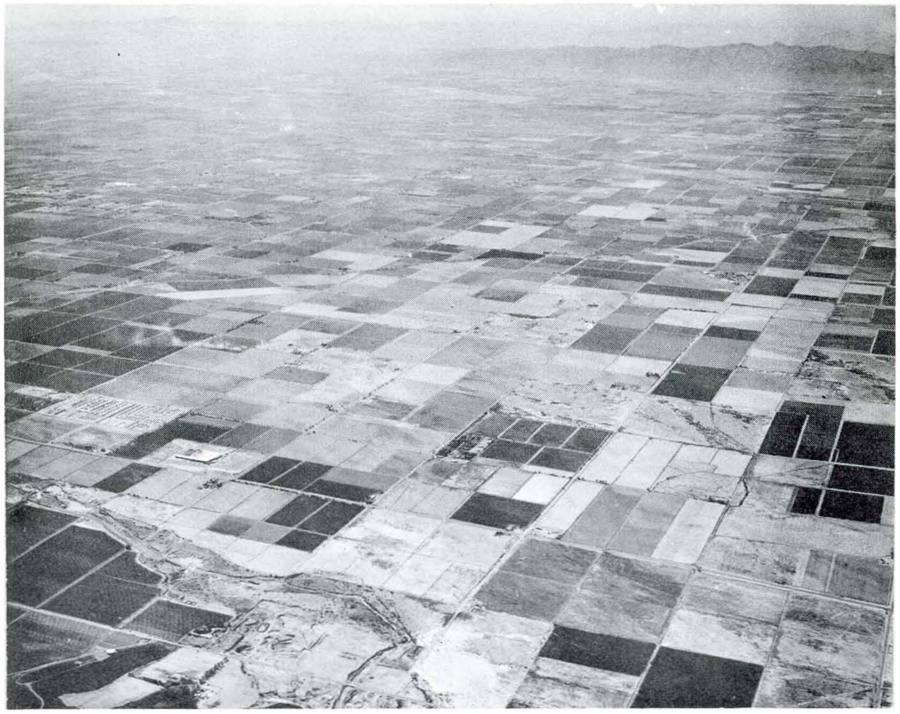
General Description

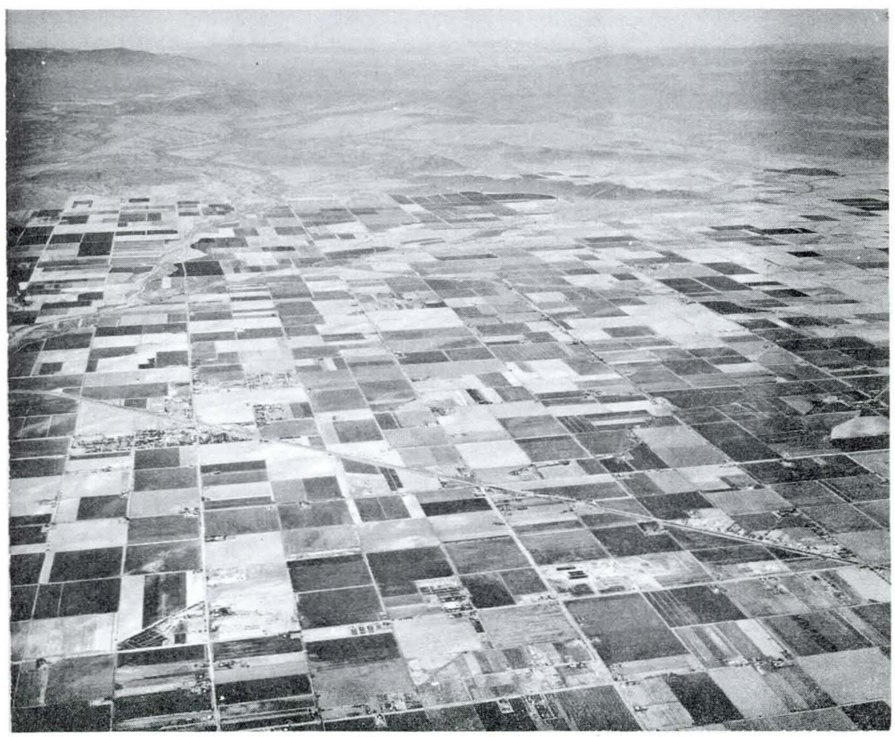
The Gila River Basin has a 58,100-square mile drainage area extending from the Continental Divide in west central New Mexico to the Colorado River at Yuma, Arizona, and roughly encompasses the southern half of the State of Arizona. Climatic conditions and native vegetation vary from the low altitude and rainfall Sonoran Zone to the Alpine Zone found in the mountains up to 12,000 feet elevation. Population centers have developed principally in the agricultural valleys, along the transportation arteries, and to a lesser extent around mining and lumbering activities. In 1960, 1,125,000 people lived in this area.

The alluvial Salt River and Gila River valleys in Central Arizona have developed into an extensive and prosperous agricultural economy due to the fertile soils, excellent and long growing season, and the initial availability of a water source. The recent agricultural development which started about 1870 in the Salt River Valley developed along traces of ancient canal systems of the earlier Indian culture. The early expansion of the area was retarded until control and storage of flood waters of the Salt River were effected by construction of Roosevelt Dam. Subsequent development and expansion of irrigation were made possible by additional reservoir construction on the Gila, Verde, Salt and Agua Fria Rivers, and the advent of the deep-well turbine pump. The growth and development occurring during the last 30 years have been made possible partly by mining the ground-water basins.

The development of the mountain and forest land of the upper Salt, Verde, and Gila River watersheds has been supported principally by range livestock operations, lumbering, mining activities and some irrigated agriculture.

MARICOPA COUNTY AGRICULTURAL LANDS





Recently, recreation center activities have accelerated the growth. The prior appropriation of surface water for the lower agricultural valleys now limits the growth possibilities of these upper river areas.

Settlement

Since obtaining territorial status in 1863, Arizona has experienced a continuing growth pattern accelerated at times by mining activity, but provided a steady base by development of livestock and agricultural operations. Early agricultural development, which supplied local military and mining community needs, continued to grow after railroad transportation became generally available by 1887. Growth has always been related to water supply and control and has been continuous since agriculture was placed on a firm productive basis by establishment of the Salt River and other irrigation projects. Eighty-five percent of Arizona's population lives within the Gila River basin. The rapid population increase since the 1947 report has been accompanied by an influx of light manufacturing industries, with an attendant growth of service industries. Influencing this population explosion have been the technological advances made in air transportation, climate modifying air-conditioning equipment, and the general economic well-being of the states and the Nation.

Project Area

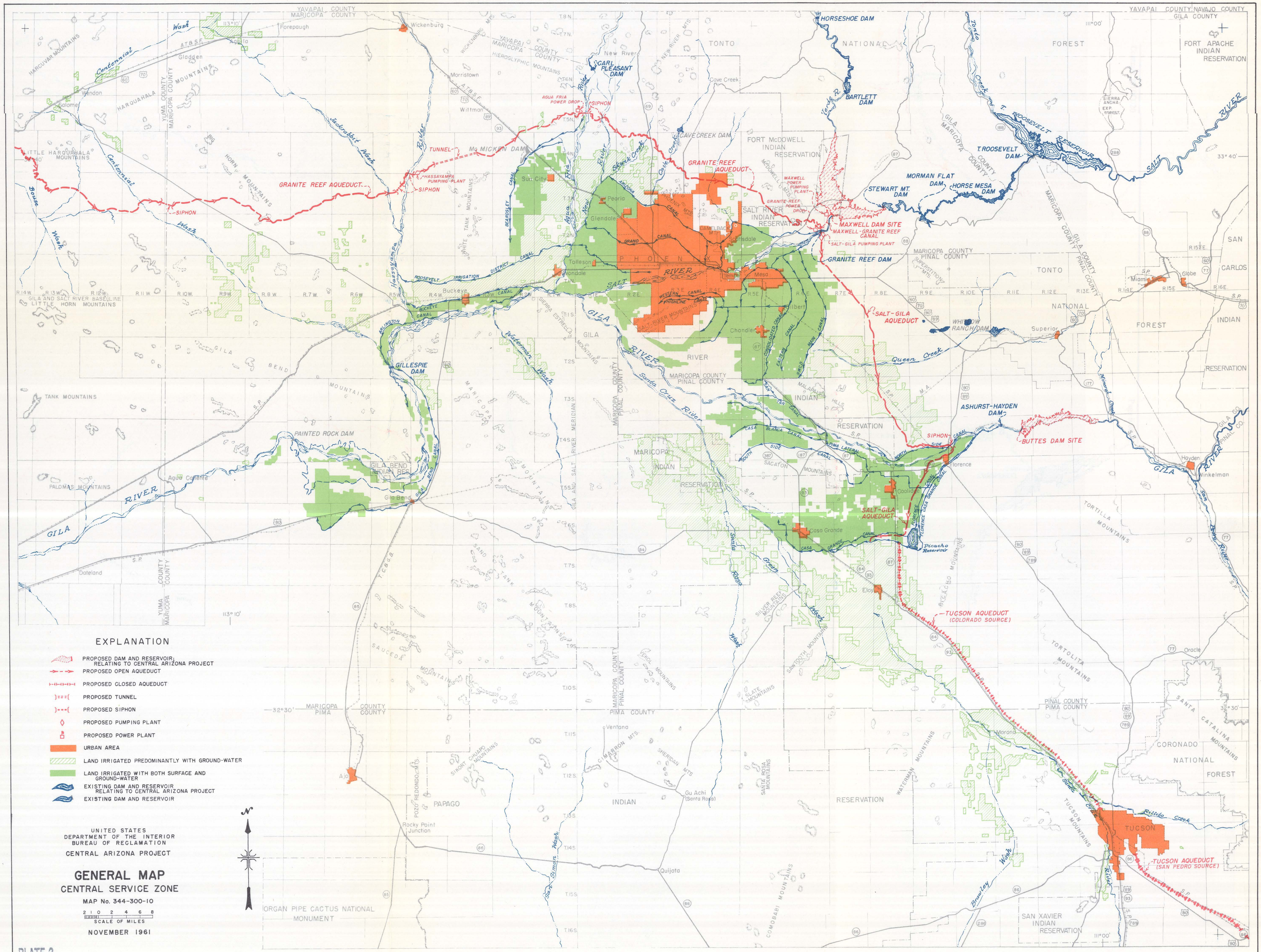
In appraising the Central Arizona Project, it is necessary to examine the water demands and resources within the hydrologic entity where they occur. For this reason the Central Arizona Project area has been divided into two separable zones designated in this report as the Central Service Zone and the Upper Tributaries Zone. The Central Service Zone contains those lands primarily in Maricopa, Pinal, and Pima counties of Arizona to which direct delivery of Colorado River water could be made. The Central Service Zone is depicted on plate 2, which shows the present development in the area and the location of project facilities. The Upper Tributaries Zone embraces those watershed areas, including the San Pedro River and upper Gila River watersheds of Arizona and New Mexico, in which associated project facilities were included in the 1947 report and to which additional water could be made available through exchange arrangements for Colorado River water.

Natural Resources

The Central Arizona Project area which occupies a strategic location in the southwestern United States is richly endowed with land, climate, and mineral resources. The unprecedented growth that has occurred and the potential still offered are dependent on water supply availability.

Climate--The attractiveness of the Southwest winter climate is a magnet that annually draws thousands of persons, as individuals and families, to seek relief from extreme cold. Seasonal residence often leads to permanent relocation. The hot summers and the mild winters give a long growing season, producing high yields. The climate variation within the Gila River Basin makes it possible to change from desert conditions to conifer forests within 2 to 3 hours drive from the population centers. Air conditioning equipment in business, home, and vehicle has extended the range of human tolerance to the summer season. Precipitation occurs seasonally throughout the project area in the winter and during the late summer. The range is from 7 inches in the Phoenix area to 12 inches at Cliff, New Mexico.

Lands--Arable lands with a sustained irrigation history are more extensive than can be provided a firm water supply from the Central Arizona Project. In 1960, 1,162,000 acres were developed for irrigation in the Central


EXPLANATION
PROPOSED DAM AND RESERVOIR RELATING TO CENTRAL ARIZONA PROJECT
PROPOSED OPEN AQUEDUCT
PROPOSED CLOSED AQUEDUCT
PROPOSED TUNNEL
PROPOSED SIPHON
PROPOSED PUMPING PLANT
PROPOSED POWER PLANT
URBAN AREA
LAND IRRIGATED PREDOMINANTLY WITH GROUND-WATER
LAND IRRIGATED WITH BOTH SURFACE AND GROUND-WATER
EXISTING DAM AND RESERVOIR RELATING TO CENTRAL ARIZONA PROJECT
EXISTING DAM AND RESERVOIR
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CENTRAL ARIZONA PROJECT
GENERAL MAP
CENTRAL SERVICE ZONE
MAP No. 344-300-10
SCALE OF MILES
NOVEMBER 1961
PLATE 2
GRANITE REEF AQUEDUCT
SALT-GILA AQUEDUCT
TUCSON AQUEDUCT (COLORADO SOURCE)
TUCSON AQUEDUCT (SAN PEDRO SOURCE)
HORSESHOE DAM
BARTLETT DAM
ROOSEVELT RESERVOIR
STEWART MT. DAM
MORMAN FLAT DAM
HORSE MESA DAM
GRANITE REEF DAM
MAXWELL DAM SITE
BUTTES DAM SITE
ASHURST-HAYDEN DAM
GILLESPIE DAM
PAINTED ROCK DAM
McMICKEN DAM
CAVE CREEK DAM
CARL PLEASANT DAM
PHOENIX
TUCSON
GILA RIVER
SALT RIVER
Picacho Reservoir

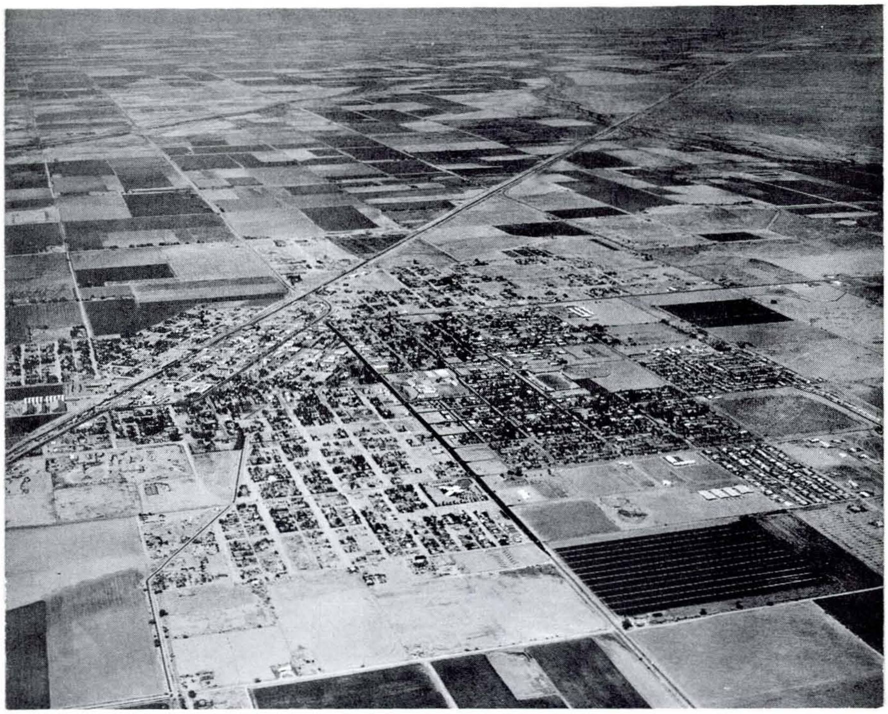
GPO 983510

Arizona Project area. In the Gila River Basin, 6,000,000 acres is the order of magnitude of arable lands suitable for irrigation. Extensive areas of arable land will long remain locked in the reserve vaults of an arid climate, offering a vast potential for future ages when the supply of agricultural lands becomes critical. The productivity of the existing irrigated acreage demonstrates its suitability for profitable agricultural use. The Central Arizona Project is oriented to sustain the economic base and reduce ground-water overdraft; therefore no new lands within the Central Service Zone are being considered for project development. At the present time, agricultural lands are being retired from production in some areas as the ground-water levels fall below the economic pumping depth.

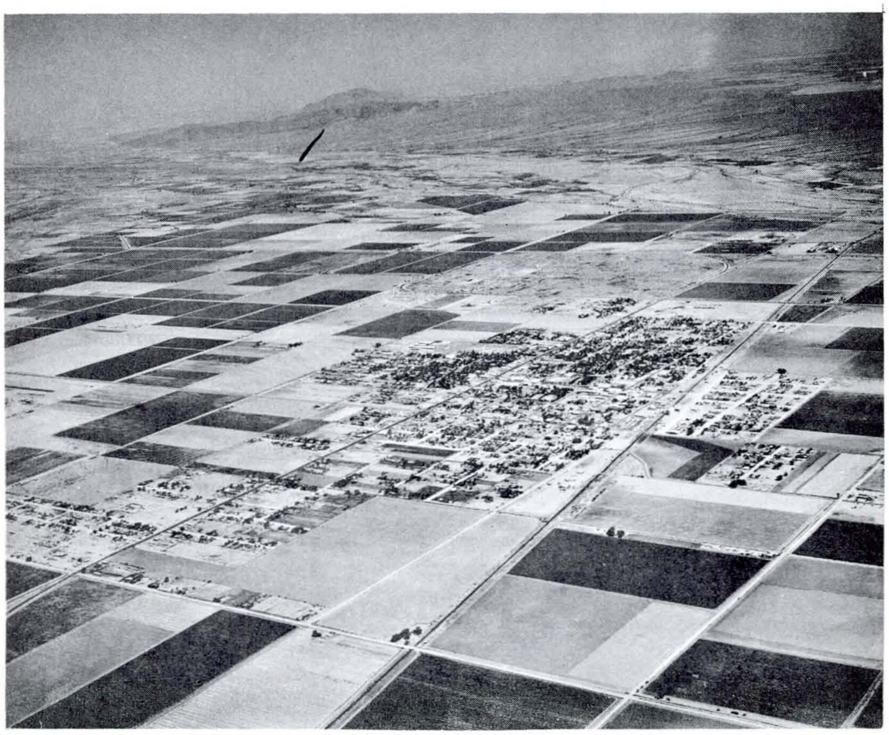
Water--At the start of the present cultural era in the Gila River Basin, the surface-water resources were more than adequate in volume to supply all the demands. As development increased, natural flows were overappropriated and storage and regulation became necessary to provide an adequate supply. Regulation of the Salt River started in 1910, before completion of Roosevelt Dam in 1911. Other reservoirs have added to the control, including Coolidge Dam on the Gila River in 1928 and Bartlett Dam on the Verde River in 1939. With practically all surface water being controlled and put to beneficial use, further agricultural expansion of the area has continued in recent years by development of the ground-water reservoirs for large scale irrigation uses.

The surface-water supply, averaging 1,460,000 acre-feet annually, and current ground-water withdrawals of 4,300,000 acre-feet, provide for the present demands. Ground-water withdrawals greatly exceed the natural recharge and water levels are dropping rapidly.

PINAL COUNTY AGRICULTURAL LANDS AND COMMUNITIES



CASA GRANDE



COOLIDGE

Minerals--Arizona has led the Nation in nonferrous mineral production for many years and produced over 38 percent of the United States value in 1960. Income from mining activities in Arizona totaled over $400,000,000 in 1960. New Mexico ranks fifth nationally in nonferrous mineral production. Continuing exploration and technological advances are proving extensive mineral deposits, unknown or undeveloped in the past, which will continue to play a major role in the economy of the area. Water availability is a prime requirement for developing and processing mineral deposits which will continue to influence mining activity and, in turn, influence other requirements for water.

Economy of the Area

The Gila River Basin, in general, is a dynamic sector of the Nation's economy. For the period 1946-1960, Arizona ranks as the Nation's leader in such rate of growth indices as population, income, nonagricultural employment, agricultural income, manufacturing employment, and nonferrous mineral production. New Mexico ranks from second to no lower than eighth in the same statistics.

At the present time, the Central Service Zone is a modern, progressive area with highly developed community centers affording its residents a standard of living higher than the national average. The 1960 census enumerated a population of about 1,000,000 people for the area, an increase of almost 100 percent since 1950.

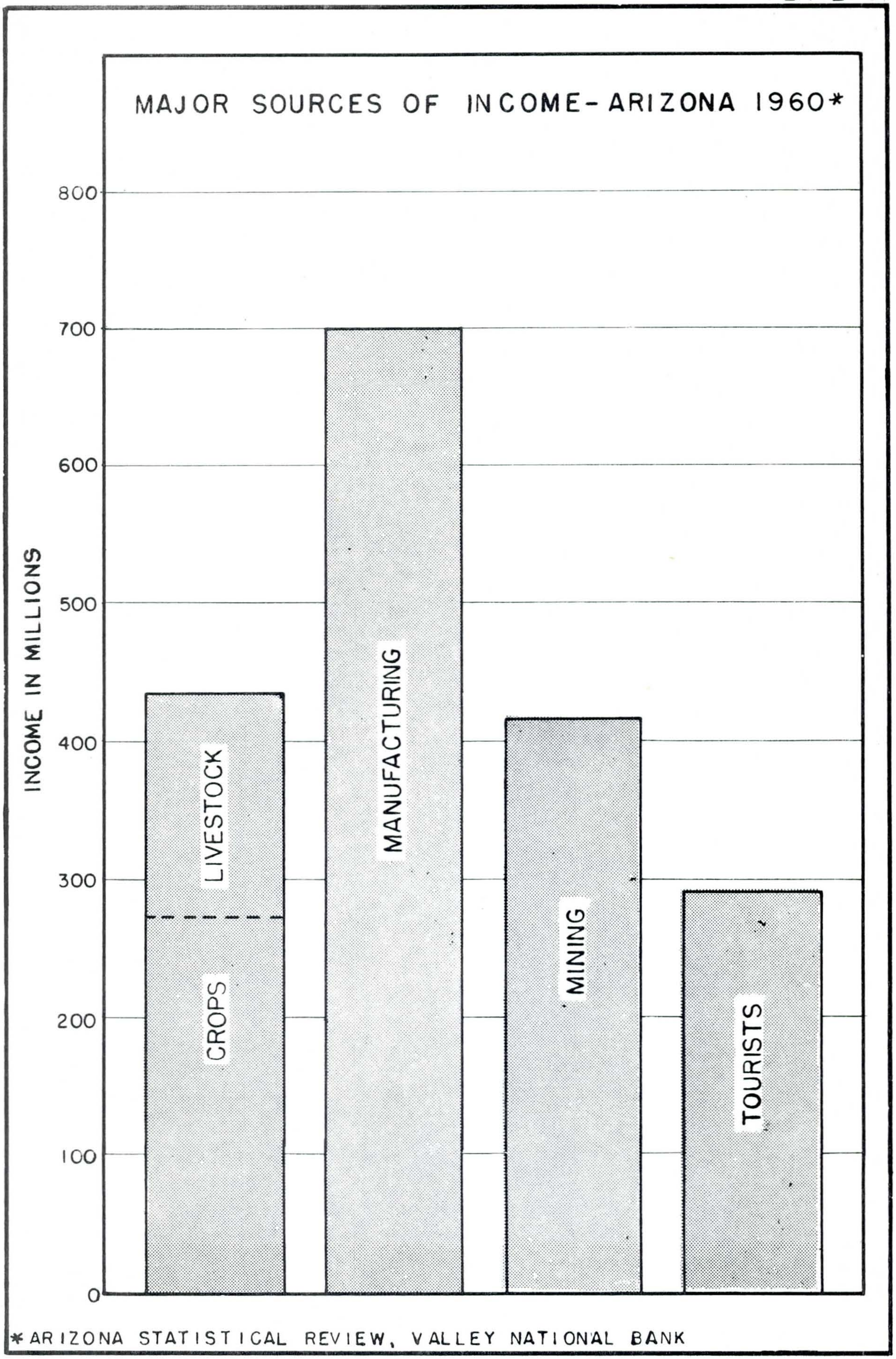
The Upper Tributaries Zone and adjoining areas are also being subjected to the pressures of expanding population and economic growth. New roads are decreasing the distance and time between the population centers in Arizona and New Mexico. Additional development of natural resources is providing a larger industrial base. The increasing development of the mountain and plateau areas is a result of the general western population and economic growth, augmented by the recreational needs and the natural attraction of the Southwest to people seeking a milder climate.

The entire area is readily accessible through an excellent system of all-weather Federal, State, and county roads. The Southern Pacific and the Atchison, Topeka and Santa Fe Railroads traverse the region. Transcontinental air transportation is available at Phoenix, Tucson, and other cities throughout the area.

A well-developed system of wholesale and retail outlets, service firms, credit facilities, and other community services is readily available locally to residents and businesses. Electric power, telephone, radio, and television service are also available throughout the entire area. Natural gas service is not limited to household uses in the population centers but is widely used as an energy source for irrigation pumping, electrical power production, and industry in general. Fourteen daily newspapers are published in the various cities and towns.

Agriculture--Agriculture is a vital factor in the economy of the area. The importance of agriculture in Arizona is shown on plate 3. At the present time, three major types of agricultural enterprises exist in the area: field crops, tree and vine crops, and livestock. The area is one of the world's leaders in the production of long staple cotton and is also an important source of winter vegetables and other specialty crops. For the project area within Arizona, the total value of the agricultural products in 1960 produced was about $320,000,000.

Urban growth and expansion--The doubling of population in the past 10 years in Maricopa County has included the urbanization of rural areas, since most of the new residents have been absorbed through the expansion of cities


MAJOR SOURCES OF INCOME-ARIZONA 1960*
INCOME IN MILLIONS
800
700
600
500
400
300
200
100
0
LIVESTOCK
CROPS
MANUFACTURING
MINING
TOURISTS
* ARIZONA STATISTICAL REVIEW, VALLEY NATIONAL BANK

and towns. Expansion of urban areas in the Salt River Valley to accommodate the population growth has been largely onto the farm lands of the Salt River Project and adjoining agricultural areas. In 1960, Phoenix alone included 43,500 acres of Salt River Project lands which were formerly irrigated. City limits have been expanded, encompassing lands of low population density, which will provide corporate administration and services to these outlying areas as the densities increase. Water availability within the agricultural zones will tend to concentrate urban growth for some time as in the past. The economic dynamics of large subdivision development, however, have caused a scatteration of high population density clusters held apart by large extents of low population density acreage. The continuing growth of the urban areas will increase the population density in the central metropolitan area as the vacant land is utilized and vertical construction continues. As the urban growth encroaches on the agricultural lands, the water supply formerly used for irrigation will serve domestic and other municipal purposes. In Tucson, parts of metropolitan Phoenix, and other localities, similar growth has taken place over desert lands not previously irrigated. Under these circumstances, possibilities are not present for transferring existing water supplies from agricultural to urban use.

Industry--In manufacturing for 1960, the food and kindred products processing industry was second only to the aircraft and transportation equipment industry. Other important industries include primary metals, electrical and other machinery, printing and publishing, stone, clay, and glass products, metal fabrication, chemicals, and apparel. Manufacturing is followed by mining and tourism in economic importance to the area.

Income and valuation--The present economic strength of the area is reflected through values of financial indicators. In Arizona for 1960, the average annual wage of $4,894 compared with a national average of $4,705, and personal income amounted to $2,650,000,000.

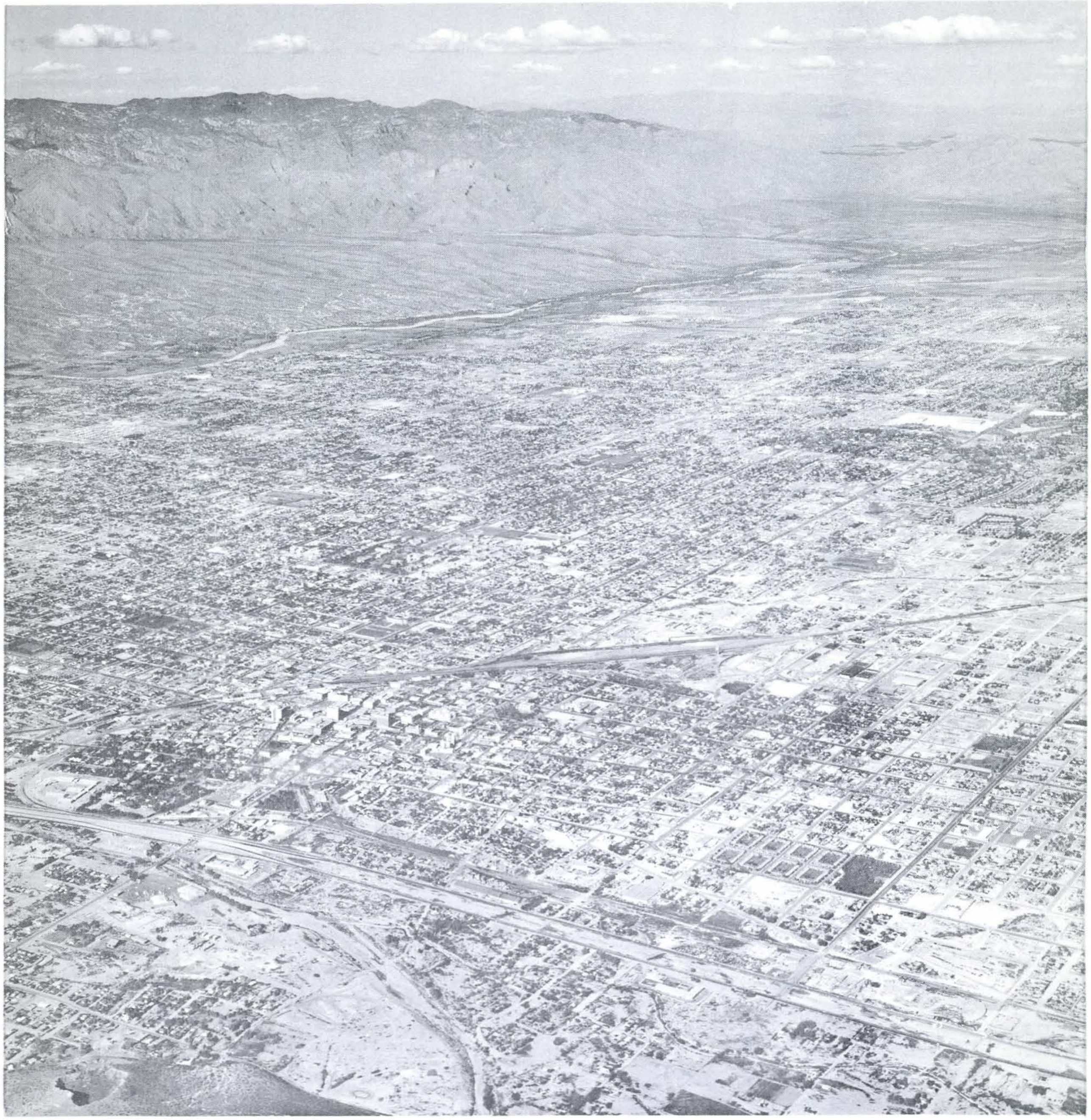
In the Central Service Zone the net assessed 1960-61 valuation of $1,123,487,000 was 70.3 percent of the State valuation.

Problems of the Area

The lack of a water supply adequate to meet the water demands is the basic problem of the area. The local surface sources have been appropriated beyond their capabilities and the ground-water basins are being depleted of water stored prior to this era.

The economy of the area, starting from a mining and agricultural base, has grown with the rise of transportation, taking advantage of the climate to add strong recreational and tourist segments to an increasing industrial and manufacturing growth. The western population explosion has brought into sharp focus the necessity of providing supplemental water to meet the existing agricultural, municipal and industrial demands and, through coordinated development to provide for the recreational, fish and wildlife, and flood control requirements.

Inadequacy of present water supplies--In simple terms, the area is using far more water each year than is annually replaced. This excess of use over supply is a condition which has existed in varying degrees for over a quarter century and is continuing at an ever-increasing rate to this day. Some idea of the overall unbalance between water supply and use can be gained by considering that since the early settlers found themselves in an area of seasonal surplus, irrigated agriculture in the Gila River Basin has (1) made essentially



TUCSON

full use of all of the streamflow of the area, and (2) created an extensive overdraft on the ground-water basin.

Needs of the Area

Corollary to the water supply inadequacy are the resulting economic needs. On a quantitative basis, the major water need is, and probably always will be, for irrigation since agricultural water demands will exceed urban demands under all foreseeable conditions. However, from the standpoint of preserving the economic health and well-being of the area and providing for future growth and development, the municipal and industrial water requirements may be of equal or greater importance. As previously indicated, much of the urban growth has been, and will continue in the future to be, at the expense of agricultural acreage for which a local water supply is available. Nevertheless, the conversion of agricultural land is accompanied by urbanization of desert lands both in the Phoenix and Tucson metropolitan areas--and imported water is essential to permit such growth to continue. Without import water, future municipal and industrial demands could be met only by the purchase and retirement of irrigated lands outside the urban area. Such forced reduction of the agricultural economy undoubtedly would be reflected in reduced urban growth.

With respect to irrigated lands, the water shortages are increasing crop production costs because existing wells must be deepened and re-equipped, or new ones drilled, as ground-water levels continue to decline. Concurrently, increasing quantities of power and energy are required to lift the water from deeper levels with the result that pumping costs increase progressively. Water shortages also influence the economy by depressing land values, by increasing interest rates, and by reducing the availability of lending capital to the farmers.

Other important consequences of the prevailing water shortages result from the uncertainty such shortages inject into the farmer's cropping plans. Under these uncertain conditions the farmers tend to limit their rotation programs to crops promising a high-value, short-term return and eliminate soil-building crops such as alfalfa because they require more water than may be available or profitable. These uncertain water conditions also introduce an element of risk into the farmer's long-term plans, as orchards and livestock enterprises are particularly vulnerable to water shortages.

The Central Arizona Project area does now possess, and with an adequate water supply would continue to possess, many advantages in the production and marketing of agricultural products. The long growing season, a wide crop-adaptability, high land fertility, and an ever-expanding nearby market, are some of these advantages. At the present time, new land is being developed in outlying ground-water basins removed from previous development in response to the landowners' desire to capitalize on these advantages. This development is extending the already overburdened water supplies, and is adding to the overall water supply problem. Unless additional water supplies are made available, presently developed lands will be forced out of production at an accelerating rate and economic disaster could result.

A positive solution to the water problems of the area is needed because of the pressures being exerted by the ever-increasing population. Municipal expansion, highways, and other nonagricultural uses have encroached upon the Salt River Project lands, and the area diverted from agriculture is expected to increase in the future as the population grows. To save the existing diversified agricultural economy, as well as the lifeblood of an expanding municipal and industrial base, positive action is essential. The area's water problems must be met by prompt action to import additional water to bring supply into closer balance with use.

There can be no single answer to the question, "How much water is needed?" because, in the Central Arizona Project area, water use has for many years been dictated by availability rather than by need. For this reason, it is necessary to define a minimum and a maximum water requirement within which any anticipated future water need will fall. The potential water demands of the area far exceed any known water resource of the area and, therefore, development always will be limited by the available augmented water supply. The supplemental water required by the entire area is estimated to be about 2,190,000 acre-feet annually under the present water supply-water use regimen. At the other extreme, the greatest water need would occur if all of the arable lands of the area were fully developed and all future municipal and industrial requirements were provided for.

Prospects for future economic health--Without Colorado River water, the amount of land in production will decrease to the point where the remaining lands will be using only as much water as is available. With Colorado River water, the area has a tremendous potential for the future growth of its already billion-dollar-plus economy. Future economic health is obviously contingent upon the importation and development of additional water supplies.

Water Service Organizations

Local interest in the solution of the water problems of the Central Arizona Project area is amply demonstrated by the existence of a large number of water service organizations. The activities undertaken by these organizations vary according to the particular law under which they were organized and their relation to surface-water diversions. However their specific functions may be limited, they all have one thing in common--they were all created to deal with water problems.

At the present time, activities are in progress to form additional organizations and to alter the forms of others to allow for additional functions to be performed. Among the public organizations making known their interests in additional water supplies are six irrigation districts and water conservation districts, seven cities and municipalities, and five electrical cooperatives. Various industries, companies, and unorganized area associations have also expressed their needs and interests. Several of the existing organizations presently receive surface water, and all utilize ground water. All are potential subscribers to the water service plan described in this report. As of December 1961, five existing organizations have requested water or expressed interest in negotiating with the Bureau of Reclamation for water service. During the past year, the Bureau of Reclamation has received expressions of interest from 30 organizations supporting the Bureau's studies of the water problem of the area. The Bureau has also received informal expressions of support from many more.

Since 1960, Arizona has appropriated $250,000 for this appraisal and a water resources inventory of the State. New Mexico has contributed $30,000 for work of the same scope covering the Gila River Basin in New Mexico.

Voluntary organizations, such as the Central Arizona Project, Hooker Dam, and Charleston Dam associations, have been active in educating those unfamiliar with, or unaware of, conditions and problems of the area, and in advocating action to remedy the situation.

CHAPTER II

LAND AND WATER UTILIZATION

CHAPTER II - LAND AND WATER UTILIZATION

Present and future use of the land resources will, in large measure, determine the location and magnitude of the water requirements. In addition to the agricultural and municipal and industrial requirements for water that occur in the Gila River Basin, there are growing needs for recreation, fishery and wildlife, and flood control protection. In attempting to satisfy these requirements, the overall needs of the Central Service Zone to which direct diversion of import water may be made, must be considered in conjunction with the requirements of the other areas in the Gila River Basin and their relationship to the States.

Hydrologic Study Areas

In analyzing the land utilization, water uses, and water requirements, hydrologic study areas have been established within the Central Service Zone and Upper Tributaries Zone. These separable hydrologic entities, governed primarily by sources of water supply and ready availability of data, are shown on plate 4, Hydrologic Study Areas. Within the Central Service Zone are the Centennial, Maricopa, Pinal, and Santa Cruz areas, to which direct delivery of Colorado River water may be made. Within the Upper Tributaries Zone are the Upper Gila, San Pedro, and Upper River areas, to which water can be made available by exchange.

General Land Characteristics

Since 1917, limited soil surveys, covering lands in the proposed project area, have been made by the University of Arizona and the Department of Agriculture. Detailed soil studies by the Soil Conservation Service are constantly expanding the mapped area. The Bureau of Reclamation has made a detailed land classification of the San Carlos Project, which

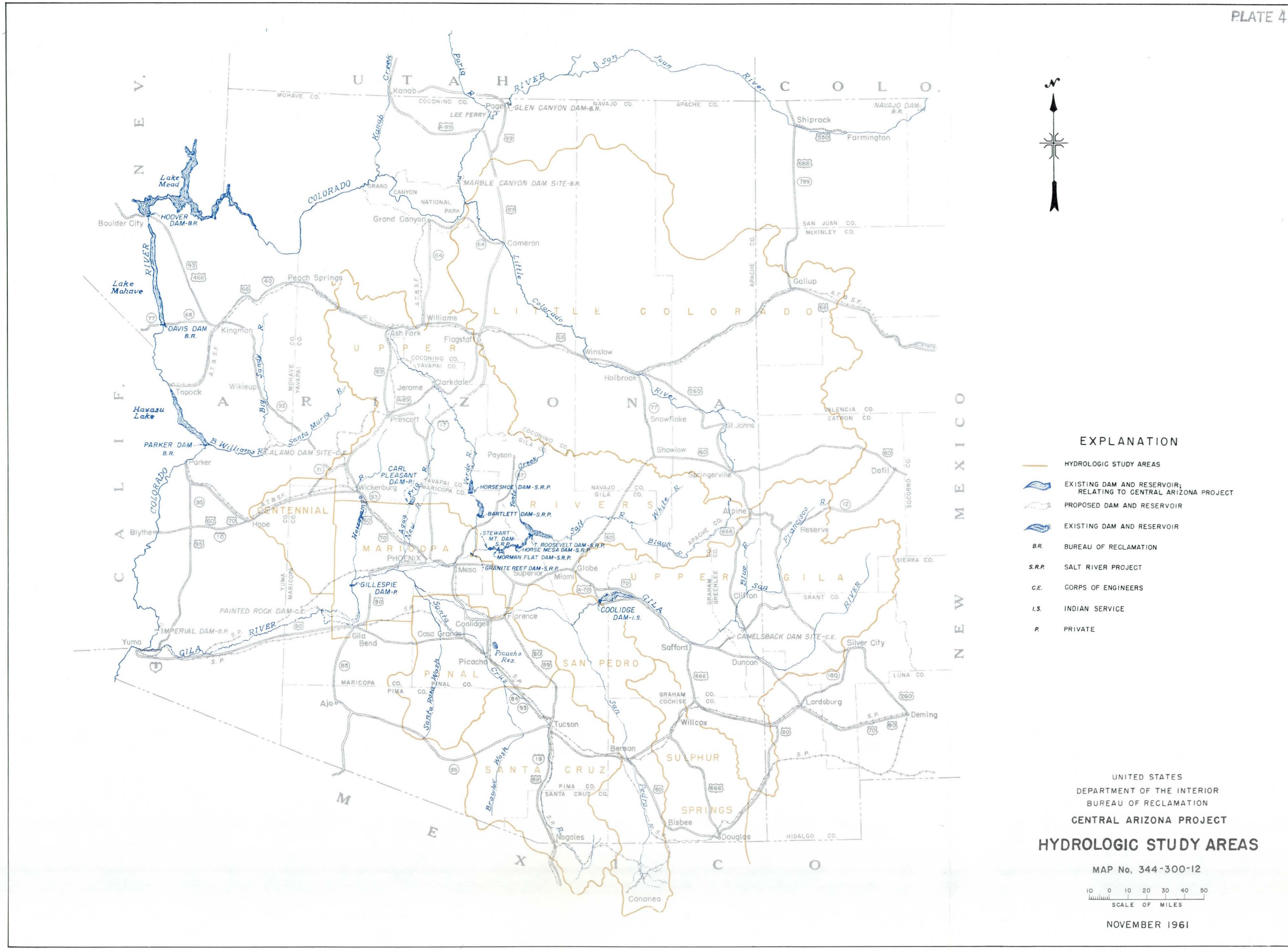


PLATE 4
EXPLANATION
HYDROLOGIC STUDY AREAS
EXISTING DAM AND RESERVOIR; RELATING TO CENTRAL ARIZONA PROJECT
PROPOSED DAM AND RESERVOIR
EXISTING DAM AND RESERVOIR
B.R. BUREAU OF RECLAMATION
S.R.P. SALT RIVER PROJECT
C.E. CORPS OF ENGINEERS
I.S. INDIAN SERVICE
P. PRIVATE
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CENTRAL ARIZONA PROJECT
HYDROLOGIC STUDY AREAS
MAP No. 344-300-12
10 0 10 20 30 40 50
SCALE OF MILES
NOVEMBER 1961
UTAH
COLO.
NEV.
CALIF.
ARIZONA
NEW MEXICO
MEXICO
LITTLE COLORADO
UPPER
CENTENNIAL
MARICOPA
RIVERS
UPPER GILA
PINAL
SAN PEDRO
SANTA CRUZ
SULPHUR SPRINGS
GLEN CANYON DAM-B.R.
HOOVER DAM-B.R.
DAVIS DAM B.R.
PARKER DAM B.R.
COOLIDGE DAM-I.S.
GILLESPIE DAM-P.
PAINTED ROCK DAM-C.E.
IMPERIAL DAM-B.R.
MARBLE CANYON DAM SITE-B.R.
ALAMO DAM SITE-C.E.
CAMELSBACK DAM SITE-C.E.
HORSESHOE DAM-S.R.P.
BARTLETT DAM-S.R.P.
GRANITE REEF DAM-S.R.P.
MORMAN FLAT DAM-S.R.P.
HORSE MESA DAM-S.R.P.
Lake Mead
Lake Mohave
Havasu Lake
PHOENIX
Tucson
Yuma
Flagstaff
Prescott
Kingman
Safford
Nogales
Douglas
Bisbee
Globe
Gallup

GPO 983510

comprises about 100,000 acres. Other than this, no Bureau of Reclamation surveys have been made.

Irrigated lands were developed mostly on alluvial fans which descend from the rugged mountains. Slopes on these fans are steep at the higher elevations, but gradually flatten out as they approach the axis of the valley to coalesce with other fans and form an alluvial plain or playa. The coarse, stony, gravelly, or sandy materials were deposited on the higher, steeper parts of the fans, whereas the finer materials were carried down onto the alluvial flats. Recent alluvial materials are confined to the stream bottoms and make up only a small percentage of the total irrigated area.

The soils suitable for irrigation can be broadly characterized as Red Desert soils in the bulk of the area and Brown soils at the higher elevations. With only minor exceptions these soils have good water-holding capacity and are well adapted to irrigation.

Red Desert soils are usually calcareous throughout and the subsoils are frequently cemented to form caliche horizons. The soils have a surface soil which may vary from coarse- to fine-textured, but is usually a fine sandy loam, loam, or clay loam. Subsoil textures usually become coarser with depth. Permeable sands or gravels are characteristic below a depth of 7 or 8 feet.

Brown soils, which occur in the lower foothill areas, comprise a much smaller total of the irrigable acreage but are locally quite important because of their suitability for orchards. They tend to be browner in color than the Red Desert soils, and the surface soils are more compact. Profile characteristics are generally similar to the Red Desert soils, but the soils tend to be coarser, more gravelly, and have less effective soil depth. The lime horizon is usually leached to 20 inches or more in these soils. Natural drainage is usually excellent and these soils respond well to irrigation.

The alluvial stream-deposited soils along the river bottoms are also important to irrigation in the area. In places, these bottom areas are typically mellow and pervious throughout, but locally are influenced by high water tables and high salinity conditions. Reclamation by drainage and leaching, where necessary, has proven to be economically feasible.

Present Land and Water Use

It is estimated that there are approximately 1,162,000 acres of land developed for irrigation in the Central Arizona Project area, of which an average of about 880,000 acres were in production during the 5-year period 1955-60. The irrigated acreage fluctuates from year-to-year in accordance with available water supplies. In general, the acreage of developed lands increases somewhat from year-to-year as additional lands are being continually developed for irrigation wherever isolated ground-water supplies can be found. Some 280,000 acres of developed lands, currently out of production, include lands temporarily idle because of deficient surface-water supplies, and also lands which have been abandoned as pumping costs have increased beyond the point of diminishing returns as a result of falling ground-water tables. Table 1 shows the estimated urban population and agriculturally developed acreage within the various hydrologic study areas.

As indicated by table 1, the major urban centers have developed within the Maricopa and Santa Cruz hydrologic study areas. The principal city in

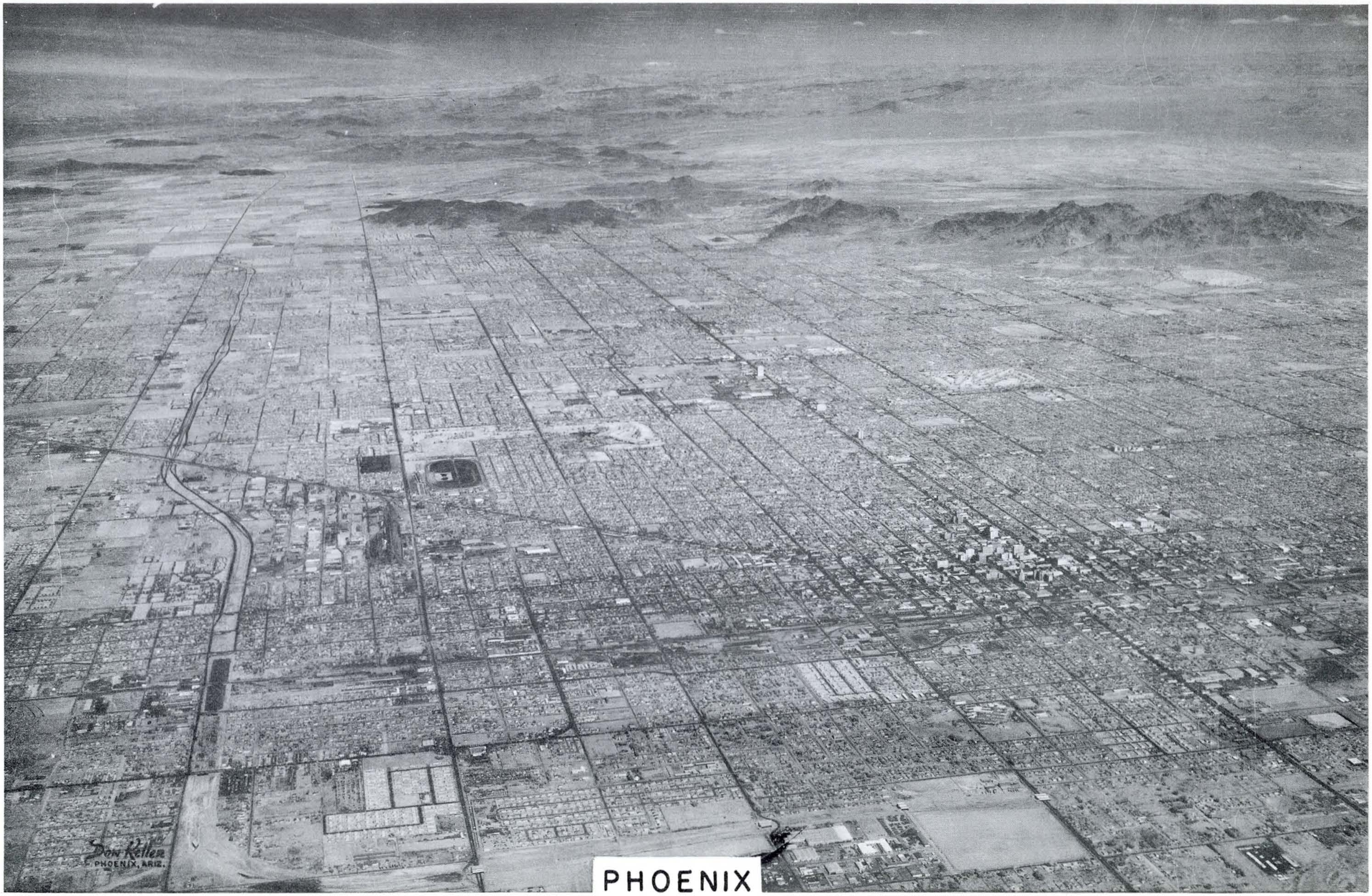
Table 1.--Central Arizona Project developed areas - 1960

Hydrologic Study Area	Urban Area Population	Agriculturally Developed Area (Acres)
Centennial	1,000	35,500
Maricopa	662,000	589,000
Pinal	46,300	379,000
Santa Cruz	267,000	73,500
San Pedro	36,000	15,000
Upper Gila:		
Arizona	27,900	37,400
New Mexico	2,450	12,500
Upper Rivers	57,300	20,000
Total	1,099,950 or	1,161,900 or
(Rounded)	1,100,000	1,162,000

the Maricopa area is Phoenix which, according to U.S. Census reports, increased in population from 106,818 in 1950 to 439,170 in 1960. Phoenix ranks 29th in population among leading U. S. cities following immediately below Columbus, Kansas City, Indianapolis, and Minneapolis, in that order. The city limits of Phoenix embrace over 120,000 acres, a large portion of which is previously irrigated land of the Salt River Project. The photograph of Phoenix shows the urban developments spreading over previously irrigated lands and onto the desert areas beyond. The major portion of the city presently lies within the project boundaries and has an adequate water supply from local sources, since Salt River Project water is transferred from irrigation to municipal use as irrigated lands are subdivided. Lands within the city, but outside the Salt River Project area, must obtain water from nonproject sources.

The major city of the Santa Cruz area is Tucson. Census reports show the population of this city increased from 45,454 in 1950 to 212,892 in 1960. Tucson ranks 54th in population among U. S. cities, following immediately below Syracuse, Richmond, Wichita, and Tulsa. The city limits of Tucson embrace approximately 45,000 acres, the major portion of which were desert lands with no previous history of irrigation and for which no possibilities are present for transferring irrigation supplies to municipal use. Plate 5 illustrates the historic population growth of Arizona and the major urban areas of the Central Service Zone.

Table 2 shows the present estimated water uses in the various irrigated and urban areas. Water uses were estimated from data obtained from municipalities and water user organizations and by computations based on the Blaney-Criddle method of estimating consumptive uses with adjustments



PHOENIX

POPULATION TRENDS AND PROJECTIONS

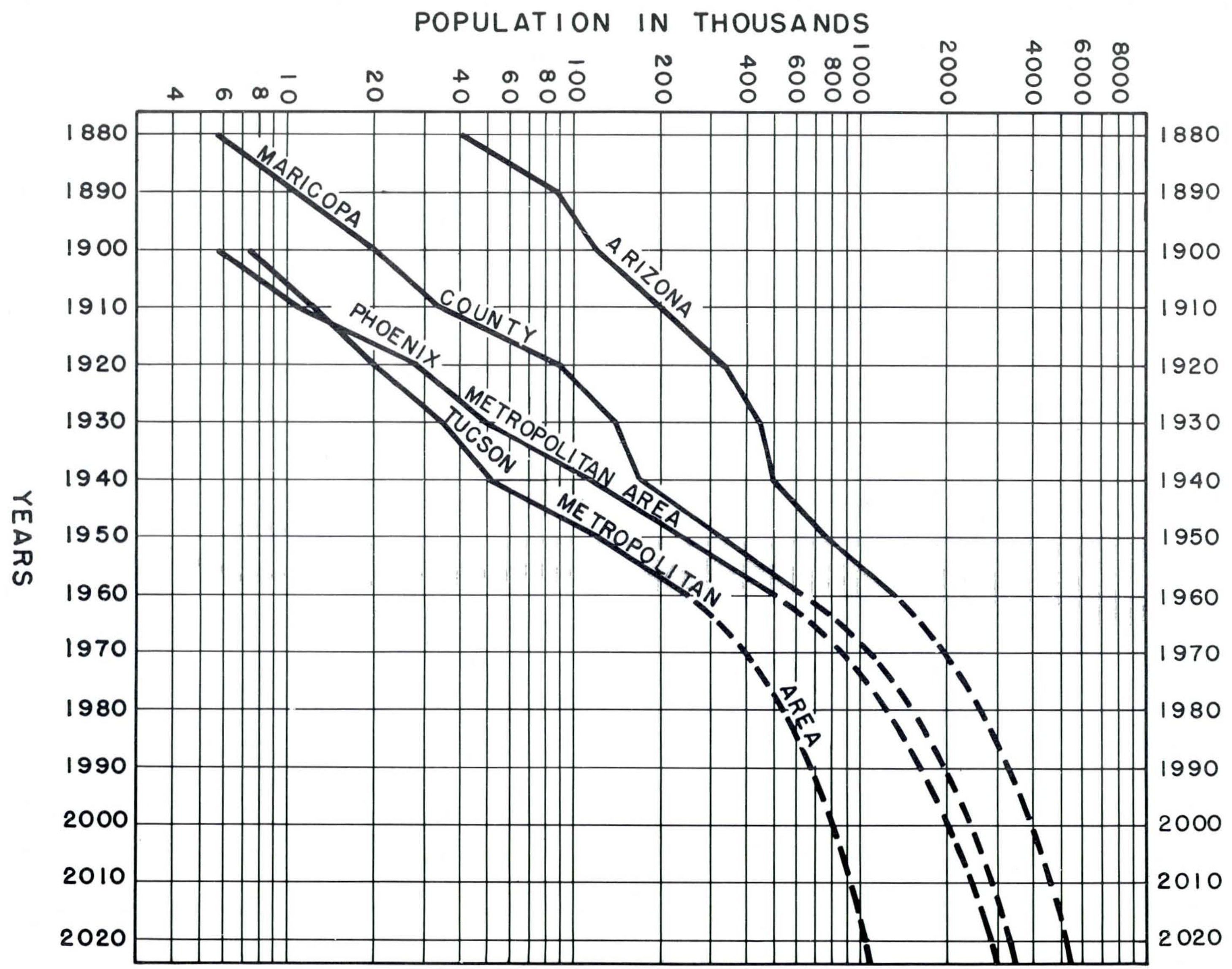


PLATE 5

Table 2.--Present estimated water uses 1/
(quantities in acre-feet)

Hydrologic Study Area	Irrigation Uses	Municipal and Industrial Uses	Total
Centennial	119,000	1,000	120,000
Maricopa	2,331,000	205,000	2,536,000
Pinal	1,208,000	15,000	1,223,000
Santa Cruz	290,000	44,000	334,000
San Pedro	56,000	20,000	76,000
Upper Gila	185,000	18,000	203,000
Total	4,189,000	303,000	4,492,000

1/ At farm headgate and at water system.

for nonbeneficial uses, losses, and waste.

Some agricultural lands in the Upper Gila, San Pedro, and Santa Cruz areas have already been purchased by mining and municipal interests for retirement from production when growing municipal and industrial demands so require. In the Upper Tributaries Zone, lands of the watersheds are used to a large extent for grazing, timber production, and recreation. Irrigation farming, however, is important to the local economies.

Future Land and Water Use

It is contemplated that urban development will have a major influence on future land and water use in the Central Service Zone. Numerous recent evaluations of anticipated population growth have been made for this area by economists, engineers, planners, and business forecasters, all of which show quantitative variations as would be expected. The population projections, which are also shown on plate 5, are based on these evaluations and indicate the magnitude of growth that may be expected under conditions of an adequate water supply and barring any National economic or other catastrophe.

On the basis of these projections it is estimated that, as the combined populations of the Phoenix and Tucson metropolitan areas approach 4,000,000, municipal and industrial water requirements in the Central Service Zone will increase from the present use of about 300,000 acre-feet per year to about 1,400,000 acre-feet per year. A major portion of these water requirements is expected to be met by the transfer of existing local irrigation water supplies to municipal and industrial use. However, a significant portion of the future expansion necessarily must occur in desert areas having little or no present water supply capability. It is estimated that approximately 312,000 acre-feet of additional import water will be required to satisfy demands in these areas under project conditions.

The quantity of municipal and industrial water needed in the Upper Tributaries Zone has not been defined, and additional studies will be required for this item. In present studies, it was not possible to evaluate future needs which will result from exploitation of extensive mineral deposits in the Upper Tributaries Zone. It is anticipated, however, that substantial additional supplies will be needed for proposed mining activities and for use by urban growth which will naturally result from these activities. In this connection, it should be noted that both Arizona and New Mexico are among the Nation's leaders in nonferrous mineral production, and that extensive mineral deposits are known to exist in the Upper Gila River Basin for which development is planned within the near future.

Present studies indicate that the future use of water for irrigation will decrease progressively with increased demand for municipal and industrial water since sufficient water cannot be made available to sustain the present irrigated acreage and the potential municipal and industrial requirements. It is estimated that the use of water for irrigation on the presently developed area will decrease during the period of analysis from present use of about 4,190,000 acre-feet per year to about 3,100,000 acre-feet per year as agricultural land is urbanized.

<u>Water Conservation Requirements</u>

In view of the short water supply conditions that can be expected to exist in the area throughout the foreseeable future, it will be necessary that every effort be made to conserve the available water supplies, both local and imported. Toward this end, it appears essential that all new distribution systems constructed to deliver water to areas now dependent solely upon private pumps should be built with modern impervious linings or pipe systems. It also appears evident that existing unlined systems should be rehabilitated by the water users to provide lined or pipe systems throughout the project area. In addition to the improvement of water delivery facilities, it will be necessary that farm practices be improved to increase irrigation efficiency to the maximum extent possible. Average irrigation efficiencies of approximately 70 percent should be expected under projected conditions as compared to the present average of about 50 percent. Expanded programs of soil and moisture conservation upon the watershed lands, river channels, and overflow lands will be needed as a partner to the construction of project works and the improvement of distribution systems and farm practices.

Flood control--Proposed channelization flood control protection of the Phoenix urbanized area should be coordinated with the Granite Reef and Salt-Gila Aqueducts and the Maxwell Reservoir features of the Central Arizona Project. Buttes Reservoir on the middle Gila River and Charleston Reservoir on the San Pedro River would provide flood control protection subsidiary to the conservation benefits. In the Upper Gila hydrologic area, authorized channel improvement of the Corps of Engineers would coordinate well with storage at the Hooker site. Potential developments on the San Francisco River and associated downstream conservation and flood control requirements may result in modifications of functions and facilities at the Corps of Engineers' proposed Camelsback development.

Recreation and fishery and wildlife--Fishery and wildlife consumptive uses, like recreational purposes, are very small in relation to the quantity of water regulated and transported. The requirement is more for surface area of water than for consumption, and this surface may be provided in reservoir storages created, or along the aqueduct alignments, between the origin and terminus points. Specific locations and requirements along the aqueduct alignment, in addition to the Maxwell storage and Salt-Gila balancing reservoirs, will be identified during future studies. Within the Central Arizona Project area, easy accessibility to reservoir fishery and recreational areas is now limited. The potential Bridge Canyon, Buttes, Charleston, and Hooker Reservoirs will extend the area of recreational opportunities.

CHAPTER III

WATER SUPPLY

CHAPTER III - WATER SUPPLY

This chapter presents the existing hydrologic conditions and water supply and operation under assumed project conditions.

Present Water Supply

Within the Central Arizona Project area, both surface- and ground-water supplies are available. The surface sources are natural flows, return, waste, and effluent flows, and storage on upper reaches of the major streams. The ground-water sources are the underground reservoirs filled prior to man's recent activity and continuously recharged by surface waters applied to the areas over which development has occurred. Rainfall in the developed areas generally is not significant as a source of water for crop production or ground-water recharge.

The water supply studies for this appraisal are reconnaissance in nature and limited by the data presently available. In analyzing the present water supply, the period 1921-1959 has been considered to be representative of average surface-water conditions which might be expected in areas having upstream storage available. The average annual long-term surface-water supply was determined from the available records of diversions associated with the inflow to major storage reservoirs modified as necessary to reflect increasing reservoir storage capacity and water adjudications. In areas where surface water diversions are not directly influenced by upstream reservoirs, shorter term periods of record were used in order to reflect present conditions. These areas include the Gila River above Coolidge Dam, San Pedro River, and the lower reach of the Gila River below the confluences of the Salt and Agua Fria Rivers.

The ground-water supply analysis, due to paucity of adequate data, both qualitative and quantitative, and the limited time factor, necessitated the use of applicable rapid methods of analyses dictated by the type of data readily available for each hydrologic area.

For the Maricopa and Pinal hydrologic areas, a graphical method of determining safe yield was employed. The safe yield, expressed as gross pumpage, was developed by plotting average annual water level change versus annual gross pumpage. The accuracy of this determination is tempered by the limited data available on average water level change and gross pumpage as estimated and published by the U. S. Geological Survey.

For the Centennial, Santa Cruz, San Pedro, and Upper Gila hydrologic areas, a reconnaissance-grade analysis, general in nature, was employed. The safe yield was developed as the estimated average annual recharge, as qualified by the trend in ground-water levels which are affected by pumpage, average annual streamflow through an area, or inflow-outflow comparison. Data published by the U.S. Geological Survey were used freely.

Surface sources--The primary sources to the project area are the Salt, Verde, Agua Fria, Gila, and San Pedro Rivers. The present surface-water supply, estimated to average 1,460,000 acre-feet annually at the diversion structure, occurs as shown in table 3. This yield is developed from direct diversion and storage provided by the reservoirs shown in table 4. The development on the Salt and Verde Rivers has been most effective in controlling the runoff of all but exceptionally wet seasons. In 1941, the last major escape of water occurred, with accompanying flood damage. Since that time, no flows of consequence have escaped the project area or reached

Table 3.--Present water requirements and supply
(quantities in acre-feet)

Hydrologic Study Area	Water Requirements (At Farm Headgate and at Water System)			Present Average Annual Water Supply						Indicated Present Deficiency
				At Diversion Point			At Farm Headgate and at Water System 1/			
	Irrigation	Municipal	Total	Surface	Ground	Total	Surface	Ground	Total	
Centennial	119,000	1,000	120,000	--	20,000	20,000	--	20,000	20,000	100,000
Maricopa	2,331,000	205,000	2,536,000	1,117,000	890,000	2,007,000	782,000	756,000	1,538,000	998,000
Pinal	1,208,000	15,000	1,223,000	195,000	300,000	495,000	130,000	255,000	385,000	838,000
Santa Cruz	290,000	44,000	334,000	--	130,000	130,000	--	110,000	110,000	224,000
San Pedro	56,000	20,000	76,000	4,000	60,000	64,000	3,000	51,000	54,000	22,000
Upper Gila	185,000	18,000	203,000	147,000	110,000	257,000	103,000	93,000	196,000	7,000
Total	4,189,000	303,000	4,492,000	1,463,000	1,510,000	2,973,000	1,018,000	1,285,000	2,303,000	2,189,000
Rounded	4,190,000	300,000	4,490,000	1,460,000	1,510,000	2,970,000	1,020,000	1,280,000	2,300,000	2,190,000

1/ After appropriate allowance for conveyance losses.

Table 4.--Reservoir storage capacity

River	Dam	Reservoir	Storage Capacity (acre-feet)	Completion Date
Salt	Roosevelt	Roosevelt	1,382,000	1911
	Horse Mesa	Apache	245,000	1927
	Mormon Flat	Canyon	58,000	1925
	Stewart Mountain	Saguaro	70,000	1930
		Subtotal	1,755,000	
Verde	Bartlett	Bartlett	179,500	1939
	Horseshoe	Horseshoe	142,800	1945
		Subtotal	322,300	
Agua Fria	Carl Pleasant	Carl Pleasant	163,800	1927
Gila	Coolidge	San Carlos	1,205,000	1928
Total			3,446,100	

the mouth of the Gila River.

San Carlos Reservoir has effected complete control of the Gila River at that point. Summer stormflows originating on the Upper Gila River and on its tributaries, the San Francisco above Clifton, and the San Pedro above Redington, still require additional regulation for flood control and water salvage. The Agua Fria River, controlled by the Carl Pleasant Dam, has also had no spills since 1941. High discharge summer stormflows, as they escape past diversion dams, are mostly lost to evaporation and stream channel vegetative growth.

Salt-Verde Rivers system--The Verde River contributes 41 percent of the average water supply of the Salt River system; however, only 16 percent of the system reservoir storage capacity is on the Verde. With storage location and storm runoff from tributaries discharging below the storage reservoirs, flood spills cannot be prevented at the Granite Reef Diversion Dam. The most frequent spills are minor in magnitude. The last spill of consequence, amounting to 890,000 acre-feet, occurred in 1941.

The average annual yield for the period 1921-1959 at Granite Reef Diversion Dam was 965,000 acre-feet. The average annual yield has not been exceeded since 1945; however, it was exceeded 17 years in the 25 years preceding 1946.

Agua Fria River--The estimated average annual yield at the Lake Pleasant Diversion Dam for the 1921-1959 period was 52,000 acre-feet. The computed average annual yield was last exceeded in 1953; however, since that time diversions have averaged less than 16,200 acre-feet annually.

Gila River--The Gila River has storage and diversions above, and diversions below, the confluences of the Salt and Agua Fria Rivers.

Below the confluence of the Salt River there are canals diverting from the Gila River. It is estimated that about 100,000 acre-feet is available annually for diversion from tributary inflows, spills, and return flows from irrigated areas. Thus, the average annual yield in the Maricopa hydrologic study area is estimated to be about 1,117,000 acre-feet.

Above the mouth of the Salt River in the Pinal hydrologic study area the Ashurst-Hayden Dam diverts, for the San Carlos Project service area, stored water released from Coolidge Dam and uncontrolled flows from the San Pedro River. Average yield at the diversion dam is estimated to be 195,000 acre-feet annually.

Without regulatory storage, surface-water supplies in the Upper Gila hydrologic study area above Coolidge Dam are dependent on uncontrolled river flows. The Gila Decree has governed water diversions in the reach of the Gila River between Virden and the San Carlos Project since January 1936. Recorded diversions to the Duncan-Virden and Safford Valleys for the period 1937-1959 average 20,800 and 98,600 acre-feet, respectively. The annual consumptive use in the areas above the Duncan-Virden Valley has been estimated as 13,662 acre-feet, requiring an estimated diversion of about 4 acre-feet-per-acre, or 28,000 acre-feet annually. The estimated total diversion in the Upper Gila hydrologic area would average about 147,000 acre-feet annually.

San Pedro River--The drainage area of the San Pedro River includes some 700 square miles in Mexico. At Charleston damsite the runoff averaged 45,000 acre-feet annually for the period 1921-1959. About 50 percent of this runoff resulted from high-intensity, short-duration summer storms. The estimated runoff at the mouth of the San Pedro is about 60,000 acre-feet annually.

Records of river diversions are not available; however, an average annual diversion of approximately 4,000 acre-feet is indicated. The highly fluctuating nature of the runoff, with large sediment load and a lack of regulatory structures, has discouraged diversions. Channel erosion has also entrenched the stream to make diversions difficult.

Ground-water sources--The alluvial valleys of the Gila River Basin afford ground-water reservoirs which are being used excessively to supplement the available surface supplies.

The project area encompasses a group of structurally controlled depressions formed in crystalline and metamorphic rocks. These valleys are believed to be bounded by faults of large displacement subsequently obscured by erosion and alluviation. Commonly, along the base of the mountain fronts small bedrock masses protrude through the relatively thin overlying alluvium. These areas, termed pediments, represent erosional bedrock surfaces having, roughly, a slightly steeper slope than the valley fill. Valleyward, the pediments terminate abruptly at the structural boundaries.

The ground-water reservoirs comprising the individual structural basins are a heterogeneous complex of clay, silt, and fine sand, enclosing lenses and tongues of medium-course sand and gravel. In several basins, logs of deep drill holes indicate that the earliest deposits consist of conglomerates of volcanic and granitic material. These deposits are overlain by mostly fine-grained lakebed materials commonly exhibiting individual strata of blue, green, or gray color indicative of a reducing environment. Overlying the lakebed deposits are the younger, coarser sediments constituting the most permeable section of the reservoir.

The total thickness of the section ranges from 0 to 5,000 feet or more from the margins of the valleys to their deepest parts.

Ground water contained in the younger sediments constitutes the main supply for agricultural and domestic use in all of the basins, although recent deep-well development has penetrated the lakebed deposits into the older sediments, tapping permeable zones in both deposits. Generally, the deeper aquifers are not as productive because of a greater degree of cementation and finer-grained texture.

Ground water is ideally thought of as occurring under water table (unconfined) or artesian (confined) conditions. Perfect examples of either type are rare in nature. Because of the heterogeneity of the alluvial deposits in the various basins, confinement is merely a matter of degree. There is a sufficient hindrance of hydraulic continuity between aquifers so that a head differential occurs during periods of heavy pumping, but during periods of little-to-no discharge hydraulic heads recover to a common level with the water table. Such a condition is generally called semiconfined. All three of these conditions are thought to exist within the proposed project area.

From a water supply analysis standpoint, the surface and ground waters of the Gila River Basin are considered to be one and the same. There is believed to be little subsurface inflow to the ground-water basins. These basins store whatever surface flows are percolated. In this light, the ground-water basins provide the same basic function which is normally associated with surface reservoirs; i.e., they store streamflow during periods when water use is less than runoff for later use during periods when the use-runoff relationship is reversed. In the case of the Central

Service Zone, the ground-water reservoir provides both short- and long-term regulation of surface flows.

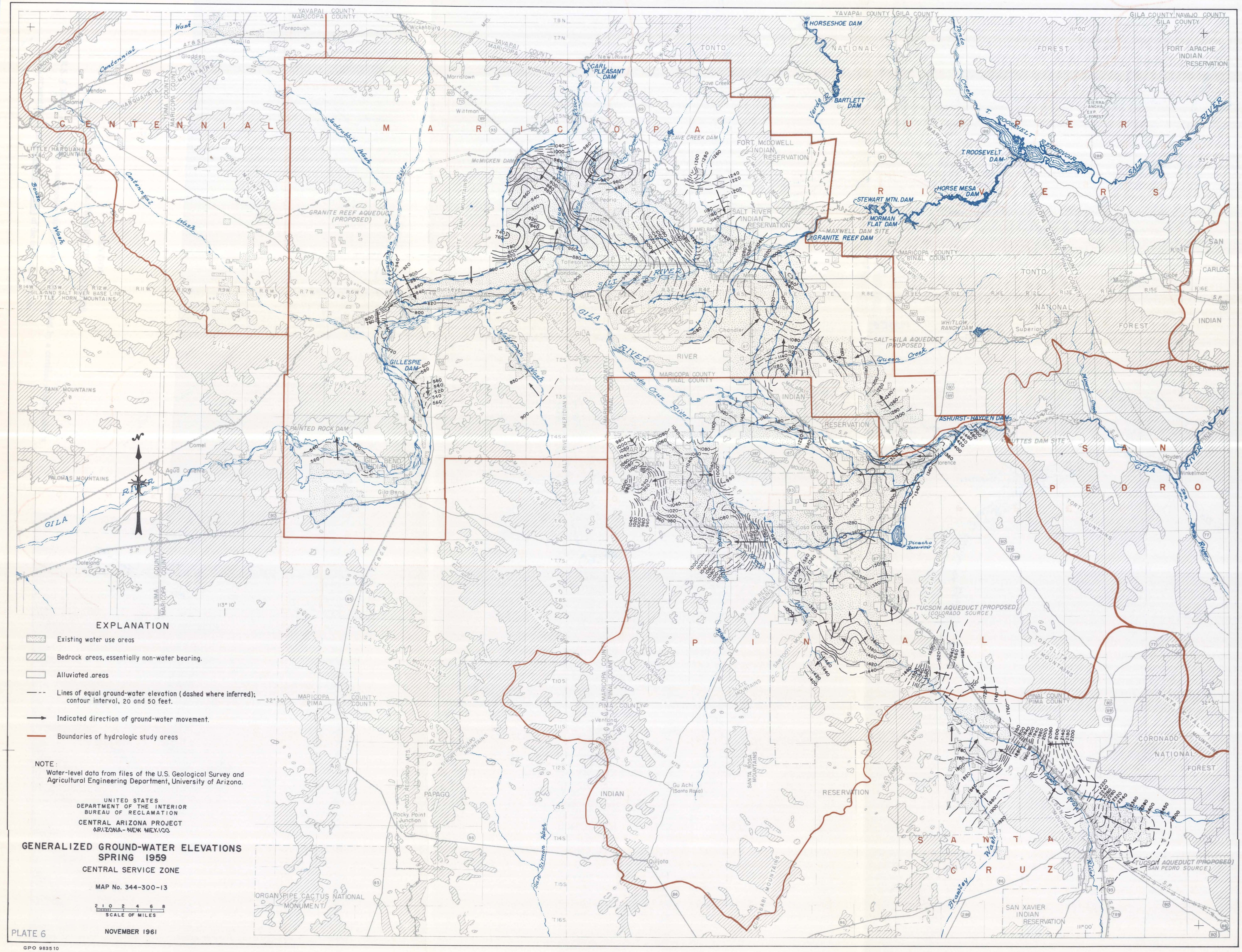
On a short-term basis, winter and summer stormflows which occur beyond the capacity for direct diversion escape past the dams, and that portion not lost to evaporation and phreatophytes percolates to the underground reservoir. It is this type of operation which is the basis for the statement that substantially all of the surface inflow to the area is presently being used, as there has been essentially no escape from the basin since 1941.

It is in the long-term storage function of the ground-water reservoir wherein lie the water problems of the area. The annual use of ground water is far greater than the annual recharge, and has been for many years. In terms of the quantities involved during the past 5 years, water requirements are estimated to have averaged about 4,490,000 acre-feet annually. Comparison of this present requirement with the average annual long-term surface supply of 1,020,000, as shown in table 3, indicates that ground-water reservoir must have supplied the difference, or 3,470,000 acre-feet annually. Ground-water annual safe yield, expressed as gross pumpage, has been estimated to be about 1,510,000 acre-feet, or 1,280,000 acre-feet after appropriate allowance for conveyance losses. Thus, the average annual water supply deficiency, on the basis of long-term ground-water and surface-water yields, is estimated at about 2,190,000 acre-feet. The net result has been a general overdraft on the ground-water reservoir and a constant lowering of ground-water levels. This overdraft has enabled an agricultural economy to continue, although on a changing economic basis. Irrigated acreage of the lower payment capacity crops is going out of production as the water level drops and pumping costs increase. To be sure, there is some replenishment of water each year as unconsumed winter and summer runoff goes into storage, but this replenishment is obscured as these same flows, and more, are pumped during the growing season. On an annual basis, it has been many years since water supply has exceeded water use and hence much of the water being used to meet today's needs is being derived from streamflows stored in the ground-water reservoir many years ago.

Water level elevation contour maps are of great value in the study of ground-water conditions within individual basins and also on a regional basis, integrating numerous basins to illustrate the interrelationships of the basins. They show not only the elevation of the water surface, which can be compared with land surface elevation to obtain the depth to water, but also the direction of movement and the gradient producing the movement. The direction of ground-water movement in various basins is illustrated on plate 6. The more notable features on plate 6 are the pumping troughs in the Chandler-Gilbert-Mesa area, west of Picacho Reservoir, along the Stanfield-Maricopa area, and northwest of Phoenix in the Deer Valley and Beardsley areas.

Depths to water, spring 1959, and water level changes, 1952-1959, are shown on plate 7. Depths to water in the Central Service Zone range from 40 to 460 feet. Water level declines for the 7-year period range from 0 to 180 feet, with the more severe declines in the Stanfield-Maricopa, Magma, Deer Valley and Gilbert areas.

A continuing and rapid lowering of ground-water level has resulted in localized below-surface consolidation of valley alluvial fills.



EXPLANATION
Existing water use areas
Bedrock areas, essentially non-water bearing.
Alluviated areas
Lines of equal ground-water elevation (dashed where inferred); contour interval, 20 and 50 feet.
Indicated direction of ground-water movement.
Boundaries of hydrologic study areas
NOTE:
Water-level data from files of the U.S. Geological Survey and Agricultural Engineering Department, University of Arizona.
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CENTRAL ARIZONA PROJECT
ARIZONA-NEW MEXICO
GENERALIZED GROUND-WATER ELEVATIONS
SPRING 1959
CENTRAL SERVICE ZONE
MAP No. 344-300-13
SCALE OF MILES
NOVEMBER 1961
PLATE 6
C E N T E N N I A L
M A R I C O P A
U P P E R
S A L T
R I V E R
S A N
P E D R O
P I N A L
S A N T A
C R U Z
HORSESHOE DAM
BARTLETT DAM
CARL PLEASANT DAM
T. ROOSEVELT DAM
HORSE MESA DAM
STEWART MTN. DAM
MORMAN FLAT DAM
GRANITE REEF DAM
GILLESPIE DAM
PAINTED ROCK DAM
ASHURST-HAYDEN DAM
GILA RIVER
SALT RIVER
Santa Cruz River
GRANITE REEF AQUEDUCT (PROPOSED)
SALT-GILA AQUEDUCT (PROPOSED)
TUCSON AQUEDUCT (PROPOSED) (COLORADO SOURCE)
TUCSON AQUEDUCT (PROPOSED) (SAN PEDRO SOURCE)
Picacho Reservoir

GPO 983510

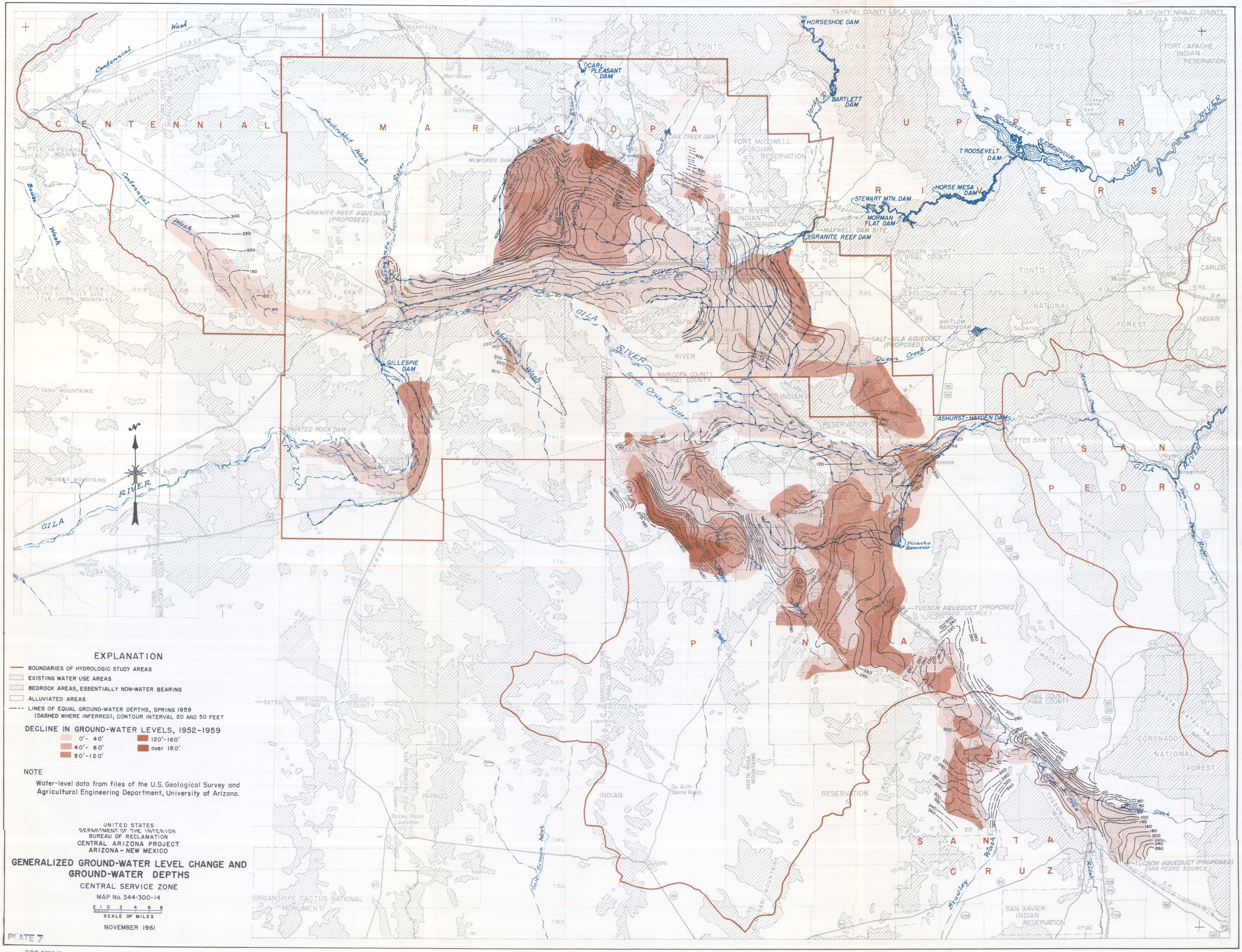


PLATE 7

GPO 983510

Manifestations of this subsidence have been increasingly noticeable for the past several years throughout the Central Service Zone. This phenomenon is recorded in the instances of earth fissures, collapsed well casings, differential movement between benchmarks, and ground settlement under pump base slabs. Subsidence of over 3 feet in local areas has been identified. Deep subsidence will continue as the dewatering and consolidation of the fine-grained sediments occur.

Quality of Water

The surface and ground waters of the Central Arizona Project study areas are characterized by a wide range in the type and concentration of chemical constituents, both areally and vertically. This variance is not only related to the differences in the quality of surface waters that are used directly, or as recharge to the ground-water reservoirs, but also to chemical changes that occur within the ground-water reservoir proper.

The quality of local surface waters will remain about the same as at present. Typical chemical analyses indicate the waters are of adequate quality for agricultural and municipal and industrial uses.

Analyses of ground water indicate that moderate concentrations of dissolved solids are prevalent, except for localized areas of highly mineralized water caused either by deep-seated sources or where constructions or barriers impede subsurface ground-water movement out of basins. With continuing overdraft, the areas of highly mineralized waters are indicated to be increasing in areal extent. Generally, the ground waters are considered to be good-to-excellent for irrigation and are satisfactory for domestic and industrial use, except for small local areas.

Water Supplies for the Central Arizona Project

Development within the Gila River Basin has effectively integrated the surface-water and ground-water supplies available, which now provide an average annual yield estimated at about 2,300,000 acre-feet at point of use. The Colorado River offers the most readily available source from which to augment the supply in the Central Arizona Project area.

Assumed water supply from Colorado River--As in the original report, the present Central Arizona Project plan assumes a diversion quantity of 1,200,000 acre-feet annually to be pumped from the Colorado River at Havasu Reservoir. This quantity, assumed and subject to settlement of litigation, would provide a critically needed water supply augmentation. Seepage and evaporation losses would reduce to 1,020,000 acre-feet the primary direct Colorado River deliveries into the Central Arizona Project area.

Water supply under assumed project conditions--The Central Arizona Project would be a conveyance and storage system designed to convey and regulate those flows of the Colorado, Salt, Verde, Gila, and San Pedro Rivers, which are available for control and use. Under assumed project conditions, higher conveyance and distribution efficiencies are expected through lining of canals and improved irrigation practices. The location of the various features required is shown on plates 1 and 2. Physical data relating to them are presented in the Plan of Development chapter.

Colorado River water pumped into the aqueduct system would flow to the Central Service Zone at a uniform rate during 11 months annually. Turnout service to contracting entities along the conduit line would provide a base supply. Regulatory storage available in Maxwell Reservoir and on the Salt-Gila Aqueduct would be able to adjust minor variations in demand rate and develop the highest efficiency of the aqueduct.

From the augmented supply applied as irrigation water there would be deep percolation to the ground-water basins, increasing the safe yield under project conditions. With the additional municipal and industrial uses, effluent flows from project sources would provide an additional quantity estimated at 150,000 acre-feet which may be processed for ground-water recharge or direct irrigation diversion.

Assuming 1,200,000 acre-feet is diverted from the Colorado River, it is estimated that the Central Arizona Project would augment the present area supply by about 1,020,000 acre-feet through direct deliveries. Water conservation, through operation of the Buttes Reservoir and other Gila River storage, would add 50,000 acre-feet. There would be additional water in the area by reuse of deep percolation, waste, and effluent flows, although the amount thereof has not been precisely evaluated in this report.

The coordination of conservation and control facilities involving surface-water supplies would be essential to realization of the optimum benefits from the introduction of an import supply. The construction of the Maxwell, Buttes, Charleston, Hooker, and Camelsback, or alternative reservoirs, would provide operational and regulatory control of surface water above the upstream places of use and make exchanges possible. The additional regulation obtained would make possible higher utilization efficiencies in the conveyance and distribution systems. Control of stormflows and improvement of irrigation practices could provide an additional usable water supply.

Through this hydrologic coordination, comprehensive water conservation would be achieved by the combination of water salvage through channel improvement, storage control, and watershed soil and moisture programs. For maximum project benefit, direct use of the import water as a base flow would be necessary, requiring seasonal variation in ground-water pumping and storage reservoir draft.

Within the Maricopa area, the regimen change from agricultural to urban uses will alter the hydrologic cycle. Flows which formerly reached the ground-water reservoir by deep percolation of applied water will, in the future, become increasingly available at treatment plant outfalls. The magnitude of these import and local supply return flows may approach 650,000 acre-feet annually under full project conditions. Flows from this source would be of a quality adequate for agricultural purposes, and would probably be of sufficient magnitude to supply agricultural lands within economical transport distance. This water, utilized as a surface supply, would leach through the soil and carry excessive dissolved solids through and below the root zone. Drainage of the lands upstream from the barrier at Gillespie Dam would require a system of open drains and drainage wells. The magnitude of future drainage water discharge over Gillespie Dam has not been evaluated in this report.

Canalside water delivery quantities shown in table 5 indicate the potential project water service to water needs of the Central Service Zone. These quantities are used for establishing facility design requirements and for economic analyses. Subsequent modifications may be expected after later determinations are made on distribution to various areas of need.

Table 5.--Assumed project water supply and service

Source	Average Annual Supply (acre-feet)	
Colorado River (Import)	1,020,000	
Gila River	50,000	
Total	1,070,000	
Service	**Deliveries 1/ (acre-feet)**	**Deliveries 2/ (acre-feet)**
Municipal and Industrial	256,000	312,000
Agricultural	814,000	758,000
Total	1,070,000	1,070,000

1/ Average annual at canalside--50-year period.

2/ Annual canalside--years 26 through 50.

Water rights--It is not presently contemplated that existing rights to water service would be altered when project operating conditions occur. Water service would be provided through the use of integrated facilities and coordinated operation. The concept of integration of upper watershed sources with the import supply was discussed in the original report. The continued economic growth of the Central Arizona Project area adds emphasis to the necessity for integration of all sources and potential future developments. Inasmuch as water exchange is a present practice within the project area, additional exchanges to further hydrologic integration have an accepted and sound basis for postulating future project operating conditions.

CHAPTER IV

PLAN OF DEVELOPMENT

CHAPTER IV - PLAN OF DEVELOPMENT

General

To make Colorado River water available for the Central Arizona Project area, the aqueduct system starting from Havasu Reservoir on the Colorado River at Parker Dam would raise and deliver the water directly into the Central Service Zone. The relation of facilities of the Central Arizona Project to existing facilities is shown on the General Location Map (plate 1). By these facilities, the imported waters and the water resources of the Gila River Basin would be coordinated. Through hydrologic coordination and exchanges, vital and essential basinwide water uses would be possible for continuing economic health. The project is designed to make use of powerheads for the generation of electric energy for commercial and irrigation uses. Additional purposes would include flood control, recreation, fish and wildlife conservation, sediment retention and salinity control.

Project Facilities

The keystone facility for the Central Arizona Project is the Bridge Canyon Dam, Reservoir and Powerplant which would provide the energy for pumping to the Central Service Zone. The imported water would make exchanges possible for the Upper Tributaries Zone.

Present conditions within the Central Service Zone have dictated the modifications of the facilities presented in the original report. Costs have been revised with additional data to reflect current conditions. Modifications of the aqueduct system are required to meet the rapid and extensive urbanization and agricultural growth. The primary facilities for the Central Service Zone, as shown on plate 2, are:

Havasu and Hassayampa Pumping Plants

Granite Reef Aqueduct

Salt-Gila Aqueduct and Pumping Plant

Maxwell Dam and Reservoir

Tucson Aqueduct--(Colorado source)

Buttes Dam and Reservoir

Within the Upper Tributaries Zone, the growth of the Gila River Basin economy, since the original report, is causing increasing water demands. Minor water control and conservation facilities are being planned and constructed by the Bureau of Land Management and the Soil Conservation Service. The Corps of Engineers has recently reported on the authorized channelization of the middle Gila River. A potential flood control storage reservoir at the Camelsback site has also been proposed by the Corps of Engineers. The integration of a facility at the Camelsback site into the basin plan may be found desirable during continuing studies as a means to provide the essential water supplies and regulation for these upstream areas. Facilities included for the Upper Tributaries Zone in this appraisal of the proposed Central Arizona Project are shown on plate 1, and are:

Hooker Dam and Reservoir

Charleston Dam and Reservoir

Tucson Aqueduct--(San Pedro source)

Potential works not included in the proposed plan are water reuse facilities and potential water salvage and exchange facilities now being investigated.

Bridge Canyon Dam and Powerplant--Bridge Canyon Dam would be located in the Lower Granite Gorge of the Colorado River, approximately 53 airline miles northeast of Kingman, Arizona, and about 20 miles from the nearest paved highway and railway. The site is at the upper end of Lake Mead, 117.5 miles upstream from Hoover Dam.

The concrete thin-arch dam, rising 673 feet above streambed with a crest length of 1,950 feet, would require about 2,650,000 cubic yards of concrete. The 1,500,000-kilowatt-capacity powerplant would have six turbines and generators. It is estimated that the average annual energy generation at this plant would be about 5,800,000,000 kwh.

Storage of water in the reservoir to its normal water surface elevation would raise the water surface through the Grand Canyon National Monument for a distance of 39 miles. Upstream from about the mouth of Havasu Canyon, the monument and Grand Canyon National Park share a common boundary along the river. At the lower end of the park the water surface would be raised about 89 feet above natural conditions at normal flow. In the event of infrequent flood conditions the surface of the river would be somewhat higher for periods of short duration. This depth would gradually lessen going upstream from Havasu Canyon until the effect becomes imperceptible at about 17 miles under all conditions of the flow.

Pumping Plants--Starting from the deep water Bill Williams River arm of Havasu Lake, the three in-series Havasu Pumping Plants, each with a total capacity of 1,890 c.f.s., would have a total dynamic lift of 995 feet. The discharge from these plants then flows by gravity through the saddle between the Ranegras and Harquahala Plains to the Hassayampa Pumping Plant. The Hassayampa Pumping Plant would be located northwest of the White Tank Mountains at the Hassayampa River. This plant, with a 119-foot total dynamic lift, would enable the aqueduct to skirt the expanding Phoenix urbanization between the Beardsley area and Granite Reef.

Granite Reef Aqueduct--The Granite Reef Aqueduct would transport water diverted from Lake Havasu by the Havasu Pumping Plants, 219 miles to Granite Reef on the Salt River. The aqueduct's designed capacity of 1,800 c.f.s., would be provided by a concrete-lined canal having a bottom width of 22 feet, a depth of 15.15 feet, and side slopes of $1\frac{1}{2}$:1. Three tunnels and three siphons would be located in the first 19 miles of aqueduct location in the extremely rough, rocky terrain of the Buckskin Mountains lying along the south bank of Bill Williams River. Throughout its length to the Hassayampa River, the aqueduct would pass along the southern slopes of the Little Harquahala and Big Horn Mountain ranges and across flat desert land between these ranges. From the Hassayampa River Pumping Plant the aqueduct would pass to the north of White Tank Mountains by means of a 6-mile tunnel, then it would traverse to its terminus at Granite Reef Dam.

Power drops--Along the Granite Reef Aqueduct, the major turnouts would be through power drops to recover a portion of the energy previously used. The Agua Fria power drop would use 94 feet of head for 3,000 kw of capacity produced by flows released for use in the central Maricopa area. The Granite Reef power drop, with 113 feet of head, would have 3,500 kw capacity produced by flows diverted to the existing Salt River Project canals or to Maxwell Reservoir.

Salt-Gila Aqueduct and Pumping Plant--The 1,275 c.f.s. capacity Salt-Gila Aqueduct would receive water from an 80-foot total dynamic lift pumping plant at the terminus of the Granite Reef Aqueduct and convey it 66.5 miles through a concrete-lined canal having a bottom width of 20 feet, a depth of 13.2 feet and side slopes of $1\frac{1}{2}$:1. In the Pinal area, connections would be made with the existing San Carlos Project facilities. Additional turnout facilities would be constructed for systems serving lands presently serviced by groundwater pumping only and presently not organized as irrigation districts. A turnout for the Tucson Aqueduct (Colorado source) would be provided.

Maxwell Dam and Reservoir--Located on the Salt River just downstream from its junction with the Verde River, the Maxwell Dam (formerly McDowell) would be integrated with the present Salt River Project storage system. Sediment-laden stormflows originating on tributaries below Bartlett and Stewart Mountain Dams would be regulated and controlled. Coordinated with the Granite Reef Aqueduct it would provide terminal storage as needed, either by retention of Salt-Verde flows, or by lift pumping from the aqueduct. In its multiple-purpose role it would, as an afterbay, reregulate releases from upstream reservoirs and develop a powerhead, improve the Salt River Project operating conditions by removing sediment, create a recreational area with fish and wildlife conservation uses and, in combination and coordination with the upstream reservoirs, provide storage to meet the flood control requirements of the Salt River through the Phoenix area.

Maxwell Dam, an earthfill structure rising 169 feet above streambed, would have a crest length of 5,180 feet at elevation 1494. The reservoir would provide conservation and sediment storage--188,000 acre-feet; controlled flood storage--672,000 acre-feet; and flood surcharge--270,000 acre-feet.

Maxwell Power-Pumping Plant--Operational flexibility essential to maintain the Granite Reef Aqueduct at its maximum flow rate during low demand periods in the winter, and following heavy summer storms, would be provided by a power-pumping plant with a reversible flow canal between Maxwell Dam and the headworks of the Arizona and South Canals at Granite Reef. This dual operation (pump-storage) plant operating at a rated head of 75 feet would produce

11,000 kw of generating capacity or would pump 1,400 c.f.s. of Colorado River water from the Granite Reef Aqueduct into storage.

Tucson Aqueduct (Colorado source)--An aqueduct to deliver 100,000 acre-feet annually to the Tucson metropolitan area would originate in the vicinity of the San Carlos Project's Picacho Reservoir. This municipal supply would be conveyed 56 miles through a 150 c.f.s. capacity pipeline and would be lifted about 920 feet against a total dynamic head of 1,130 feet.

Buttes Dam and Reservoir--Investigated and reported previously as a separate facility, the Buttes Dam and Reservoir is included as an integral part of the Central Arizona Project. An earthfill structure at the Buttes site rising 210 feet above streambed would form a reservoir of 366,000 acre-foot capacity. Conservation storage would be 100,000 acre-feet through exchange coordination. Some 266,000 acre-feet would be initially used for sediment and flood control purposes.

Charleston Dam and Reservoir--On the San Pedro River between Tombstone and Fort Huachuca, a concrete gravity structure rising 158 feet above streambed with earthen wing dams would create a 238,000 acre-foot capacity reservoir. Water conservation would be provided through exchanges. Recreation, fish and wildlife uses, sediment detention, and flood control benefits would also accrue.

Tucson Aqueduct (San Pedro source)--From the Charleston Reservoir, a conduit to convey about 12,000 acre-feet annually to Tucson and vicinity has been retained from the original report. This supply is capable of being used in the eastern Tucson area, or other neighboring municipal and industrial areas but, in coordination with the Colorado River source, it may be found desirable to maintain this San Pedro source for use in the San Pedro Basin.

Hooker Dam and Reservoir--Hooker Dam on the upper Gila River in New Mexico would create a 98,000 acre-foot capacity reservoir above the Cliff-Gila area by means of a concrete gravity structure rising 222 feet above streambed. This reservoir, through exchanges, would provide water conservation, fish and wildlife uses, recreation, sediment detention and flood control. Additional study is indicated to insure optimum development through channel vegetation control and soil and moisture conservation, and to assist in meeting future municipal and industrial water and power requirements in New Mexico.

Transmission system--The project plan contemplates the construction of a high voltage transmission system which would make possible the delivery of power and energy to project pumps, sale of commercial power and energy at load centers, and integration of operations at Bridge Canyon with other plants on the Colorado River for maximum utilization of the hydroelectric power potential. The transmission lines would interconnect Bridge Canyon Powerplant with the Havasu Pumping Plants, load centers in the power market area, and the Parker-Davis and Colorado River Storage Project transmission systems. Substations and switching stations would be provided as required. Excess capacity in existing transmission and distribution lines would be utilized wherever practicable to serve the smaller project pumps and power drops and reach the smaller, more remote load centers. Over this interconnected system, the minor generation of the power drops would also be integrated.

Distribution systems--In all areas, an improvement in conveyance and distribution system efficiencies is essential to obtain optimum water development and use. Widely varying capabilities and conditions exist among and between the various organized districts and unorganized areas. Lining of presently unlined and future conveyance and distribution systems would be provided by, and would be the responsibility of, existing or to-be-formed districts. This is particularly applicable in the Pinal, Upper Gila, and San Pedro hydrologic areas.

The existing facilities of the Salt River and San Carlos Projects, the Maricopa County Municipal Water Conservation District, and several other districts, are based on integrated surface- and ground-water supplies. Rehabilitation and lining of conveyance and distribution works in progress by these districts to improve their system efficiencies would be completed under project conditions.

Distribution systems costs for concrete-lined or underground pipe systems have been estimated on the basis of cost values per acre of area under system service because water assignments to specific district areas for design data purposes are inappropriate at this time. A total area of about 500,000 acres is considered to require distribution facilities.

Drainage and reuse facilities--The control, use, and disposal of the return and effluent flows in an arid climate will require additional study to properly evaluate the benefits accruing from reuse with the physical facilities and attendant costs. Drainage facilities contemplated as part of the project works are open drains and drainage wells upstream from Gillespie Dam.

Additional works--Growing and potential water needs of the area require facilities in addition to those included in the project works. Facilities of other agencies, which could be integrated operationally into the Central Arizona Project, are the authorized channelization by the Corps of Engineers in the Safford Valley and middle Gila River, the proposed Camelsback Reservoir, and the continuing soil and moisture conservation programs of the Bureau of Land Management and Soil Conservation Service. Natural channels used for water transport are basically canals and, when used as part of a system, their efficiency should be commensurate with their use. Lining of presently unlined conveyance and distribution systems and river channelization in the Lower Colorado River Basin are essential.

Project Operations

The full operation of project facilities would make possible direct diversion of Colorado River water into the Central Service Zone and to the city of Tucson. The companion storage features would provide desired regulation of existing water supplies and make possible exchange arrangements to supply the Upper Tributaries Zone in Arizona and New Mexico with additional water; provide a power supply for project pumping and for commercial sale; and, in addition, accomplish the other multipurpose benefits from flood control, fish and wildlife, recreation, and sediment control. The designation of specific works to serve all of the variable needs within the areas studied is considered beyond the scope of this report and is a matter for further study.

Power Requirements, Service, and Production

The estimated installed capacity and average energy generation at project powerplants are estimated to be as follows:

Plant	Installed Capacity (kilowatts)	Average Annual Energy Generation (1,000 kwh)
Bridge	1,500,000	5,800,000
Agua Fria	3,000	13,600
Granite Reef	3,500	16,340
Maxwell	11,000	39,370
Total	1,517,500	5,869,310

With allowance for transmission losses, the power and energy available at load centers are estimated to be 1,365,750 kw and 5,399,765,000 kwh annually. Of these amounts, about 258,450 kw and 1,849,570,000 kwh would be needed for project pumping. The remaining 1,107,300 kw and 3,550,195,000 kwh would be available for commercial sale. It is recognized that, during years of low water supply, supplemental off-peak energy may be purchased in order to permit supplying project pumps and firm energy for commercial power customers. Conversely, in years of above-average water supply there would be energy for commercial sales in excess of the firm energy shown above. Based on a preliminary analysis, it is estimated that the surplus energy would average about 400,000,000 kwh annually and that the purchases would be a like amount plus transmission losses.

Power Market Requirements

In the "Power Market Survey - Colorado River Storage Project," prepared by the Federal Power Commission in June 1958, it was estimated that by 1970 the electric powerload in Arizona would have reached about 2,630,000 kw and that the load in southern Nevada would be about 541,000 kw. By 1980, the loads were estimated to be about 4,290,000 kw and 826,000 kw, respectively, representing a total load increase in the two areas of 1,985,000 kw in the 10-year period, or about 198,000 kw per year. Recent information received from the Federal Power Commission indicates that in the 1970-1980 period the load in southern California is expected to increase from 11,300,000 kw to 17,700,000 kw, an annual increase of 640,000 kw per year. These increased capacity requirements must be met by construction of feasible hydroelectric power developments, as well as through construction of thermal electric powerplants which depend at present upon the availability of an adequate supply of nonrenewable fuels. The Colorado River is the last major source of hydroelectric power development in the Pacific Southwest. It is apparent that a ready market exists for any hydroelectric capacity that can economically be developed on the river.

Cost Estimates

The facilities required under the plan of development consist of storage and balancing reservoirs, canals and pipelines, pumping plants, powerplants, and power transmission lines. It is contemplated that these facilities will be constructed and operated under terms of Reclamation law. The plan also includes water distribution systems, although the construction and operation of these features are considered to be the responsibility of the water users.

The construction cost of the Government-constructed project facilities is estimated to be $971,329,000. Distribution systems to be provided by the water users will cost an additional $100,000,000.

Construction considerations--Much of the data used in preparing the cost estimates for the Central Arizona Project features were collected in the field by means of field surveys, surface and subsurface geologic investigations, and by visual inspection of the proposed construction sites. These field investigations indicated that the construction of the various features of the plan, at the sites and in the sizes proposed, will not present any unusual construction problems. None of the features would be of unprecedented size.

Design and cost considerations--There were many factors considered in the preparation of cost estimates for the features of the Central Arizona Project. Some of the factors are general in nature in that they would influence the cost of all features of the plan, while others are more specific since they would affect the costs of individual works only. Some of the more important general cost-influencing factors which were considered are: accessibility of rights-of-way, probable flash floodflows from local drainages, excavation and foundation conditions, sources of construction materials, the relocation of existing facilities, and the availability of housing and community facilities for the construction workers.

Designs and estimates for Bridge Canyon Dam and Powerplant and Buttes Dam are of feasibility grade, while designs and estimates of all other project features are of reconnaissance grade.

The specific cost-influencing factors which were considered pertain to the type of canal linings required and the nature and extent of the power transmission lines. In the case of the canal linings, the cost estimates contained in this report consider that all waterways would be concrete lined. Cost estimates for the power transmission lines are based on a Government-constructed system which would interconnect Bridge Canyon Powerplant with the Havasu Pumping Plants, load centers in the power market areas, and the Colorado River Storage Project and existing Parker-Davis Project transmission systems. The Hassayampa, Maxwell, Salt-Gila and Tucson Aqueduct Pumping Plants would utilize excess capacity in existing transmission and distribution lines wherever practicable.

The distribution system needs of lands in the Central Arizona Project area are varied. Some areas have, or are in the process of constructing, efficient water-saving, concrete-lined systems. Others are in need of rehabilitation, and still others have none at all. In order to satisfy these varying needs, it has been considered a matter of local responsibility to provide an adequate distribution system and to repay its costs. The repayment of cost of these distribution facilities is treated as a farm budget allowance in computing payment capacity for project water delivered at aqueduct canalside.

Capital cost estimates--The estimated construction costs shown on tables 6 and 7 for the various features of the Central Arizona Project include feasibility grade estimates for the Bridge Canyon Dam and Powerplant and Buttes Dam, and reconnaissance grade estimates for all other project features. These estimates are based on unit prices prevailing in July 1961. The costs shown include an allowance for contingencies, together with the cost required to

Table 6

Form PF-1
(3-57)
Bureau of Reclamation

OFFICIAL ESTIMATE

Project: CENTRAL ARIZONA

Date of Estimate: December 1961

Sheet 1 of 1

Prepared by: ____ Approved by: ____

Cost Classification (1)	DESCRIPTION (2)	Quantity (3)	Unit Cost (4)	Total Estimate (5)	Labor and materials by contractor (6)	Materials and Supplies by Govt. (7)	Labor by Government Forces (8)	Service Facilities (9)	Investigations, Engineering and Other Costs (10)	Previous Official Estimate (11)
	SUMMARY									
01.01	Bridge Canyon Dam and Reservoir	3,710,000 af		119,440,000						
.02	Maxwell Dam and Reservoir	860,000 af		31,865,000						
.03	Buttes Dam and Reservoir	366,000 af		29,432,000						
.04	Hooker Dam and Reservoir	98,000 af		28,128,000						
.05	Charleston Dam and Reservoir	238,000 af		15,974,000						
03.01	Havasu Pumping Plant No. 1 TDH=315'	1,800 cfs		10,890,000						
.02	Havasu Pumping Plant No. 2 TDH=435'	1,800 cfs		14,180,000						
.03	Havasu Pumping Plant No. 3 TDH=245'	1,800 cfs		14,180,000						
.04	Hassayampa Pumping Plant TDH=119'	1,800 cfs		12,730,000						
.05	Salt-Gila Pumping Plant TDH= 80'	1,275 cfs		5,120,000						
.06	Tucson Pumping Plant (San Pedro Source) TDH=331'	18 cfs		240,000						
.07	Tucson Pumping Plant (Colorado Source) TDH=1130'	150 cfs		6,170,000						
05.01	Granite Reef Aqueduct 219.2 miles	1,800 cfs		222,310,000						
.02	Salt-Gila Aqueduct 66.5 miles	1,275 cfs		31,800,000						
.03	Maxwell-Granite Reef Canal 2.8 miles	3,650 cfs		3,301,000						
.04	Buttes Canal 3.5 miles	1,200 cfs		2,011,000						
.05	Tucson Aqueduct (San Pedro Source) 68.6 miles	18 cfs		15,528,000						
.06	Tucson Aqueduct (Colorado Source) 56.0 miles	150 cfs		35,860,000						
07.01	Drainage System			10,500,000						
11.01	Bridge Canyon Power Plant	1,500,000 kw		140,530,000						
.02	Maxwell Power-Pumping Plant	11,000 kw		5,906,000						
.03	Agua Fria Power Drop	3,000 kw		1,248,000						
.04	Granite Reef Power Drop	3,500 kw		1,510,000						
13.01	Transmission System			189,690,000						
15.01	General Property 1/			14,523,000						
.02	Recreation Facilities			8,263,000						
	TOTAL CONSTRUCTION COST FOR ALLOCATION			971,329,000						
	Distribution System Costs 2/ 500,000 acres @ $200/ac.			100,000,000						
	TOTAL PROJECT CONSTRUCTION COST			1,071,329,000						

1/ Includes: Permanent operating facilities, temporary camp, O&M housing, and service facilities at Bridge Canyon Dam.

2/ These costs to be borne by irrigation entities requiring distribution systems and covered by individual repayment contracts or constructed by local interests. Allowance made in farm budgets to recognize this additional required repayment.

GPO 845720

LEGEND: Types of Activity

Preconstruction — Construction

LINE NO.	CLASS AND ACCOUNT	PROGRAM ITEM	QUANTITY	UNIT	ESTIMATED TOTAL	TOTAL TO JUNE 30, 1965	FISCAL YEARS 1	2	3	4	5	6	7	8	9	10	BALANCE TO COMPLETE	ESTIMATED COMPLETION DATE	LINE NO.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
1		Irrigation Service Land - New	None																1
2		Irrigation Service Land - Supplemental	1,162,000	ac															2
3		Municipal and Industrial Water Supply	312,000	af															3
4		Power Development, Hydro	1,517,500	kw						11,000			506,500	500,000	500,000				4
5																			5
6	108	CONSTRUCTION PROGRAM																	6
7	.01.01	Bridge Canyon Dam	3,710,000	af	119,440,000	384,000	7,500,000	14,500,000	15,500,000	21,500,000	21,500,000	21,500,000	17,056,000						7
8	.02	Maxwell Dam	860,000	af	31,865,000	237,000	3,000,000	8,000,000	12,500,000	8,128,000									8
9	.03	Buttes Dam	366,000	af	29,432,000	356,000	400,000	265,000	9,435,000	11,400,000	6,000,000	1,576,000							9
10	.04	Hooker Dam	98,000	af	28,128,000	132,600					200,000	300,000	6,000,000	11,500,000	9,995,400				10
11	.05	Charleston Dam	238,000	af	15,974,000	150,000	180,000	180,000	3,000,000	7,000,000	5,494,000								11
12	.03.01-04	Havasu & Hassayampa Pumping Plants TDH=1114'	1,800	cfs	51,980,000	230,000	510,000	2,000,000	8,000,000	12,500,000	13,500,000	8,000,000	7,240,000						12
13	.05	Salt-Gila Pumping Plant TDH=80'	1,275	cfs	5,120,000	23,000				80,000	400,000	1,400,000	2,000,000	1,217,000					13
14	.06	Tucson Pumping Plant (San Pedro Source)TDH=331'	18	cfs	240,000	1,000				39,000	100,000	100,000							14
15	.07	Tucson Pumping Plants (Colorado Source)TDH=1130'	150	cfs	6,170,000	27,000						150,000	700,000	1,600,000	2,600,000	1,093,000			15
16	.05.01	Granite Reef Aqueduct 219.2 miles	1,800	cfs	222,310,000	984,400	2,000,000	3,000,000	52,000,000	48,000,000	43,000,000	43,000,000	30,325,600						16
17	.02	Salt-Gila Aqueduct 66.5 miles	1,275	cfs	31,800,000	141,000					400,000	1,600,000	12,000,000	17,659,000					17
18	.03	Maxwell-Granite Reef Canal 2.8 miles	3,650	cfs	3,301,000	24,000	48,000	200,000	1,400,000	1,629,000									18
19	.04	Buttes Canal 3.5 miles	1,200	cfs	2,011,000	24,000				100,000	570,000	1,317,000							19
20	.05	Tucson Aqueduct (San Pedro Source) 68.6 miles	18	cfs	15,528,000	69,000		200,000	800,000	3,600,000	6,200,000	4,659,000							20
21	.06	Tucson Aqueduct (Colorado Source) 56.0 miles	150	cfs	35,860,000	160,000						400,000	1,200,000	10,500,000	12,500,000	11,100,000			21
22	.07.01	Drainage System			10,500,000	47,000											10,453,000		22
23	.11.01	Bridge Canyon Powerplant	1,500,000	kw	140,530,000	433,000	2,000,000	2,000,000	10,000,000	30,000,000	30,000,000	30,000,000	18,500,000	11,000,000	6,597,000				23
24	.02	Maxwell Power-Pumping Plant	11,000	kw	5,906,000	44,000	600,000	2,100,000	2,100,000	1,062,000									24
26	.03-04	Aqueduct Powerplants	6,500	kw	2,758,000	12,000				30,000	200,000	1,200,000	1,316,000						25
26	.13.01	Transmission System			189,690,000	585,000	900,000	11,000,000	500,000	3,200,000	27,000,000	42,000,000	50,000,000	36,000,000	18,505,000				26
27	.15.01	General Property 1/			14,523,000	45,000	50,000	6,300,000	8,128,000										27
28	.02	Recreation Facilities			8,263,000	0			21,000	353,000	573,000	2,580,000	2,380,000	2,216,000	70,000	70,000			28
29																			29
30		TOTAL CONSTRUCTION COST			971,329,000	4,109,000	17,158,000	49,745,000	123,384,000	148,621,000	155,137,000	159,782,000	148,717,600	91,692,000	50,267,400	12,263,000	10,453,000		30
31																			31
32		Less Nonappropriation Transfers 2/			-1,857,000	-1,857,000													32
33	.06	Distribution System 3/	500,000	ac	100,000,000	0													33
34		TOTAL			1,069,472,000	2,252,000													34
35																			35
36																			36

Notes:

1/ Includes permanent operating facilities, temporary camp, O&M housing, and service facilities at Bridge Canyon Dam.

2/ Represents nonreimbursable investigation cost from Colorado River Development Fund, $1,527,000; contributions by the States of Arizona and New Mexico, $330,000.

3/ $100,000,000 for distribution system costs to be constructed as required and repaid under separate contract.

▲ Represents completion of construction on a feature.

▲ Represents completion of individual Bridge Canyon Powerplant generators. Transmission facilities scheduled to parallel generator completion.

HEP 1/26/62

Recommended: C A Pugh (Project Head) 12/14/61 (Date)

Recommended: A. B. West (Regional Director) 1-29-62 (Date)

Recommended: ______ (Director of Programs & Finance) ______ (Date)

Approved: ______ (Commissioner) ______ (Date)

Revised: ______ (Date) SHEET ___ OF ___ SHEETS

Form PF-2 DEC. 1956

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

CONTROL SCHEDULE
CENTRAL ARIZONA PROJECT
APPRAISAL REPORT DATA

Phoenix, Arizona (OFFICE) — Dec. 14, 1961 (DATE) — 3 (REGION)

☐ GENERAL INVESTIGATIONS ☐ OPERATION & MAINTENANCE
☒ CONSTRUCTION ☐ OTHER

Table 7

GPO 843937

meet investigation, engineering, administration, and supervision expenses. Table 7 also shows the estimated construction periods for the various features, together with the estimated overall sequence of construction for the entire project.

Operation, maintenance and replacement cost estimates--Estimated annual operation, maintenance, and replacement costs under full operating conditions are shown on table 8. These costs include allowances for the wages of operators, ditchriders, maintenance labor, and administrative personnel, together with the cost of maintenance and transportation equipment, office, warehouse and special facilities, and materials and supplies. They also include the cost of replacing project facilities at the end of their useful lives, the cost of furnishing project-use energy from Bridge Canyon Powerplant, and the storage-delivery charge from the Boulder Canyon Project.

Subsidiary Facilities

The construction of certain Central Arizona Project features would materially aid in the development of important and nationally beneficial subsidiary facilities. For example, the construction of Bridge Canyon Dam, with an access road from U.S. Highway 66 on the south, would provide opportunity for opening up one of the most scenic and inaccessible regions of the United States through an extension of the road from the dam, northerly to U.S. Highway 91. Such a road would not only provide unmeasured recreational benefits through access to the spectacular Lake Mead National Recreation Area and the Grand Canyon National Monument, but would also benefit the isolated northern Arizona strip country which presently is accessible to its own county seat and the balance of Arizona only by traveling through the States of Nevada or Utah. It is estimated that as much as $30,000,000 might be required to bridge the Colorado River at the

Table 8.--Annual operation, maintenance, and replacement cost.

Item	O&M	Replacement
Dams and reservoirs		
Bridge Canyon	$ 84,900	$ 13,800
Maxwell	17,900	-
Buttes	13,900	-
Charleston	12,500	-
Hooker	11,900	-
Aqueducts	1,554,000	-
Pumping plants	451,400	124,100
Bridge Canyon powerplant	1,500,000	323,200
Power drops	122,700	21,100
Transmission system	1,806,400	595,900
Recreation facilities	356,000	-
Permanent facilities	-	13,600
Storage-delivery charge 1/	300,000	-
Energy purchase	151,000	-
Total	$6,259,900 or	$1,091,700 or
Rounded	$6,260,000	$1,092,000

1/ Arizona Water Delivery Contract charge included in payout study but treated as a sunk cost in benefit-cost analysis where it is excluded.

dam and extend the access road to the north boundary of the National Recreation Area. If it should be determined that such a bridge and highway are to be included in the project plan, it is assumed that the cost would be assignable to recreation on a nonreimbursable basis and thus would not affect the payout analysis included in this report. It is pointed out, however, that if these facilities are included on a reimbursable basis there are insufficient surplus power revenues in the payout analysis for this purpose. Extensions of the road from the National Recreation Area boundary to existing highways could properly be left to cooperative efforts of the States of Arizona, Nevada, and Utah. Opportunities for similar subsidiary benefits are present on a smaller scale at nearly all project dams and reservoirs. The limited scope of present studies did not permit consultations with the National Park Service and the several affected states regarding their interest in these facilities.

CHAPTER V

ECONOMIC AND FINANCIAL ANALYSIS

CHAPTER V - ECONOMIC AND FINANCIAL ANALYSES

Previous chapters have presented the Central Arizona Project plan and described facilities associated with importation of an assumed quantity of additional water to the project area. This chapter presents the economic justification and financial feasibility of constructing the project. The economic justification is measured by comparing the costs required to construct and operate the Central Arizona Project works with the benefits which will result from construction of such works. The financial feasibility is measured by demonstrating the manner in which the costs of the project may be repaid.

Agricultural Economy

Although construction of the Central Arizona Project as presently envisioned would generate many benefits to the States of Arizona and New Mexico, the Lower Colorado River Basin, and the Nation as a whole, the principal objective of the original plan was, and still is, the stabilization and prevention of retrenchment of the agricultural economy of the project area. Without an imported supply of water, some irrigated lands will eventually have to be abandoned and urban developments resulting from the population increase in the area will encroach on other irrigated lands. The exact time and magnitude of these events cannot be foretold with any degree of certitude.

In order to evaluate the economic effects and payment capacity resulting from the imported water that could be delivered to existing developed farm land, the farm budget method of analysis has been employed. This method compares farm production costs, including investment in land, buildings, and necessary equipment, with gross returns to the farm to evaluate the economic productivity of the farm operation.

In making the farm budget analyses for the Central Arizona Project, studies of crop patterns, average yields, and other related items of a farm operation were analyzed for various areas that could receive project water. A total of 18 different analyses was made representative of anticipated future conditions. A weighted average, on the basis of various existing farm operating units, was then determined from these studies. These studies assumed that all irrigated lands would be served through a modern concrete distribution and lateral system. An allowance was made in the studies to provide revenue to pay costs for such works if not now constructed, or to provide a credit if they were already constructed. Similarly, estimates of water requirements and other production items were based on the assumption that modern irrigation practices would be followed throughout the project area.

The farm budget analyses were made on a generalized new land equivalent basis and did not attempt to evaluate, in detail, what would result to the farm operations and income if a supplemental amount of water was simply added to the existing supply. The method used assumes that all water on the farm has the same value, which often is not the case in a deficient water operation. For many crops, the last increment of water supplied results in the difference between success and failure and often would have a higher value than indicated by the more conservative method used.

On the basis of the farm budget analyses, the weighted average payment capacity for an acre-foot of water at canalside in the Central Arizona area was computed to be $12.53. Obviously, as this is a weighted average representative of all lands in the service area, certain lands will not have this high a repayment potential, whereas for other lands payment capacity will be higher. Actually, under present conditions many farms are now paying more per acre-foot for irrigation water than is reflected by this weighted average value.

Economic Justification

The Central Arizona Project, if constructed, would provide several different types of benefits to the economy and well-being of the area. The nature of these benefits, and the methods by which they were derived, are described in the following paragraphs. Derivation of the other major element required in showing economic justification--the project's cost--has been described in the preceding chapter and is summarized in table 6.

Irrigation benefits--By far the largest single type of benefit which would result from construction of the Central Arizona Project would be that resulting from the delivery of an additional supply of irrigation water to presently irrigated and developed lands. These irrigation benefits fall into three major divisions. Two of these, the direct and indirect benefits, are real and tangible in that they can be evaluated in monetary terms. The third, the general or public benefit, will be briefly described, but only the numerically evaluated benefits have been used in the benefit-cost comparison.

Direct irrigation benefits are measured as the increase in net farm income resulting from the application of project water to the irrigated lands in the project area. As discussed in the preceding section, in analyzing the agricultural effects of the imported water the study was based, and values determined, on an average value-per-acre-foot under a new land equivalent concept. If additional water is not provided to the agricultural lands of the project area, presently developed lands will be forced out of production. Thus, the imported water may be considered to serve the equivalent of new land to be placed in production. By this method of analysis, the average annual direct irrigation benefits resulting from the project water would be $17,094,000. Additional benefits would accrue from use of return flows and sewage effluent from the cities and industries for agricultural purposes. However, in this report no attempt has been made to assign a monetary value for these additional benefits.

The second major division of irrigation benefits is that which would result from the movement of additional farm products through the channels of trade and industry after leaving the farm. These indirect benefits are, in effect, a measure of the increased net income of persons other than the farmer which can be attributed to the additional water supplies. Indirect benefits were evaluated through the use of appropriate factors applied to the increase in farm sales derived from the representative farm budgets. Since much of the agricultural produce of the Central Arizona Project area is marketed on a nation-wide basis, and because a substantial amount of local processing is involved, the indirect irrigation benefits would be an important segment in the economic justification of the Central Arizona Project. The average indirect irrigation benefits have been evaluated as being $26,048,000 annually.

Because the general, or public, benefits are intangible--albeit real and significant--considerations must be included in the analysis of an undertaking such as the Central Arizona Project. One example of this type of benefit is the maintenance and improvement of local standards of living.

Another is the continuance and improvement of such public institutions as schools, hospitals, churches, and libraries. In an area of ground-water overdraft such as the Central Service Zone, the intangibles are of major importance, since overdraft areas are particularly susceptible to reductions in living standards and public service values as water supplies become exhausted. The maintenance, alone, of existing living standards and present public service values would constitute a considerable intangible benefit to the project area. Likewise, many other general and public benefits would result from the stabilization and prevention of retrenchment that would otherwise occur in the Central Arizona area if additional water supply is not obtained.

Municipal and industrial benefits--Municipal and industrial benefits are those which would result from the provision of a supplemental water supply of 312,000 acre-feet annually to the Phoenix and Tucson metropolitan areas. A true measure of these benefits is practically impossible to evaluate in monetary terms. The benefits associated with this aspect of the water service to be provided by the project for the purpose of this study were assumed to equal the alternative single-purpose cost of providing a similar quantity of municipal and industrial water to the areas of use. The average annual equivalent of this cost was computed to be $7,624,000 and this is the assumed value of these benefits.

Fish and wildlife benefits--The construction and operation of the Central Arizona Project features would affect the fish and wildlife values of the project area in many ways. The nature of some of these effects is described briefly in the following paragraphs.

The fish and wildlife values of existing streams would be enhanced by the reservoirs of the Central Arizona Project. As estimated by the Bureau of Sport Fisheries and Wildlife, the construction of Bridge Canyon, Maxwell, Hooker, Charleston, and Buttes Reservoirs would enhance fishery resources by creating lake fisheries where none exist today. The annual value of these benefits has been estimated by this agency to be $684,000. Enhancement of the stream fishery in the upper Gila River area may occur because of the stabilized and increased flows available from Hooker Reservoir; however, no value has been assigned to this item.

Habitat changes within the agricultural service area would not be appreciably altered by the additional water supply. The coordination of the storage reservoirs at Buttes and Maxwell with flood control channelization may decrease the extent of destruction of white wing dove nesting area habitat.

Flood control benefits--Oddly enough, in light of the inability of Gila River Basin streams to meet today's water needs, many of these same streams and contributing areas periodically produce damaging floodflows. However, with the construction of the reservoirs and aqueducts described in this report, a considerable portion of this flood hazard would be eliminated. As estimated by the Corps of Engineers, four of the reservoirs-Charleston, Buttes, Maxwell, and Hooker--would provide measurable flood control benefits. In addition to these measurable benefits, the construction of the Granite Reef and Salt-Gila Aqueducts, and the integrated operation of existing Salt River and Verde River Reservoirs, would improve the flood protection available to downstream areas. However, this improved protection has not been evaluated and monetary benefits therefore have not been assigned. The annual flood control benefits have been estimated by the Corps of Engineers to be $780,000.

Recreation benefits--The construction of the major reservoirs of the Central Arizona Project would create areas which would have a considerable potential value for recreation. The National Park Service has prepared a reconnaissance report describing the cost of the minimum basic recreational facilities which would be required to utilize this potential value, together with the benefits to be derived. The cost of the features has been included as a project cost. The estimated annual value of the benefits is $1,528,000.

Power benefits--The power generation of the Central Arizona Project would provide all the pumping energy and capacity required to transport the augmented water to the area. In excess of the pumping requirements would be energy and capacity available for commercial sale on a peaking basis. It was assumed that the most likely alternative source of power and energy for both commercial and project use, in the absence of the project, would be steam electric plants located near load centers in the Lower Colorado River Basin power market area. The lowest cost source in the area, according to information available from the Federal Power Commission, would be a publicly-owned non-Federal gas-fired steam plant in the Los Angeles area. The cost of energy produced at such a plant was used as the basis for an estimate of alternative costs at the various load centers. The average annual equivalent value of this cost is $32,992,000, which was used as an estimate of power benefits for the Central Arizona Project.

Benefit and cost summaries--Table 9 summarizes the total benefits, on an annual equivalent basis, which can be attributed to the operation of the Central Arizona Project under fully developed conditions of project

Table 9--Project benefits
Central Arizona Project

Purpose	Equivalent Annual Benefit	Total Benefits 50-year Period	100-year Period
Irrigation 1/	$ 43,142,000	$ 1,223,606,000	$ 1,579,606,000
Direct	(17,094,000)	(484,825,000)	(625,882,000)
Indirect	(26,048,000)	(738,781,000)	(953,724,000)
Power	32,992,000	935,729,000	1,207,972,000
M&I water	7,624,000	216,234,000	279,146,000
Flood control	780,000	22,123,000	28,559,000
Fish and wildlife	684,000	19,400,000	25,044,000
Recreation	1,528,000	43,338,000	55,946,000
Total	$ 86,750,000	$ 2,460,430,000	$ 3,176,273,000

1/ Computed on basis of 814,000 acre-feet average annual demand at canalside, with $21 per acre-foot for direct and $32 per acre-foot for indirect irrigation benefits.

use for 50-year and 100-year periods of analysis. Table 10 summarizes the derivation of the annual equivalent costs which would be required to construct and operate the project facilities. All annual equivalents, both benefits and costs, are based on $2\frac{1}{2}$ percent interest for 50- and 100-year periods of analysis.

Benefit-cost analysis--As shown in tables 9 and 10, the annual equivalent benefits and costs attributable to the construction and operation of the Central Arizona Project would be $86,750,000 and $35,170,000, respectively, for the 100-year period of analysis. The resultant benefit-cost ratio of 2.5 to 1.0 effectively demonstrates the economic justification of the plan. For a 50-year period of analysis the ratio is 2.0 to 1.0. If only direct benefits are used, the ratio on a 50-year period is 1.4 to 1.0.

Financial Feasibility

In the sections which follow, the financial feasibility of the Central Arizona Project will be shown through a demonstration of the manner in which the costs could be repaid. Only those costs associated with the main project features have been included in this repayment analysis. The costs of distribution and local drainage systems are not included, as the study has assumed these to be financed by the various water user organizations separately from the main project works.

Cost allocation--For purposes of the cost allocation analysis, the costs associated with the Central Arizona Project have been allocated to irrigation, municipal and industrial water service, commercial power, fish and wildlife purposes, and flood control, by the separable cost-remaining benefits method. Only the specific costs were assigned to recreation. A summary of the total

Table 10--Summary of Federal economic costs

Central Arizona Project

Item	50-year period of analysis 1/	100-year period of analysis 2/
Construction cost 3/	$ 967,220,000	$ 967,220,000
Interest during construction	62,283,000	62,283,000
Total	$1,029,503,000	$1,029,503,000
Average annual equivalent cost (at 2½ percent interest)	36,298,000	28,118,000
Annual operation, maintenance and replacement cost (includes recreation)	7,052,000	7,052,000
Total annual equivalent cost	$ 43,350,000	$ 35,170,000

1/ 2½ percent interest - 50-year factor = 0.0352580

2/ 2½ percent interest - 100-year factor = 0.0273118

3/ Does not include investigation costs.

project cost allocation is shown in table 11.

Repayment required--As shown on table 12, the costs of the Central Arizona Project are allocated to irrigation, commercial power, municipal and industrial water service, flood control, fish and wildlife purposes, and recreation. The costs allocated to irrigation, municipal and industrial water service, and commercial power, are considered reimbursable and to be repaid. Repayment of water service facility costs has been computed in this study on the basis of average annual deliveries which reflect the conversion of some present agricultural supplies to municipal and industrial uses. In view of the existing ground-water overdraft conditions, full use of import supplies is assumed at the start of project water operations. These average annual deliveries, over a 50-year period, are 814,000 acre-feet and 256,000 acre-feet for irrigation and municipal and industrial uses, respectively. The sale of all commercial power produced is also assumed to begin upon completion of all the power facilities, since the demand for power in the market area will exceed the available supply at that time. The investments allocated to the remaining functions are considered to be national responsibilities and are, therefore, nonreimbursable. Also returnable through revenues are interest charges on the investments allocated to the commercial power and municipal and industrial water service functions. Charges for interest during construction on the investments allocated to commercial power and municipal and industrial water use for the Central Arizona Project must also be repaid.

Summary of cost allocation and possible repayment--Table 12 shows the estimated revenues, by years, which could result from the operation of the Central Arizona Project as described in this report. The table also shows

Table 11--Tentative cost allocation summary

Central Arizona Project

(100-year period of analysis - 2½ percent interest)

Item	Capital cost	Interest during construction	Operation, maintenance and replacement costs
Nonreimbursable			
Flood control	$9,788,000	$ 498,000	-0- 2/
Fish and wildlife	8,334,000	425,000	-0- 2/
Recreation	8,263,000	293,000	356,000
Total nonreimbursable	26,385,000	1,216,000	356,000
Reimbursable			
Irrigation	317,173,000	21,419,000	1,601,600
Commercial power	433,811,000	28,901,000	4,124,500
M&I water service	192,103,000	10,747,000	969,500
Total reimbursable	943,087,000	61,067,000	6,695,600
Total project cost	$ 969,472,000 1/	$ 62,283,000	$ 7,051,600 2/

1/ Excludes $1,857,000 nonreimbursable investigation costs.

2/ For the purpose of this analysis it was assumed that the power function would pay the small amount of OM&R associated with flood control and fish and wildlife. An appropriate adjustment has been made in the capital cost allocation to these functions.

Table 12--Tentative composite repayment analysis of Central Arizona Project

Year	Power: Firm Commercial Energy Revenue	Power: Nonfirm Energy Revenue	Power: Total Operating Revenue	Power: Operation, Maintenance and Replacement	Power: Net Operating Revenue	Power: Interest On Unpaid Balance	Power: Unpaid Balance	Power: Surplus
0							465,508,000	
1	21,301,170	100,000	21,401,170	4,124,500	17,276,670	12,764,229	460,995,559	0
2						12,640,498	456,359,387	
3						12,513,374	451,596,091	
4						12,382,765	446,702,186	
5						12,248,574	441,674,090	
10						11,520,367	414,388,374	
15						10,686,696	383,150,933	
20						9,732,286	347,389,451	
25						8,639,651	306,448,720	
30						7,388,772	259,578,642	
40						4,317,293	144,491,147	
49						745,018	10,638,956	0
50	21,301,170	100,000	21,401,170	4,124,500	17,276,670	291,720	0	6,345,994
Total	1,065,058,500	5,000,000	1,070,058,500	206,225,000	863,833,500	391,979,506	0	6,345,994

Year	Municipal and Industrial: Operating Revenue	Municipal and Industrial: Operation, Maintenance and Replacement	Municipal and Industrial: Storage Charges	Municipal and Industrial: Total Annual Charges	Municipal and Industrial: Net Operating Revenue	Municipal and Industrial: Interest On Unpaid Balance	Municipal and Industrial: Unpaid Balance
0							203,889,300
1	8,581,100	969,500	71,750	1,041,250	7,539,850	5,590,645	201,940,095
2						5,537,197	199,937,442
3						5,482,285	197,879,877
4						5,425,866	195,765,893
5						5,367,901	193,593,944
10						5,053,343	181,807,536
15						4,693,228	168,314,132
20						4,280,958	152,866,509
25						3,808,980	135,181,602
30						3,268,647	114,935,477
40						1,941,883	65,221,973
49	8,581,100				7,539,850	398,793	7,402,820
50	8,647,055	969,500	71,750	1,041,250	7,605,805	202,985	0
Total	429,120,955	48,475,000	3,587,500	52,062,500	377,058,455	173,169,155	0

Year	Irrigation: Operating Revenue	Irrigation: Operation, Maintenance and Replacement	Irrigation: Storage Charges	Irrigation: Total Operation, Maintenance, and Replacement and Storage Costs	Irrigation: Net Operating Revenue	Irrigation: Unpaid Balance
0						317,173,300
1	8,172,560	1,601,600	228,250	1,829,850	6,342,710	310,830,590
2						304,487,880
3						298,145,170
4						291,802,460
5						285,459,750
10						253,746,200
15						222,032,650
20						190,319,100
25						158,605,550
30						126,892,000
40						63,464,900
49	8,172,560				6,342,710	6,380,510
50	8,210,360	1,601,600	228,250	1,829,850	6,380,510	0
Total	408,665,800	80,080,000	11,412,500	91,492,500	317,173,300	0

Average annual revenue from facilities computed on the following basis: power; firm commercial energy 3,550,195,000 kwh @ 6 mills; nonfirm energy 400,000,000 kwh @ 2.5 mills; municipal and industrial water 256,000 acre-feet @ $33.52 per acre-foot; and irrigation water 814,000 acre-feet @ $10.04 per acre-foot.

the functional source of these anticipated revenues, together with the manner in which they could be used to retire the various components of cost which must be returned. As presented in this table, irrigation water revenues based on $10.04 per acre-foot at project canalside delivery would be sufficient to repay the project costs allocated to irrigation in 50 years. The costs assigned to municipal and industrial water uses would require a rate of $33.52 per acre-foot in order to pay out in 50 years at an interest rate of 2.742 percent. Commercial energy retailed at load center at a rate of 6 mills per kilowatt-hour would repay the allocated power costs, including interest at 2.742 percent, in 50 years.