UNITED STATES
DEPARTMENT OF THE INTERIOR
Stewart L. Udall, Secretary

BUREAU OF RECLAMATION
Floyd E. Dominy, Commissioner

Region 3
A. B. West, Regional Director

SUPPLEMENTAL REPORT
CENTRAL ARIZONA PROJECT

PROJECT DEVELOPMENT REPORT

June 1963

152

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DEPARTMENT OF THE INTERIOR
Stewart L. Udall, Secretary

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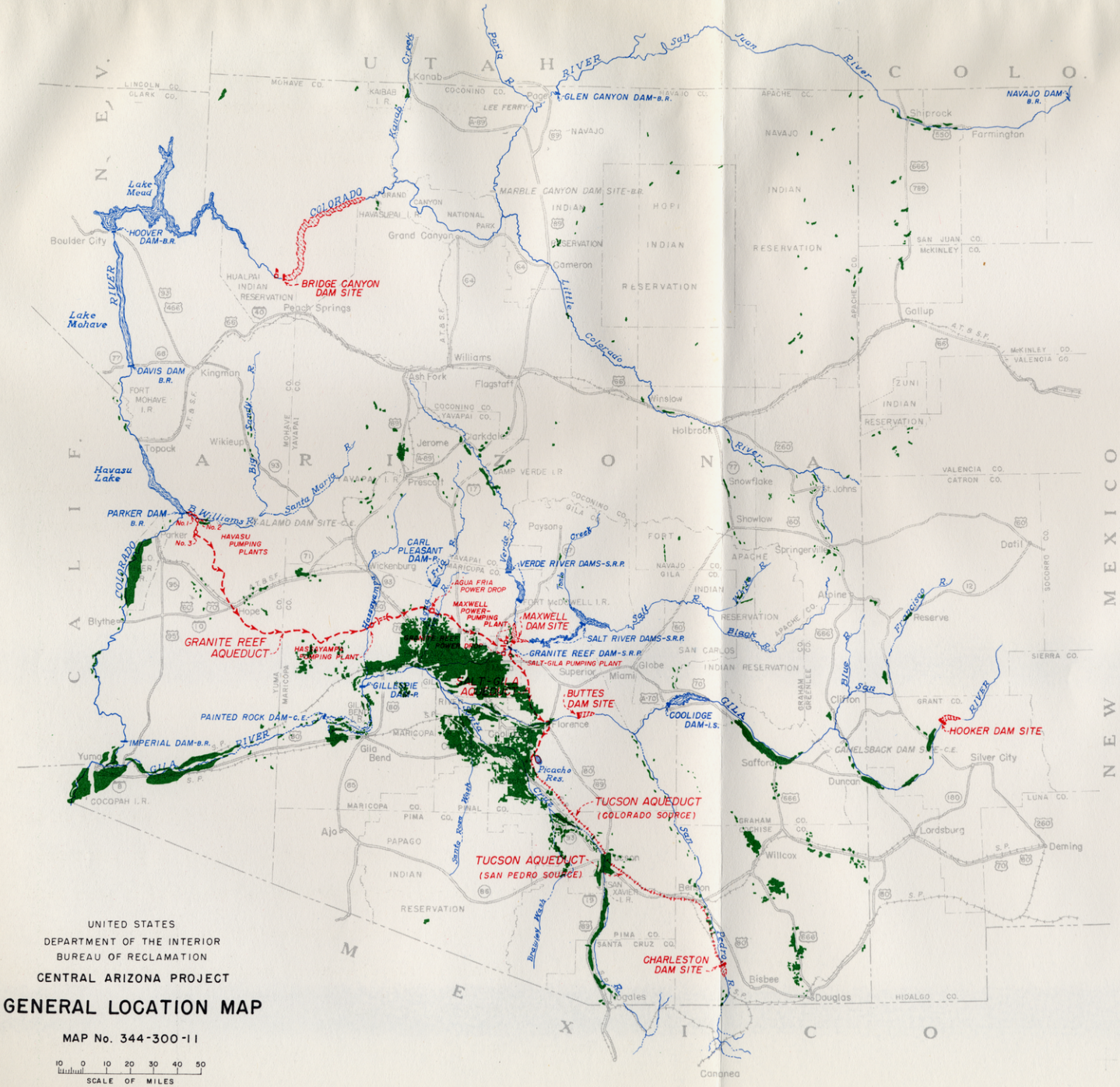
REGION 3
A. B. West, Regional Director

SUPPLEMENTAL REPORT
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June 1963

Interior-Reclamation
Boulder City, Nevada

PLATE I


Paria R.
GLEN CANYON DAM-B.R.
San Juan River
NAVAJO DAM-B.R.
Kanab Creek
Lake Mead
HOOVER DAM-B.R.
Boulder City
COLORADO RIVER
BRIDGE CANYON DAM SITE
MARBLE CANYON DAM SITE-B.R.
Little Colorado
Lake Mohave
DAVIS DAM-B.R.
Kingman
Big Sandy R.
Santa Maria R.
Havasu Lake
PARKER DAM-B.R.
Williams R.
ALAMO DAM SITE-C.E.
HAVASU PUMPING PLANTS
CARL PLEASANT DAM-P.
Hassayampa R.
Agua Fria R.
AGUA FRIA POWER DROP
VERDE RIVER DAMS-S.R.P.
Verde R.
Tonto Creek
Salt R.
MAXWELL DAM SITE
MAXWELL POWER-PUMPING PLANT
SALT RIVER DAMS-S.R.P.
GRANITE REEF AQUEDUCT
HASSAYAMPA PUMPING PLANT
GRANITE REEF DAM-S.R.P.
SALT-GILA PUMPING PLANT
GILLESPIE DAM-P.
GILA AQUEDUCT
BUTTES DAM SITE
COOLIDGE DAM-I.S.
San Carlos R.
Black R.
San Francisco R.
San Simon Wash
HOOKER DAM SITE
PAINTED ROCK DAM-C.E.
IMPERIAL DAM-B.R.
Gila R.
CAMELSBACK DAM SITE-C.E.
Picacho Res.
TUCSON AQUEDUCT (COLORADO SOURCE)
Santa Rosa Wash
TUCSON AQUEDUCT (SAN PEDRO SOURCE)
Brawley Wash
CHARLESTON DAM SITE
San Pedro R.
Cananea
Flagstaff
Williams
Prescott
Jerome
Clarkdale
Ash Fork
Peach Springs
Grand Canyon
Cameron
Tuba City
Winslow
Holbrook
Gallup
Shiprock
Farmington
Snowflake
St. Johns
Show Low
Springerville
Alpine
Reserve
Datil
Payson
Globe
Miami
Superior
Florence
Casa Grande
Eloy
Maricopa
Phoenix
Gila Bend
Ajo
Yuma
Blythe
Parker
Wickenburg
Wikieup
Topock
Safford
Duncan
Clifton
Silver City
Willcox
Lordsburg
Deming
Bisbee
Douglas
Nogales
Benson
Tucson
Ajo
Havasupai Indian Reservation
Hualapai Indian Reservation
Navajo Indian Reservation
Hopi Indian Reservation
Zuni Indian Reservation
San Carlos Indian Reservation
Fort Mohave I.R.
Camp Verde I.R.
Fort McDowell I.R.
Gila River Indian Reservation
Salt River Indian Reservation
Papago Indian Reservation
San Xavier I.R.
Cocopah I.R.
Grand Canyon National Park
Lake Mead National Recreation Area
Lake Mohave Recreation Area
Havasu Lake Recreation Area
Gila Bend S.P.
Picacho S.P.
Lincoln Co.
Clark Co.
Mohave Co.
Coconino Co.
Kaibab I.R.
Navajo Co.
Apache Co.
San Juan Co.
McKinley Co.
Valencia Co.
Catron Co.
Yavapai Co.
Maricopa Co.
Pinal Co.
Graham Co.
Greenlee Co.
Pima Co.
Santa Cruz Co.
Cochise Co.
Grant Co.
Luna Co.
Sierra Co.
Socorro Co.
Hidalgo Co.
A.T.&S.F.
S.P.
U.S. 89
U.S. 66
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U.S. 70
U.S. 80
U.S. 180
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U.S. 666
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U.S. 163
U.S. 160
U.S. 64
U.S. 89A
U.S. 180
U.S. 70

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 3
BOULDER CITY, NEVADA

IN REPLY
REFER TO:

JUN 7 1963

To: Commissioner, Washington, D. C.

From: Regional Director, Boulder City, Nevada

Subject: Supplemental Report on Central Arizona Project, Arizona-New Mexico

This is my report on the reevaluation of the Central Arizona Project.

It supplements and brings current the data and concepts originally presented in the December 1947 Central Arizona Project report which, with review comments, was published as House Document No. 136, 81st Congress, 1st Session.

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, particularly the Act of March 4, 1921 (41 Stat. 1404), the Boulder Canyon Project Act (45 Stat. 1057), and the Boulder Canyon Project Adjustment Act (54 Stat. 774). Costs for preparation of this report were paid from both contributed and appropriated funds. The contributed funds were provided by the States of Arizona and New Mexico under 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.

Background Chronology

The 1947 Central Arizona Project report presented a comprehensive plan for importation of water from the Colorado River to supplement the inadequate supplies available to the Gila River Basin in central Arizona and western New Mexico. The report was reviewed by the appropriate State and Federal agencies, and subsequently approved by the Secretary of the Interior in February 1948. 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 postponed by the House Committee on Interior and Insular Affairs in 1951 until such time as Arizona's right to the use of Lower Colorado River water was adjudicated or settled by other means. This action in the House was in line with comments of the State of California in its review of the 1947 report, from which the following is quoted:

> "It is only because a determination of the respective rights of the lower-basin States to the waters of the Colorado River system has not been made that California submits any criticism of your proposed report. Whenever it is finally determined what water belongs legally to Arizona, it should be permitted to use that water in any manner or by any method considered best by Arizona, so long as it does not conflict with the right of California to the use of its water from the Colorado River system."

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. On December 5, 1960, the Special Master for the case submitted his report and recommended decree to the Supreme Court and on June 3, 1963, the Supreme Court rendered a decision which upheld Arizona's contention that it is entitled to 2,800,000 acre-feet annually of Colorado River mainstream flows.

During the years following issuance of the 1947 Central Arizona Project report, 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 became so critical that Arizona officials deemed it essential to reexamine and update costs for the Central Arizona Project in order that current information on the project could be provided the Congress immediately following a Supreme Court decision. Toward this end, an emergency appropriation by the Arizona Legislature in March 1961 made $100,000 available to the Arizona Interstate Stream Commission for contribution to the Bureau of Reclamation to update costs for Bridge Canyon Dam and Powerplant and to appraise the Central Arizona Project plan in the light of present conditions. Arizona also contributed $100,000 for a statewide inventory of water resources under which much of the basic data used in reexamining the 1947 report were assembled. An additional $30,000 was contributed by the New Mexico Interstate Stream Commission to finance the New Mexico portion of the project investigations.

Work on updating and reevaluating the Central Arizona Project plan was undertaken by the Bureau of Reclamation in May 1961 under the terms of the previously mentioned contract of April 24, 1961, between the United States and the Arizona Interstate Stream Commission. The results of these investigations were presented to the Commission in an appraisal report dated January 1962. The appraisal report prepared for the States of Arizona and New Mexico was based on the assumption of a water diversion of 1,200,000 acre-feet annually from the Colorado River. This is the same assumption that was used in the 1947 report and also in this supplemental updating report.

Present Conditions

Studies show that the present economy of central Arizona is now supported by essentially full utilization of the local surface-water supplies and by excessive pumpage and resultant depletion of the 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. Water levels are dropping progressively year by year and, unless remedial measures are taken without delay, the present economy will suffer before an additional water supply can be brought into the area.

Since 1951, when Congressional hearings were last held regarding the project, the population of the project area has approximately doubled. Over one million people now live in the area and large areas of land, formerly irrigated, have been subdivided for or have been converted into 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. Recent estimates place the mid-1963 population of the cities of Phoenix and Tucson at about 505,000 and 220,000, respectively. The municipal and industrial water supply requirements of these and other cities in the project area have increased proportionately with the population growth, and these needs are expected to accelerate in future years. Present projections indicate that the population of the area may be expected to double in the next 10 to 15 years.

The pumpage of ground water, which exceeded the natural recharge of the basin in 1947 and which was discussed in the 1947 report, has more than doubled since that time 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. Paradoxically, within this region of dynamic growth, distressed economic conditions exist on the extensive Indian reservations and in certain rural counties which qualify the areas for assistance under the Area Redevelopment Act of 1961.

Purpose or Scope of this Report

The purpose of this report is to reevaluate and supplement the 1947 Central Arizona Project report in the light of present-day

conditions. It differs from the January 1962 appraisal report which was financed entirely by the States, principally in that it includes further refinements of the data previously mentioned, as well as my recommendations in the light of the June 3, 1963, decision of the Supreme Court. It provides data on present water usage and problems in the area within the framework of the national policy for the use and development of water and related land resources which have been adopted since the 1947 report was issued. The water supply available to the area from local surface and underground sources has been reexamined and reanalyzed on the basis of present conditions.

This report presents essentially the same plan as in the 1947 report. Most project works have been redesigned in accordance with recent engineering advancements, and all project costs have been reestimated at July 1961 price levels. All project features have been actually located in the field or designed on the basis of field data. Estimated costs presented in this supplement are suitable for the purpose of evaluating feasibility of the project under present conditions.

Plan of Development

The plan of development, as originally set forth in the 1947 report, provides for the conveyance and delivery of Colorado River water through the main project aqueduct system, extending from Lake Havasu to the Central Arizona Project service area. In accordance with the concepts outlined in the 1947 report, direct deliveries of Colorado River water in central Arizona would, through water exchanges, also permit additional water uses to be made in other areas.

All the basic project features included in the 1947 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 functions. Glen Canyon Dam and Reservoir, now under construction on the Colorado River, were not considered in the 1947 report to be in operation prior to the proposed Bridge Canyon Dam and Reservoir. Because much of the Colorado River sediment load and streamflow above Bridge Canyon Dam will be controlled by Glen Canyon Dam and Reservoir, Bluff and Coconino Dams have been eliminated in this supplement.

The present reanalysis confirms that the basic plan presented in the 1947 report is 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.

This supplement contemplates the sale of Colorado River import water at a canalside delivery point. Any proposed distribution of specific amounts of Colorado River water to specific areas would be premature pending completion of more detailed service area studies which are now in progress; thus, no attempt has been made in this report to delineate water or lands. Even after completion of the project, a water supply deficiency would continue to exist. It is essential, therefore, that all water supplies be distributed in lined canals or underground pipe systems as soon as practicable. It is anticipated

that new systems to supplement existing systems would be required in areas now served exclusively from ground-water pumping. The lining and rehabilitation of existing distribution systems and the construction of new systems, where required, to deliver project water to lands served would need to be accomplished and financed by local water-using entities or by the Bureau of Reclamation under separate repayment contracts.

The project functions to be served under present conditions are the same as those proposed in the 1947 report, but the magnitude and relative importance of these functions have changed materially. In the 1947 report, it was proposed that about 1 percent of the total water supply would be allotted for municipal and industrial purposes; whereas, this reanalysis contemplates that approximately one-third of the assumed project water would be assigned to municipal and industrial uses. The new water supply studies have recognized the need for conservation and use of the large quantities of usable return flow that will be available from the projected municipal and industrial water systems. Such return flows would have the effect of augmenting the potential import water supply and increasing the overall efficiency of use; however, the limited scope of this supplement did not permit the evaluation of these potentialities. Full consideration has been given 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. The water exchange concepts advanced in the 1947 report have been retained in this reevaluation.

Project Operations

The full operation of project facilities would make possible the conveyance and direct delivery of Colorado River water into the central portion of the Gila River Basin. The companion storage features in the basin would provide desired regulation of existing local water supplies and make possible optimum water utilization in the higher elevations of Arizona and New Mexico; provide a power supply for project pumping and for commercial sale; and, in addition, accomplish the other multi-purpose benefits from flood control, fish and wildlife, recreation, and sediment control. Close coordination will be required with the other agencies planning reservoir developments in these upper areas to achieve maximum benefits. Specific areas eligible under Area Redevelopment Act provisions would also be aided.

Existing and potential water-using agencies in the area have expressed a desire to contract for water service. It is contemplated that water will be delivered at turnout points along the main canal. The contracting entity, or agencies, would be responsible for distributing water supplies from the main canal to the point of use. No further plans have been formulated for distribution or administration of the imported water supply.

Estimated Costs and Benefits

All costs and benefits for the Central Arizona Project were reestimated and economic and financial aspects of the project were reanalyzed in this supplemental report. The current estimated construction cost of the project is $997,222,000, exclusive of $4,109,000 investigation costs. The average annual operation, maintenance, and replacement costs are $8,611,000. The total estimated average annual equivalent benefits for a 100-year period of analysis are $125,468,000. The benefit-cost ratio for this period would be 3.03 to 1. For a 50-year period, the benefit-cost ratio would be 2.54 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 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 $38 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 with interest and, in addition, could provide necessary assistance for irrigation. 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.

Summary and Conclusions

The economy of the State of Arizona is growing at a rapid rate. The urban centers of Phoenix and Tucson, which have a combined population of over 700,000, are to a large extent dependent upon ground-water supplies to maintain present and provide for future growth. The extensive rural development in Maricopa, Pinal, and Pima Counties is being sustained by overdraft of the ground-water supply through mining of the ground-water reservoirs. Development of the Upper Gila River Basin is, in general, restricted due to overappropriation or deficiency of the surface-water supply.

The economy of a major portion of the Upper Gila River Basin in New Mexico is in a generally depressed condition. Potential growth through water resource development is retarded by water right restrictions or vagaries of native streamflow.

The Central Arizona Project would help to offset the present water supply deficiency and assist in insuring the continued economic health of a vital and important segment of economy of the Southwestern United States.

The Central Arizona Project is not a proposal to bring new lands under cultivation.

The Central Arizona Project has economic justification and financial feasibility.

Recommendations

It is recommended that the works comprising the Central Arizona Project be authorized for construction, operation, and maintenance by the Bureau of Reclamation, Department of the Interior, in accordance with the Federal Reclamation Laws (Act of June 17, 1902, and acts amendatory thereof and supplementary thereto) substantially in accordance with the plan of development set forth in the December 1947 Central Arizona Project report as updated by this supplemental report with such modifications, omissions, or additions as the Secretary of the Interior may find necessary and proper for carrying out the purposes of the project.

A. B. West

CENTRAL ARIZONA PROJECT

SUPPLEMENTAL REPORT

PREFACE

This updating supplement to the 1947 report on the Central Arizona Project is presented as a self-contained document to avoid repetitious references to the basic report. Pertinent descriptive material has been extracted from the original report and brought up to date to provide continuity. Reference should be made to the 1947 report and its appendices for further details and background information on the project.

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CHAPTER I

THE AREA = ITS PROBLEMS AND NEEDS

CHAPTER I - THE AREA--ITS PROBLEMS AND NEEDS

The problems and needs of the Central Arizona Project area are essentially the same as discussed in the 1947 report but are now far more serious due to the subsequent growth and development that has occurred. The project area, which is comprised of the Gila River Basin of central Arizona and western New Mexico, is one of the most dynamic growth areas in the United States. Favorable climatic conditions have encouraged population and industrial expansion well above the national averages. The expansion that has taken place since the 1947 report has placed new and heavy demands on existing water supplies and has made more urgent the need for supplemental water to sustain the existing economy.

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 of the mountains nearing 12,000 feet in 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.

Project Area

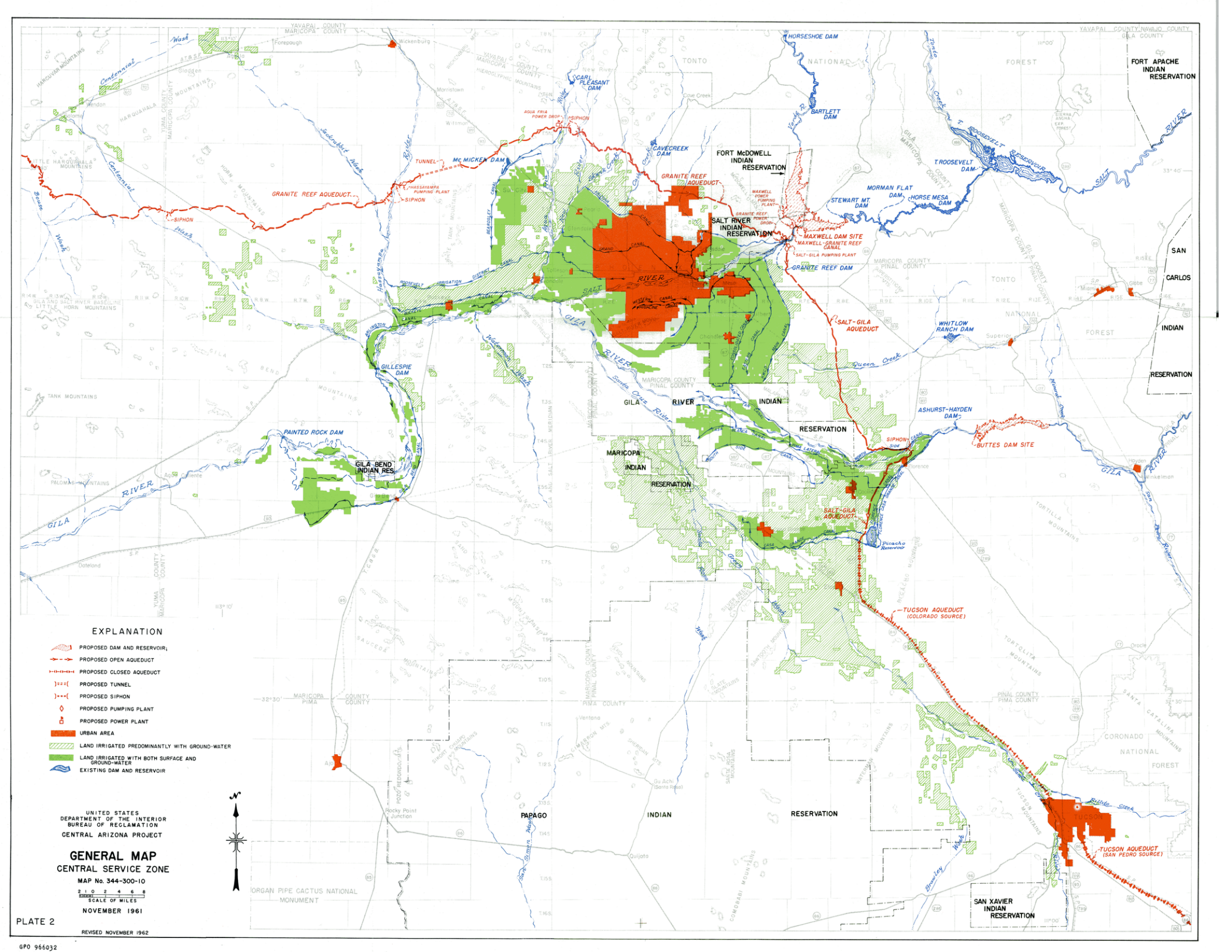
In reevaluating the Central Arizona Project, it was necessary to reexamine the water demands and resources under present conditions

within the hydrologic entity where they occur. For this purpose, the Central Arizona Project area has been divided into two separable zones designated in this supplement 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 would 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 annually draws people and industries to the area in increasing numbers. The hot summers and mild winters give a long growing season, producing specialty crops and high yields. Precipitation occurs throughout the project area in the winter and during the late summer. The average annual precipitation range is from 7 inches in the Phoenix area to 12 inches at Cliff, New Mexico, and 10 inches at Tucson.


EXPLANATION
PROPOSED DAM AND RESERVOIR
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
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
REVISED NOVEMBER 1962
GPO 966032
HORSESHOE DAM
BARTLETT DAM
CARL PLEASANT DAM
CAVECREEK DAM
GRANITE REEF AQUEDUCT
MC MICKEN DAM
TUNNEL
SIPHON
AGUA FRIA POWER DROP
HASSAYAMPA PUMPING PLANT
FORT McDOWELL INDIAN RESERVATION
SALT RIVER INDIAN RESERVATION
MAXWELL POWER PUMPING PLANT
GRANITE REEF POWER DROP
MAXWELL DAM SITE
MAXWELL-GRANITE REEF CANAL
SALT-GILA PUMPING PLANT
GRANITE REEF DAM
ROOSEVELT DAM
ROOSEVELT RESERVOIR
MORMAN FLAT DAM
HORSE MESA DAM
STEWART MT. DAM
FORT APACHE INDIAN RESERVATION
SAN CARLOS INDIAN RESERVATION
SALT-GILA AQUEDUCT
WHITLOW RANCH DAM
ASHURST-HAYDEN DAM
BUTTES DAM SITE
SIPHON-CANAL SIDE
GILLESPIE DAM
PAINTED ROCK DAM
GILA BEND INDIAN RES.
MARICOPA INDIAN RESERVATION
GILA RIVER INDIAN RESERVATION
PAPAGO INDIAN RESERVATION
SAN XAVIER INDIAN RESERVATION
TUCSON AQUEDUCT (COLORADO SOURCE)
TUCSON AQUEDUCT (SAN PEDRO SOURCE)
ORGAN PIPE CACTUS NATIONAL MONUMENT
SALT RIVER
GILA RIVER
Picacho Reservoir
Rocky Point Junction
Ajo
Gila Bend
Aguila
Wickenburg
Morristown
Wittmann
Surprise
Peoria
Glendale
Phoenix
Tempe
Mesa
Chandler
Gilbert
Florence
Coolidge
Casa Grande
Eloy
Superior
Globe
Miami
Hayden
Winkelman
Oracle
Tucson
Ajo
Why
Gila Bend
Sentinel
Dateland
Quijota
Ventana
Cove Creek
Forepaugh
Sloddon
Congress
Yarnell
Kirkland
Humboldt
Dewey
Prescott
Chino Valley
Paulden
Ash Fork
Williamson Valley Wash
Centennial Wash
Jackrabbit Wash
Bouse Wash
Hassayampa River
Agua Fria River
Verde River
New River
Cave Creek
Queen Creek
Santa Cruz River
San Pedro River
Rillito Creek
Pinal Creek
Black Canyon Creek
Tonto Creek
Salt River
Gila River
Roosevelt Irrigation District Canal
Arlington Canal
Waterman Wash
Harquahala Mountains
Little Harquahala Mountains
Hieroglyphic Mountains
Harcuvar Mountains
Little Horn Mountains
Tank Mountains
Palomas Mountains
Gila Bend Mountains
Maricopa Mountains
Sierra Estrella
Sand Tank Mountains
Saucedas
Growler Mountains
Cimarron Mts.
Sheridan Mts.
Sierra Blanca
Sierra Estrella
Table Top Mountains
Superstition Mountains
Goldfield Mountains
Mazatzal Mountains
Sierra Ancha Exp. Forest
Tonto National Forest
Coronado National Forest
Tortilla Mountains
Santa Catalina Mountains
Tucson Mountains
Picacho Mountains
Silver Reef Mountains
Sawtooth Mountains
Comobabi Mountains
Waterman Mountains
Sierra Blanca
Gu Achi (Santa Rosa)
Pozo Redondo
Short Camp Mountains
Yavapai County
Maricopa County
Pinal County
Pima County
Navajo County
Gila County

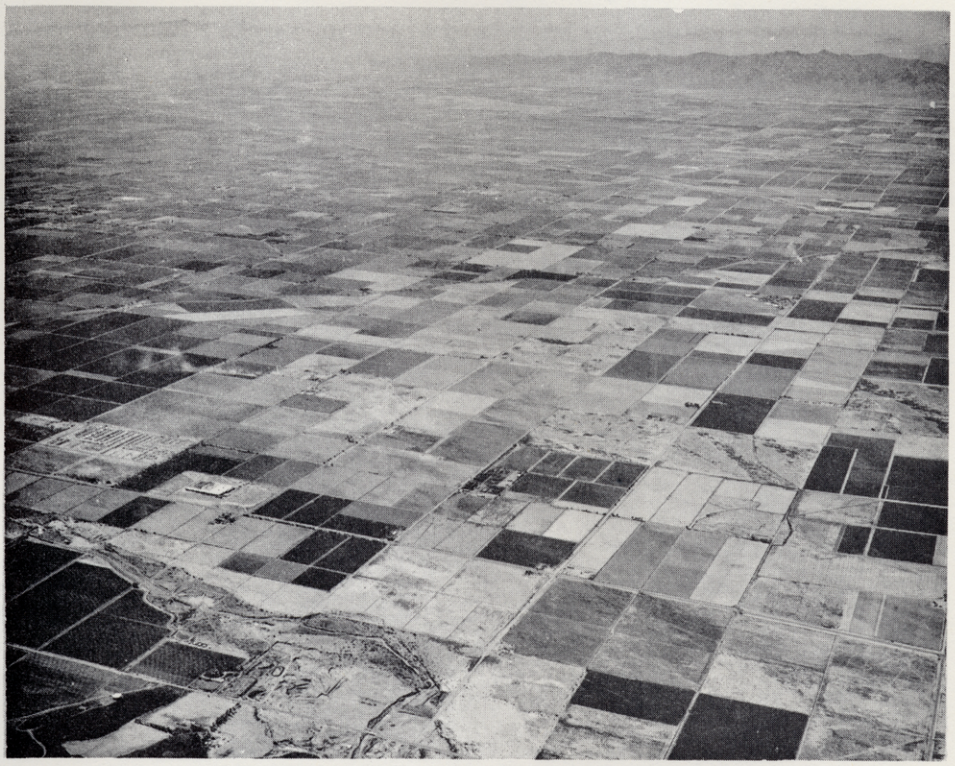
Lands--Arable lands in the project area are more extensive than can be provided a firm water supply from any feasible source. In 1960, 1,202,000 acres were developed for irrigation in the Central Arizona Project area. In the Gila River Basin, there are about 6,000,000 acres of arable lands suitable for irrigation. The purpose of the Central Arizona Project is to sustain the economic base and reduce ground-water overdraft; therefore, no new lands are being considered for project development. At the present time, agricultural lands are being retired from production in some areas as the aquifers are completely drained or ground-water levels fall below the economic pumping depth.

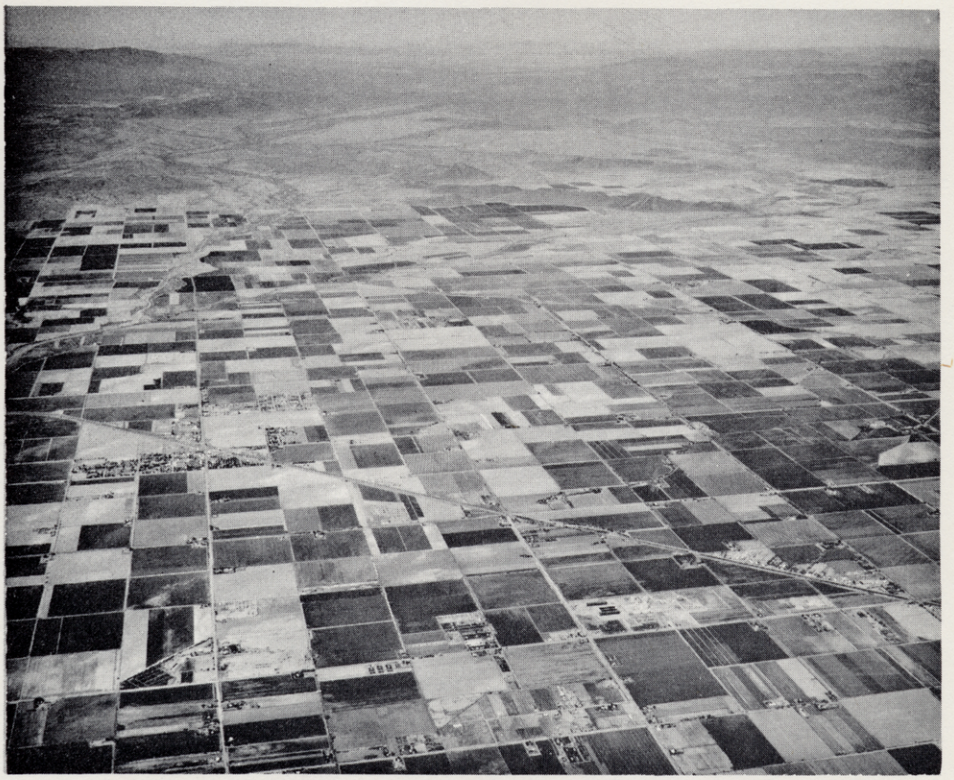
Another aspect of the land resources is the ownership and its relationship to water availability. The following tabulation shows the distribution of ownership in the entire State of Arizona:

Owner or Trust Holder	Acres 1/
Patented (Deeded and Private)	8,810,900
State of Arizona	9,943,600
National Forests (Department of Agriculture)	11,323,500
National Parks, Monuments, Refuges, Grazing, and Reclamation (Department of the Interior)	17,470,000
Department of Defense	3,645,900
Indian Reservations	21,491,500
Other Federal Agencies	2,600
Total	72,688,000

1/ Acreage rounded.

MARICOPA COUNTY AGRICULTURAL LANDS





The deeded and private lands hold most of the claimed rights to surface waters in the State, and contain the highest population densities. In the Gila River Basin in New Mexico, a similar ownership pattern also exists. Indian reservations hold most of the remaining claimed rights to surface waters.

Water--At the start of the present cultural era in the Gila River Basin, the annual surface-water resources were more than adequate in volume to supply all the demands although seasonal shortages and excesses occurred. 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 been made possible in recent years by overdevelopment of the ground-water reservoirs.

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 are almost double the natural recharge and water levels are dropping rapidly.

Minerals--Arizona has led the Nation in nonferrous mineral production for many years and produced over 38 percent of the total value of the United States production 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 that extensive mineral deposits, unknown or undeveloped in the past, will continue to play a major role in the economy of the area. Water availability, which is a prime requirement for developing and processing mineral deposits, will continue to influence mining activity and, in turn, influence other requirements for water.

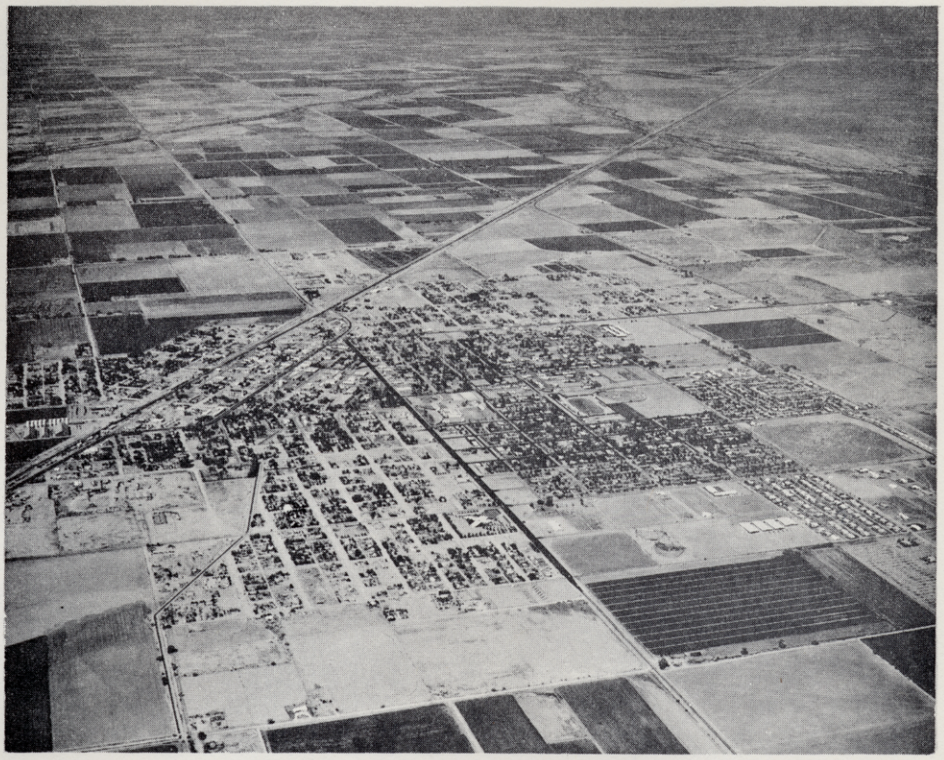
National Forests--Over 11,000,000 acres of land within the National Forests in Arizona provide both direct and indirect benefits to the Arizona economy. Annual sustained yield timber cuts and livestock grazing add tangibly to the economy. The forests, with their outdoor recreational aspects, including fishing, hunting, and scenic trips, add indirectly to the economy by providing a sharp contrast to the desert terrain surrounding the populous centers and are heavily utilized by both transient weekend visitors and permanent summer home colonies.

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--all primarily concentrated in the Gila River Basin. 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

PINAL COUNTY AGRICULTURAL LANDS AND COMMUNITIES



CASA GRANDE



COOLIDGE

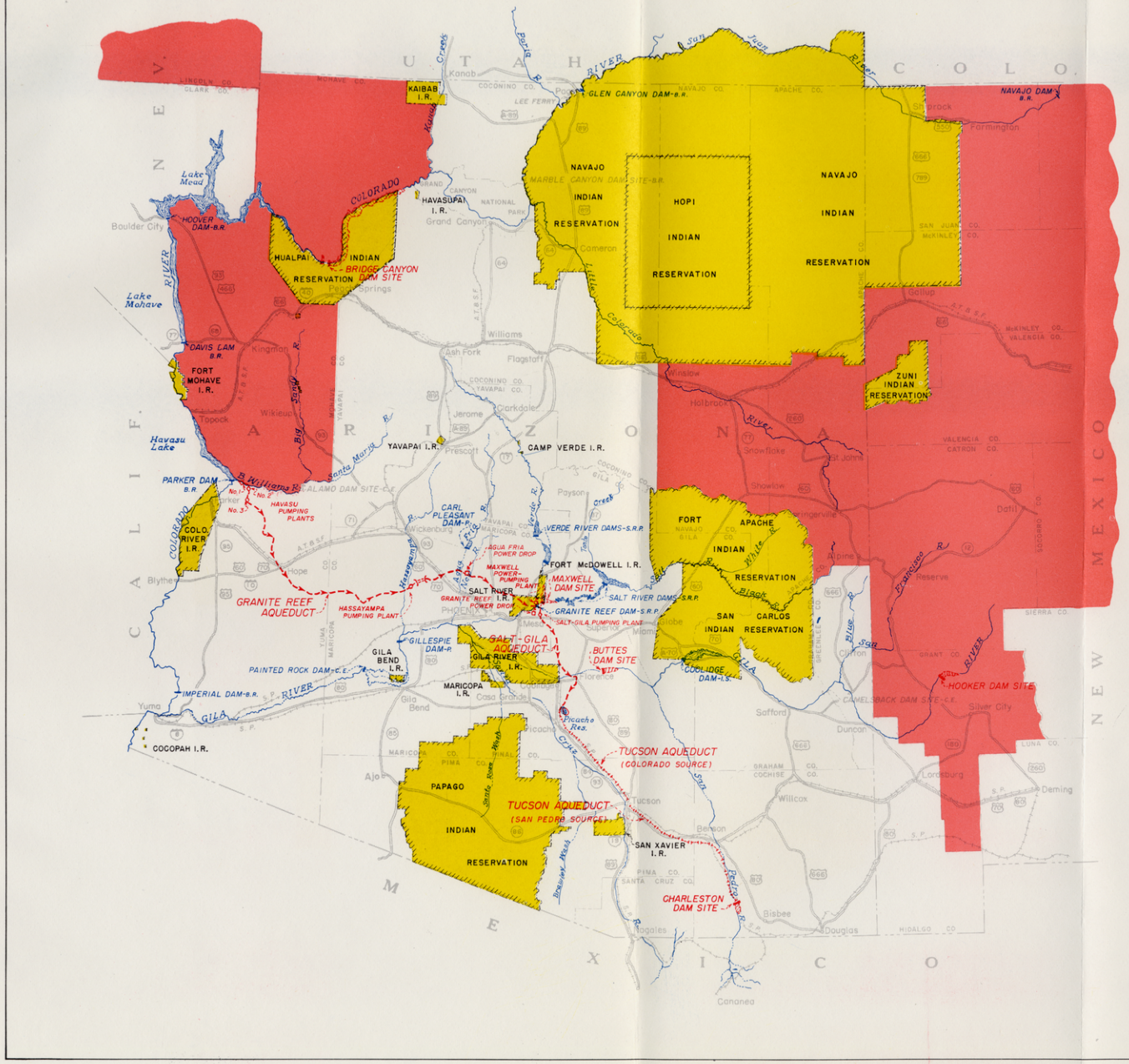
its residents a high standard of living. The 1960 census enumerated a population of about 1,000,000 people for the area, an increase of almost 100 percent since 1950.

The Upper Tributaries Zone is also being subjected to the pressures of expanding population, recreation demands, and needed 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 westward population movement, and is augmented by the recreational needs of the populous valleys and the natural attraction of the Southwest to people seeking a milder climate.

An anomaly, but not unlike other parts of the Nation, is the existence of designated redevelopment areas where unemployment, underemployment, or low income persist adjacent to areas of economic health. Some of those designated areas are Indian reservations where tribal economics have not progressed proportionately with the adjacent off-reservation cultures. Plate 3 shows the designated redevelopment areas and Indian reservations and their relationship to facilities of the Central Arizona Project.

Agriculture--Agriculture is a vital factor in the economy of the area as shown on plate 4. 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

PLATE 3



EXPLANATION

- PROPOSED DAM AND RESERVOIR
- PROPOSED OPEN AQUEDUCT
- PROPOSED CLOSED AQUEDUCT
- PROPOSED TUNNEL
- PROPOSED PUMPING PLANT
- PROPOSED POWER PLANT
- DESIGNATED REDEVELOPMENT AREAS
- INDIAN RESERVATIONS
- INDIAN REDEVELOPMENT AREAS
- 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

INDIAN RESERVATIONS AND DESIGNATED REDEVELOPMENT AREAS

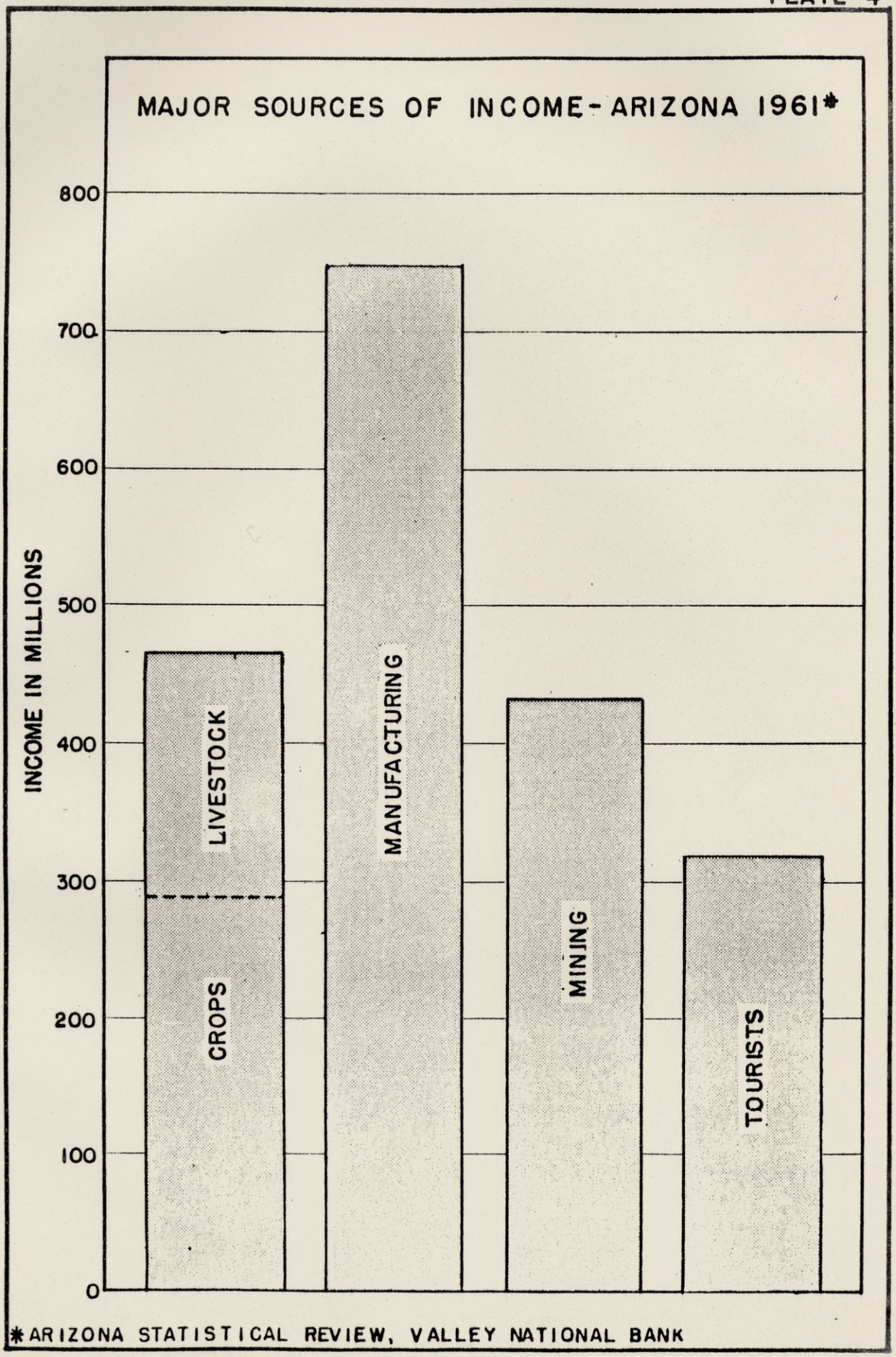
MAP No. 344-314-36

10 0 10 20 30 40 50
SCALE OF MILES

DECEMBER 1962

GPO 966032

PLATE 4

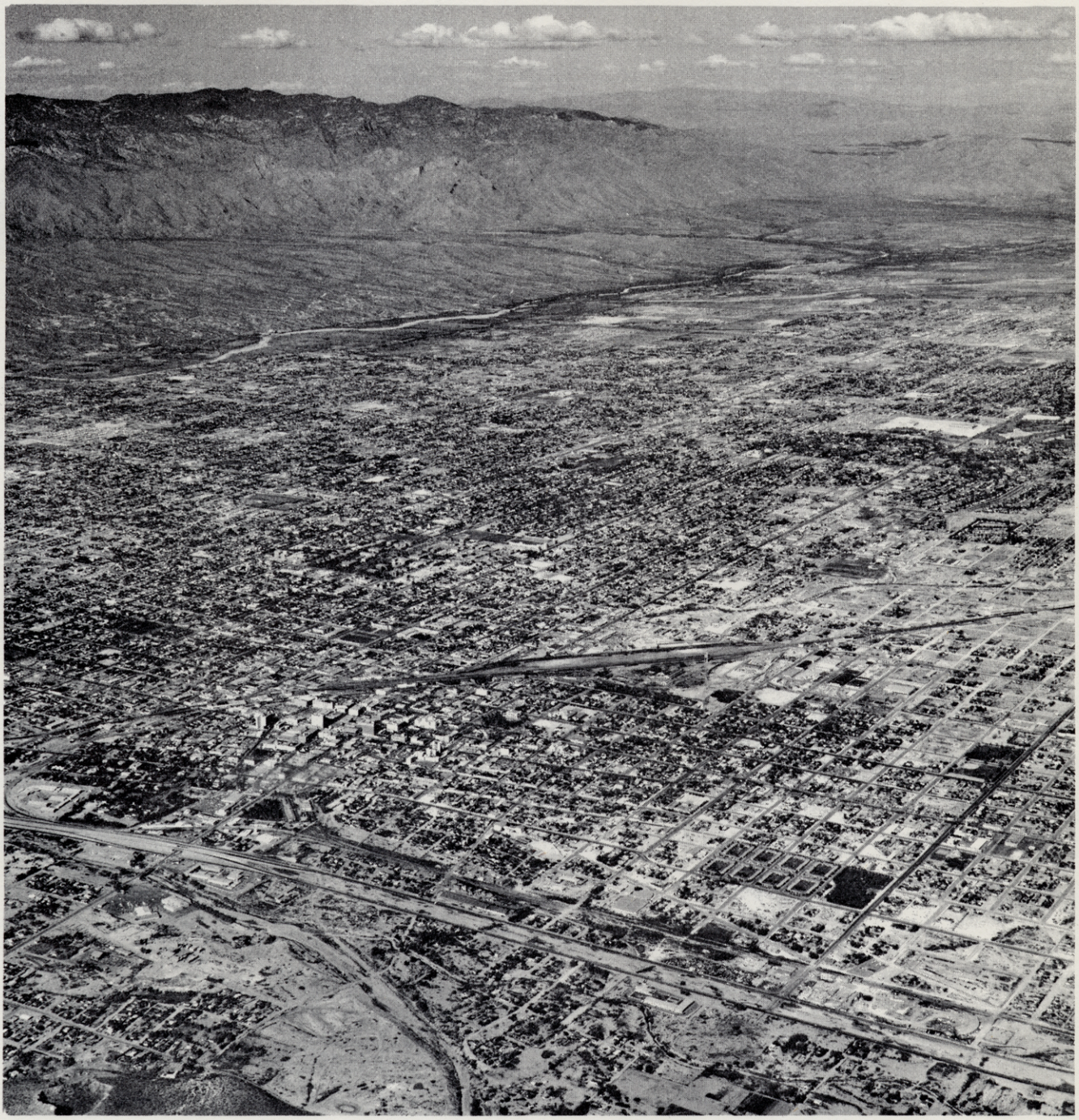


344-314-37

source of nationally distributed winter vegetables and other special crops. For the project area within Arizona, the total value of the agricultural products produced in 1960 was about $320,000,000.

Urban growth and expansion--The doubling of the population in the past 10 years has included the urbanization of rural areas, and most of the new residents have been absorbed through the expansion of cities and towns. Expansion of urban areas in the Salt River Valley to accommodate the population growth has been largely onto the farmlands of the Salt River Project and adjoining agricultural areas. The city of Phoenix, in Maricopa County, increased in population from 106,818 in 1950 to an estimated 505,000 in 1963, and ranked 29th in the Nation. In 1963, the Phoenix metropolitan area included about 62,000 acres of Salt River Project lands which were formerly irrigated. As the urban growth encroaches on the agricultural lands, the water supply formerly used for irrigation is taken over to serve domestic and other municipal purposes.

Tucson, in Pima County, increased in population from 45,454 in 1950 to an estimated 220,000 in 1963, and ranked 54th in the Nation. In Tucson, parts of metropolitan Phoenix, and other localities, much of the urban growth has taken place over desertlands not previously irrigated. Under these circumstances, possibilities are not present for transferring existing water supplies from agricultural to urban use and municipal and industrial water supplies are obtained by pumping from the ground-water reserve.



TUCSON

Industry--Manufacturing is Arizona's most important source of income, as shown on plate 4. 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. Also of great importance to the area are the numerous types of service facilities which cater to the needs of the winter vacationists.

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 1960-1961 valuation of $1,123,487,000 was 70.03 percent of the State valuation.

Problems and Needs of the Area

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 increasing industrial and manufacturing growth.

The local surface-water sources have been appropriated beyond their capabilities, and the ground-water basins are being depleted of water stored prior to this era. In simple terms, the area is using far more water each year than is annually replaced, and this excess of use over supply is continuing at an ever-increasing rate.

Since present uses are approximately double the sustained supply available from the surface- and ground-water basins, the effect of a progressive reduction of water use upon the economic health of this dynamic growth area cannot be estimated.

On a quantitative basis, the major water need probably always will be for irrigation; however, the future municipal and industrial water requirements may be of greater importance. Much of the urban growth has been, and will continue to be, at the expense of agricultural acreage for which a limited local water supply is available. This conversion of agricultural land is also accompanied by urbanization of desertlands surrounding the metropolitan areas for which only a declining ground-water supply is available.

While the agricultural, municipal, and industrial water needs are of paramount importance, they must be coordinated with the increasing requirements for recreation, fish and wildlife, flood control, and electrical power.

A positive solution to the water needs of the area is needed to meet the demands of the ever-increasing population. To prevent a progressive decline of the economy of the area resulting from diminishing water supplies, the importation of additional water from the Colorado River is essential.

Indian reservations and redevelopment areas--Within the area susceptible to influence by the proposed Central Arizona Project are Indian reservations and designated redevelopment areas which are shown on plate 3.

Efforts are now being made to aid the tribal groups to establish themselves within the framework of our present social and economic structure. Past efforts to develop an agricultural base on reservation lands have been defeated in large measure by the lack of a firm and adequate water supply. Conflicting viewpoints exist regarding water right priorities between Indian and non-Indian lands. In part due to this, action to advance Indian self-sufficiency has been held back through lack of funds. Water deliveries made possible through facilities of the proposed Central Arizona Project may make this aid more effective and complete by provision of adequate water supplies for irrigation farming, mineral resource development, and recreation.

Redevelopment area designations under the Area Redevelopment Act, Public Law 87-27, 87th Congress, are applicable to Indian reservations and counties where low income and unemployment loads create problems of economic and social concern.

Water Service Organizations

The activities undertaken by the large number of water service organizations in the Central Arizona Project area 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.

Many public and private organizations have made known their interests in additional water supplies. Several of the existing water service organizations presently receive surface water, all utilize

ground water, and all are potential subscribers to the water service plan described in this report. Many existing organizations have requested water or expressed interest in negotiating with the Bureau of Reclamation for water service. The Bureau of Reclamation has received informal expressions of support from many other groups.

Since 1960, Arizona has contributed $200,000 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

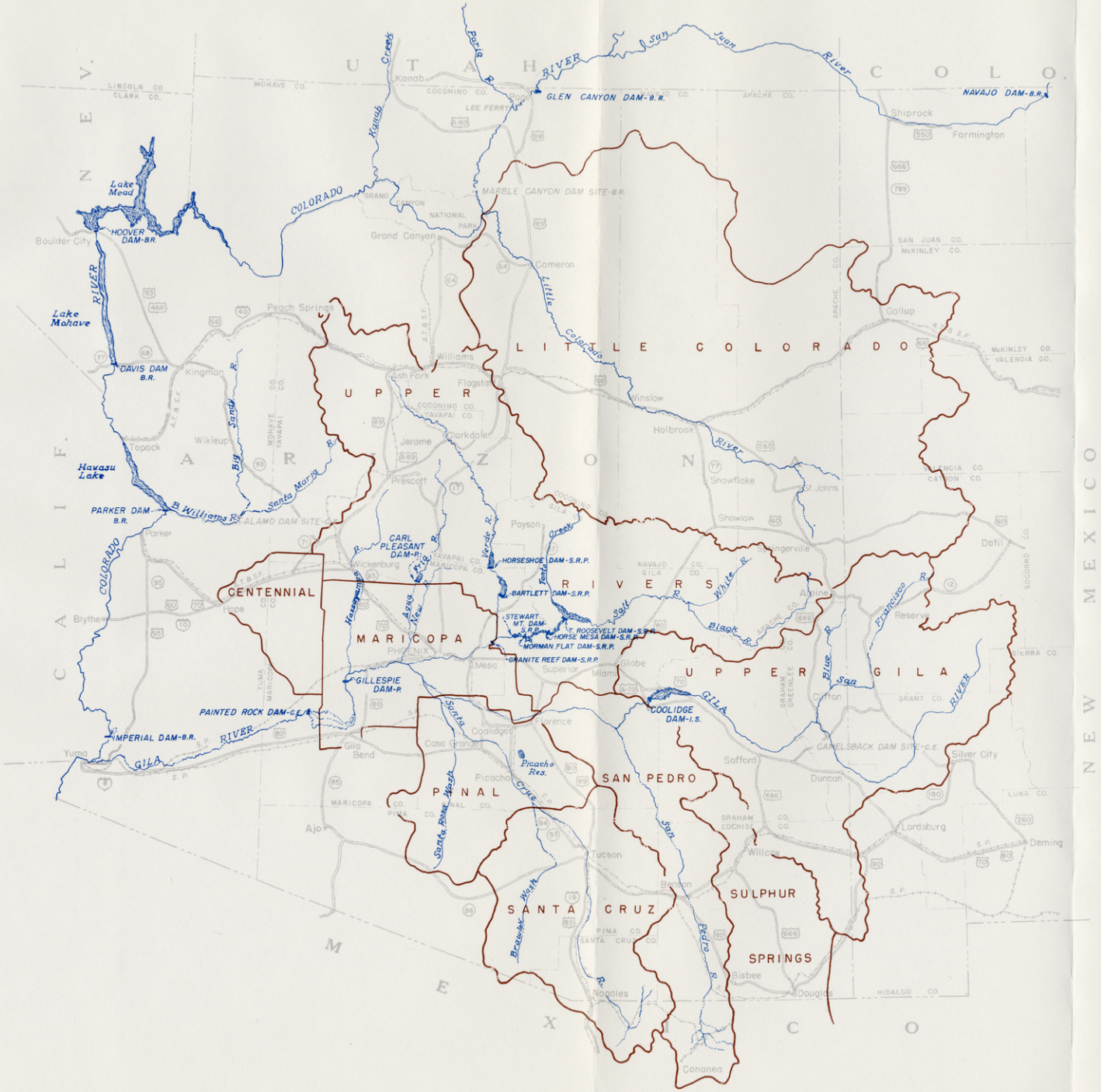
CHAPTER II - LAND AND WATER UTILIZATION

The most significant changes which have occurred in the Central Arizona Project area since the 1947 report was issued are the changes in land and water utilization resulting from the growth and development of the area. With the doubling of the population, large areas of farm and desert lands have been urbanized. As a consequence, some available water supplies have been transferred from irrigation to municipal and industrial uses, and the diminishing ground-water resources have been further exploited. The 1947 plan contemplated that only about 1 percent of project water would be provided for municipal and industrial purposes, whereas the present reanalysis contemplates that at least one-third of the total project water supply will be used for such purposes. This chapter provides up-to-date data on land and water utilization which were used in the project reanalysis.

Hydrologic Study Areas

In reanalyzing the land utilization, water uses, and water requirements to reflect present and projected future conditions, hydrologic study areas were 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 5, 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 could be made. Within the Upper Tributaries Zone are the Upper Gila, San Pedro, and Upper River areas, to which water could be made available by exchange.

PLATE 5



EXPLANATION

- HYDROLOGIC STUDY AREAS
- EXISTING DAM AND RESERVOIR
- DAM SITE
- P. PRIVATE
- B.R. BUREAU OF RECLAMATION
- S.R.P. SALT RIVER PROJECT
- C.E. CORPS OF ENGINEERS
- I.S. INDIAN SERVICE

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
REVISED NOVEMBER 1962

GPO 966032

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 areas. The Bureau of Reclamation has completed a detailed land classification of the San Carlos Project, which comprises about 100,000 acres. Classification of other portions of the project area is in progress.

The Bureau of Indian Affairs has classified as suitable for irrigation 101,479 acres of Indian reservation lands within the Central Arizona Project area. In the absence of an adequate supply of water, extensive sections of other Indian reservations having similar soils have not been classified.

Irrigated lands have been 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 surface soils may vary from coarse to fine textures, but are 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 1,202,000 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 1955-1960. These figures include 75,000 acres of Indian reservation lands which were irrigated during this period. The irrigated acreage, as shown on table 1, fluctuates from year to year in accordance with available water supplies. Some 322,000 acres of developed lands are currently out of production and 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.

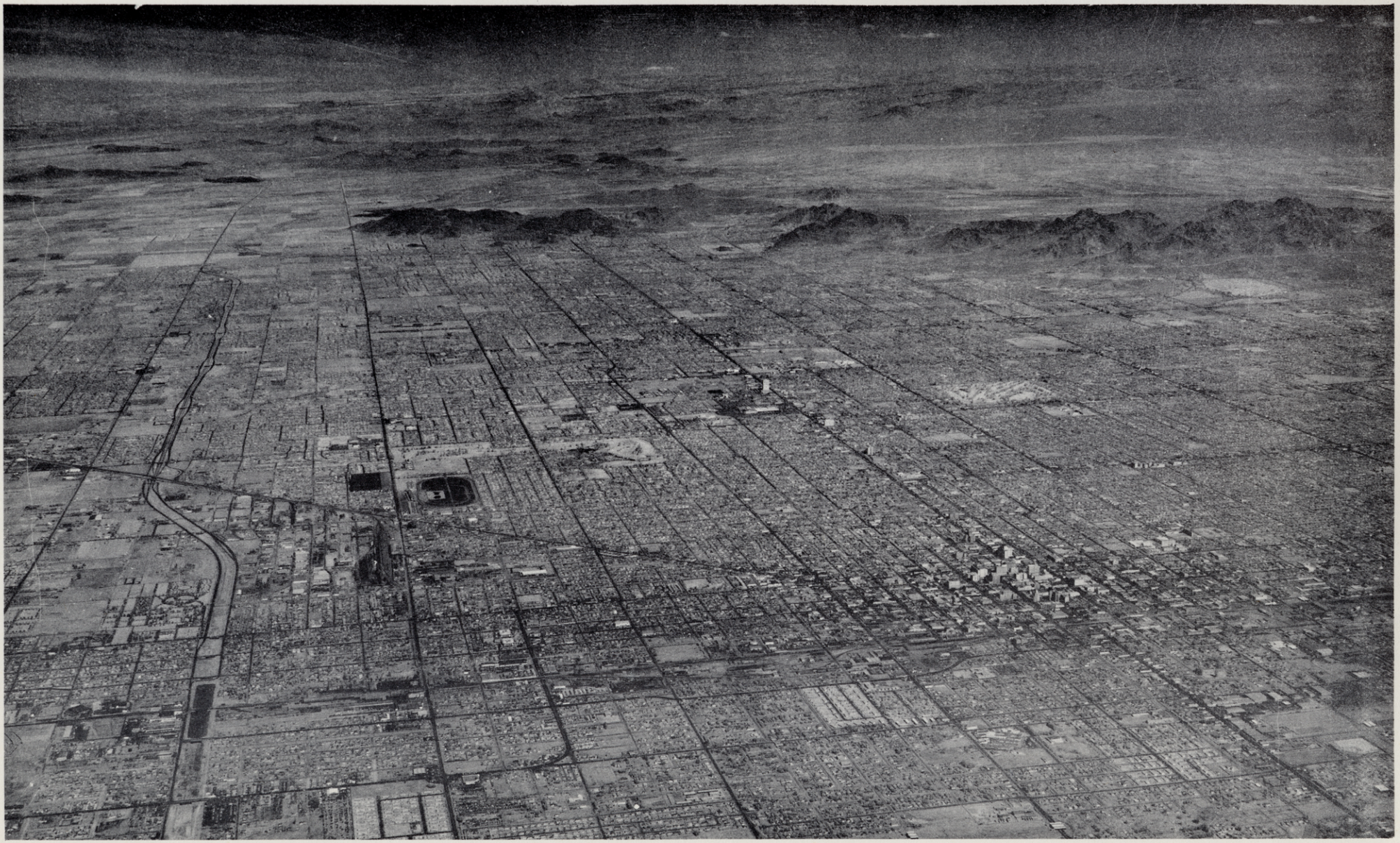
As indicated by table 1, the major urban centers have developed within the Maricopa and Santa Cruz hydrologic study areas. The city limits of Phoenix within the Maricopa study area embrace over 140,000 acres, a large portion of which is previously irrigated land of the Salt River Project. The photograph 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 Salt River Project boundaries, and its water supply is obtained by transferring Salt River Project water from irrigation to municipal use as irrigated lands are subdivided and from other surface or underground sources. Lands within the city, but outside the Salt River Project boundary, must obtain water from other than Salt River Project sources.

The city limits of Tucson within the Santa Cruz study area embrace approximately 45,000 acres, the major portion of which were desertlands

Table 1--Central Arizona Project developed areas - 1962

Hydrologic Study Area	Urban Area Population	Agriculturally Developed Land[1/] (Acres)	
		Private	Indian Reservation
Centennial	1,000	35,500	0
Maricopa	662,000	574,550	14,450
Pinal	46,300	324,700	54,300
Santa Cruz	267,000	71,900	1,600
San Pedro	36,000	14,960	40
Upper Gila:			
Arizona	27,900	71,450	2,150
New Mexico	2,450	12,500	0
Upper Rivers	57,300	21,000	3,100
Total	1,099,950	1,126,560	75,640
	or	or	or
Rounded	1,100,000	1,127,000	75,000

1/ Developed lands as used in this report are those lands which are presently irrigated or have a previous history of irrigation.



PHOENIX

with no previous history of irrigation and for which no possibilities are present for transferring irrigation supplies directly to municipal use. Plate 6 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 for nonbeneficial uses, losses, and waste.

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 future projections 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, shown on plate 6, represent high and low estimates and indicate the range of growth that can be expected in the project area under normal economic conditions.

On the basis of these projections, it is estimated that municipal and industrial water requirements for Arizona, which are concentrated around Phoenix and Tucson, could increase from the present use of about 370,000 acre-feet per year to about 1,500,000 to 2,500,000 acre-feet per year by the year 2020. 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 probably will occur in desert areas

PLATE 6

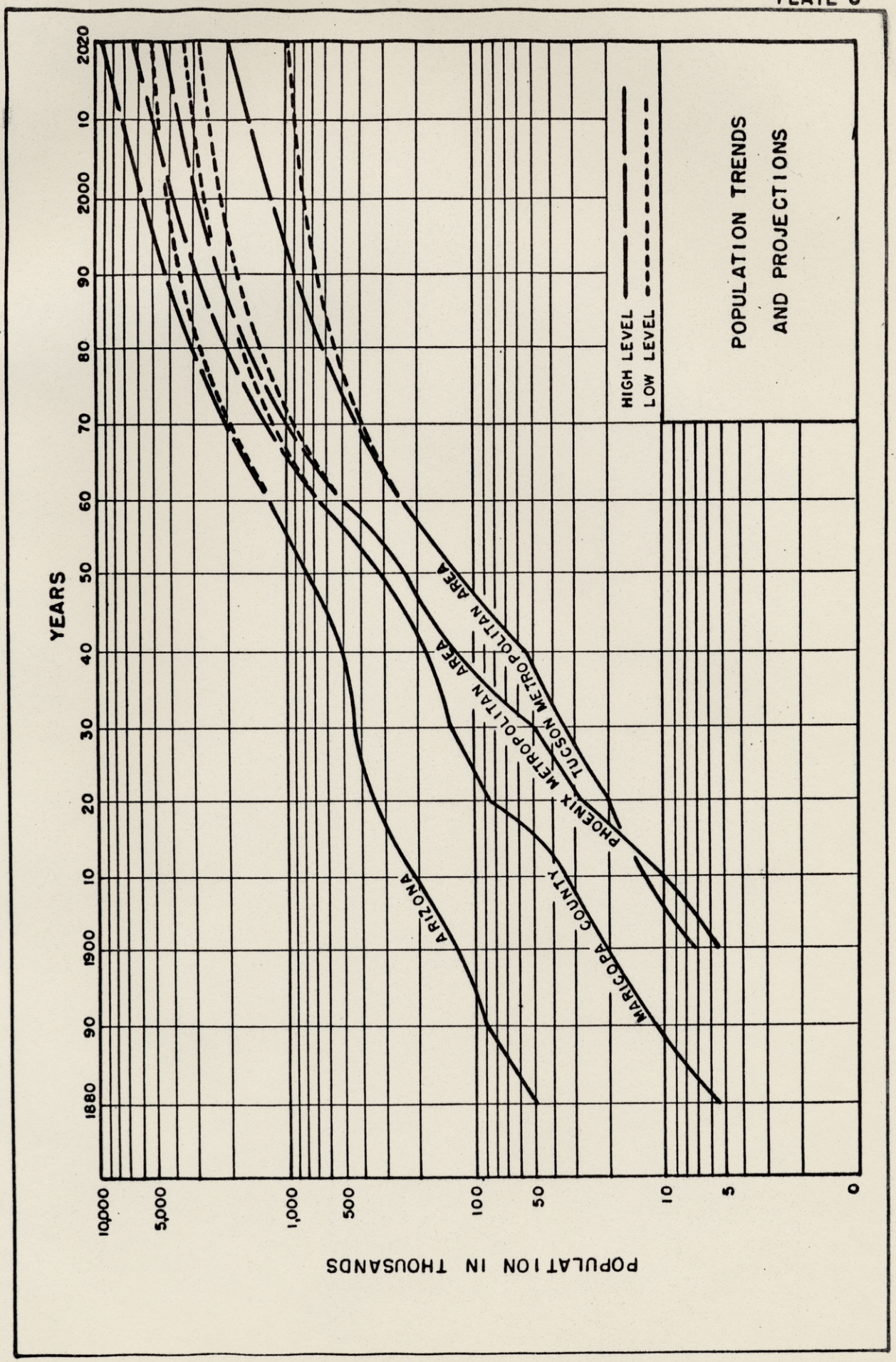

POPULATION TRENDS
AND PROJECTIONS
HIGH LEVEL
LOW LEVEL
YEARS
1880
90
1900
10
20
30
40
50
60
70
80
90
2000
10
2020
POPULATION IN THOUSANDS
10,000
5,000
1,000
500
100
50
10
5
0
ARIZONA
MARICOPA COUNTY
PHOENIX METROPOLITAN AREA
TUCSON METROPOLITAN AREA

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.

having little or no present water supply capability. It is estimated that approximately 312,000 acre-feet of import water will be required to satisfy demands in these desert areas under project conditions.

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.

Continuing and widespread mineral exploration activities are extending the range and scope of future industrial requirements. Mining interests have estimated that future requirements for additional water from the Gila River and tributaries may range from 20,000 to 40,000 acre-feet or more annually in the Upper Gila River Basin alone. It is anticipated, however, that substantial water supplies in addition to those above will be needed for proposed mining activities and for use by the 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.

Water Conservation Requirements

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 (McDowell) 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, the authorized Camelsback Dam and channel improvement by the Corps of Engineers would coordinate well with storage at the Hooker site.

Recreation and fishery and wildlife--Fishery and wildlife consumptive uses, like recreational uses, are very small in relation to the quantity of water regulated and transported. The requirement is for surface area of water rather than for consumption, and this surface will 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 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, Maxwell (McDowell), 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

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

Hydrologic Study Area	Water Requirement (At Farm Headgate and at Water System)			Present Average Annual Water Supply						Indicated Present Deficiency
				At Diversion Point			At Farm Headgate & 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.

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 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

Table 4.--Reservoir storage capacity

River	Dam	Reservoir	Storage Capacity (acre-feet)	Completion Date
Salt	T. Roosevelt	T. 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	

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 are 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 and 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 riverflows. Water diversions in the reach of the Gila River from Virden to the San Carlos Project have been subject to

the Gila Decree 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 streams 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-coarse 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.

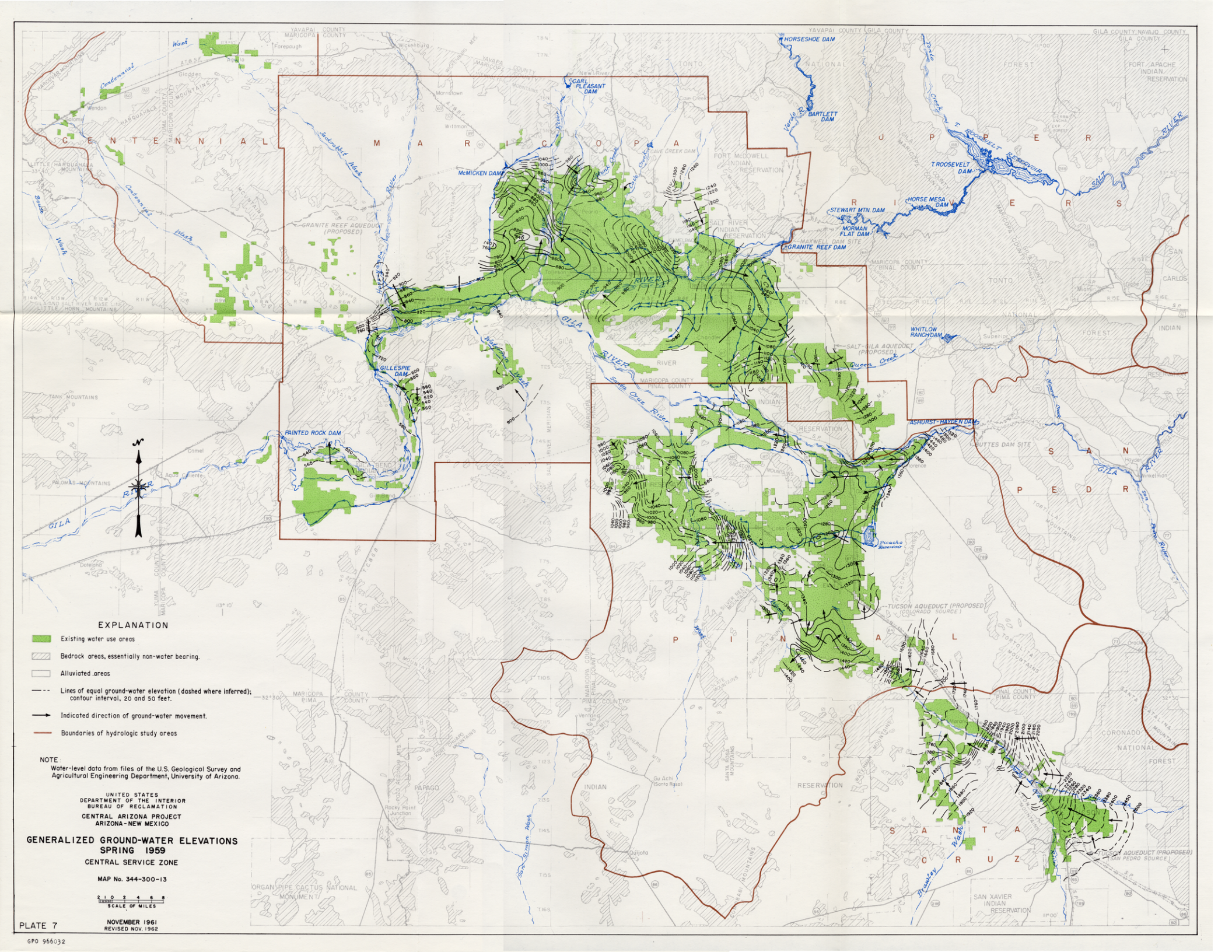
It is in the long-term storage function of the ground-water reservoir wherein lie the water problems of the area. The annual use of ground water is far greater than the annual recharge, and has been for many years. In terms of the quantities involved during the past 5 years, water requirements are estimated 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 the 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 in some of the less dependable water supply areas. To be sure, there is some replenishment of water each year as

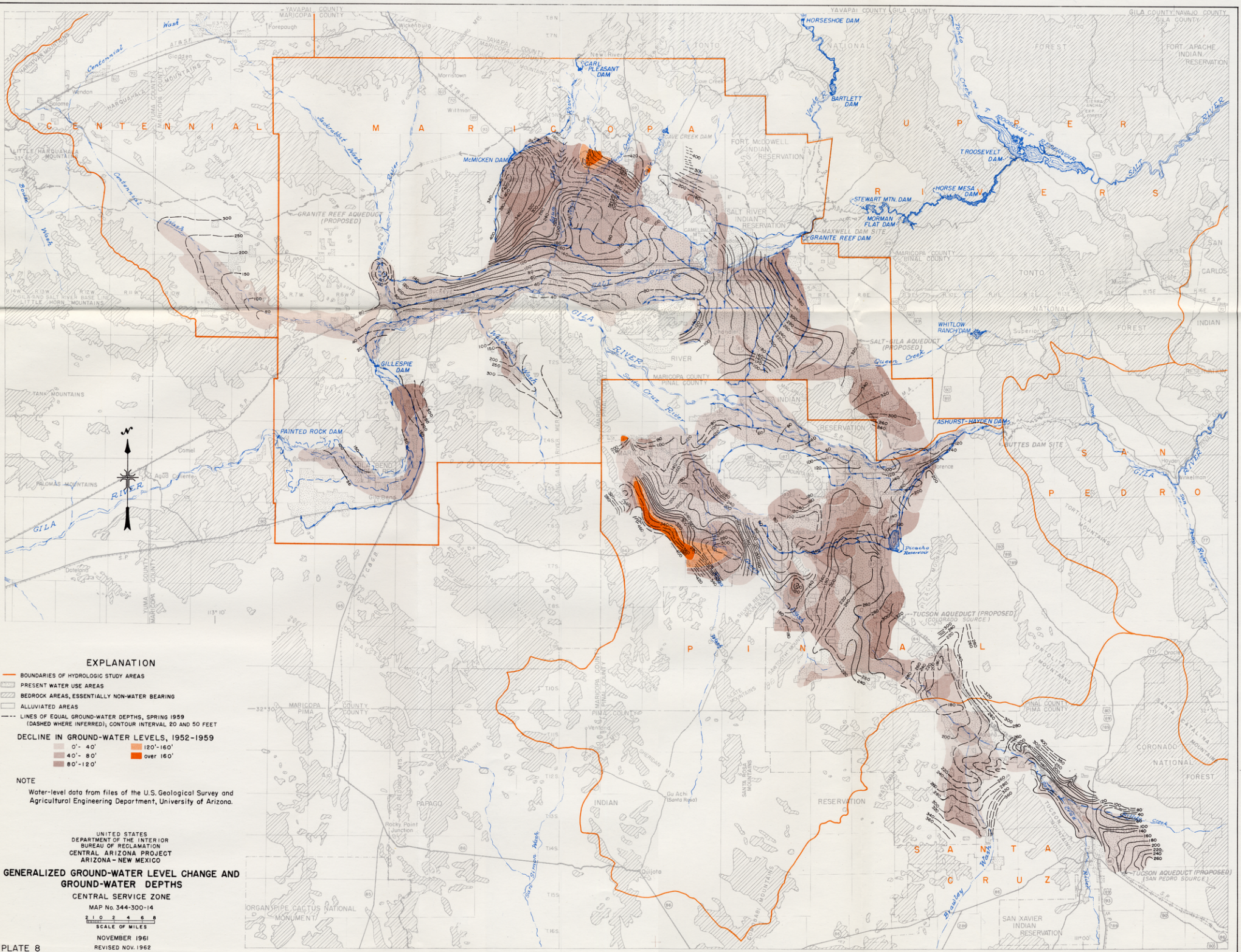
unconsumed winter and summer runoff goes into storage, but this replenishment is obscured as these same flows, and more, are pumped during the growing season. On an annual basis, it has been many years since water supply has exceeded water use and hence much of the water being used to meet today's needs 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 7. The more notable features on plate 7 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 8. 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 same 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


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
2 1 0 2 4 6 8
SCALE OF MILES
PLATE 7
NOVEMBER 1961
REVISED NOV. 1962
GPO 966032
CENTENNIAL
MARICOPA
UPPER
SALT RIVER VALLEY
PINAL
SAN PEDRO
SANTA CRUZ
HORSESHOE DAM
CARL PLEASANT DAM
BARTLETT DAM
McMICKEN DAM
GRANITE REEF AQUEDUCT (PROPOSED)
GILLESPIE DAM
PAINTED ROCK DAM
T. ROOSEVELT DAM
ROOSEVELT RESERVOIR
HORSE MESA DAM
STEWART MTN. DAM
MORMAN FLAT DAM
MAKWELL DAM SITE
GRANITE REEF DAM
WHITLOW RANCH DAM
SALT-GILA AQUEDUCT (PROPOSED)
ASHURST-HAYDEN DAM
BUTTES DAM SITE
Picacho Reservoir
TUCSON AQUEDUCT (PROPOSED) COLORADO SOURCE
TUCSON AQUEDUCT (PROPOSED) SAN PEDRO SOURCE
SALT RIVER
GILA RIVER
Santa Cruz River
San Pedro River
Agua Fria River
Verde River
Queen Creek
Sacaton
Casa Grande
Florence
Coolidge
Chandler
Mesa
Tempe
Phoenix
Glendale
Peoria
Buckeye
Gila Bend
Ajo
Casa Grande Mountains
Picacho Mountains
Tortolita Mountains
Santa Catalina Mountains
Superior
Globe
Miami
Winkelman
Hayden
Florence
Oracle
Tucson
Ventana
Rocky Point Junction
Quijota
Gu Achi (Santa Rosa)
Dateland
Comel
Aqua Caliente
Wickenburg
Morristown
Wittman
Cave Creek
Fort McDowell Indian Reservation
Salt River Indian Reservation
Gila River Indian Reservation
San Xavier Indian Reservation
Papago Indian Reservation
Fort Apache Indian Reservation
Tonto National Forest
Coronado National Forest
Organ Pipe Cactus National Monument
Tank Mountains
Palomas Mountains
Little Harquahala Mountains
Harquahala Mountains
Little Horn Mountains
Buckskin Mountains
Sierra Estrella
Superstition Mountains
Pinal Mountains
Mineral Creek
Black Canyon
Agua Fria
Centennial Wash
Buckskin Wash
Hassayampa River
Waterman Wash
Powerline Wash
Vekol Wash
Santa Rosa Wash
Brawley Wash
Yavapai County
Maricopa County
Pinal County
Pima County
Gila County
Navajo County


EXPLANATION
BOUNDARIES OF HYDROLOGIC STUDY AREAS
PRESENT WATER USE AREAS
BEDROCK AREAS, ESSENTIALLY NON-WATER BEARING
ALLUVIATED AREAS
LINES OF EQUAL GROUND-WATER DEPTHS, SPRING 1959 (DASHED WHERE INFERRED), CONTOUR INTERVAL 20 AND 50 FEET
DECLINE IN GROUND-WATER LEVELS, 1952-1959
0'- 40'
40'- 80'
80'-120'
120'-160'
over 160'
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 LEVEL CHANGE AND GROUND-WATER DEPTHS
CENTRAL SERVICE ZONE
MAP No. 344-300-14
SCALE OF MILES
NOVEMBER 1961
REVISED NOV. 1962
PLATE 8
GPO 966032
CENTENNIAL
MARICOPA
UPPER
SALT RIVER
SAN PEDRO
PINAL
SANTA CRUZ
HORSESHOE DAM
BARTLETT DAM
CARL PLEASANT DAM
McMICKEN DAM
ROOSEVELT DAM
HORSE MESA DAM
STEWART MTN. DAM
MORMAN FLAT DAM
GRANITE REEF DAM
GRANITE REEF AQUEDUCT (PROPOSED)
WHITLOW RANCH DAM
SALT-GILA AQUEDUCT (PROPOSED)
GILLESPIE DAM
PAINTED ROCK DAM
ASHURST-HAYDEN DAM
COOLIDGE DAM SITE
TUCSON AQUEDUCT (PROPOSED) (COLORADO SOURCE)
TUCSON AQUEDUCT (PROPOSED) (SAN PEDRO SOURCE)
GILA RIVER
SALT RIVER
SANTA CRUZ RIVER
SAN PEDRO RIVER
Picacho Reservoir
FORT McDOWELL INDIAN RESERVATION
SALT RIVER INDIAN RESERVATION
GILA BEND INDIAN RESERVATION
PAPAGO INDIAN RESERVATION
SAN XAVIER INDIAN RESERVATION
ORGAN PIPE CACTUS NATIONAL MONUMENT
TONTO NATIONAL FOREST
CORONADO NATIONAL FOREST
FORT APACHE INDIAN RESERVATION
YAVAPAI COUNTY
MARICOPA COUNTY
PINAL COUNTY
GILA COUNTY
NAVAJO COUNTY
PIMA COUNTY
YUMA COUNTY

fill. 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 constrictions 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 available surface-water and ground-water supplies 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 1947 report, this reevaluation assumes a diversion quantity of 1,200,000 acre-feet annually to be pumped from Lake Havasu on the Colorado River. This assumed quantity 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 (McDowell) 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 are 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 (McDowell), Buttes, Charleston, and Hooker 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 is altering the hydrologic cycle. Flows which formerly reached the ground-water reservoir by deep percolation of applied water are becoming 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.

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 since 1947 adds emphasis to the necessity for integration of all sources and potential future developments.

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.

CHAPTER IV

PLAN OF DEVELOPMENT

CHAPTER IV - PLAN OF DEVELOPMENT

General

As originally set forth in the 1947 report, the Central Arizona Project plan of development would make Colorado River water available to the project area through a pumping and aqueduct system which would raise and convey the water from Lake Havasu, on the Colorado River, directly into the Central Service Zone. The relation of proposed project facilities to existing facilities is shown on the General Location Map (plate 1). By these facilities, the use of imported waters and the local water resources of the Gila River Basin would be coordinated. Through hydrologic coordination, vital and essential basinwide water uses would be possible. The project is designed to make use of powerheads for the generation of electric energy for use in pumping water for irrigation, municipal and industrial purposes, and for commercial sale. Additional purposes provided by the project include flood control, recreation, fish and wildlife conservation, sediment retention, salinity control, and area redevelopment.

Project Facilities

The keystone facilities for the Central Arizona Project would be the high Bridge Canyon Dam, Reservoir, and Powerplant which would provide the energy for pumping Colorado River water to the Central Service Zone and for commercial sale.

Present conditions within the Central Service Zone have dictated minor changes in the 1947 aqueduct location to meet the extensive urbanization and development that have taken place since the original

studies were made. 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 (designated as McDowell Dam and Reservoir in the 1947 report)

Tucson Aqueduct and Pumping Plants (Colorado source)

Buttes Dam and Reservoir

Within the Upper Tributaries Zone, growth and development have also occurred since the 1947 report and are now causing increasing water demands. Minor water control and conservation facilities are being planned and constructed by the Bureau of Land Management, Soil Conservation Service, and Indian Tribal Councils. Channel improvement of the middle Gila River and the construction of Camelsback Dam by the Corps of Engineers have recently been authorized. Project facilities located in the Upper Tributaries Zone, and shown on plate 1, are:

Hooker Dam and Reservoir

Charleston Dam and Reservoir

Tucson Aqueduct (San Pedro source)

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 high dam, rising 673 feet above streambed with a crest length of 1,650 feet, would require about 2,650,000 cubic yards of concrete. The reservoir capacity would be 3,710,000 acre-feet. 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, at a distance of about 17 miles, the effect becomes imperceptible under all flow conditions.

Pumping plants--Starting from the deep water Bill Williams River arm of Lake Havasu, three in-series Havasu Pumping Plants, each with a total capacity of 1,890 c.f.s., would have a static lift of 969 feet. The discharge from these plants would then flow 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 115-foot static 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 designed capacity of the aqueduct is 1,800 c.f.s. It would be concrete lined, with 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 desertland between these ranges. From the Hassayampa River Pumping Plant, the aqueduct would pass through the north edge of White Tank Mountains by means of a 6-mile tunnel, and it would pass some 4 miles north of Phoenix en route to its terminus at Granite Reef Dam.

Power drops--Along the Granite Reef Aqueduct, the major turnouts would be through power drops to dissipate the energy of the falling water and thus to recover a portion of the energy previously used for pump lifts. The Agua Fria Powerplant would have 94 feet of head and an installed capacity of 3,000 kw to utilize the flows released for use in the central Maricopa area. The Granite Reef Powerplant, with 113 feet of head, would have 3,500 kw of installed capacity to utilize the flows diverted to the existing Salt River Project canals or to Maxwell (McDowell) Reservoir.

Salt-Gila Aqueduct and Pumping Plant--The 1,275-c.f.s.-capacity Salt-Gila Aqueduct would receive water from a 77-foot static 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 ground-water pumping only and presently not organized as irrigation districts. A turnout for the Tucson Aqueduct (Colorado source) would be provided.

Maxwell (McDowell) Dam and Reservoir--Located on the Salt River just downstream from its junction with the Verde River, the Maxwell Dam, which was designated the McDowell Dam in the 1947 report, 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 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 (McDowell) 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 (McDowell) 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 (McDowell) 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 have 11,000 kw of installed 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 and industrial water supply would be conveyed 56 miles through a 150-c.f.s.-capacity pipeline and would be lifted 920 feet by a series of pumping plants.

Buttes Dam and Reservoir--Although investigated and reported previously as a separate facility, Buttes Dam and Reservoir was included as an integral part of the Central Arizona Project in the 1947 report and in this supplemental report. An earthfill structure at the Buttes site rising 210 feet above streambed would form a

reservoir of 366,000 acre-foot capacity. Conservation storage capacity would be 100,000 acre-feet, and 266,000 acre-feet of capacity would be 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)--This conduit would convey about 12,000 acre-feet annually from the Charleston Reservoir to Tucson and vicinity.

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 would provide water conservation, fish and wildlife uses, recreation, sediment detention, and flood control.

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.

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 system 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 to be made available in the project area will require additional study to properly evaluate the benefits accruing from reuse and the attendant costs of physical facilities. The cost of such facilities would not affect economic and financial aspects of the project as presented in this report because these units would have to be justified by benefits over and above those considered herein. 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. Existing facilities of other agencies which could be integrated operationally into the Central Arizona Project include dams, reservoirs, and irrigation works serving proposed contracting agencies in the project area.

Project Operation and Administration

Direct delivery of Colorado River water would be made to the Central Service Zone through project facilities. The assumed 1,070,000 acre-feet delivered to water service agencies would, through hydrologic coordination, provide means whereby essential uses may be furnished from regulation by companion storage features in Upper Tributaries areas. Power generated at the Bridge Canyon Powerplant would provide project pumping energy, with the remaining capacity and generation available for commercial sale. Operational advantages

at Bridge Canyon accruing from the Glen Canyon Dam constructed upstream have not been evaluated.

Full utilization of all available water is a prime necessity. The details of operation and administration of the Central Arizona Project for water deliveries, conservation, and reuse require comprehensive studies to develop and delineate the specific service areas, beneficiaries and contracting entities.

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 Canyon	1,500,000	5,800,000
Agua Fria	3,000	13,600
Granite Reef	3,500	16,340
Maxwell (McDowell)	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 to reserve water to produce 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 Lower Colorado River Basin Power Market Area Survey, prepared by the Federal Power Commission in November 1962, it was estimated that by 1970 the electric powerload in Arizona would have reached about 3,600,000 kw and that the load in southern Nevada would be about 803,000 kw. By 1980, the loads were estimated to be about 7,000,000 kw and 1,354,000 kw, respectively, representing a total load increase in the two areas of 3,951,000 kw in the 10-year period, or about 395,000 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 12,981,000 kw to 23,595,000 kw, an annual increase of 1,061,000 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 to 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 $1,001,331,000. Distribution systems to be provided by the water users will cost an additional $100,000,000.

Construction considerations--Much of the data used in updating and reestimating costs 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 reestimating costs 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.

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 (McDowell), 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 for various Central Arizona Project features are shown on tables 6 and 7. 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 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, the purchase of firming energy, and the storage-delivery charge from the Boulder Canyon Project. Article 9 of the "Contract for Delivery of Water" between the Secretary of the Interior and the State of Arizona, dated February 9, 1944, provides that a charge not to exceed 25 cents per acre-foot of water shall be made upon all water users in Arizona not having a perfected right on the river at the time of the Act for storage of water in Lake Mead or for delivery of such water diverted at a point or points below Hoover Dam.

Form PF-1
(5-57)
Bureau of Reclamation

OFFICIAL
ESTIMATE

Project: CENTRAL ARIZONA

Date of Estimate: December 1961--Rev. January 1963

Prepared by: _____ Approved by: _____

Sheet 1 of 1

Cost Classification	DESCRIPTION		Quantity	Unit Cost	Total Estimate	Labor and materials by contractor	Materials and Supplies by Govt.	Labor by Government Forces	Service Facilities	Investigations, Engineering and Other Costs	Previous Official Estimate
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	SUMMARY										
01.01	Bridge Canyon Dam and Reservoir		3,710,000 af		149,440,000						
.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	H=300'	1,800 cfs		10,890,000						
.02	Havasu Pumping Plant No. 2	H=430'	1,800 cfs		14,180,000						
.03	Havasu Pumping Plant No. 3	H=239'	1,800 cfs		14,180,000						
.04	Hassayampa Pumping Plant	H=115'	1,800 cfs		12,730,000						
.05	Salt-Gila Pumping Plant	H= 77'	1,275 cfs		5,120,000						
.06	Tucson Pumping Plant (San Pedro Source)	H=300'	18 cfs		240,000						
.07	Tucson Pumping Plant (Colorado Source)	H=920'	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				189,688,000						
15.01	General Property 1/				14,523,000						
.02	Recreation Facilities				8,267,000						
	TOTAL CONSTRUCTION COST FOR ALLOCATION				1,001,331,000						
	Distribution System Costs 2/ 500,000 acres @ $200/ac.				100,000,000						
	TOTAL PROJECT CONSTRUCTION COST				1,101,331,000						

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.

Table 6

GPO 865720

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						12,000			506,500	500,000	500,000				4
5																			5
6	108	CONSTRUCTION PROGRAM																	6
7	.01.01	Bridge Canyon Dam	3,710,000	af	149,440,000	438,000	9,360,000	18,147,000	19,379,000	20,908,000	20,908,000	20,908,000	21,336,000						7
8	.02	Maxwell Dam	860,000	af	31,865,000	236,000	3,000,000	8,000,000	12,500,000	8,129,000									8
9	.03	Buttes Dam	366,000	af	29,432,000	306,000	400,000	265,000	9,435,000	11,400,000	6,000,000	1,578,000							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	150,000	180,000	3,000,000	7,000,000	5,494,000								11
12	.03.01-04	Havasu & Hassayampa Pumping Plants H = 1,084'	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 H = 77'	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) H = 300'	18	cfs	240,000	1,000				39,000	100,000	100,000							14
15	.07	Tucson Pumping Plants (Colorado Source) H = 920'	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	985,400	2,000,000	3,000,000	52,000,000	48,000,000	43,000,000	43,000,000	30,394,600						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	25,000	48,000	200,000	1,400,000	1,625,000									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	159,000						400,000	1,200,000	10,500,000	12,500,000	11,101,000			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	411,000	2,000,000	2,000,000	16,042,000	30,005,000	30,005,000	30,005,000	18,503,000	11,101,000	6,595,000				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
25	.03-04	Aqueduct Powerplants	6,500	kw	2,756,000	12,000				30,000	200,000	1,200,000	1,316,000						25
26	.13.01	Transmission System			109,668,000	556,000	900,000	11,002,000	500,000	3,200,000	27,000,000	47,067,000	50,005,000	36,005,000	18,506,000				26
27	.15.01	General Property 1/			14,523,000	42,000	50,000	6,300,000	5,130,000										27
28	.02	Recreation Facilities			6,267,000	0	467,000	974,000	1,325,000	1,715,000	1,200,000	1,222,000	984,000	64,000	56,000				28
29																			29
30		TOTAL CONSTRUCTION COST			1,001,331,000	4,109,000	19,531,000	54,368,000	128,591,000	155,396,000	161,421,000	163,844,000	151,621,600	89,546,000	58,255,400	12,194,000	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			1,099,474,000	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.

A Represents completion of construction on a feature.

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

HEE 1/24/62

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

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

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

Approved: _____ (Commissioner) _____ (Date)

Revised: JUN 4 1963 (Date) SHEET ____ OF ____ SHEETS

Form PF-2 UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION DEC. 1956

CONTROL SCHEDULE
CENTRAL ARIZONA PROJECT
APPRAISAL REPORT DATA

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

☐ GENERAL INVESTIGATIONS ☐ OPERATION & MAINTENANCE
☒ CONSTRUCTION ☐ OTHER

GPO 842987

Table 7

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

Item	O&M	Replacement
Dams and reservoirs		
Bridge Canyon	$ 84,900	$ 13,800
Maxwell (McDowell)	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	1,683,700	595,900
Recreation facilities	356,000	
Permanent facilities		13,600
Storage-delivery charge 1/	300,000	
Energy purchase	1,510,000	
Drainage	200,000	
Total	$7,818,900	$1,091,700

1/ 25¢ charge per acre-foot as per Article 9 of "Contract for Delivery of Water" between the Secretary of the Interior and the State of Arizona.

CHAPTER V

ECONOMIC AND FINANCIAL ANALYSES

CHAPTER V - ECONOMIC AND FINANCIAL ANALYSES

Previous chapters have described the proposed Central Arizona Project facilities and updated the project costs. This chapter presents an analysis of the economic justification and financial feasibility of constructing the project based on current Bureau of Reclamation policies. 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 could be repaid.

Agricultural Economy

Although construction of the Central Arizona Project 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 project is the stabilization and prevention of retrenchment of the economy of the project area. Even with an imported supply of water, some presently irrigated lands will eventually have to be abandoned because of water shortages, 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 accuracy.

In order to evaluate the economic effects and payment capacity resulting from the imported water that would be delivered to existing developed farmland, 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 farm returns 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 would receive project water. 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 modern concrete distribution and lateral systems. An allowance was made in the studies to provide revenue to pay costs for such works if not now constructed, or 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 in accordance with a generalized new land equivalent concept and did not attempt to evaluate, in detail, what would result to the farm operations and income if supplemental water were 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 has a higher value than indicated by the method used.

On the basis of the farm budget analyses, allowing a 25 percent contingency factor, the weighted average payment capacity for an

acre-foot of water at the canalside in the central Arizona area was computed to be $10.75. 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 the payment capacity will be higher.

Economic Justification

The Central Arizona Project 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--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 water to presently irrigated and developed lands. The irrigation benefit falls 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, is briefly described, but has not been numerically evaluated or 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 continue to 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 are $34,579,000. Additional direct 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 resulting from the movement of additional farm products through the channels of trade and industry. These indirect benefits are, in effect, a measure of the increased net income to 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 nationwide basis, and because a substantial amount of local processing is involved, the indirect irrigation benefits are an important segment in the economic justification of the Central Arizona Project. The average indirect irrigation benefits have been evaluated at $36,915,000 annually.

The general, or public, benefits, although intangible and not readily susceptible to monetary evaluation, are nevertheless quite real and significant. One example of this type of benefit is the

continuance and improvement of local standards of living. Another is the continuance and improvement of such public institutions as schools, hospitals, churches, and libraries. A third is the maintenance of the secondary industries dependent on the farming operations for a livelihood. In an area of ground-water overdraft such as the Central Service Zone, these intangibles are of major importance, because living standards and public service values are subject to reduction in overdraft areas as the available 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 the retrenchment that will otherwise occur in the central Arizona area if an additional water supply is not obtained.

Municipal and industrial benefits--Municipal and industrial benefits will result from the provision of the supplemental water supply. The delivery of 312,000 acre-feet annually ultimately will be made to the Phoenix and Tucson metropolitan areas under projected conditions. 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 have been assumed to equal the alternative single-purpose cost of providing a similar quantity of municipal and industrial water to the same areas of use. The average annual equivalent of this cost was computed to be $7,624,000.

Fish and wildlife benefits--The construction and operation of the Central Arizona Project features will enhance 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 will 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 (McDowell), Hooker, Charleston, and Buttes Reservoirs will 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 also 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 will not be appreciably altered by the additional water supply. The coordination of the storage reservoirs at Buttes and Maxwell (McDowell) with flood control channelization will also decrease the extent of destruction of the white-wing dove nesting area habitat. However, in this study no value has been assigned to this benefit.

Flood control benefits--Although Gila River Basin streams are unable to meet today's water needs, many of these same streams and contributing areas periodically produce damaging floodflows. However, with the construction of the Central Arizona Project reservoirs and aqueducts, a considerable portion of this flood hazard will be eliminated.

As estimated by the Corps of Engineers, four of the reservoirs--Charleston, Buttes, Maxwell (McDowell), and Hooker--would provide measurable flood control benefits.

The annual flood control benefits have been estimated by the Corps of Engineers to be $780,000.

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. This improved protection, however, has not been evaluated for this report, and monetary benefits have not been assigned.

Recreation benefits--The construction of the major reservoirs of the Central Arizona Project will create areas which have a considerable potential value for recreation. Economic stimulation from recreational opportunities will occur on the Hualapai and Havasupai Indian Reservations as a result of the high Bridge Canyon Dam, and on the Fort McDowell and Salt River Indian Reservations from Maxwell (McDowell) Dam. Recreation areas will also develop from construction of the Buttes, Charleston, and Hooker Dams located on the Gila River and tributaries. The National Park Service, in cooperation with the Bureau of Outdoor Recreation, has prepared a report describing the cost of the minimum basic recreational facilities required to utilize this potential value, together with the benefits which will develop. 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 will provide all the pumping energy and capacity required to transport the Colorado River water to the area. Commercial energy and capacity will also be available for sale on a peaking basis. In Arizona and southern California, the powerload in the area is presently served by a combination of public and private systems. It was assumed that the most likely alternative source of additional 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 alternative source value for these systems is a composite based on estimates for capacity and energy developed by the Federal Power Commission. The values used for evaluating the power benefits are $18.22 per kilowatt-year for capacity and $0.00336 per kilowatt-hour for energy. The average annual equivalent benefit value is $43,027,000. This value is representative for all power generation and includes that part which will be used for pumping irrigation and municipal and industrial water.

Area redevelopment benefits--Within the framework of the national policy for water and related land resources, the benefits attributable to project activities falling within the scope of the Area Redevelopment Act (Public Law 87-27) are considered in project economic evaluation. Central Arizona Project facilities will provide employment opportunities during construction, and improved economic possibilities following construction. The average annual equivalent of this benefit is estimated to be $331,000 for construction labor only. Additional benefits would accrue from operation and maintenance activities and

service facilities, but data were not adequate to compute these values for this study.

Benefit and cost summaries--Table 9 summarizes the total benefits, on an annual equivalent basis, which can be attributed to the construction and operation of the Central Arizona Project under fully developed conditions of project use. 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 2.875 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 $125,468,000 and $41,357,000, respectively, for the 100-year period of analysis. The resultant benefit-cost ratio of 3.03 to 1.0 effectively demonstrates the economic justification of the plan. For a 50-year period of analysis, the ratio is 2.54 to 1.0.

Financial Feasibility

In the sections which follow, the financial feasibility of the Central Arizona Project is 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 separately by the various water-user organizations.

Table 9--Project benefits

Central Arizona Project

Purpose	Equivalent Annual Benefits	Total Benefits 50-Year Period (2.875% interest)	Total Benefits 100-Year Period (2.875% interest)
Irrigation	$ 71,494,000	$1,883,996,000	$2,340,636,000
Direct	(34,579,000)	(911,219,000)	(1,132,083,000)
Indirect	(36,915,000)	(972,777,000)	(1,208,553,000)
Power	43,027,000	1,133,839,000	1,408,672,000
M&I Water	7,624,000	200,906,000	249,586,000
Flood Control	780,000	20,554,000	25,536,000
Fish & Wildlife	684,000	18,025,000	22,394,000
Recreation	1,528,000	40,266,000	50,025,000
Area Redevelopment	331,000	8,722,000	10,854,000
Total	$125,468,000	$3,306,308,000	$4,107,703,000

Table 10--Summary of Federal economic costs

Central Arizona Project

Item	50-Year Period of Analysis 1/	100-Year Period of Analysis 2/
Construction costs 3/	$ 997,222,000	$ 997,222,000
Interest during construction	74,858,000	74,858,000
Total	$1,072,080,000	$1,072,080,000
Average annual equivalent costs (at 2.875 percent interest)	40,683,000	32,746,000
Annual operation, maintenance and replacement costs (includes OM&R on nonreimbursable purposes)	8,611,000	8,611,000
Total annual equivalent costs	$ 49,294,000	$ 41,357,000

1/ 2.875 percent interest - 50-year factor 0.037948

2/ 2.875 percent interest - 100-year factor 0.0305445

3/ Excludes investigation costs $4,109,000

Cost allocation--The costs associated with the Central Arizona Project have been allocated, by use of the separable costs-remaining benefits method, to irrigation, municipal and industrial water service, commercial power, recreation, fish and wildlife purposes, area redevelopment, and flood control. A summary of the cost allocation results is shown in table 11.

Repayment required--The costs allocated to irrigation, municipal and industrial water service, and commercial power are considered reimbursable and are 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 for irrigation and 256,000 acre-feet for municipal and industrial uses. The sale of all commercial power produced is also assumed to begin upon completion of 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, therefore, nonreimbursable. Also returnable through revenues are interest charges on the capital investments allocated to the commercial power and municipal and industrial water service functions and interest charges during construction on the investments allocated to these two purposes.

Table 11--Tentative cost allocation summary

Central Arizona Project

100-Year Period of Analysis - 2.875% Interest

Item	Construction Costs	Interest During Construction	Annual Operation Maintenance and Replacement Costs
Nonreimbursable			
Flood control	$ 15,291,000	$ 947,000	$ 44,000
Fish & Wildlife	10,645,000	709,000	26,000
Recreation	22,513,000	1,617,000	391,000
Area redevelopment	3,859,000	286,000	7,000
Subtotal	$ 52,308,000	$ 3,559,000	$ 468,000
Reimbursable			
Commercial power	$401,013,000	$34,157,000	$4,624,000
M&I water service	210,763,000	13,477,000	1,155,000
Irrigation	335,390,000	23,665,000	2,364,000
Subtotal	$947,166,000	$71,299,000	$8,143,000
Total project costs	$999,474,000 1/	$74,858,000	$8,611,000

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

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 supplement. The table also shows 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 per acre-foot at project canalside delivery would not be sufficient to repay all the project costs allocated to irrigation in 50 years. The costs assigned to municipal and industrial water uses will require a rate of $38 per acre-foot in order to pay out in 50 years at an interest rate of 2.875 percent. Commercial firm energy sold at load center at a rate of 6.0 mills and nonfirm energy at 2.5 mills per kilowatt-hour would repay the allocated power costs, including interest at 2.875 percent, and also repay the remaining irrigation allocation not paid by water revenues within the 50-year period. The surplus revenue shown on table 13 could be utilized to provide additional financial assistance to irrigation, if desired, or used for other water resource development in the area.

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

Year	Power									Municipal and Industrial							Irrigation					
	Firm Commercial Energy Revenue	Nonfirm Commercial Energy Revenue	Total Operating Revenue	Operation, Maintenance and Replacement	Net Operating Revenue	Interest On Unpaid Balance	Unpaid Balance	Irrigation Assistance	Surplus	Operating Revenue	Operation, Maintenance and Replacement	Storage Charges	Total Annual Charges	Net Operating Revenue	Interest On Unpaid Balance	Unpaid Balance	Operating Revenue	Operation, Maintenance and Replacement	Storage Charges	Net Operating Revenue	Irrigation Assistance	Unpaid Balance
						2.875%	435,170,100								2.875%	224,240,700						335,390,800
1	21,301,200	1,000,000	22,301,200	4,624,500	17,676,700	12,511,160	430,404,540			9,735,750	1,154,500	71,750	1,226,250	8,509,500	6,446,920	222,178,120	8,140,000	2,363,900	228,250	5,547,850		329,842,350
2						12,362,631	424,690,471								6,387,621	220,056,241						324,294,500
3						12,209,851	419,223,622								6,326,617	217,873,358						318,786,650
4						12,052,679	413,599,601								6,263,859	215,627,717						313,198,800
5						11,890,989	407,813,890								6,199,297	213,317,514						307,650,950
10						11,010,075	376,292,513								5,847,553	200,731,200						279,911,700
15						9,995,037	339,971,796								5,442,254	186,228,536						252,172,450
20						8,825,452	298,121,006								4,975,245	169,517,743						224,433,200
25						7,477,791	249,898,154								4,437,131	150,262,621						196,693,950
30						5,924,938	194,333,048								3,817,085	128,075,776						168,954,700
35						4,135,654	130,307,783								3,102,634	102,510,837						141,215,450
40						2,073,939	56,534,243								2,279,402	73,053,464						113,476,200
41						1,625,359	40,482,902								2,100,287	66,644,252						107,928,350
42						1,163,883	23,970,085								1,916,022	60,050,773						102,380,500
43						689,160	6,982,525								1,726,460	53,267,733						96,832,650
44						200,768	-0-	10,493,427							1,531,447	46,289,680					10,493,427	80,791,373
45						-0-		17,676,700							1,330,828	39,111,408					17,676,700	57,566,823
46								17,676,700							1,124,441	31,725,949					17,676,700	34,342,273
47								12,150,873	5,525,827						912,121	24,128,570					12,150,873	16,643,550
48								-0-	23,202,527						693,696	16,312,766					-0-	11,095,700
49									40,879,227	9,735,750				8,509,500	468,992	8,272,258						5,547,850
50	21,301,200	1,000,000	22,301,200	4,624,500	17,676,700				58,555,927	9,736,335	1,154,500	71,750	1,226,250	8,510,085	237,827	-0-	8,140,000	2,363,900	228,250	5,547,850		-0-
Total	1,065,060,000	50,000,000	1,115,060,000	231,225,000	883,835,000	332,111,273		57,997,700	58,555,927	486,788,095	57,725,000	3,587,500	61,312,500	425,475,585	201,234,885		407,000,000	118,195,000	11,412,500	277,392,500	57,997,700	

Average annual revenue from facilities computed on the following basis: Power; firm commercial energy 3,550,195,000 kwh @ 6 mills; nonfirm energy 400,800,000 kwh @ 2.5 mills; municipal and industrial water 256,000 acre-feet @ $35.03 per acre-foot; and irrigation water 814,000 acre-feet @ $10.00 per acre-foot. Storage charges for irrigation and municipal and industrial water computed on the basis of $0.28 per acre-foot, 814,000 acre-feet irrigation water and 256,000 acre-feet of municipal and industrial water.

CHAPTER VI

CONCLUSIONS

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The hydrologic, engineering, and economic studies made during this reevaluation and supplementing of the 1947 Central Arizona Project report have forcibly brought to attention the following conditions, facts, and conclusions:

1. Since the 1947 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 project area exceed the available safe annual local 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, an accelerated reduction in the presently irrigated 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 present reevaluation studies are 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 1947 report.

6. Present reevaluation studies confirm that the Central Arizona Project plan, as originally set forth in the 1947 report and updated in this supplemental report, provides a feasible means of accomplishing the purposes of the project.

7. Present demands for supplemental irrigation and municipal and industrial water supplies exceed the quantity assumed for diversion from the Colorado River; therefore, it will be necessary to achieve maximum conservation of existing water supplies. Toward this end, all present and future irrigation distribution systems in the area should be constructed or rehabilitated to include impervious linings or closed conduit systems.

8. 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.

9. The investigations carried out under this updating study are adequate for the evaluation of the project under present conditions. No project features are of unprecedented size or of unusual engineering design.

10. The Central Arizona Project plan of development 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 present reevaluation studies indicate that the project has economic justification and financial feasibility. The benefit-cost ratio for a 100-year period of analysis is estimated to be 3.03 to 1. The charge for water is estimated to be within the payment ability of water users, and the rate for 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.

11. Supplemental water supplies may be provided to several Indian reservations.

12. Stimulation from recreational opportunities and from benefits that could be obtained under Area Redevelopment Act provisions will expand economic potential on the Hualapai and Havasupai Indian Reservations as a result of the construction and operation of Bridge Canyon Dam and Reservoir, on the Fort McDowell and Salt River Indian Reservations from the construction and operation of Maxwell (McDowell) Dam and Reservoir, and on the Gila River Indian Reservation from construction of Buttes Dam and Reservoir.

13. The normal water surface of the reservoir above Bridge Canyon Dam would extend 17 miles along the boundary of the Grand Canyon National Park and would thereby provide navigable water for additional access to Havasu Canyon and the Havasupai Indian Reservation and extend recreational opportunities to this area.

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

15. Present water deficiencies and projected future water demands necessitate full cooperative efforts be expended to obtain maximum utilization of sewage effluent and other return flows.

16. Power revenues could provide financial assistance beyond that assumed for this report.

17. The reanalysis and updating of the Central Arizona Project report have clearly illustrated the fact that the present economy of the project area is being supported at the expense of a diminishing ground-water supply. Without additional water, a substantial part of the presently irrigated lands will be forced out of production, and growth and development of the area will be retarded. It is also clear that, while the project is the first step, additional steps must be taken to chart a long-range course of water conservation and development that will ultimately permit the area to obtain water supplies of the magnitude that will be required to provide for the rapidly increasing population of the future.