Report on Feasibility, Bridge Canyon Rt.

Central AZ Project

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

REGION III
Boulder City, Nevada

February 14, 1947.

To: Commissioner

From: Regional Director

Subject: Transmittal of "Report on Feasibility---Bridge Canyon Route--Central Arizona Project" and a memorandum supplement covering the feasibility of the Parker Route and comparison of the Parker and Bridge Canyon Routes.

1. In conformance with the decisions reached at a conference held in Washington, D. C., in February 1946, among officials of the State of Arizona, Bureau of Reclamation representatives, and Arizona's congressional delegation, a report has been prepared which deals with the engineering and economic feasibility of the Bridge Canyon Route. A memorandum supplement, bound in a separate volume, accompanies the report.

2. This report, and its memorandum supplement, have been prepared under the authorization provided by the Federal Reclamation Laws (Act of June 17, 1902, 32 Stat. 388, and acts amendatory thereof or supplementary thereto). The investigations of the Central Arizona Project are being conducted under an agreement with the State of Arizona under which the State participates in the costs of the investigations.

3. The report discusses only the studies of the engineering and economic feasibilities of the Bridge Canyon Route alternative of the Central Arizona Project, and presents the conclusions drawn therefrom. The memorandum supplement presents in its Part I a parallel treatment of the studies of the feasibilities of the Parker Route alternative, omitting descriptive material covered by the report, and, in Part II, provides a comparison of the relative feasibilities of the two alternatives. The surveys and studies upon which the report and its supplement are based are preliminary in nature, but are believed to be adequate for the purpose of providing an acceptable measure of the relative feasibilities of the two alternative plans.

4. The report presents the conclusion that the Bridge Canyon Route alternative is feasible as to engineering, in the sense that there are no insuperable physical obstacles to its construction. It explains the conditions under which this alternative would be self-liquidating, and demonstrates that returns from this alternative would not be sufficient to meet the repayment requirements of existing Reclamation Law.

5. The memorandum supplement, in its Part I, presents the conclusion that the Parker Route alternative likewise presents no insuperable construction problems. It explains the conditions under which this alternative would be self-liquidating, and demonstrates that returns from this alternative would not be sufficient to meet the repayment requirements of existing Reclamation Law. Part II of the memorandum supplement discusses several factors which should be considered in comparing the Bridge Canyon and Parker Routes. This portion of the memorandum also presents a bar diagram which provides a ready means of comparing the economic feasibilities of the two alternatives. The conclusion to be drawn from Part II is that the Parker Route is the better of the two alternatives, all factors considered.

6. Part II of the memorandum supplement contains the recommendation that detailed studies of the Central Arizona Project be concentrated on the plan employing the Parker Route. You will note that by my endorsement of the memorandum supplement I have approved this recommendation.

- - -

E. Mowitz

R.H.F.

UNITED STATES
DEPARTMENT OF THE INTERIOR
J. A. Krug, Secretary

BUREAU OF RECLAMATION
Michael W. Straus, Commissioner

REGION III
E. A. Moritz, Regional Director

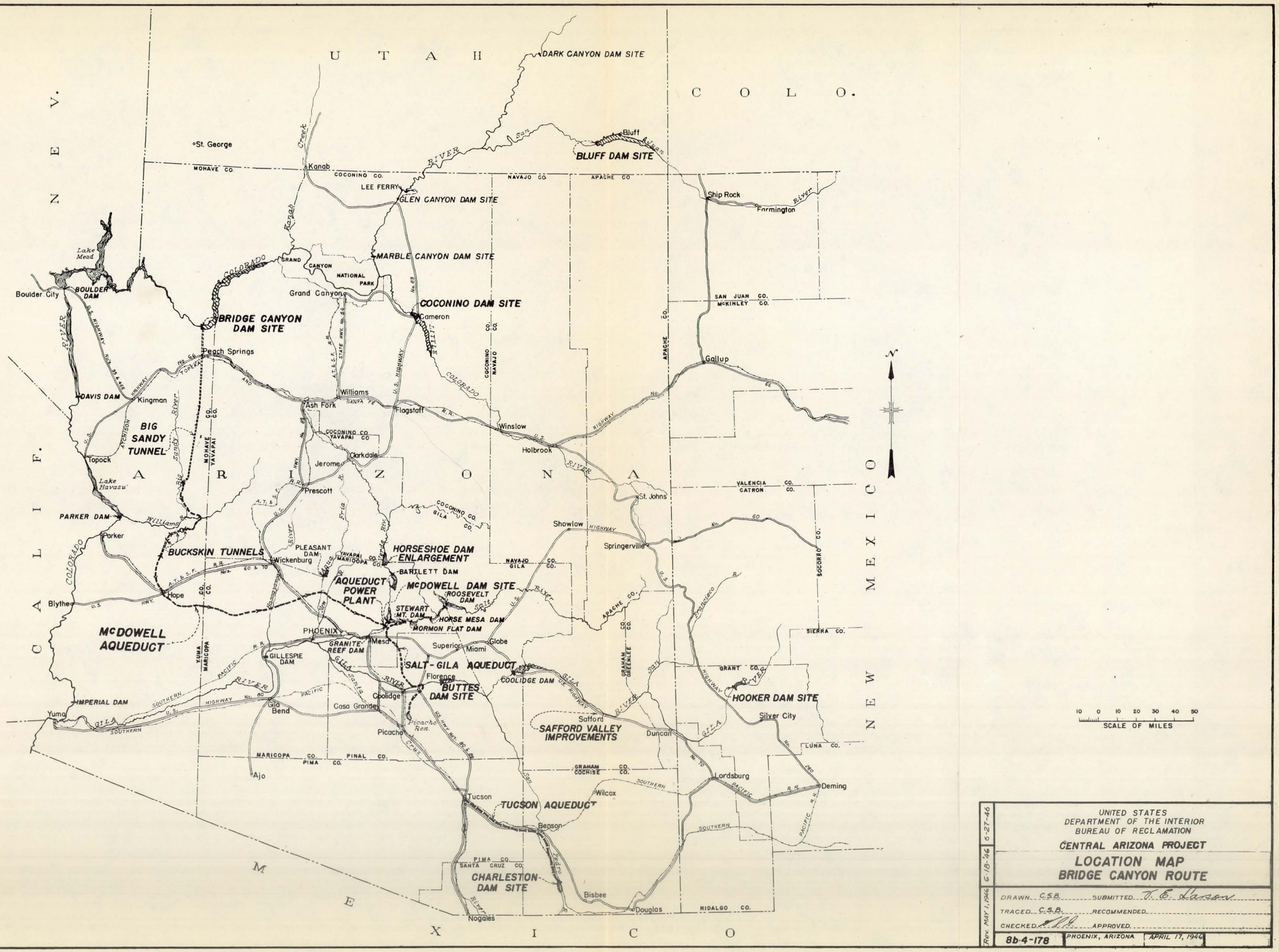
REPORT ON FEASIBILITY
BRIDGE CANYON ROUTE

CENTRAL ARIZONA PROJECT

PROJECT PLANNING REPORT NO. 3-8b.4-1

FEBRUARY 1947

COPY NO. 201



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

CENTRAL ARIZONA PROJECT

LOCATION MAP
BRIDGE CANYON ROUTE

Rev. MAY 1, 1946	6-18-46	6-27-46	
DRAWN C.S.B.	SUBMITTED V. E. Larson		
TRACED C.S.B.	RECOMMENDED		
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CONTENTS

CONTENTS (Continued)

CONTENTS (Continued)

LIST OF TABLES

LIST OF MAPS AND DRAWINGS

SYNOPSIS

In February 1946, a conference was held in Washington, D.C., by officials of the State of Arizona, Bureau of Reclamation representatives, and the State's congressional delegation to determine the most effective program for proceeding with the planning of the potential Central Arizona Project. The congressional delegation urged that the next step in the planning program be the preparation and issuance of a feasibility report on the Bridge Canyon Route on the basis of Senator McFarland's proposed modification of the Reclamation Law.

Following the conference, Senator E. W. McFarland of Arizona introduced in the United States Senate a bill (Senate Bill 2346) to authorize construction of the Central Arizona Project under the plan of development known as the Bridge Canyon Route. The Bill contains provisions for changing cost allocations and repayment periods as established by the existing Reclamation Law.

As a result of the conference, the Bureau of Reclamation undertook preparation of this report. This report outlines current conditions and anticipated conditions under ultimate project development, the plan for stabilizing the established economy of the area, and the costs and returns that would accrue under the potential project.

Agriculture in Maricopa and Pinal Counties, Arizona, was originally developed through diversion of surface flows from the Gila River and its tributaries. Continuing expansion of agriculture, combined with a reduction in available surface flows due to drought, has led to extensive development of pump irrigation. Overdrafts on the groundwater are exhausting long-term water storage. If only that land which can be adequately supplied with water be maintained in production, nearly one-third of the presently irrigated land would be forced out. In the alternative, a reduction from adequate supplies, would maintain a larger acreage but the crop production per acre would be reduced.

The San Pedro and upper Gila River areas also have a history of acute water shortages. The principal factors which tend to produce these shortages are: (1) the lack of storage reservoirs for surface water, (2) low stream flow during peak irrigating months, and (3) senior water rights of downstream users which force upstream users to bypass water in the river for the satisfaction of those prior rights. In an effort to obtain an adequate water supply, upstream users supplement their surface diversions by pumping from the underground.

The potential Central Arizona Project would alleviate actual or threatened water shortages for these lands, and by stabilizing the area's agriculture, prevent the economic decline that would accompany forced retrenchment.

Primary benefits to be realized under the project would consist of improvement of irrigation and municipal water supplies, and power generation. Of secondary importance would be flood control, silt control, recreation, and fish and wildlife propagation.

The plan of development considered in this report has been designated the Bridge Canyon Route. The principal features would consist of a high dam on the Colorado River upstream from Lake Mead; a long tunnel extending southward from the reservoir formed by this dam to connect with an aqueduct which would transport the water through canals, short tunnels, and siphons to a point adjacent to the confluence of the Salt and Verde Rivers; a canal to deliver water from the Salt River area to lands on the Gila and Santa Cruz flood plain; storage facilities on the Salt, Verde, Gila, and San Pedro Rivers; a distribution system as required to deliver irrigation water to project lands; hydroelectric plants; a power transmission system; a municipal water supply for the city of Tucson; and a drainage system to prevent the excessive accumulation of salt in the project area.

Operation of the project would include the introduction of Colorado River water to the Salt River area, the diversion of water from the Salt River area to the middle Gila River area, and the regulation and conservation of water in the middle and upper Gila River areas and along the San Pedro River to allow for increased diversions.

The amount of water available for diversion from the Colorado River to the Central Arizona Project cannot be precisely determined at this time. However, on the basis of interpretations of existing compacts and contracts for Colorado River water by responsible officials of the State of Arizona, the amount available for the project, including a credit for estimated return flow, has been computed as 1,200,000 acre-feet a year. In addition, 132,000 acre-feet of new water a year would be conserved from other sources.

The power potentialities of the Central Arizona Project have been studied on the basis of coordinated operation of existing and authorized power plants on the lower Colorado River with the potential plants of the Central Arizona Project. The power plants of the project would have an installed capacity of 731,100 kilowatts and an average annual production of 3,894,000,000 kilowatt-hours of firm power.

Estimates of costs have been based on construction cost levels prevailing during the first quarter of 1946. Returns have been estimated on the basis of expected long-time revenues from irrigation and municipal water, and from the sale of power.

Since the Central Arizona Project's feasibility depends upon several unresolved factors, hypotheses have been selected to illustrate the feasibility of the project under different assumed conditions. As a further step, a feasibility ratio of 1 to 1 was

developed for each of the basic hypotheses by (1) determining the length of time that would be required for the project to pay out under the conditions outlined in the basic hypotheses and (2) determining the rate at which power would have to be sold to attain that ratio.

The Central Arizona Project would aid in stabilizing the economy of this highly developed area. The project has engineering feasibility in the sense that there are no insuperable physical obstacles to its construction. Under certain of the hypotheses, the project would be self liquidating, but the project is not shown to be self liquidating within the provisions of existing Reclamation Law.

I INTRODUCTION

1. Geographical Location

The potential Central Arizona Project would embrace the greater part of the developed farm lands within the drainage basin of the Gila River in Arizona and New Mexico upstream from Sentinel, Arizona. Most of the lands to be benefited lie on a broad flood plain ranging in elevation from 900 to 1600 feet above sea level.

2. Soils and Climate

Fertile soils and the warm, mild climate make the project area one of the most productive agricultural sections in the Nation. "Double-cropping," or the growing of two crops a year on the same land, is widely practiced when sufficient irrigation water is available.

3. Water Supply

a. General. The project area seriously needs additional irrigation water. If no additional supply of water is developed, it can reasonably be assumed that the agricultural productivity of the area will be reduced by at least one-third. Expressed in another fashion: If it be assumed that sufficient land would be taken out of production to assure a full water supply for that remaining, the abandonment of about one-third of the land now cultivated in the area would result.

This curtailment of production may take one, or a combination of several forms. It may be brought about through the abandonment of land now in production, as stated above; a change to crops requiring less water than those now grown; or a reduction in the yield of crops now grown. Regardless of the form which this curtailment might take, the net effect upon the economy of the area would be very much the same.

b. Surface water. Existing reservoirs regulate most of the stream flows of the rivers in Central Arizona. Dams contemplated for construction of these rivers would control silt, prevent some of the channel losses, and conserve some flood waters which are not now available for irrigation. However, only a small amount of additional water will become available because of these conservation measures.

c. Groundwater. Districts holding surface water rights have, for many years, followed a practice of supplementing their water supply by pumping from the underground water basins. In addition, many areas have been developed which depend solely upon pumping as a source of supply. The expansion of irrigated acreage has brought about an increased dependence on underground storage until about half the water used in the area now comes from that source. This pumpage greatly exceeds the safe annual yield of the groundwater basins.

Water tables in some parts of the project area have been lowered to a point where higher pump lifts have substantially increased water costs. In some areas the yield of the wells has decreased to the point where a part of the land has been forced out of cultivation. Groundwater conditions generally have not yet deteriorated to the extent that pump irrigation is infeasible with the present high prices and strong demand for farm products.

d. Salinity. Surface water diverted to the area introduces about 845,000 tons of salts annually. Some of these salts are deposited in the soil as a result of evaporation and lack of adequate drainage. That portion of the irrigation water which percolates back into ground storage carries with it a certain amount of these salts. Inasmuch as the underground water is held within a virtually closed basin, salinity of the groundwater is becoming progressively greater. A major factor aggravating this problem is the intensive re-use of groundwater.

e. Municipal water supply. The growth of the city of Tucson and its environs has brought about a serious water supply problem in that area. Heavy pump drafts are exhausting the available storage in the groundwater basin which now supplies the city. In order to avoid depletion of the groundwater basin now supplying the city of Tucson, an adequate new source of municipal water must be developed.

4. Power

Development of the Central Arizona Project would entail the construction of five power plants including one major plant on the Colorado River. At the present time there is an urgent need for additional generating capacity in the Arizona, southern California, and southern Nevada power market area and there is every reason to believe that power shortages will soon become critical unless additional installations are made in the near future. The Central Arizona Project would provide 731,100 kilowatts of additional capacity to meet these needs. Normal increase in demand is expected to absorb this additional capacity in less than seven years.

5. Benefits

The Central Arizona Project would provide the following direct benefits: It would (1) provide supplemental water to those agricultural lands which do not now receive an adequate supply; (2) substitute new water developed by the project for water now obtained by overdraft on the groundwater basins; (3) increase the recharge to the groundwater basins; (4) replace with fresh water that amount of salt-laden water which will ultimately need be drained from the project area to provide for salinity control; (5) provide needed electric energy; (6) provide additional control of flood waters on the Gila River and certain of its tributaries; (7) provide recreational facilities of local and national import; (8) provide for preservation and propagation of fish and wildlife; (9) provide a supplemental municipal water supply;

and (10) provide for silt control. Some of the indirect benefits of the project would be: (1) a stabilizing effect on the economy of the area, (2) an increased supply of agricultural products for the Nation, (3) a greater diversification of crops throughout the area, and (4) alleviation of water shortages and minimization of crop failures.

6. Previous Investigations

A number of plans for the diversion of Colorado River water to Central Arizona have been advanced by various groups during the last quarter century. The Bureau of Reclamation made some preliminary investigations of a potential diversion route late in 1940.

7. Present Investigations

In February 1944, the Arizona State Legislature appropriated $200,000 to be used in cooperation with the Bureau of Reclamation to "make surveys, investigations and compilations of the water resources of the State and their potential development." The State's appropriation was matched by the Bureau, and investigations were begun under a formal agreement executed July 31, 1944. Because of a serious water shortage in Central Arizona, investigations have first been concentrated on the possibility of importing water to this area from the Colorado River. The Colorado is the only remaining source of water within the State sufficient to meet the needs of these lands.

On the basis of preliminary studies, the Bureau in 1944 selected three routes for further investigation. They were designated the Marble Canyon Route (gravity), the Bridge Canyon Route (gravity), and the Parker Route (pumping). These studies are outlined in the preliminary draft of the Bureau of Reclamation report, "Comparison of Diversion Routes, Central Arizona Project," dated September 1945. As a result of these studies the Marble Canyon Route was eliminated from further consideration. The studies also indicated that further investigation of the Bridge Canyon and Parker Routes would be required before a final selection could be made.

8. Reasons for this Study

At a conference called in Washington, D.C., in February 1946, which was attended by officials of the State of Arizona, representatives of the Bureau of Reclamation, and the State's congressional delegation, the Bureau was urged to prepare a report on the engineering and economic feasibility of the Bridge Canyon Route that would include financial studies under the provisions of existing Reclamation Law and under certain modifications. On June 18, 1946, Senator E. W. McFarland of Arizona introduced for consideration Senate Bill 2346 in the United States Senate to authorize the Central Arizona Project on the basis of the Bridge Canyon Route. In several respects this bill would modify the present Reclamation Law, the principal changes being that the period of repayment for costs allocated to irrigation would be

changed from 40 to 80 years and that the interest rate for costs allocated to power would be changed from 3 to 2 percent. In addition, the bill provides that allocations to flood control, silt control, river regulation, recreation, and fish and wildlife propagation would be non-reimbursable.

9. Scope and Purpose of this Report

This report is based upon the best information now available. It would not be practicable to work out the numerous details at the present stage of planning. The solution to all of these problems would require detailed investigations that would entail unnecessary expense and represent an unwarranted refinement at this time. The purpose of the present investigation is to explore the engineering and economic feasibility of the potential project development. It is believed that the present investigations are in sufficient detail to permit such determination to be made.

II WATER SUPPLY

A. New Water Developed

1. Water Sources

a. General. Under the Central Arizona Project, Bridge Canyon Route, water would be developed from the Colorado, the Verde, the Gila, and the San Pedro Rivers.

b. Colorado River. The average annual virgin flow of the Colorado River at Lee Ferry, the point of demarcation between the upper and lower Colorado River basins, is estimated to be 16,270,000 acre-feet. The amount of this flow which may be diverted for use in the State of Arizona must fall within the provisions of various compacts, agreements, and contracts and a treaty between the United States and Mexico. Many of these documents are subject to conflicting interpretations. It is not the intent of this report to interpret the legal aspects of allocating the water of the Colorado River. Responsible officials of the State of Arizona have made interpretations of existing contracts and compacts for Colorado River water.

On the basis of these interpretations it is estimated that the Colorado River may be depleted by 1,077,000 acre-feet a year for the Central Arizona Project. It is assumed that diversions from the Colorado River for the Central Arizona Project may be made to the full extent of the 1,077,000 acre-feet plus any water which would return to the Colorado River as a result of this development. It would ultimately be necessary to release water from the area to maintain proper salt balance. Since the net effect of such a release would be to return about 10 percent of the diverted water to the Colorado River it is estimated that 1,200,000 acre-feet could be diverted annually.

c. Verde River. The enlargement of Horseshoe Dam on the Verde River would provide reservoir capacity to impound flood water which cannot now be put to beneficial use. With the reservoir enlarged to a capacity of 298,000 acre-feet, an additional yield of 42,000 acre-feet a year would be provided.

d. Other sources. All the features in the middle and upper Gila River areas, the San Pedro River area, the irrigation distribution system, and the drainage system have been placed in one group which is titled, "Developments Beyond Granite Reef." It is estimated that these features would develop an additional 90,000 acre-feet of water a year.

2. Aqueduct Losses

a. McDowell Aqueduct. Water will be lost through seepage and evaporation while in transit between the diversion point and the

district headgates. These losses are considered as a depletion of the new water supply. The diversion of 1,200,000 acre-feet a year from the Colorado River through the McDowell Aqueduct would result in a loss of 8,000 acre-feet by evaporation and 192,000 acre-feet by seepage, annually.

b. Salt-Gila Aqueduct. Under ultimate conditions, the Salt-Gila Aqueduct would divert 471,000 acre-feet annually, of which 2,000 acre-feet would be lost through evaporation and 48,000 through seepage.

3. Summary

New surface water which would be available at the district headgates under the Central Arizona Project as it would ultimately be developed is summarized as follows:

Table I

SUMMARY OF NEW WATER DEVELOPED

	Acre-feet a year	
Colorado River water diverted	1,200,000	
Developed by Horseshoe Dam enlargement	42,000	
Developments Beyond Granite Reef	90,000	
Gross new water		1,332,000
Losses from McDowell Aqueduct	200,000	
Losses from Salt-Gila Aqueduct	50,000	
Total Losses		250,000
New surface water available at district headgates		1,082,000

B. Water Needed

1. General

The need for water on lands of the Central Arizona Project is five-fold. Additional water is needed to permit: (1) reduction of pumping and thus limitation of withdrawals from the underground basins to their safe yields; (2) delivery of a supplemental supply to lands now in production but inadequately irrigated; (3) delivery of an adequate supply to lands having an irrigation history but now idle because of lack of water; (4) delivery of an adequate supply of water to the city of Tucson; and (5) the drainage of excess salts out of the basin.

2. Acreage

About 662,000 acres of land within the project area is either under cultivation now or has been in the past. The 1940-1944 average cultivated acreage was about 575,000.

3. Surface Water

Surface water in the area has been extensively developed. Under present conditions the flow which passes unused through the project area is very small. San Carlos Reservoir on the Gila River has never filled and the Salt River reservoir system has spilled but once in the past twenty years. Despite this high degree of regulation some of the lands, dependent upon surface water as a source of supply, experience frequent water shortages, and diversions to such lands must occasionally be limited.

4. Groundwater

Studies by the Groundwater Division of the Geological Survey in cooperation with the State of Arizona and the Bureau of Reclamation indicate that the average annual inflow to the underground basin of the project area, exclusive of the upper Gila River and the San Pedro River areas, is about 612,000 acre-feet. It has been determined that during the period 1940-1944, inclusive, about 1,149,000 acre-feet of pump water was used in that area annually. This was about 537,000 acre-feet in excess of the safe annual yield.

Despite the extent of present overdevelopment of the groundwater, with the consequent lowering of the groundwater table and increased pumping costs, the use of such water for irrigation is steadily increasing. In 1944, about 1,290,000 acre-feet was pumped for irrigation within the area outlined above.

5. Salinity

At present approximately 845,000 tons of salt are introduced into the Central Arizona Project area annually. Since there is insufficient drainage from the area, these salts are accumulating in the soil and groundwater. In some portions of the area the salt content of the water has already become a serious problem. These concentrations will continue to increase until some areas are forced out of production, unless adequate provision is made for salt removal. It has been demonstrated in this area that water containing concentrations of 5.5 tons of salt per acre-foot, or about 4,000 parts per million, is detrimental to most crops. Based on the assumption that all water having this concentration should be released and that the tonnage released annually must equal the annual inflow, a total release of 154,000 acre-feet annually would be needed to carry away the 845,000 tons of salt that is now entering the area annually.

6. Requirements for Ultimate Development

During the period 1940-1944, the average pumping overdraft is estimated to have been 537,000 acre-feet a year. The diversion of 1,200,000 acre-feet of new water from the Colorado for the area would increase the recharge to the groundwater basin by about 399,000 acre-feet a year. The resulting increased recharge would reduce the rate of groundwater depletion to 138,000 acre-feet a year. However, the increased inflow would result in the need of increased outflow to maintain a salt balance. Studies indicate that ultimately 378,000 acre-feet would need be released from the area to maintain a suitable salt balance. To establish a balance between withdrawals from the underground basin and the recharge of the basin, the required reduction in pumping for irrigation would be 138,000 acre-feet plus 378,000 acre-feet, or 516,000 acre-feet a year. 1/ The loss of pump water between the pumps and headgates is estimated as 15 percent. On that basis, the amount of water required at the farmers' headgates for replacement is estimated as 85 percent of 516,000 or 439,000 acre-feet a year. That amount of water must be replaced by new surface water made available to the area. Losses of surface water between the district headgates and the farms are estimated as 30 percent. To effect the required replacement of pumping, 439,000 acre-feet divided by 70 percent or 627,000 acre-feet of additional surface water would need to be delivered to the district headgates.

In addition to the water needed to allow for the reduction of pumping as outlined above, 143,000 acre-feet a year would be required as a supplemental supply for lands now irrigated, 12,000 acre-feet a year would be required for municipal water supply and 300,000 acre-feet a year would be available for use on 52,560 acres of land now idle but having an irrigation history. 2/

7. Summary

Table II summarizes the project area's requirements for new water at the district headgates under ultimate conditions of project development.

1/ It is recognized that all water released from the area would not necessarily be pump water. However, in lieu of a definite determination, these studies assume that all the water released would be pumped.

2/ Although 52,560 acres does not represent all the lands in the area having an irrigation history but now idle because of lack of water, it does represent the apparent maximum that could be returned to cultivation with new water the project would make available.

Table II

SUMMARY OF REQUIREMENTS UNDER ULTIMATE DEVELOPMENT

	Acre-feet a year
Reduction in pumping required to conform present use to present safe annual yield	537,000
Increase in yield of underground basin due to 1,200,000 acre-feet diverted from Colorado River	399,000
Reduction in pumping required to establish equilibrium of underground basin, without release to maintain salt balance	138,000
Outflow required to maintain salt balance	378,000
Net reduction in underground water available for irrigation	516,000
Reduction in water available at farm headgate assuming 15% loss for pumped water (516,000 X 0.85)	439,000
Surface diversions required to replace 439,000 A.F./Yr. assuming losses of 30% for diverted water (439,000 divided by 0.70)	627,000
Supplemental water needed for lands now irrigated	143,000
Required for municipal water supply	12,000
Water available for 52,560 acres now idle	300,000
	1,082,000

C. Operation

The purpose of the potential Central Arizona Project would be to sustain the existing economy of the project area. Maintenance of the existing agriculture of the area depends upon an adequate, firm water supply which the project would furnish. Because of the varying requirements for Colorado River water, diversions under ultimate conditions would be greater than under initial conditions. The difference between the amount of water that would be diverted under initial and ultimate conditions would be based on the area's requirements for water to be used in the control of salinity.

At present, concentrations of salts are increasing in the irrigation water of some portions of the project area. The introduction of Colorado River water is expected to halt further salinity concentrations for a time. However, since this would be only a temporary condition, provision would need be made for supplying fresh water to the area to replace water which would be released to carry away toxic salts. Under initial conditions it is planned to divert 850,000 acre-feet a year from the Colorado River. That amount would be increased to provide for the drainage of salt-laden water from the area until, under ultimate conditions, 1,200,000 acre-feet would be diverted annually. The control of water outlined would preclude the use of Colorado River water for irrigation of new land. It would not be desirable under initial conditions, to divert surplus water for the development of new land which would later have to revert to desert as the need for that water for salinity control arose.

III PLAN OF DEVELOPMENT

A. Engineering Feasibility

1. General

All features of the Central Arizona Project under the Bridge Canyon Route have been determined, on the basis of available information, to have engineering feasibility in the sense that none of the items included in the project would offer difficulties impossible to solve with established construction methods.

2. Special

Of all the items included in the Bridge Canyon Route of the Central Arizona Project, only the Big Sandy Tunnel would present problems of a serious nature. This tunnel, which would divert water from the reservoir formed by Bridge Canyon Dam, would be 77.2 miles long and about 18 feet in diameter. It would have a maximum depth below ground surface of 3,900 feet. Inasmuch as no subsurface explorations have been made, the conditions to be encountered must be anticipated on the basis of surface examinations, past experience, and judgment. To assist the Bureau of Reclamation in solving these problems, a consulting board composed of some of the Nation's leading geologists and engineers was appointed. After making a field trip over the tunnel site and studying available information, the Board approved the tentative location previously selected by the Bureau of Reclamation. On the basis of that location and the available information, the Board and the Bureau of Reclamation prepared a joint cost estimate which has been used in the cost studies for this report. The Board recommended that any program of more detailed investigations include additional studies of surface geology, core drilling to tunnel grade at each proposed shaft site, drilling at points likely to present construction problems as determined from surface studies, and tests to determine groundwater and temperatures at tunnel grade. As pointed out in the consulting board's report, the recommended investigations may provide data that would require adjustments in the construction costs presently estimated for the tunnel. If the investigations disclose conditions more favorable to construction than are now estimated, it might be possible to reduce somewhat the present cost estimates. If, however, the investigations disclose difficulties not now assumed, an increase in the cost estimates will be required. If the difficulties prove to be particularly serious, a complete relocation of the tunnel or abandonment of the plan for diversion from Bridge Canyon Reservoir might be required.

B. Description

1. Bluff Dam

This dam would be constructed on the San Juan River at a point 12 miles downstream from the town of Bluff, Utah, and 132 miles upstream

from the confluence of the San Juan and Colorado Rivers. It would be used for silt control, flood control, and river regulation. Of concrete gravity-section design, it would have a crest length of 950 feet at elevation 4487 and a reservoir capacity of 3,000,000 acre-feet.

2. Coconino Dam

This structure would be located on the Little Colorado River, 49 miles upstream from its confluence with the Colorado River. It would provide silt control and flood control. Having a crest length of 350 feet at elevation 4255, it would be a gravity-section concrete dam with an open-slot uncontrolled spillway of 100,000 second-foot capacity. It would form a retarding reservoir of 1,600,000 acre-foot capacity which would provide for temporarily holding flood waters and reduce the maximum probable flood to a flow of about 100,000 second-feet.

3. Bridge Canyon Dam and Power Plant

This development would be constructed on the Colorado River 117½ miles upstream from Boulder Dam at the head of Lake Mead and 237½ miles downstream from Lees Ferry. It would form a diversion reservoir for the Big Sandy Tunnel. In addition, the development would generate power, partially regulate floods, and retain silt which would otherwise be carried into Lake Mead. The dam would be a concrete, gravity-arch structure having a 1,950-foot crest length at elevation 1877 and would form a reservoir having a capacity of 3,720,000 acre-feet. The power plant would have an installed capacity of 700,000 kilowatts.

4. Big Sandy Tunnel

This tunnel would serve as the outlet conduit for irrigation diversions from Bridge Canyon Reservoir. The inlet portal of the tunnel, which would be located on the south side of the canyon wall about one mile upstream from the dam, would have an invert elevation of 1800. The tunnel would be approximately 18 feet in diameter and 77.2 miles long, and would be concrete lined throughout. The outlet portal would be located on the east side of the Big Sandy Wash, at which point the McDowell Aqueduct would begin.

5. McDowell Aqueduct

This feature would extend from the outlet portal of the Big Sandy Tunnel to the terminal storage reservoir which would be formed by the potential McDowell Dam. Water to satisfy immediate irrigation requirements in the Salt River area would be released directly through turnout structures located along the aqueduct and through the Aqueduct Power Canal. The Aqueduct would consist of 226.4 miles of canal, 14.4 miles of tunnels, and 7.7 miles of siphons. It would have a capacity of 1,800 second-feet.

6. McDowell Dam and Power Plant, and Phoenix Water Supply Replacement

The dam would provide terminal storage, as needed, for water diverted from the Colorado River as well as flood control on the Salt and Verde Rivers. It would also regulate releases from upstream reservoirs. As contemplated, this would be a slab-and-buttress dam having an overflow spillway and earth embankment wing sections. It would have a crest length of 4,100 feet at elevation 1451 and would impound 578,000 acre-feet. The power plant would have a capacity of 4,100 kilowatts.

An infiltration gallery in the Verde River which now supplies the city of Phoenix with naturally filtered water would be flooded by McDowell Reservoir. To replace this development, an intake and a filtration and softening plant of 30,000,000-gallon-per-day capacity would be constructed and connected to the city water supply system.

7. Aqueduct Power Plant and Canal

The Aqueduct Power Plant would generate power from water which would be diverted from the McDowell Aqueduct to Granite Reef Diversion Dam to serve immediate irrigation demand and for which no terminal storage would be required. Of 11,000-kilowatt capacity, the power plant would be constructed adjacent to Granite Reef Dam and would be served by 1,620 feet of concrete lined canal of 1,800 second-foot capacity, intake structures, and a penstock about 370 feet long.

8. Horseshoe Dam (Enlargement) and Power Plant

The contemplated development at Horseshoe Dam would entail the enlargement of the existing structure and the installation of a 10,000-kilowatt power plant. The enlarged dam would be of the earth-and-rock-fill type and would have a crest length of 1,600 feet at elevation 2080. A nearby natural saddle would be utilized for the spillway. The enlarged reservoir would have a capacity of 298,000 acre-feet.

9. Transmission System

The construction of a transmission system to deliver power generated by hydroelectric plants of the project to market areas and to connect these plants with existing transmission lines is included in the plan of development.

10. Developments Beyond Granite Reef

The features considered here are very closely related to each other and to the remaining features of the project. A resolution of certain problems must be made before a complete plan of development can be prepared. The problems for which a resolution is required include, among others: (1) the development of adequate legal means

of transfer or exchange of water from one area to another without infringment of existing water rights, and (2) the establishment of a State water code for regulation of pumping from the groundwater basin. Because of these unresolved problems it is believed that a detailed investigation of the items included under the title "Developments Beyond Granite Reef" is unwarranted at this time. A variation in the cost of these features would have little effect on the feasibility of the overall project. Studies of the overall project needs show, however, that features such as are mentioned hereafter would be required. Potential developments for the upper Gila River area have not been investigated sufficiently by the Bureau of Reclamation for a plan of development for the area to be evaluated. However, in recognition of the needs of the upper Gila River area for relief from water shortages and flood and silt damage, the most promising known potential developments have been considered. Such developments, however, are subject to revision as investigations proceed. Data for some of the features included in these Developments Beyond Granite Reef were obtained from the United States Engineer Office's "Report on Survey, Flood Control, Gila River and Tributaries Above Salt River, Arizona and New Mexico, December 1, 1945," and were used with the consent and cooperation of that office.

The distribution of water imported from the Colorado River could be provided by a series of canals connecting the aqueduct with the distribution systems. Drainage of salt-laden water of the project area could be provided by pumping. The transportation of water from the Salt River area to the middle Gila River area would require a canal that could be located as shown on Drawing No. 8b.4-178. For purposes of flood and silt control, conservation of water, and generation of power, a dam could be built at the Buttes site on the Gila River. To conserve water, control silt and floods, and provide domestic water for the city of Tucson, a dam could be built at the Charleston site on the San Pedro River. Domestic water for the city of Tucson could be supplied from the Charleston Reservoir and transported to the city of Tucson, as shown on Drawing No. 8b.4-178. Conservation of water and a supplemental water supply could be provided for the Safford Valley area. In the upper Gila River area in New Mexico, water conservation and regulated stream flow could be provided for lands in that area.

Developments Beyond Granite Reef are shown on Drawing No. 8b.4-178 to acquaint the reader with the general location of potential developments. Some of the names used and locations shown are tentative and should not be construed as the only possible developments.

IV POWER DEVELOPMENT

A. Present Facilities and Utilization

1. Sources of Energy

Present power developments in the power market area range from large hydroelectric and fuel burning plants to small local power plants in the more isolated camps and towns. Construction of Boulder and Parker Power Plants on the Colorado River and their associated transmission lines has made possible the delivery of large amounts of low-cost power to the metropolitan areas of Arizona, southern California, and southern Nevada. These plants produce by far the major portion of the low-cost electric energy available to this power market area.

When the generating units now under construction or authorized are completed the total installed capacity in the market area will be about 3 million kilowatts. This capacity will be distributed about as follows: Colorado River hydroelectric plants, 55 percent; southern California (all types), 33 percent; Arizona (all types), 12 percent. Southern Nevada is almost entirely dependent upon Boulder Power Plant for electrical energy.

2. Transmission Lines

Transmission lines in the State of Arizona are inadequate to meet the growing demand. Interconnection between the lines is impeded by the fact that two generating frequencies, 25 and 60 cycles, are used. In southern California most of the transmission systems are interconnected, although some lack adequate ties for the desired integration.

B. Potential Power Development

Under the potential Central Arizona Project, power plants would be constructed at Bridge Canyon, Horseshoe, and McDowell Dams and at Buttes Dam which is a feature of Developments Beyond Granite Reef. In addition to these power plants, the Aqueduct Power Plant would be constructed adjacent to Granite Reef Dam to generate power with water released from McDowell Aqueduct to meet immediate irrigation demands. The total installed capacity of these plants would be 731,100 kilowatts. The reservoirs would serve multiple uses, and therefore the operation of most of the power plants would be influenced by requirements for storing and releasing water to supply irrigation needs and for flood control.

C. Potential Power Features and Power Output

1. Power Plants

The power plants as contemplated under the Central Arizona Project are listed on Table III together with pertinent data on capacities, power heads, and output.

2. Transmission Lines

Transmission lines would be required to provide distribution to the market areas and interconnection between plants of the project and plants of the lower Colorado River basin. This interconnection would provide for the complete exchange of power.

3. Operation

In evaluating energy production it has been assumed that full coordination could be maintained. Inasmuch as the value of secondary energy would be small, only the firm output has been considered. Studies of coordinated operation of the Bridge Canyon, Boulder, Davis, and Parker Power Plants indicate that the firm output of these plants could be delivered with a maximum monthly system load factor of 54 percent and an average annual system load factor of 46 percent.

D. Power Market

1. Location and Demand

The power market area for hydroelectric plants of the lower Colorado River basin includes the State of Arizona, southern California, and southern Nevada. The population of this area is in excess of 4,500,000 with an average annual per-capita consumption of about 2,500 kilowatt-hours. A study of the demand for electrical energy in the power market area which could be served by the potential Central Arizona Project reveals that exceptionally rapid growth has taken place. This constantly increasing demand in the area comprising the State of Arizona, southern California, and southern Nevada, is expected to continue. The energy requirements of the area have increased from 1.5 billion kilowatt-hours in 1920 to 6.5 billion kilowatt-hours in 1940. Total energy consumption in the area during 1945 was in excess of 11 billion kilowatt-hours, with a corresponding peak demand of about 2,000,000 kilowatts. Based on very conservative estimates all power generated by the Central Arizona Project plants would be absorbed in about seven years. There is every reason to believe that all power produced by this project would be utilized as soon as it could be made available.

Table III

SUMMARY OF POWER PLANTS

Power Plants	Installed Capacity in kw	Gross Average Power Head Feet	Annual Firm Energy in Million kwhr		
			Condition A 1/	Condition B 2/	Condition C 3/
Bridge Canyon	700,000	645	4,000	3,734	3,468
Aqueduct	11,000	102	52	64	76
McDowell	4,100	54	23	21	19
Horseshoe	10,000	141	40	40	40
Buttes	6,000	144	35	35	35
Totals	731,100		4,150	3,894	3,638
Stewart Mountain Replacement 4/			25	28	32
Totals			4,125	3,866	3,606
Reduction in output of 5/					
Boulder			374	451	528
Davis			89	108	126
Totals			463	559	654
Net annual capability of new plants after replacing reduction caused by diversion			3,662	3,307	2,952

1/ Assumes Upper Basin depletion of 2,952,000 acre-feet per annum and diversions to Central Arizona Project of 850,000 acre-feet per annum.

2/ Upper Basin depletions are assumed to be the mean between conditions A and C, with diversions to the project of 1,025,000 acre-feet.

3/ Fifty years after condition A assuming 75,000,000 acre-feet at Lee Ferry during 10-year low period; 1,200,000 acre-feet annual diversion to Central Arizona, and no coordination needed because of fully regulated condition of stream flow.

4/ Replacement of energy which would be required if diversion for the Salt-Gila Aqueduct were made from above Stewart Mountain Dam.

5/ Caused by upstream diversion at Bridge Canyon for Central Arizona Project.

2. Summary

Table IV, based on studies by the Federal Power Commission, indicates the anticipated demand for power in the market area in 10 year increments between the years 1950 and 1980.

Should the Central Arizona Project be constructed, the production of the potential plants would provide a substantial portion of the estimated increased annual demand of the State of Arizona. Additional outlets for energy would also be afforded in the balance of the market area.

Table IV

ANNUAL ENERGY REQUIREMENTS AND PEAK DEMANDS
LOWER COLORADO RIVER BASIN MARKET AREA

Year	Estimated Annual Energy Requirements Million Kilowatt-hours		Estimated Annual Peak Demand Thousand Kilowatts 60% Load Factor
	Total	Increase for 10-year period	
1940	6,512		1,239
1950	14,164	7,652	2,695
1960	20,687	6,523	3,935
1970	25,971	5,284	4,942
1980	30,000	4,029	5,708

V FINANCIAL STUDIES

A. Cost Estimates

Cost estimates were prepared by the Branch of Design and Construction, the Branch of Power Utilization, and the Phoenix Office of Project Planning. Basic data were obtained by the Phoenix office. In addition, estimates of certain features of the project, as investigated and reported by the United States Engineer Office, have been used. All cost estimates are based on first quarter 1946 construction cost levels.

B. Basic Data

1. General

All existing information and data, if available and adequate, have been used. Additional studies and field work were accomplished by the Phoenix Office of Project Planning to supply the broad range of material required for this report.

2. Bridge Canyon Dam

Detailed investigation of the Bridge Canyon Dam site has been completed and data contained in the preliminary draft of the report of the investigation, together with cost estimates prepared in connection with the investigation, have been used for this report.

3. Big Sandy Tunnel

The Big Sandy Tunnel estimate is based on costs for comparable tunnel construction, as adjusted to fit local conditions. The location was made from aerial mosaics of the route and field reconnaissance. A board of consultants was appointed to assist in determining the feasibility and costs of this feature.

4. Aqueducts

Construction costs for the McDowell and Salt-Gila Aqueducts were estimated, for the most part, from data obtained by a reciprocal stadia traverse and profile run along the routes, with prominent topographic features and slope of ground noted. Available topographic maps were also used.

5. Other Dam Sites

Detailed transit-planetable topography has been made of the McDowell Dam site. Investigations by the Bureau of Reclamation at other dam sites have been confined to preliminary surveys where existing maps and data in sufficient detail were not available.

6. Geology

Geological data for all features are based on surface indications of formations or on data available from previous explorations.

7. Other Data

Engineering data and cost estimates contained in the United States Engineer Office's "Report on Survey, Flood Control, Gila River and Tributaries Above Salt River, Arizona and New Mexico, December 1, 1945" were used, with the consent and cooperation of that office. The data contained in that report are sufficiently detailed so that additional investigation by the Bureau of Reclamation is considered unnecessary at present.

The cost estimates prepared by the United States Engineer Office are based on 1939 construction cost levels. These figures have been adjusted by the Bureau of Reclamation to reflect construction cost levels for the first quarter of 1946.

8. Power Plants and Transmission Lines

Plans for power plants, transmission lines, and other features not previously discussed were developed from available data, supplemented where necessary by data obtained from additional surveys and studies.

C. Cost Allocations

1. General

Two sets of cost allocations have been prepared. One set has been developed in accordance with existing Reclamation Law which provides for reimbursable allocations to irrigation, power production, and municipal water, and for non-reimbursable allocations to flood control, navigation, and fish and wildlife propagation. The other set of allocations has been prepared in accordance with the provisions of Senate Bill 2346 introduced in Congress by Senator McFarland of Arizona. In addition to all the allocations authorized by present Reclamation Law, the bill provides for non-reimbursable allocations to river regulation, silt control, and recreation.

In the allocation of costs of the Central Arizona Project, each feature has been given individual consideration. Many of the features would be constructed for a single function only, and the costs of such features are considered chargeable solely to the function involved. Where multiple purposes would be served by a feature, the costs of the jointly-used facilities have been allocated among the purposes served.

In general, construction costs of multiple purpose features have been apportioned among the various functions on the basis of estimated benefits to be derived from the completed project. Exceptions to this

general rule have been made for the Big Sandy Tunnel, McDowell Aqueduct, and McDowell Dam and Phoenix Water Supply Replacement. For these features the method has been varied slightly to meet special conditions.

2. Single-Purpose Features

As shown in Tables V and VI, the entire construction cost of single-purpose features of the Central Arizona Project has been charged to the single purpose served.

3. Multiple-Purpose Features

In allocating the construction costs of features serving multiple functions, it has been found that a single method of allocation is not strictly applicable to all features. A description of the methods used, together with a list of the features to which each method applies, is presented in the following paragraphs.

Bluff, Coconino, Bridge Canyon, and Horseshoe Dams, and Developments Beyond Granite Reef compose most of the multiple-purpose features of the Central Arizona Project. Allocations of construction costs for these features among the functions served have been made strictly on the basis of the proportion of the total benefits that would accrue to each function.

4. Flood Control Benefits

In determining the national benefits applicable to the various functions, those applying to flood control at other than Bluff, Coconino, Bridge Canyon, and McDowell Reservoirs have been based on data supplied by the United States Engineer Office, Los Angeles, California.

Flood control benefits would accrue at Bluff, Coconino, and Bridge Canyon Reservoirs. These benefits allow for a reduction in the size of the spillway at Bridge Canyon Dam and a reduction in the amount of flood control storage in Lake Mead. Since the reduction in the size of the spillway at Bridge Canyon Dam allows for reduced construction costs, these benefits are indirectly evaluated in the cost estimates. Since the flood control benefits at Lake Mead have been credited to previous construction, no additional flood control benefits can be allocated to Bluff, Coconino, and Bridge Canyon Dams. Flood control benefits at McDowell Reservoir have been evaluated on the basis described on page 23.

5. Silt Control Benefits

The silt control benefits allocable to Bluff, Coconino, and Bridge Canyon Reservoirs have been evaluated on the basis of the benefit which would accrue to the Boulder Canyon Project. Replacement cost of Lake Mead storage has been used to arrive at a monetary value for the silt

control benefits. The value of silt control in the Developments Beyond Granite Reef has been determined from data obtained from the United States Engineer Office, Los Angeles, California.

6. Recreational, and Fish and Wildlife Benefits

The evaluation of recreational benefits has been prepared by Region III of the National Park Service. Fish and wildlife conservation benefit evaluations have been based primarily on information provided by the Arizona State Fish and Game Commission.

7. Power, Irrigation, and Municipal-Water Benefits

The evaluation of power, irrigation, and municipal-water benefits presents a problem that is somewhat different from the determination of the non-reimbursable benefits. Although the actual irrigation, power, and municipal-water revenues have been determined, the direct computation of the national benefits resulting from these functions has been found impracticable. The multiplicity of factors involved makes it impossible to evaluate monetarily many of these benefits. Consequently, an indirect approach has been adopted.

For the purpose of making allocations it has been assumed that, because of the "rescue" nature of the Central Arizona Project, construction of each feature to provide the desired functions of irrigation, power, and municipal-water supply would be justified regardless of any incidental non-reimbursable benefits that might accrue. Under such an assumption, the sum of the national benefits accruing to the functions of irrigation, power, or municipal-water supply are considered, for the purpose of making allocations, as being equal to the construction cost of the feature providing them.

The determination of benefits, if any, accruing to each of the three reimbursable functions was made by apportioning the total construction cost of each feature between the functions on the basis of the comparative use each function would make of the feature in question. The benefit accruing to each single function would thus be equivalent to that function's share of the joint cost as measured by the extent of its use.

After all benefits were determined on the basis of the principles outlined above, the cost allocation of each feature was made by determining the percentages that the benefits to each of the several functions were of the sum of all the benefits accruing to the feature. These percentages were then applied to the total construction cost of the feature to give the actual allocation.

The Big Sandy Tunnel and the McDowell Aqueduct were both allocated between irrigation and power on the basis of a slightly different method than that described above. Although the two features would actually be constructed for irrigation use, a power benefit would also

accrue because of the power produced by aqueduct water deliveries at the Aqueduct and McDowell Power Plants. Apportioning the costs between the two functions strictly on the basis of revenues accruing from the sale of power and irrigation water would result in such high allocation to the power function that the provision of the two power plants would not be economically practical. Therefore, the portion of the cost of the two features allocated to power has been made equal to the value of the power revenues when capitalized at 3 percent on a 50-year basis. The irrigation allocation has been taken as the portion of the construction cost remaining after the deduction of the power allocation.

The potential McDowell Dam and Phoenix Water Supply Replacement are so interrelated that the costs of the two features have been combined and the allocation made as though they were a single feature. The construction of the Phoenix Water Supply Replacement would be made necessary because of the flooding of the existing water supply intake area by McDowell Reservoir. Consequently, the cost of the feature can be considered as being a part of the cost of McDowell Dam and Reservoir.

Since no new benefit to municipal-water supply results from the development, no allocation of the cost of the two features can be made to that function. The returns or benefits that would accrue consist of power, irrigation, flood control, recreation, and fish and wildlife propagation. Evaluations have been made of all returns or benefits except flood control. Preliminary studies have indicated that actually some flood control benefit would result from the construction of the potential dam, but the evaluation of that benefit has not been determined. Therefore, estimates were made for two different-sized dams at the site. The lower dam would provide only enough reservoir capacity to meet irrigation requirements. The higher dam, which would provide a certain amount of flood control storage, has been selected for inclusion in this report. Thus the difference in the cost of these two structures would be the cost of providing the flood control benefit, and this difference is taken as the flood control allocation. Since costs allocated to this function are non-reimbursable, the additional cost of providing flood control would have no effect upon reimbursable construction costs. Should future studies indicate that the increased cost of providing flood control is not justified, the lower dam could be substituted with little effect upon the overall feasibility of the project.

In the allocation of costs to the other functions of the two features, the combined construction cost remaining after the flood control allocation has been deducted, has been apportioned among the functions served on the basis of proportionate benefits as described in the discussion of the allocation of the first features considered.

8. Developments Beyond Granite Reef

Developments Beyond Granite Reef were allocated on the basis of the principles described above.

Table V

SUMMARY OF COSTS
CENTRAL ARIZONA PROJECT
BRIDGE CANYON ROUTE

1,200,000 acre-foot diversion
Based on unit prices as of April 1946
Allocations based on Senate Bill No. 2346

Item	Feature	Construction Costs								Annual Expense	
		Total	Allocation							Operation and Maintenance	Reserve for Replacement
			Power Interest-bearing	Irrigation Interest-free	Municipal Interest-bearing	Flood Control (Non-reimburs.)	Silt Control (Non-reimburs.)	Recreation (Non-reimburs.)	Fish & Wildlife (Non-reimburs.)		
1	Bluff Dam & Reservoir	$25,696,000	$15,212,000	$2,082,000	$ -	$ -	$5,730,000	$77,000	$2,595,000	$ 20,000	$ 6,500
2	Coconino Dam & Reservoir	6,356,000	2,371,000	324,000	-	-	3,464,000	197,000	-	14,800	2,200
3	Bridge Canyon Dam & Reservoir	164,195,000	116,250,000	15,927,000	-	-	17,897,000	11,001,000	3,120,000	22,500	67,100
4	Bridge Canyon Power Plant	57,290,000	57,290,000	-	-	-	-	-	-	1,006,200	601,300
5	Big Sandy Tunnel & Inlet Structure	400,808,000	4,589,000	396,219,000	-	-	-	-	-	200,400	1,500
6	McDowell Aqueduct	142,684,000	1,638,000	141,046,000	-	-	-	-	-	1,100,500	33,700
7	Aqueduct Power Plant & Canal	1,774,000	1,774,000	-	-	-	-	-	-	55,100	15,000
8	McDowell Dam & Reservoir & Phoenix Water Supply Replacement	13,671,000	4,909,000	4,853,000	-	2,437,000	-	719,000	753,000	467,000	16,200
9	McDowell Power Plant	810,000	810,000	-	-	-	-	-	-	33,000	7,200
10	Horseshoe Dam (Enl) & Reservoir	5,890,000	2,415,000	2,150,000	-	-	-	783,000	542,000	5,900	1,900
11	Horseshoe Power Plant	1,992,000	1,992,000	-	-	-	-	-	-	53,200	16,300
12	Power Transmission System	81,674,000	81,674,000	-	-	-	-	-	-	1,205,400	923,700
13	Developments Beyond Granite Reef	108,659,000	6,800,000	76,878,000	11,135,000	4,657,000	6,930,000	613,000	1,646,000	758,100	19,800
	Totals	$1,011,499,000	$297,724,000	$639,479,000	$11,135,000	$7,094,000	$34,021,000	$13,390,000	$8,656,000	$4,942,100	$1,712,400

8b-4-235 A

Table VI

SUMMARY OF COSTS
CENTRAL ARIZONA PROJECT
BRIDGE CANYON ROUTE

1,200,000 acre-foot diversion
Costs based on unit prices as of April 1946
Allocations based on existing Reclamation Law

Item	Feature	Construction Costs						Annual Costs	
		Total	Allocation					Operation and Maintenance	Reserve for Replacement
			Power Interest-bearing	Irrigation Interest-free	Municipal Interest-bearing	Flood Control Non-reimbursable	Fish & Wildlife Non-reimbursable		
1	Bluff Dam & Reservoir	$25,696,000	$19,658,000	$2,672,000	$ -	$ -	$3,366,000	$ 20,000	$ 6,500
2	Coconino Dam & Reservoir	6,356,000	5,593,000	763,000	-	-	-	14,800	2,200
3	Bridge Canyon Dam & Reservoir	164,195,000	141,208,000	19,211,000	-	-	3,776,000	22,500	67,100
4	Bridge Canyon Power Plant	57,290,000	57,290,000	-	-	-	-	1,006,200	601,300
5	Big Sandy Tunnel & Inlet Structure	400,808,000	4,589,000	396,219,000	-	-	-	200,400	1,500
6	McDowell Aqueduct	142,684,000	1,638,000	141,046,000	-	-	-	1,100,500	33,700
7	Aqueduct Power Plant & Canal	1,774,000	1,774,000	-	-	-	-	55,100	15,000
8	McDowell Dam & Reservoir Phoenix Water Supply Replacement	13,671,000	5,246,000	5,179,000	-	2,437,000	809,000	467,000	16,200
9	McDowell Power Plant	810,000	810,000	-	-	-	-	33,000	7,200
10	Horseshoe Dam (Enl) & Reservoir	5,890,000	2,786,000	2,480,000	-	-	624,000	5,900	1,900
11	Horseshoe Power Plant	1,992,000	1,992,000	-	-	-	-	53,200	16,300
12	Power Transmission System	81,674,000	81,674,000	-	-	-	-	1,205,400	923,700
13	Developments Beyond Granite Reef	108,659,000	9,106,000	80,920,000	11,375,000	5,447,000	1,811,000	758,100	19,800
	Totals	$1,011,499,000	$333,364,000	$648,490,000	$11,375,000	$7,884,000	$10,386,000	$4,942,100	$1,712,400

8b-4-236A

D. Hypotheses Adopted for Financial Studies

1. General

In order that the economic feasibility of the Central Arizona Project might be explored under a number of possible conditions, eighteen hypotheses have been selected. The first six of these hypotheses may be considered as basic. The remaining twelve may be divided into two groups of six. Each group is a modification of the basic hypotheses.

a. Basic hypotheses under Senate Bill 2346. Hypotheses I, II, and III have been set up to conform to the provisions of S. B. 2346 introduced in the Congress by Senator McFarland. This bill provides that allocations made to flood control, silt control, river regulation, recreation, and fish and wildlife purposes shall be non-reimbursable; that allocations made to power shall be repaid in 50 years at 2 percent interest; and that allocations to irrigation shall be repaid in 80 years without interest.

b. Basic hypotheses under existing Reclamation Law. Hypotheses IV, V, and VI conform to existing Reclamation Law. This law provides that allocations to flood control, navigation, and fish and wildlife propagation shall be non-reimbursable; that allocations to power production shall be repaid in 50 years at 3 percent interest; and that allocations to irrigation shall be repaid without interest, in 50 years (10 year development period plus 40 year repayment period).

In all of the hypotheses, the interest component of the payments made on the power investment is considered as being applicable to the retirement of the irrigation subsidy during the power repayment period. In addition, where retirement of the irrigation investment requires a period in excess of the 50 year power repayment period, all net power revenues accruing after the power investment is repaid are applied to the repayment of the irrigation subsidy until full repayment of irrigation construction costs is accomplished.

2. Hypothesis I

Under this hypothesis it has been assumed that the Central Arizona Project would not be required to replace losses in power production at Boulder and Davis power plants caused by upstream diversion to Central Arizona. Therefore, the project has been evaluated on the assumption that the diminution of returns from power at these plants is not a "cost" within the meaning of Section 9 (a) of the Reclamation Project Act of 1939. Repayment of costs was determined in accordance with S. B. 2346, as explained in paragraph 1.a above.

3. Hypothesis II

The project has been evaluated on the premise that the Central Arizona Project would be called upon to replace losses in energy production at Boulder and Davis Power Plants caused by upstream diversion to the Central Arizona Project. Repayment of costs was determined in accordance with S. B. 2346, as explained in paragraph 1.a above.

4. Hypothesis III

Evaluation of the project has been based on the assumption that the diminution in returns from power at Boulder and Davis Power Plants is a "cost" within the meaning of Section 9 (a) of the Reclamation Project Act of 1939. Therefore, under the terms of this hypothesis the Central Arizona Project would be charged with losses of revenue (as distinguished from energy production losses) at Boulder and Davis Power Plants caused by upstream diversion to Central Arizona. Repayment of costs was determined in accordance with S. B. 2346 as explained in paragraph 1.a above.

5. Hypothesis IV

Same as Hypothesis I except that repayment of all costs was determined in accordance with existing Reclamation Law as explained in paragraph 1.b above.

6. Hypothesis V

Same as Hypothesis II except that repayment of all costs was determined in accordance with existing Reclamation Law as explained in paragraph 1.b above.

7. Hypothesis VI

Same as Hypothesis III except that repayment of all costs was determined in accordance with existing Reclamation Law as explained in paragraph 1.b above.

8. Hypothesis VII

This hypothesis determines the length of time required for the full repayment of all reimbursable project construction costs under the terms of Hypothesis I. It has been assumed that all returns accruing to the project would remain constant.

9. Hypothesis VIII

This hypothesis determines the length of time required for the full repayment of all reimbursable project construction costs under the terms of Hypothesis II. It has been assumed that all returns accruing to the project would remain constant.

10. Hypothesis IX

This hypothesis determines the length of time required for the full repayment of all reimbursable project construction costs under the terms of Hypothesis III. It has been assumed that all returns accruing to the project would remain constant.

11. Hypothesis X

This hypothesis determines the length of time required for the full repayment of all reimbursable project construction costs under the terms of Hypothesis IV. It has been assumed that all returns accruing to the project would remain constant.

12. Hypothesis XI

This hypothesis determines the length of time required for the full repayment of all reimbursable project construction costs under the terms of Hypothesis V. It has been assumed that all returns accruing to the project would remain constant.

13. Hypothesis XII

This hypothesis determines the length of time required for the full repayment of all reimbursable project construction costs under the terms of Hypothesis VI. It has been assumed that all returns accruing to the project would remain constant.

14. Hypothesis XIII

Under this hypothesis, the power rate required to effect full repayment of reimbursable project construction costs under the terms imposed by Hypothesis I has been computed. It has been assumed that all other returns accruing to the project would remain constant.

15. Hypothesis XIV

Under this hypothesis, the power rate required to effect full repayment of reimbursable project construction costs under the terms imposed by Hypothesis II has been computed. It has been assumed that all other returns accruing to the project would remain constant.

16. Hypothesis XV

Under this hypothesis, the power rate required to effect full repayment of reimbursable project construction costs under the terms imposed by Hypothesis III has been computed. It has been assumed that all other returns accruing to the project would remain constant.

17. Hypothesis XVI

Under this hypothesis, the power rate required to effect full repayment of reimbursable project construction costs under the terms imposed by Hypothesis IV has been computed. It has been assumed that all other returns accruing to the project would remain constant.

18. Hypothesis XVII

Under this hypothesis, the power rate required to effect full repayment of reimbursable project construction costs under the terms imposed by Hypothesis V has been computed. It has been assumed that all returns accruing to the project other than power would remain constant.

19. Hypothesis XVIII

Under this hypothesis, the power rate required to effect full repayment of the reimbursable project construction costs under the terms imposed by Hypothesis VI has been computed. It has been assumed that all returns accruing to the project other than power would remain constant.

E. Returns and Costs

1. Annual Returns

In computing the annual returns from the reimbursable items, unit prices shown in Table VII have been used. Studies of the repayment ability of the users of the supplemental water which would be furnished under the project have received attention commensurate as to detail with the engineering studies upon which this report is based. Five avenues of approach to this determination have been employed; detailed explanation of these studies is not within the compass of this report. All studies have used the 1939-1944 period as a base; i.e., price levels of that period have been assumed to be representative of the long period over which irrigators would be assessed for repayment of construction charges. The unit prices for power and municipal water are the anticipated rates. It was further assumed that the interest component of the annual power repayments would be applied to the irrigation repayment.

2. Annual Costs

Annual costs include charges for repayment, reserve for replacement, and operation and maintenance. Construction costs and, consequently, repayment charges, have been computed on the basis of construction cost levels prevailing during the first quarter of 1946. Reserve for replacement and operation and maintenance charges are based upon anticipated price levels assumed to prevail during the repayment period. Under Hypotheses I, II, and III and their

modifications (Hypotheses VII through IX and XIII through XV), repayment charges are based on S. B. 2346 as set forth in paragraph D.1.a above. Under Hypotheses IV, V, and VI and their modifications (Hypotheses X through XII and XVI through XVIII), repayment charges are based on existing Reclamation Law as set forth in paragraph D.1.b above.

Table VIII tabulates returns and costs, deficits, and return-cost ratios for the basic hypotheses. Tables IX and X show repayment periods or power rates required to develop 1 to 1 return-cost ratios for various hypotheses. The same information, in bar-graph form, is given in Plate I.

Table VII

UNIT PRICES FOR SOURCES OF REVENUE

	Unit	Price
Irrigation water at district headgate	acre-foot	$3.15
Irrigation water at farm headgate	acre-foot	4.50
Electrical energy at load center, firm power	kwhr	.004
Municipal water supply at city distribution system intake	1,000 gal.	.15

F. Conclusions

The following conclusions are drawn from studies made for this report:

1. General

The Central Arizona Project is needed to sustain the existing economy of the area.

The data available at present are adequate for considering the financial feasibility of the project. However, a more detailed investigation of all features of the project would be required prior to the initiation of construction.

2. Feasibility

The Central Arizona Project, Bridge Canyon Route, has been determined to have engineering feasibility in the sense that none of the physical works contemplated would present difficulties impossible to solve with established construction methods.

The conditions assumed by the hypotheses provide for the study on a broad basis of the ability of the project to repay construction and other costs under Senate Bill 2346 and under existing Reclamation Law. It is demonstrated that under certain of the hypotheses, the project would be self-liquidating. The project is not demonstrated to be self-liquidating within the provisions of existing Reclamation Law.

Table VIII

COMPARISON OF RETURNS AND COSTS
CENTRAL ARIZONA PROJECT
BRIDGE CANYON ROUTE

Based on Unit Costs as of April 1946

Hypothesis No.	Average Annual Returns	Average Annual Costs	Average Annual Deficit	Ratio of Returns to Costs
I	$19,603,100	$20,774,800	$1,171,700	0.94:1
II	17,391,100	20,774,800	3,383,700	0.84:1
III	19,603,100	21,639,000	2,035,900	0.91:1
IV	24,060,500	33,022,800	8,962,300	0.73:1
V	21,981,000	33,022,800	11,041,800	0.67:1
VI	24,060,500	33,835,400	9,774,900	0.71:1

Table IX

REPAYMENT PERIOD REQUIRED TO EFFECT
A RETURN-COST RATIO OF 1:1

Hypothesis No.	Time Required in Years
VII	90
VIII	115
IX	98
X	94
XI	Never
XII	101

Table X

POWER RATE REQUIRED TO EFFECT
A RETURN-COST RATIO OF 1:1

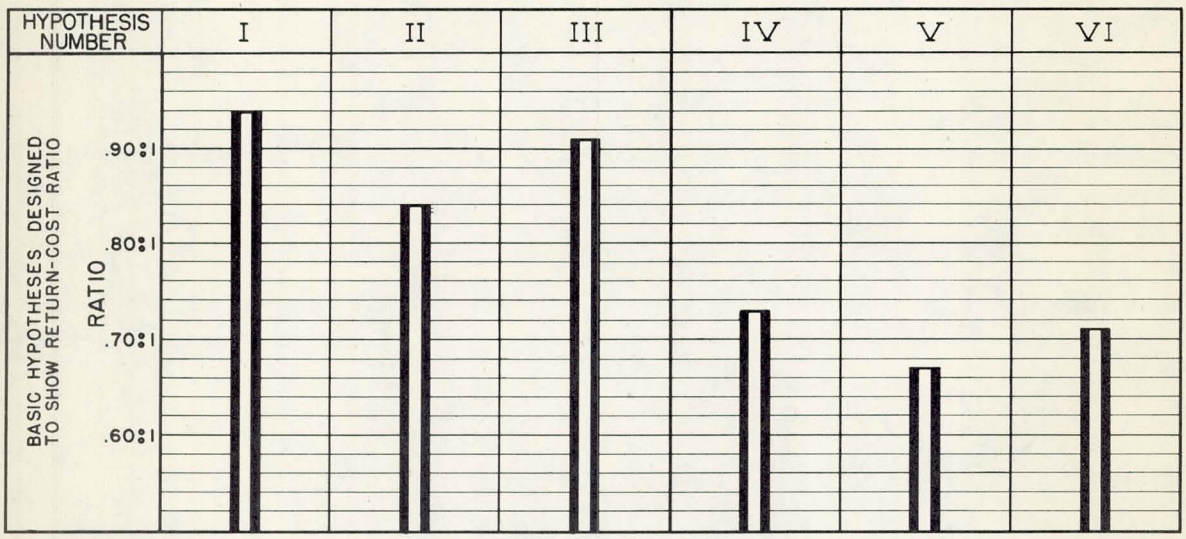
Hypothesis No.	Power Rate per kwhr
XIII	$0.00433
XIV	0.00515
XV	0.00458
XVI	0.00649
XVII	0.00759
XVIII	0.00672

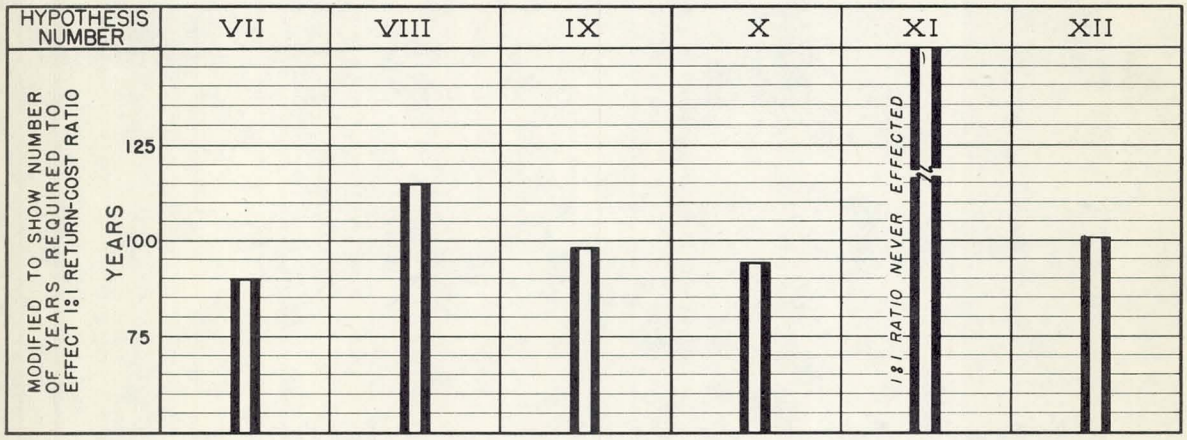
COMPARISON OF HYPOTHESES

CENTRAL ARIZONA PROJECT

BRIDGE CANYON ROUTE

BASED ON SENATE BILL NUMBER 2346			BASED ON EXISTING RECLAMATION LAW		
NO REPLACEMENT OF POWER OR REVENUE	REPLACEMENT OF POWER	REPLACEMENT OF REVENUE	NO REPLACEMENT OF POWER OR REVENUE	REPLACEMENT OF POWER	REPLACEMENT OF REVENUE





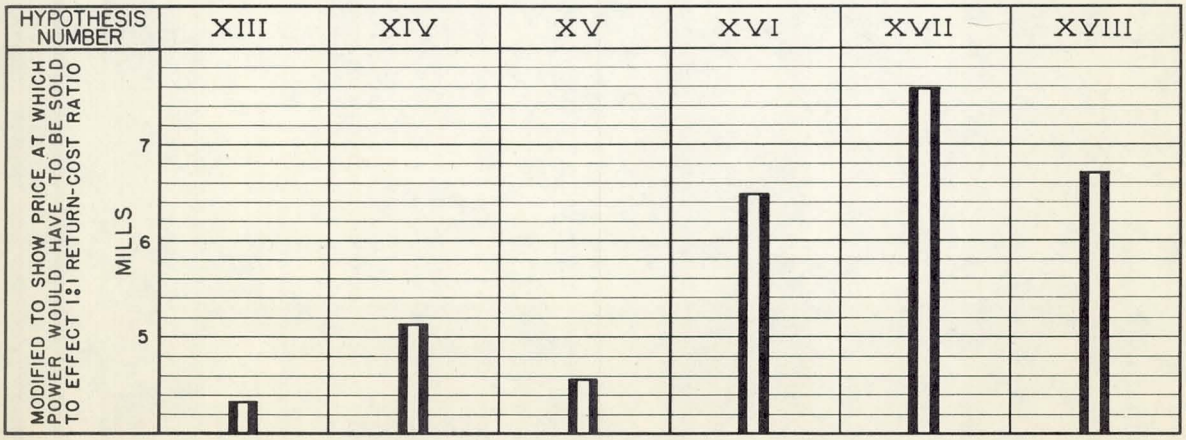


PLATE I