UNITED STATES DEPARTMENT OF THE INTERIOR
OSCAR L. CHAPMAN, Secretary

DEPARTMENT OF THE INTERIOR

BUREAU OF RECLAMATION
MICHAEL W. STRAUS, Commissioner

UNITED WESTERN INVESTIGATION
S. P. McCASLAND, CHIEF

INTERIM REPORT

ON

RECONNAISSANCE

CALIFORNIA SECTION

Jan. 1951

Salt Lake City, Utah

Report UWI-2

C O P Y

UNITED STATES
DEPARTMENT OF THE INTERIOR
Bureau of Reclamation
Washington 25, D. C.

December 22, 1950

The Secretary

of the Interior

Sir:

Herewith the Bureau of Reclamation presents an interim reconnaissance report discussing the engineering possibility and the economic justification of water developments unparalleled in our Nation's history. They are such as to widen horizons for man's planning for use of the vital water resources of the West.

This reconnaissance report entitled "United Western Investigation - California Section" projects long distance transportation of water from north to south virtually across the western United States. Without recommendation for any authorization or construction of works at this time, it creates and points out the opportunity to serve the needs of the swelling populations in the arid Southwest by moving water otherwise destined to remain surplus and to waste into the ocean.

Substantiating studies, laboriously compiled over two years' examination, illustrate the types of engineering works required and the economic factors considered. These show that water may be so delivered in large quantities at costs to users below those frequently paid today for the limited water now available in the dry areas.

The reconnaissance report herein compiled moves man's concept of meeting his water requirement beyond single river or watershed development to that of integrated inter-basin development in an important and fast growing section of the Nation. It is submitted for essential and continuing public consideration and study, for use of this type of approach could have controlling effects on our future way of life, and the location where a considerable body of citizens can live that life.

This investigation was undertaken under the basic Congressional mandate "that the Secretary of the Interior is authorized and directed to make examinations and surveys for * * * irrigation works, storage diversion and development of water * * * and report to the Congress * * * as to the results of such examinations and surveys * * *" (Sec. 2, original Reclamation Act of June 17, 1902). It was particularly prompted by the interest shown by the House Public Lands Committee as evidenced by their action July 15, 1947, in reporting out favorably H. Res. 244, 80th Congress, requesting the Secretary of the Interior, through the Bureau of Reclamation, "to investigate and report as soon as practicable to the President and the Congress on the engineering and economic feasibility and economic justification of diverting surplus waters from other basins to Southern California and the Colorado River Basin and the practica bility of exchanges of water, and other possibilities for effecting improvement in the distribution and utilization of the water resourc of the West."

The requirement for this study develops fundamentally fro full recognition of the unequal distribution of vital water resourc in the Western States and the vast and increasing influx of populati into those States with little regard to water supplies available to sustain such populations and their resulting economies and civiliza- tions. In view of the known huge surplus of water wasting into the sea to the north and the existing and potential shortage in the Sout west, those inevitable instructions were given to look into the futu possibilities of transporting surplus waters to satisfy the Southwes deficiencies. The report herewith submitted is not complete in its coverage of all possibilities. It is presented at this time in orde to make available information thus far evaluated.

While the possibilities herein considered are of a breadth, size and importance heretofore unequaled, transportation of large quantities of water through mountain ranges and across rivers and valleys to distant destinations is firmly founded in both theory or practice. America's Continental Divide is pierced by tunnels in several places for the purpose of transporting water from the Colorado River Basin to the water deficient areas to the East. Construction of the initial stage of the Central Valley Project of California is essentially complete, making possible the effective transfer of water from Shasta Dam in the northern Sacramento Basin 500 miles south to the southern San Joaquin Basin. These are but two examples of man's efforts to correct natural maldistribution of water supply to serve his needs. Such efforts have gone forward in many lands throughout history as water requirements became more stringent in controlling life. We are now face-to-face with such needs in the Southwest.

Regardless of magnitude, scope and timing of such an undertaking, if it can be shown that moving surplus waters of one area to water deficient areas elsewhere is in the realm of sound public interest, it is, in Reclamation's opinion and half century of experiences, only a matter of time before exhaustion of nearer water supplies forces the undertaking of a suitable project for that purpose. This investigation and report present a positive step in exploring those possibilities. Reclamation believes that the Congress, in providing for these investigations, exercised far-sighted wisdom in securing for itself the information upon which public considerations can be based.

This United Western Investigation - California Section interim report emphasizes certain points which must be made clear if understanding is to be assured. These are of sufficient importance to bear repetition. Briefly they are:

The report does not recommend authorization or construction of any phase of the water storage or transfer development outlined at this time.

Remaining and limited, but still unused and unconserved lesser and nearer water supplies should be developed before any construction commitments are undertaken on the United Western even if the lesser opportunities appear unequal to meeting ultimate needs.

The underlying United Western investigations considered many possibilities, many routes, and many alternatives. But for purposes of analysis and illustration only, one plan, for identification referred to as the Northern California Diversion, has received the more detailed examination and discussion possible to date.

The report adheres closely to consideration of engineering feasibility and economic justification. This does not constitute an intent to ignore or deny important and difficult problems related to fish and wildlife, water rights, State laws, recreation and local desires which are inherent in any United Western development. There are essential considerations still unresolved to the satisfaction of important interests which must be taken fully into account before any final plan can be developed. However, it is basic to have a starting point based on engineering and economic factors.

The analysis to date establishes certain specific findings, plainly of a reconnaissance nature, which are of sufficient authenticity clearly to warrant completion of the investigations. The completion of this investigation will form a firm basis on which the Congress and the country can determine whether or not final detailed investigations should be made of any of the facets of this or any alternative plan. Reclamation will proceed toward its completion in cooperation with the States and many agencies concerned as funds are made available for these purposes.

This report yields primary data establishing that in the water deficient basins west of the Continental Divide there are about 25 million acres of land susceptible to irrigation which are presently without apparent sources of sufficient water supply. The surplus flows of the streams of the other basins amount to more than four times the quantity of water which could ever be consumed in the basins of origin, with full development of an ultimate possibility of 25 million more irrigable acres in the surplus area. This potential net increase of 50 million acres of irrigation, 25 million in the areas of surplus water supply and 25 million in the water deficient areas may be compared with 25 million acres now under irrigation throughout the West. Flows wasting from water surplus areas are of sufficient magnitude to provide a supply three times as great as th probable quantities which would be consumed in the irrigation of al 25 million acres in the water deficient basins. It is reasonably probable that the transfer of a portion of the surplus flows to wat deficient areas would be economically justified and that the cost involved would be lower than higher costs required for development similar classes of water supply in many of the contemplated arid service areas.

It is further proper to emphasize that no project designe to meet the objectives of the United Western Investigation assignme should go forward until the public is properly informed and fully aware that there is fast approaching full use of existing waters in many areas and that there also exists surpluses elsewhere which can be brought to use by sound engineering and economic practices. The collateral problems can and must, be worked out during that period of public consideration.

Since the United Western Investigations were undertaken there has been appreciable, if somewhat uninformed, debate thereon proceeding concurrently with the compilation of the date upon which more qualified opinion might be based. Publication of this report will permit a far better informed consideration of such possibilities and eventual conclusion thereon in accordance with our democrat practices.

I recommend that you adopt this report as your proposed interim report on the United Western Investigation, and, in order that the information contained therein may be made generally availab to the public, that you authorize me in your behalf to transmit copi of it to the interested States and Federal agencies for their infor tion and comments, Upon receipt of their comments the report will b prepared for transmittal to the President and, subsequently, to the Congress.

Respectfully,

/s/ Michael W. Straus
Commissioner

Attachment

Approved and adopted: December 15, 1952

Oscar L. Chapman
Secretary of the Interior

Salt Lake C

UNITED STATES DEPARTMENT OF THE INTERIOR
OSCAR L. CHAPMAN, Secretary

BUREAU OF RECLAMATION
MICHAEL W. STRAUS, Commissioner

UNITED WESTERN INVESTIGATION
S. P. McCASLAND, Chief

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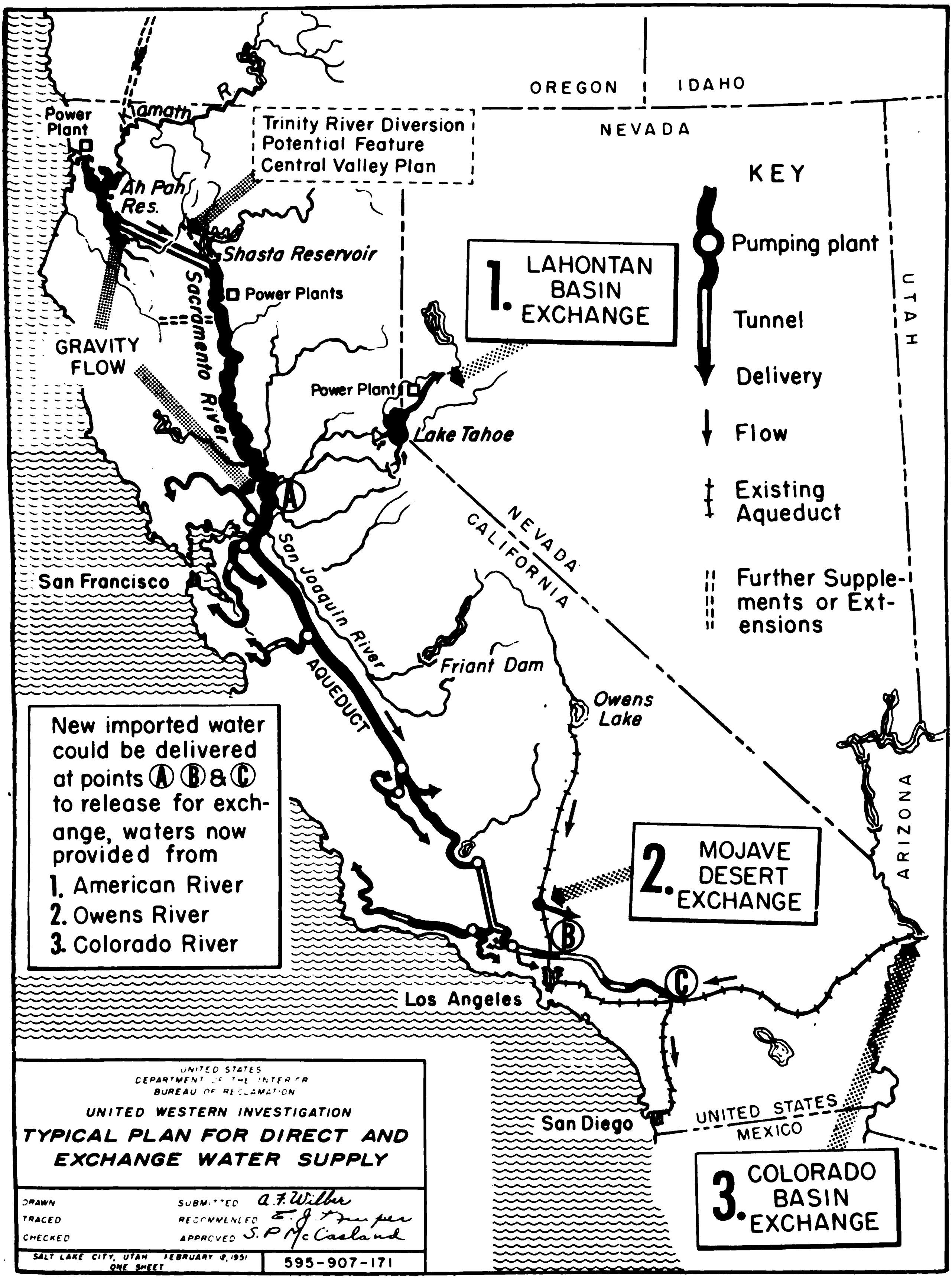
OREGON
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NEVADA
UTAH
ARIZONA
KEY
Pumping plant
Tunnel
Delivery
Flow
Existing Aqueduct
Further Supplements or Extensions
Power Plant
Klamath R.
Trinity River Diversion
Potential Feature
Central Valley Plan
Ah Pah Res.
Shasta Reservoir
Power Plants
Sacramento River
GRAVITY FLOW
1. LAHONTAN BASIN EXCHANGE
Power Plant
Lake Tahoe
NEVADA
CALIFORNIA
San Francisco
San Joaquin River
AQUEDUCT
Friant Dam
Owens Lake
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2. Owens River
3. Colorado River
2. MOJAVE DESERT EXCHANGE
Los Angeles
San Diego
UNITED STATES
MEXICO
3. COLORADO BASIN EXCHANGE
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UNITED WESTERN INVESTIGATION
TYPICAL PLAN FOR DIRECT AND EXCHANGE WATER SUPPLY
DRAWN
TRACED
CHECKED
SUBMITTED
RECOMMENDED
APPROVED
SALT LAKE CITY, UTAH FEBRUARY 8, 1951
ONE SHEET
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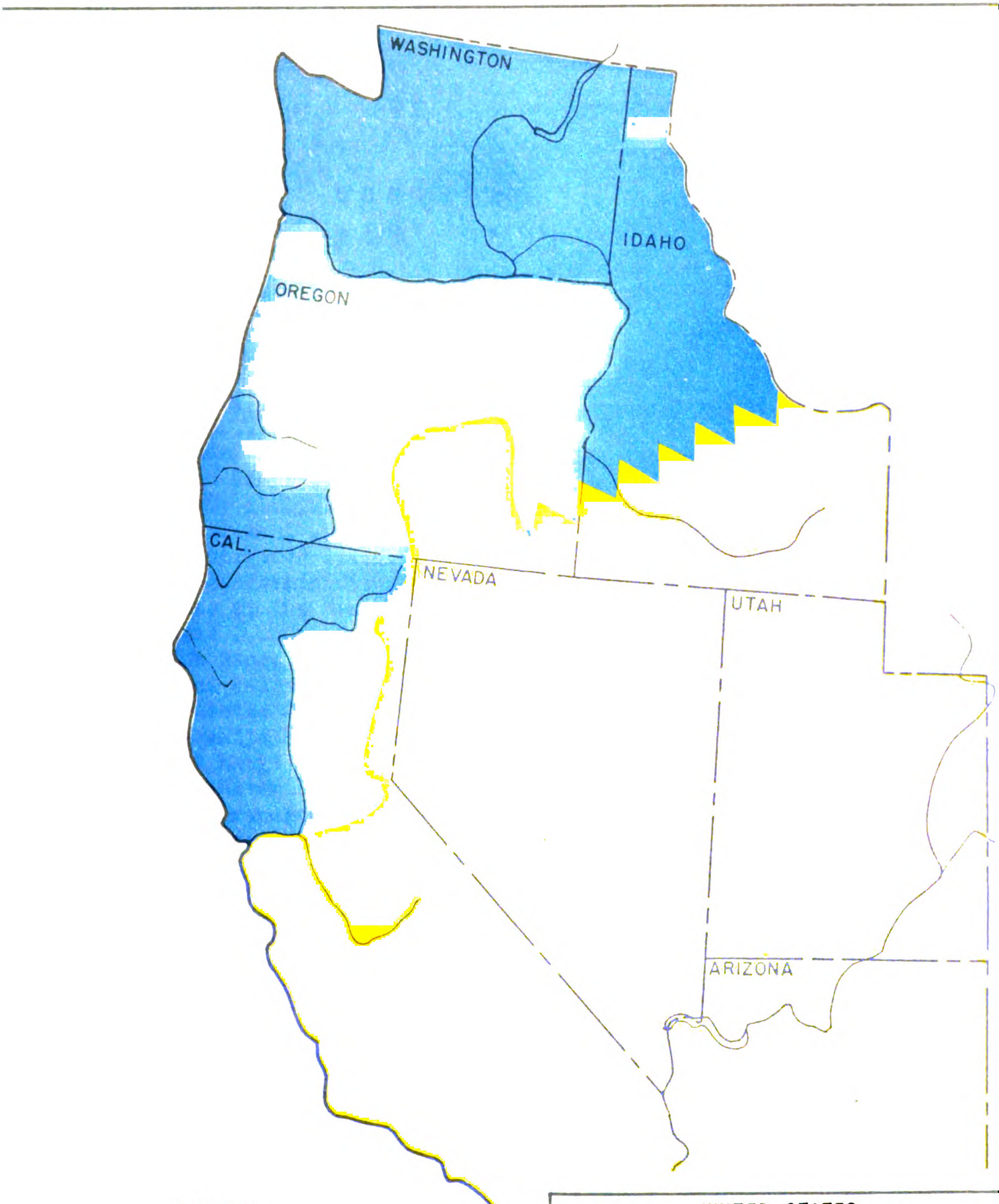

LEGEND

General area where basin-wide water supply exceeds ultimate consumptive requirement.

General area where ultimate water requirement exceeds basin-wide supply.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UNITED WESTERN INVESTIGATION

GENERAL AREAL DISTRIBUTION OF WATER SUPPLY

REVISED 12-8-50 J.B.

DRAWN: J.B. SUBMITTED: John M. Scha
TRACED: J.B. RECOMMENDED: [illegible]
CHECKED: APPROVED: S. P. McCasl

SALT LAKE CITY, UTAH 11-18-50

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FIGURE 1

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C O N T E N T S

REPORT OF THE CHIEF

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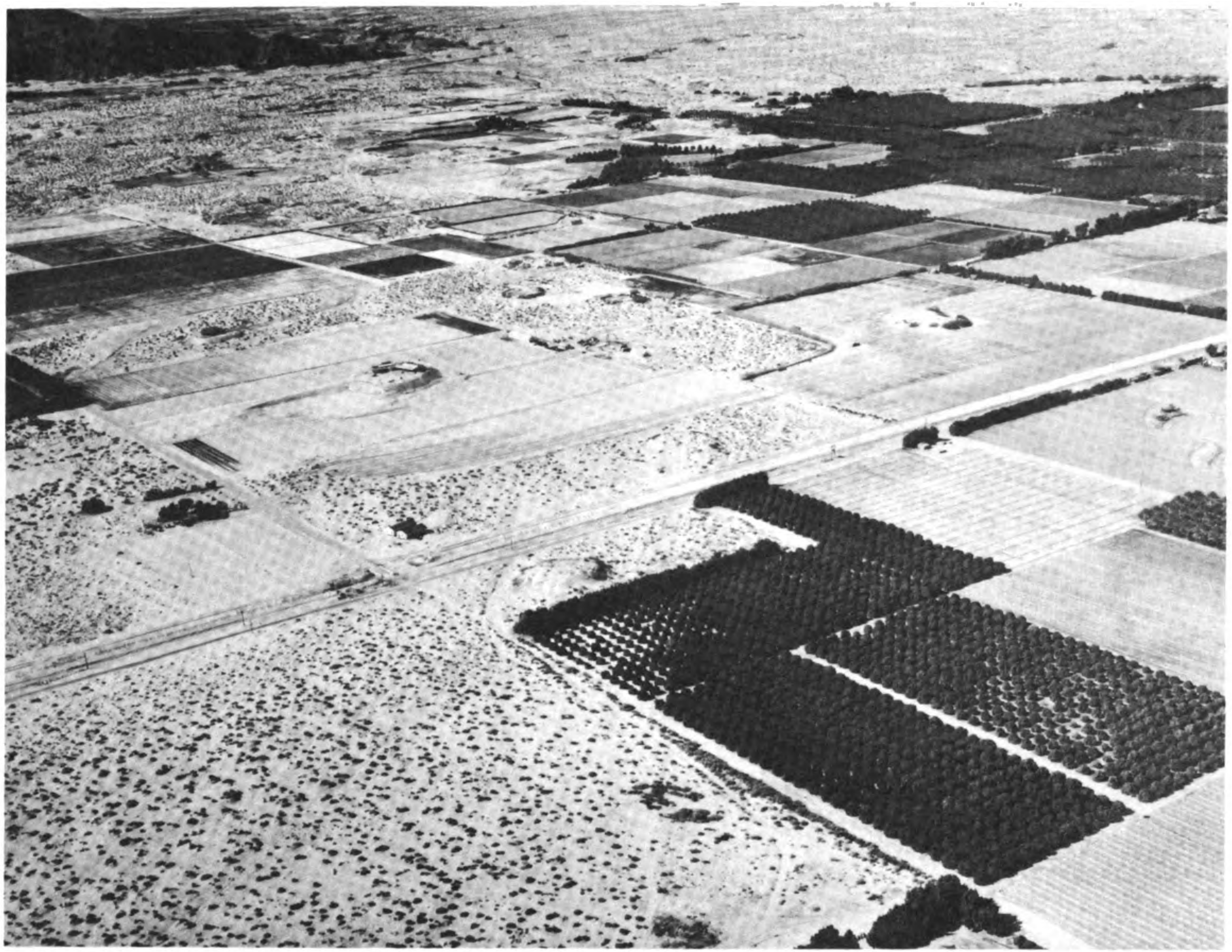

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IN REPLY REFER TO:

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

UNITED WESTERN INVESTIGATION
P. O. Box 2556
Salt Lake City 10, Utah

December 16, 1950

To: Commissioner

From: Chief, United Western Investigation

Subject: Interim Report on Reconnaissance - United Western Investigation

Transmittal

1. Presented herein, with substantiating materials, is an interim reconnaissance report on the United Western Investigation. The investigation has examined the possibility of providing a water supply for certain water deficient areas of the West through the export and exchange of surplus which is beyond ultimate needs in various areas of abundant supply. Developments which otherwise would be impossible may ultimately prove feasible in 12 or more states. Substantial progress has been made in the assembly and analysis of technical data for the over-all problem and reconnaissance conclusions have been reached for one possible plan.

2. The report is, as its title indicates, an interim report. It is submitted at this time to provide a factual basis for an understanding of the situation which is approaching the western states, and of the possibilities for resolving that situation.

3. The combined magnitude of the engineering works herein contemplated exceeds that of any project ever constructed. In any scheme of such scope, the inter-relation and conflict of many varied

interests is inevitable. Among these interests, numerous points of view will be represented and thus, at the outset of the report, certain precepts should be made clear in order to avoid a misunderstanding of the intent and findings of the investigation. These are:

The report does not recommend authorization for construction of any phase of a water storage or transfer development; in fact, it clearly indicates that such a recommendation should not be made at this time.

The investigation has covered, in varying degrees of thoroughness, numerous general plans, many possible routes for conveying water, numerous possibilities for exchange to effect water supply transfer, as well as other alternatives and combinations. For the purpose of this interim analysis, one plan to serve the Southwest is presented in more detail than the others. This does not mean that that plan is the best or only plan, or even an average plan. It is presented as a model for the purpose of illustration.

The report adheres closely to considerations of engineering feasibility and economic justification. This is not intended to ignore or deny the many related considerations such as those concerning fish and wildlife, water rights, State laws, recreation, and others. The scope of the report at this stage does not cover these admittedly difficult and important problems which are inherent in any prospective

development. Full consideration of those problems will be given as the investigation proceeds in cooperation with states and agencies concerned.

Authority

4. These investigations were executed under the general authority of the Reclamation Act of 1902 as amended and supplemented. They were conducted in recognition of the request of the House Committee on Public Lands, reflected in its action on July 15, 1947, in reporting out favorably House Resolution 244, 80th Congress, 1st Session. Resolution 244 defines the general mission of the investigation as follows: To investigate and report as soon as practicable to the President and the Congress on the feasibility of diverting surplus water from other basins to southern California and the Colorado River Basin, and the practicability of exchanges of water and other possibilities for effecting improvement in the distribution and utilization of the water resources of the West.

Problem under Investigation

5. Local supplies of water in large areas of the West are being developed at a rate which will accomplish their full exploitation within a much shorter time than generally appreciated. In some extensive areas, the limit of supply already has been exceeded (Plate 6), and expansion, or even maintenance of the accomplished development is impossible from local sources. Conversely, enormous water resources exist in other sections of the West, particularly

Typical Stream

along the Coastal Belt of northern California, Oregon, and Washington (Plate 4). The general problem is thus the maldistribution of water supply, with respect to existing and potential demand, throughout the entire West; studies are concerned with the remedial measures which may be practicable.

Purpose and Scope

6. The investigation is a preliminary appraisal of the long-range prospects of resolving this general water problem. The immediate objective has been to determine whether there is sufficient likelihood of a physically feasible and economically justified solution of the problem to warrant further investigation. The various considerations pertinent to this determination are discussed below.

Water Supply

7. At the present time the streams of Washington, Oregon, and northern California waste into the Pacific Ocean some 300 million acre-feet per year. To verify the water supplies which might be available for transfer to arid areas, a study was made of the maximum possible water requirements which could arise throughout the Northwest under ultimate conditions of full development, and of the portion of this vast outflow, if any, which might exist as surplus under those ultimate conditions. Irrigation was assumed for all lands where the farmer would use an irrigation supply under any conceivable future conditions, and an inventory of all potentially irrigable area

made on that basis. Estimates were made for the maximum consumption which would occur as a result of increased population density and for the industrial water requirements which would accompany this growth. Preliminary studies were made of mineral and other natural resources which would call for special quantities of water in processing. All of these estimates were made with the advice of locally recognized specialists and have been purposely made much larger than any development believed likely to occur so as to anticipate absolute maximum future conditions. Yet it is apparent that the maximum future consumption in the Northwest is dwarfed by the remaining surplus which would be about four times as great. As shown by Plate 4, there would exist an over-all surplus of some 240 million acre-feet per year in excess of maximum possible future consumption. In illustration of the enormity of this amount of water, it may be compared to the quantity that would be consumed in irrigating about three times all the irrigable land in water deficient stream basins west of the Continental Divide, and in satisfying at the same time, all other foreseeable needs of the West.

8. At any particular point where a diversion has been contemplated, reserves for the basin of origin have been estimated on the basis of that specific point of diversion. Allowances for all ultimate within-basin consumption, both above and below the diversion point, have been reserved with a large factor of safety. Only surpluses to these reserves have been considered available for export.

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9. It is recognized that although large quantities of water might always remain surplus to consumptive use in the Northwest, a major part of such surplus might nevertheless be in use for generation of power at the time of a United Western project. If even a small quantity were exported above points of power generation, the electrical output would, of course, decrease proportionately. For this study it was assumed that a United Western project would make energy available to offset impairment to then existing plants, in the same manner in which it would meet its own pumping power requirements.

Water Requirement

10. An inventory has been made of the potential demands in water deficient sections of the West in a manner similar to that in the zones where export may be possible. The former survey has assumed normal use of water and not maximum possible use as in the latter case. A vast amount of land was found to be potentially irrigable, and extensive other potential demands were disclosed (Plate 5 and Tables 10 and 11). Local sources of water were found to be capable of satisfying only a very small part of this demand.

11, It is difficult to forecast the rapidity with which potential demands may become acute deficiencies. However, it is significant that the population of the West increased some 40 percent in the last decade. If such growth continues, the development of demands may be very rapid indeed.

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Plans Investigated

12. The foregoing inventories have defined the geographical pattern and magnitude of both supply and demand. This definition has, in turn, suggested the general course of the investigation. Initially the major effort has been toward plans to serve the extreme Southwest, where both existing shortages and imminent potential demands are accentuated. Numerous schemes (Plate 25) were examined, in varying degrees of thoroughness. Some possibilities have been shown to have very little merit after only brief study. Others have been subjected to more careful examination before being deferred. In a few cases plans have remained attractive and are still under consideration. Various of these plans, including some of low priority, are:

Northern California Diversion
Coast Range Gravity Interception Route
Albeni Falls Diversion
Willamette Pump Route
Willamette High Line Route
Coast Range Low Level Route
Snake River Diversion
Eel-Sacramento Diversion
Salt Water Barrier

A discussion of their characteristics is presented below.

Northern California Diversion

13. Of the foregoing plans, the Northern California Diversion (Plate 15) has received the greatest amount of study. It has been subjected to complete reconnaissance analysis, and is described fully in the succeeding report to illustrate, in a specific example, one

Plans Investigated

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UNITED WESTERN RECONNAISSANCE
AND
NORTHERN CALIFORNIA DIVERSION

General:

	United States	Eleven Western 1/ States	West as percent of U.S.
Area - 1000 square miles	3,022	1,178	39
Population - 1000 (1950)	150,697	19,562	13
Farm Land (1945) - 1000 acres	1,142,000	316,000	28
Irrigated Land - 1000 acres (1940)	——	18,553	—
Potentially Irrigable land-1000 acres	——	50,000	--
Farm Income (1948) $1,000,000	31,275	5,308	17

Northern California Diversion:

Water—Ultimate Conditions

Annual delivery to Sacramento River .... 6,094,000 acre-feet

Water demands served:

Irrigation .... 5,159,000 acre-feet

Municipal .... 286,000 acre-feet

Colorado River Replacement
(Use undetermined) .... 1,212,000 acre-feet 2/

Total .... 6,657,000 acre-feet

Gross acreage served .... 2,121,600 acres

Power—Ultimate Conditions

	Kilowatts
Hydroelectric Generating Capacity Installed	389,600
Average Annual Hydroelectric Generation	148,000
Average Annual Saving--Colorado Aqueduct Pumping	272,500
Pumping Capacity	873,000
Average Annual Pump Load	481,000
Impairment--Existing and Authorized Hydro Plants 3/ ...	72,350

1/ Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming.
2/ See paragraph 17.
3/ Under conditions which would most probably prevail, and which are referred to as Case 1 in the Substantiating Material.

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Physical Data—Major Structures

Gross Storage--Ah Pah Dam	15,250,000 acre-feet
Live Storage—Ah Pah Dam	9,050,000 acre-feet
Height—Ah Pah Dam	813 feet
Total length of main and branch aqueduct	1,463 miles
Total length of tunnels	222 miles
Total length of main aqueduct	605 miles

Construction Costs 4/ 5/

Ah Pah Dam and Afterbay	$ 605,531,000
Regulatory Dams and Reservoirs	126,112,000
Aqueducts and Tunnels	1,541,346,000
Irrigation Distribution Systems	672,479,000
Pumping Plants	145,435,000
Generating Stations and Transmission	188,418,000
Miscellaneous	13,729,000
Total	$3,293,050,000

Benefits and Costs 4/

Total Annual Equivalent Benefits	$170,000,000
Total Annual Equivalent Costs	$89,000,000
Ratio of Benefits to Costs	1.9 to 1
Costs per acre-foot to amortize all capitalized (and annual) cost with 2½ percent interest in accordance with the time and quantity of scheduled water delivery	$25

4/ Pursuant to existing law and regulation, benefits are based on 1939-1944 average price level; costs are based on current construction cost level.
5/ Simple addition of estimated cost.

possible means of serving the Southwest. Further study may dictate modifications of the plan presented, or may disclose other plans having greater advantage. At this time the Northern California Diversion is employed as a model for analysis, providing the framework for comparison of project costs and benefits.

14. The above plan is herein contemplated as the "initial stage" of a larger development. As set forth it would meet the most imminent demands and could stand as a complete and final project, or might serve as the initial stage of a larger plan to meet greater demands as future economy may dictate. In the initial stage, export of some six million acre-feet per year could be made from the lower Klamath River and delivered to irrigators, industries, and municipalities in the Central Valley of California, and the central- and south-coastal areas of that state. By exchanges, similar service would be possible in the Mojave Desert of California; the Lahontan Basin of Nevada; the Colorado River Basin in California, Arizona, Nevada, Utah, Colorado, and Wyoming, and possibly elsewhere.

15. A dam some 813 feet high near the mouth of the Klamath River would provide about 9 million acre-feet of conservation storage and accomplish gravity diversion by a 60-mile tunnel entering the Sacramento Valley just above Redding. From the tunnel outlet, water would continue down the Sacramento River, passing through potential power plants at Table Mountain and Iron Canyon. Annual delivery could be made of some 225,000 acre-feet of municipal water and about

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436,700 acre-feet of irrigation water to the San Francisco Bay area. Beyond the San Joaquin-Sacramento Delta the flow would be pumped by successive lifts up the San Joaquin Valley to the vicinity of Bakersfield; 3,941,000 acre-feet per year would be delivered in the San Joaquin Valley, and a branch tunnel to the Pajaro-San Benito area would deliver 102,000 acre-feet per year. About 100,000 acre-feet annually would be supplied to the present service areas of the American River, permitting the release of a like amount from the higher watershed of that river for diversion to the Lahontan Basin of Nevada. Near Bakersfield, two pump lifts totaling 300 feet would make delivery of the main supply to the inlet of a tunnel through the Tehachapi Mountains. From that point, the supply would flow, largely by gravity, to satisfy directly some 380,000 acre-feet per year of future demand in the south-central coastal area of California and make available by direct service or exchange about $1\frac{1}{2}$ million acre-feet in the Mojave Desert, the Colorado River Basin, and southern California. Project works included in the plans and estimates would deliver irrigation water to the farm head gate and municipal water to a wholesale delivery point.

16. The suggested service of water to the Mojave Desert anticipates that the City of Los Angeles might be willing to accept water from the Northwest in exchange for water which it now diverts from

436,700 acre-feet of irrigation water to the San Francisco Bay area. Beyond the San Joaquin-Sacramento Delta the flow would be pumped by successive lifts up the San Joaquin Valley to the vicinity of Bakersfield; 2,841,000 acre-feet per year would be delivered in the San Joaquin Valley, and a branch tunnel to the Pajaro-San Benito area would deliver 102,000 acre-feet per year. About 100,000 acre-feet annually would be supplied to the present service areas of the American River, permitting the release of a like amount from the higher watershed of that river for diversion to the Lahontan Basin of Nevada. Near Bakersfield, two pump lifts totaling 300 feet would make delivery of the main supply to the inlet of a tunnel through the Tehachapi Mountains. From that point, the supply would flow, largely by gravity, to satisfy directly some 380,000 acre-feet per year of future demand in the south-central coastal area of California and make available by direct service or exchange about 1½ million acre-feet in the Mojave Desert, the Colorado River Basin, and southern California. Project works included in the plans and estimates would deliver irrigation water to the farm head gate and municipal water to a wholesale delivery point.

16. The suggested service of water to the Mojave Desert anticipates that the City of Los Angeles might be willing to accept water from the Northwest in exchange for water which it now diverts from

Owens Valley. The suggestion is presented to typify the possibilities embodied in the plan. It is possible that further study may indicate a more advantageous opportunity to use the water in some other area.

17. In view of the specific reference to the Colorado River Basin included in House Resolution 244, 80th Congress, First Session, adopted by the House Committee on Public Lands (paragraph 4), the investigations examined the possibility of making additional water available in that basin. From an engineering standpoint, the most efficient method of providing such an additional supply would be by the exchange of water from the Northwest for Colorado River water now being used or planned for use in California areas. For study purposes, such an exchange was assumed in the case of the Metropolitan Water District of Southern California. It is recognized, of course, that the claims of that entity, dependent as they are upon an ultimate disposition of the Arizona-California controversy in the Lower Colorado River, may be open to dispute, and that the outcome cannot be forecast with certainty. Yet it is apparent that without some assumptions with respect to this matter engineering analysis cannot proceed. In the substantiating material of the report, various possible assumptions are discussed. These assumptions are made without any attempt to analyze the legal problems involved and without intent to express or imply any opinion concerning the merits of any aspects of the controversy. In the resume carried by this

letter, there is presented only the most conservative outlook with respect to this exchange, indicating the lowest ratio of benefits to cost. That assumption contemplates that United Western water would be exchanged for the full claim of the Colorado River Aqueduct.

18. The Northern California Diversion could deliver water for use in the Republic of Mexico if later investigation discloses the possibility of water exchanges or other opportunity for advantage to both countries involved. Such delivery, however, is here suggested as a possibility and is not included in the plans and estimates presented.

19. For purposes of analysis, construction of the project was scheduled over a period of 20 years in four 5-year steps. The first would complete Ah Pah Dam and Power Plant; the second, all features as far south as Bakersfield; the third, the Tehachapi Tunnel and facilities immediately south of its outlet; the fourth, all remaining features in southern California. All Ah Pah power is assumed to be marketable as soon as available. New water markets which would be served as a result of steps 2, 3, and 4, are assumed to develop to their full extent uniformly over a period of 25 years from the first availability of water under each step. Project life is assumed to extend over 120 years from the start of construction or for 75 years after full development.

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20. Power installations at the Ah Pah Dam would generate power from that portion of the Klamath River flow which would be released downstream at the dam and not exported through the Trinity Tunnel to the Sacramento Valley. Between the time the dam would be completed and full development of the water market, a diminishing portion of the exportable yield would be used for such power generation. In early years the quantity would be substantial. After full development of the water market, generation would be limited to "peak power" generated from water released (and subsequently re-regulated by an afterbay) to maintain satisfactory downstream channel conditions; and to "dump power" generated during periods of reservoir spill. Substantial amounts of firm power would be produced at the Table Mountain and Iron Canyon Plants, where an increase in power generation would parallel the decline at Ah Pah. With growing water markets, additional power ultimately would be needed for project pumping; and also to offset reduction in generation on other projects, caused by United Western water transfers or exchanges and thus chargeable to the Northern California Diversion (Plate 21). This additional power could be supplied by thermoelectric generating stations. These could be situated in southwestern Utah (Plate 8) or some other locality where they would utilize low-grade coal deposits which are not now economically feasible of commercial exploitation. Transmission distance would exceed the present maximum in this country but would be no greater than that for which there is precedent in successful European practice.

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21. During the first 30 years of operation, a surplus of electrical energy would be produced by the project. Thereafter, a gradually increasing deficit would result through project year 45, after which the deficit would remain constant. For the assumed life of the project (120 years), the monetary value of the initial surplus would be more than sufficient to offset the later deficit, under the most probable conditions of interference by the Northern California Diversion with other power projects. The equivalent annual value of this surplus would be somewhat more than $4,000,000.

22. The total capitalized value of all project costs sustained by the Government (estimated at the 1950 index and including construction, contingencies, administration, operation, maintenance, and replacement reserve) computed for the year in which construction would commence is $3,246,000,000 (Plate 19). This represents the total out-of-pocket cost for all works. Amortized over 100 years at 2½ percent, it is equivalent to a uniform annual cost of about $89,000,000. For a more detailed discussion of the computation of cost, see Part II, Chapter 5 of substantiating material "Capitalization and Amortization."

23. If the above total capitalized value of all project costs were amortized, with 2½ percent interest on all unretired debt, in accordance with the assumed schedule of water delivery, considering both the time and amount of such deliveries, the cost per acre-foot would be about $25, ignoring the surplus from power revenues. This

21. During the first 50 years of operation, a surplus of electrical energy would be produced by the project. Thereafter, a gradually increasing deficit would result through project year 45, after which the deficit would remain constant. For the assumed life of the project (120 years), the monetary value of the initial surplus would be more than sufficient to offset the later deficit, under the most probable conditions of interference by the Northern California Diversion with other power projects. The equivalent annual value of this surplus would be somewhat more than $4,000,000.

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amount represents the full cost to the Government (including all interest) of providing and maintaining all the works in the project; it is not to be confused with the price which the consumer might pay for water. Repayment by the consumer is dependent on the allocation of project cost among the various purposes of irrigation, municipal supply, power, and perhaps others. Studies of such cost allocation and the succeeding repayment analysis are beyond the scope of this investigation. It may be noted, however, that the foregoing factors would reduce the amount to be paid by irrigators. Furthermore, in accordance with Reclamation law and policy, irrigators would not be required to repay interest charges on the project cost allocated to irrigation. The amount to be paid by the consumer for irrigation water, to repay fully on an interest-free basis, thus would be materially lower than the $25 per acre-foot indicated above; it might well be as low as $10 per acre-foot.

24. It is significant that in the area where the project contemplates delivery, certain organizations are currently sustaining a cost comparable to that herein anticipated in the development of water supply. Table 25 indicates examples of high development cost ranging from $11.16 per acre-foot to $64.82 per acre-foot with a weighted average of about $29 per acre-foot. Although in the same areas, many projects endowed with favorable characteristics are able to develop water at much lower costs, such costs are not a criterion, since they result mainly from favorable natural conditions. Such cheap sources of water are becoming fully exploited as evidenced by the fact that more costly supplies are coming into use. By the

time of a United Western project the cheap sources probably would have been completely developed. The examples in Table 25 demonstrate that, even at the present time, irrigation is practical under costs comparable to those anticipated for the Northern California Diversion.

25. Benefits under the project would accrue from the annual delivery of about 286,000 acre-feet of new municipal water and more than six million acre-feet of new water for irrigation and other uses. The latter quantity would provide service to southern California in greater amount than the anticipated deliveries of the Colorado River Aqueduct. That structure always would be useful for stand-by service, but its proposed diversion from the Colorado River (1,212,000 acre-feet per year) could be released to as yet undetermined use in that basin. Similarly, the present diversion of the Los Angeles Aqueduct in the Owens Valley might be released for use on the Mojave Desert, and a part of the American River flow released for diversion to Nevada. Rich lands in the San Joaquin Valley, for which no water could be provided from the Central Valley, even with full development of its water resources, would be afforded irrigation. The San Francisco Bay cities might save heavy investment which otherwise would be necessary for the development of municipal supplies. In addition to the foregoing, an annual benefit of several million dollars is expected to accrue from the project's hydroelectric installation. All monetary benefits attributable to the project during its assumed life would have a capitalized value of $6,212,000,000 discounted to the initial year of construction at 2½ percent.

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Amortized at the same interest rate over 100 years, this capitalized value is equivalent to about $170,000,000 per year. The ratio of benefit to cost is thus 1.9 to 1. No benefits from released Colorado River water have been included.

26. Intangible or unmeasured benefits would result in the categories of national defense, flood control, fish propagation, and recreation. Certain detriments also are evident in the categories of fish propagation and recreation, and it is anticipated that remedial measures would be planned in the course of continuing study in cooperation with other interested agencies. In fact such detriments might be of sufficient importance to warrant selection of a plan in which they would be minimized or avoided.

27. In the substantiating material for this report, various extremes of conditions have been assumed and the resulting benefit-cost ratio computed for these possible alternative conditions. The range has been from 1.6:1 to 3.0:1. It is apparent therefrom that considerable modification of the suggested plan could occur without a materially detrimental effect on the over-all merit of the plan, and that modification might, with equal probability, result in a more advantageous plan.

Supplements to the Northern California Diversion

28. As discussed in Part III of the substantiating material of this report, supplements to the above described project by succeeding stages could produce a substantial additional supply of water.

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Studies as to these extensions and their probable justifications are incomplete, but it appears likely that increments from various sources could provide a total additional supply of 10 to 15 million acre-feet per year, or even more. These might be delivered to the Sacramento Valley at an incremental cost (including interest at $2\frac{1}{2}$ percent) of from $5 to $25 per acre-foot, depending upon the source and plan of development. The foregoing cost is not comparable with the cost estimated for the Northern California Diversion since it includes only the cost for delivery into the Sacramento Valley. Furthermore, no carrying charges during the water market development period have been included. This applies also to all alternatives to the Northern California Diversion.

Other Plans

29. Certain of the above supplements which could be developed independently of the Northern California Diversion may also be considered alternatives. These are included with other alternatives in the brief discussions presented below.

30. Coast Range Gravity Interception Route. The Coast Range Gravity Interception Route would develop an exportable yield of about six million acre-feet per year from the Rogue and Klamath Basins by means of 7 dams. The general characteristics of the plan are indicated by the following tabulation.

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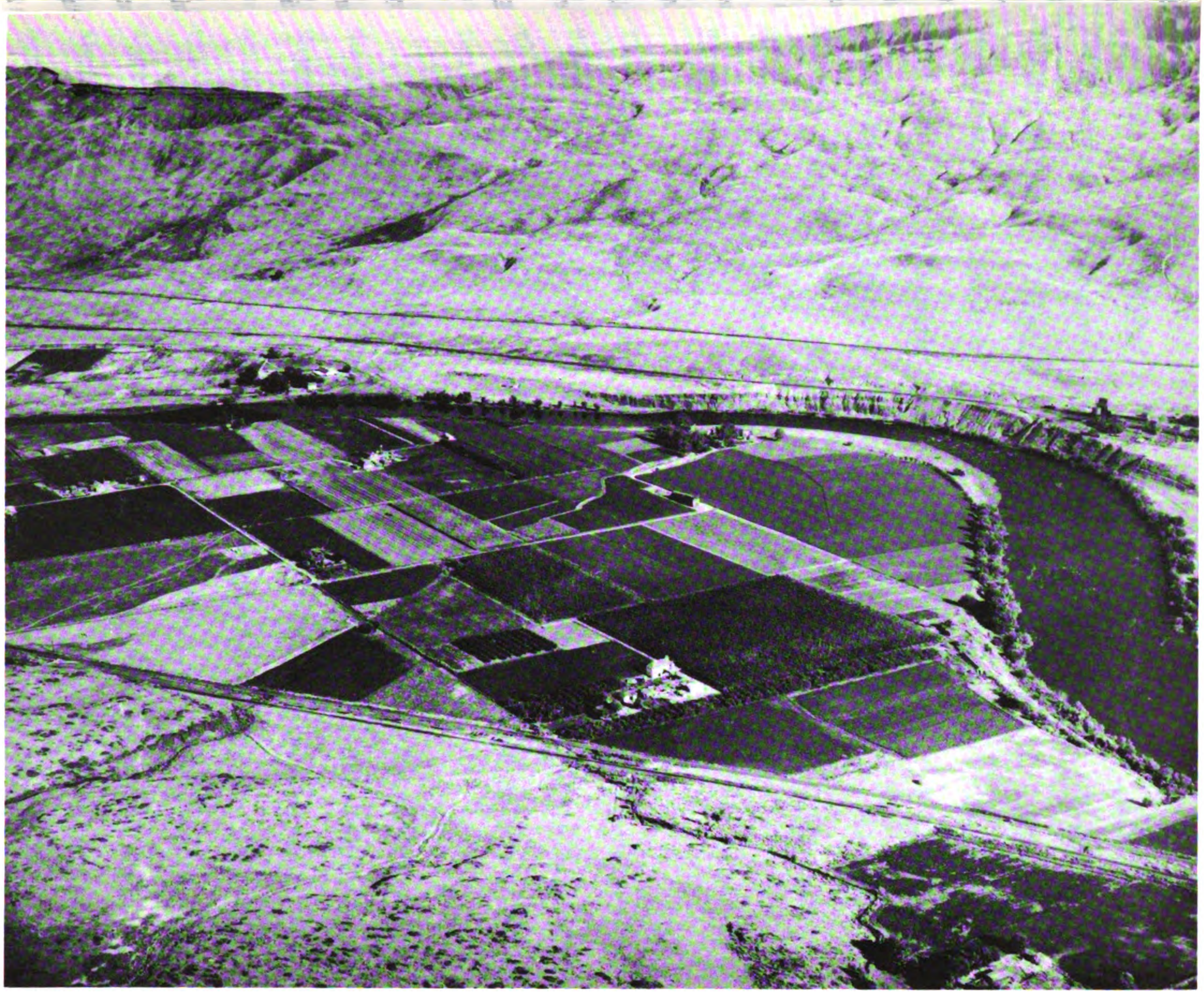

Contrast between Irrigated Lands and Virgin Sage Brush

Dam	River	Height (feet)	Net Storage (Acre-feet)	Yield (Acre-ft/yr.)
Lewis Creek	Rogue	486	1,550,000	1,400,000
Eight Dollar	Illinois	291	1,200,000	970,000*
Benjamin	Klamath	487	1,900,000	1,980,000
Red Cap	Klamath	550	1,000,000	1,070,000*
Burnt Ranch	Trinity	553	960,000	830,000*
Gaynor Peak	S. F. Trinity	600	1,080,000	940,000*
Horse Linto	Trinity	297	0	-

*Less fish release.

The cost under this plan, neglecting certain potential hydroelectric benefits, is estimated to be about $10 to $15 per acre-foot delivered to the Sacramento River. This cost has been estimated as indicated in paragraph 28.

31. Albeni Falls Diversion.—The Albeni Falls Diversion would derive water from Pend Oreille River, a tributary of the Columbia River at the Albeni Falls Dam site. The initial diversion would be at elevation 2028 and probably could be carried by gravity flow to the Klamath River above the Ah Pah Reservoir. The total length of aqueduct to the Klamath River would be about 1020 miles, of which about 290 miles would be tunnel and 40 miles in siphon. No estimates of cost were made for this plan because the necessary length of aqueduct causes it to appear unattractive, and also because tentative analysis of ultimate local water requirements indicates a lack of any substantial exportable surplus.

Columbia River near Town of Hood River, Oregon

32. <u>Willamette Pump Route</u>.--The Willamette Pump Route would divert from the Columbia River system either near Oregon City on the Willamette, or just below Bonneville on the Columbia. By a series of pump lifts, canals, tunnels, and collecting reservoirs, 10 million acre-feet or more per year could be delivered to the Sacramento Valley near Redding. The cost, on the same basis as indicated in paragraph 28, would be about $20 per acre-foot.

33. <u>Willamette High Line Route</u>.--The Willamette High Line Route is a variant of the Willamette Pump Route.

34. <u>Coast Range Low Level Route</u>.--The Coast Range Low Level Route would develop an exportable yield of approximately 12 million acre-feet per year. The surplus flows of the Rogue, Smith, and Klamath Rivers would be diverted at the furthest downstream location which would permit gravity delivery to the Sacramento Valley. Characteristics of the plan are shown by the following tabulation:

Dam	River	Height (feet)	Net Storage (Acre-feet)	Yield (Acre-ft/yr.)
Lewis Creek	Rogue	486	1,550,000	1,400,000
Eight Dollar	"	291	1,200,000	970,000
Copper Canyon	"	802	2,900,000	2,920,000
Junction	Smith	700	1,430,000	1,720,000
Ah Pah	Klamath	732	4,800,000	5,000,000

The cost per acre-foot of the above supply on the same basis as indicated in paragraph 28 would be $8 to $10, disregarding certain power benefits.

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Junction	Smith	700	1,430,000	1,720,000
Ah Pah	Klamath	742	4,800,000	5,000,000

The cost per acre-foot of the above supply on the same basis as indicated in paragraph 28 would be $8 to $10, disregarding certain power benefits.

35. Snake River Diversion.--Water supply in the Snake River, at points which would be attractive for diversion, does not appear to afford any exportable surplus. Also, the cost of all plans thus far examined has been relatively high.

36. Eel-Sacramento Diversion.--A yield of about $1\frac{1}{2}$ million acre-feet per year could be developed by a dam downstream from Dos Rios on the Eel River. This amount could be delivered to the Sacramento River for between $5 and $10 per acre-foot, estimated as indicated in paragraph 28.

37. Salt Water Barrier.--The Central Valley Plan contemplates the outflow of a substantial quantity from the Sacramento-San Joaquin River system for the repulsion of saline inflow. It is possible that a part of this could be conserved by a salt water barrier-dam. No estimates of the cost of such conservation have been made.

Other Areas of the West

38. Numerous possibilities exist for the inter-basin transfer of supplies into water-deficient areas other than those comprehended in the foregoing discussion. Studies of such plans are as yet in the most preliminary stage, and at this time it is impossible to do more than enumerate the various possibilities which have been encountered, with certain introductory remarks. Part V of the substantiating material and Table 30 present such information.

Other Means of Water Supply

39. Preliminary consideration has been given, in Part VI of the substantiating material to artificial precipitation, salt water

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36. Eel-Sacramento Diversion.--A yield of about 1½ million acre-feet per year could be developed by a dam downstream from Dos Rios on the Eel River. This amount could be delivered to the Sacramento River for between $5 and $10 per acre-foot, estimated as indicated in paragraph 28.

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39. Preliminary consideration has been given, in Part VI of the substantiating material to artificial precipitation, salt water

distillation, transportation of water by boat, and reclamation of sewage. None of these possibilities appears to offer as much advantage as that of inter-basin transfer by aqueduct.

Need for a Long Range Plan

40. The concept of water resource development and planning originally embraced only a single project. With wider needs for water, this concept grew to include whole streams and has now expanded to embrace entire river basins, the planning for which is now accepted practice. Even beyond this, numerous isolated inter-basin transfers of water have been accomplished, as in the case of the Colorado-Big Thompson Project. The United Western Investigation is an extension of this general trend of inter-basin and inter-regional planning. At the present time various agencies anticipate the expenditure, over a considerable period, of many billions of dollars for the construction of water supply projects of a generally localized, or at most, basin-wide nature. A broad, long-range plan such as that to which the United Western Investigation is directed would enable far greater efficiency in the individual projects and enhancement of their collective benefits. Instead of being designed as separate units, they could be planned in harmony with an ultimate pattern, and constructed in an orderly and progressive program as integral parts of a United Western development.

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41. The need for definitation of this pattern as a basis for a logical program of continuing water resources development exists

today, and it will become increasingly urgent as demands increase. The cost of evolving such a plan would be trivial in comparison with the savings which it would make possible.

Summary and Conclusions

42. In summary, it may be stated that the preliminary data now available indicate:

(a) In the water deficient stream basins west of the Continental Divide, about 25 million acres of land which is susceptible to irrigation are presently without an apparent water supply from local sources; large quantities of water also will be ultimately required for other uses in these basins.

(b) The foregoing acreage is in addition to the currently irrigated area of about the same magnitude in the entire West, and also in addition to potentially irrigable areas of approximately the same magnitude in the stream basins from which surplus waters might be diverted.

(c) In the streams which empty into the Pacific Ocean from northern California, Oregon, and Washington, there are surplus flows which amount to more than four times the quantity of water which, under any foreseeable demands, could ever be consumed within the basins of origin.

(d) The known surplus of water is sufficient to provide a supply three times as great as the probable quantities of

water which would be consumed in the irrigation of all the lands indicated in (a) above. Currently irrigated lands would, of course, continue to receive present supplies, and potential irrigable lands in the stream basins from which export might be made would be provided for by basic reserves in those streams.

(e) The plans discussed in this report contemplate the transfer of quantities in the order of only about 10 percent of the available surplus.

43. It is concluded that:

(a) It is reasonably probable that a portion of the surplus flow of the Northwest could be transferred to certain areas of deficient local supply by facilities which would be economically justified as illustrated by a favorable benefit-cost ratio.

(b) It is reasonably probable that the cost of transferring water would be lower than the higher levels of cost which are now required for the development of similar classes of water supply in many of the contemplated service areas.

(c) Under anticipated future conditions, the cheaper local water sources should and probably will have been exploited more fully. Under these conditions, the remaining unused local supply would entail even higher development cost than the present levels. In consequence, transfers such as

those herein discussed could have even greater future economic merit in comparison to the use of local sources.

(d) The West is now approaching full utilization of locally available water supplies in many of the water deficient areas. Consideration of a United Western plan must be continued, in order to permit the remaining possibilities for development of water supply or exchanges to receive the full benefit of coordination and physical integration with an ultimate over-all plan.

Recommendations

44. It is recommended that you adopt this report and take appropriate measures to have it made public.

S. P. McCasland

S. P. McCasland

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INTRODUCTION

Problem under Investigation

Local supplies of municipal, industrial, and irrigation water for large areas throughout the Western United States are being developed at a rate which will complete their utilization within a shorter time than generally appreciated. In many localities full utilization of all local sources can be foreseen definitely in the not-far-distant future. As local surface supplies are fully exploited and ground water reserves exhausted, expansion or even maintenance of the accomplished development depends upon some new or imported supply. In some parts of Arizona and California, and for certain districts of other states, the limit of local water resources already has been exceeded; formerly irrigated land has become idle and expansion of industry has been impeded because of failing supply. As time goes on these shortages will increase, finally becoming widespread unless some corrective measures can be effected.

In contrast to this general and localized scarcity, enormous water resources exist in the streams of other sections, particularly in the coastal belt of northern California and the remainder of the Northwest. In the Fall of 1948, a reconnaissance, designated the United Western Investigation, was initiated to determine what surpluses to ultimate local needs might exist in these streams, and, if any were established, to appraise the feasibility of transferring portions thereof to areas with deficient supply.

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Purpose of Report

Such a reconnaissance is the most preliminary phase of study. It is conducted at relatively small cost with the intent that preliminary data and short-cut methods of analysis should form the basis for results. The objective is to determine whether there is sufficient likelihood of a physically feasible and economically justified project to warrant a full and detailed investigation. Conversely, it is not the purpose of this reconnaissance to demonstrate that development itself is warranted. Such a demonstration is, in essence, the objective of the detailed investigation which the reconnaissance may justify.

Scope of Report

It is emphasized that the United Western reconnaissance is concerned with the long-range aspects of the general water problem. Estimates are made for conditions which will ensue over a period of many decades in the future, during which an approach to ultimate development may be reached. A period of many years would be required even to fully analyze and plan projects such as those under consideration. Even more time would be necessary for their construction.

The investigation, as its name implies, is a study of the means of effecting improvement in the distribution and utilization of the water resources of the entire West. As demonstrated in the text of this report, exchanges of water may be possible, permitting benefits in a wide geographical area, possibly even east of the Continental Divide.

Composition of Report

Part I of this report presents those general considerations which are common to all plans and stages of development herein contemplated.

Part II constitutes a reconnaissance report on the "Northern California Diversion," which report leads to the conclusions set forth in the Report of the Chief. The Northern California Diversion contemplates the transfer of water from the Klamath River to central and southern California, and by exchange, to and possibly beyond the Colorado River Basin, to the Great Basin, and to the Mojave Desert; the development encompassed therein might be a complete and final project, or might serve as the initial stage of a larger plan, as described in Part III.

Part III covers supplements which might be made to the Northern California Diversion by succeeding stages, as and if greater demands for water warrant. Studies of these supplements and of the potential demands which would necessitate them are incomplete, but interim results of a general nature are outlined.

Part IV considers alternatives to the Northern California Diversion. Analyses of such alternatives have been in less detail than that for the Northern California Diversion.

Part V pertains to plans for inter-regional water transfer which include other areas than those comprehended in the Northern California Diversion and its supplements. Studies of such plans are as yet in the

most preliminary stage. However, a list of the possibilities thus far encountered, and introductory remarks thereon are included.

Part VI pertains to possible alternative sources of water other than stream diversion. It includes consideration of artificial precipitation, salt water distillation, boat transportation, and sewage reclamation.

AUTHORITY

Recognizing the unequal distribution of vital water supplies in the Western States, and recognizing the vast influx of population into those states without regard to the present or ultimate water supplies which might be available to sustain such populations and their resulting economy, and for other purposes, the late Congressman Richard J. Welch of California sponsored a resolution during the 80th Congress (House Resolution 244), calling upon the Secretary of the Interior to investigate and report upon a project such as that herein contemplated. The text of the resolution is:

> "RESOLVED, That the Secretary of the Interior through the Bureau of Reclamation is requested, under and by virtue of authority conferred upon him by the Federal reclamation laws (Act of June 17, 1902, 32 Stat. 388, and Acts amendatory thereof or supplementary thereto) for general investigations relating to proposed Federal reclamation projects, to investigate and report as soon as practicable to the President and the Congress on the engineering and economic feasibility and economic justification of diverting surplus waters from other basins to southern California and the Colorado River Basin and the practicability of exchanges of water, and other possibilities for effecting improvement in the distribution and utilization of the water resources of the West: PROVIDED, That such investigations and report shall be made, among other things, in accordance with the policies and procedures laid down in section 1 of the Act of December 22, 1944 (58 Stat. 887)."

This resolution was reported out favorably by the Committee on Public Lands on July 15, 1947.

In recognition of the above resolution, the investigation is carried out under authority of the Reclamation Act of 1902 as amended and supplemented.

ACKNOWLEDGMENTS

In this reconnaissance, use has been made of existing data to the extent of its availability, and numerous agencies and individuals have contributed valuable assistance toward the results here presented. The number of these entities is so extensive that space does not permit acknowledgment here of each separate courtesy. In the body of the report mention is made of the source of basic data.

P A R T   I

UNITED WESTERN RECONNAISSANCE

CHAPTER 1

Area Covered by Report

Natural Characteristics

Geographical limits.—The United Western Reconnaissance (Figure 1) covers the United States west of the Continental Divide and, with special objectives, extends consideration also to additional territory in Montana, Wyoming, Colorado, New Mexico, Texas, and the Republic of Mexico. Studies embrace all of Regions 1, 2, 3, and 4, and parts of 5, 6, and 7 of the Bureau of Reclamation.

Physiography.—Configuration of the area varies between the widest limits. The highest elevation in the United States is Mount Whitney at 14,500 feet; only fifty miles distant is the lowest elevation in the United States, Death Valley, at minus 276 feet. Topography includes: great zones of arid desert in the Southwest, in the eastern sections of Washington and Oregon, and in parts of Idaho and Utah; great chains of jagged and barren mountains characteristic of such desert area; wide expanses of plains in Wyoming and Texas; high plateaus in Arizona and New Mexico; rugged mountain ranges such as the Rockies, Sierra-Nevada and Cascades; hills and lesser mountains in the coast ranges; and broad fertile valleys along the Willamette, Sacramento, San Joaquin, Rio Grande and other rivers.

Soils vary between limits as wide as those of topography. Large tracts of agriculturally worthless land exist in the salt-impregnated flats of the Great Basin; and steep and rocky slopes unsuitable for any type of farming cover sections of Washington, Oregon, and California. By contrast, the occurrence of soils of favorable agricultural quality is widespread; even the great expanses of desert and plains would produce bountiful crops if afforded a water supply. The areas of those lands susceptible to irrigation are shown on Plate 5; the general subject of lands and soils is discussed in greater detail later.

Climate.—In the southern end of the area under investigation, the climate is characterized by hot, dry summers and extremely mild winters. In large areas frost is rare or nonexistent. The generally mild climate extends northward along the Pacific Coast and includes the Central Valley of California and the Willamette trough of Washington and Oregon. In the high mountains there exist perpetual snow and glaciers, and on the northern plains winters also are severe, temperatures of -40° being common. In most of the northern zone, such cold winters are contrasted by hot summers equally intense. Table 2 shows a summary of climatological data for representative stations within the area under investigation.

As discussed in more detail in Chapter 2 and shown by Plate 1, the geographical distribution of precipitation is extremely variable.

Development

Population.—According to figures of the Bureau of Census, the 1950 population within eleven of the western states is 19,562,000. An increase of 5,528,000, or 40 percent, has occurred in the past ten years. This marks that area as the region of greatest growth in the United States, both in rate and in actual number of inhabitants. About 60 percent of the population is rural and essentially agricultural, while the remainder is largely confined to densely populated urban centers. Population increase has been greatest in the coastal centers, but the States of Arizona and Wyoming also have experienced phenomenal growth. These trends are indicated in the population curves shown by Plates 9 and 10 1/. At the close of World War II, it was generally expected that the increasing trend would subside, but the anticipated recession did not occur; on the contrary, the phenomenal growth continued.

Agriculture.—The agriculture of the area is extremely varied as might be supposed from the previous discussion of soils and climate. Of the total 1939 cash farm income in eleven of the western states, 49 percent came directly from irrigated land, 38 percent from dry land, and 13 percent from partly irrigated land. However, of the cash farm income from the direct sale of crops, 72 percent is

1/ Adapted from "Long Term Outlook for Western Agriculture" U.S.D.A. and U.S.D.I., by Marion Clawson and Wendell Calhoun.

estimated to have come from irrigated land. Table 5 shows the relative importance of the various crops in these western states by irrigated and dry land production.

The area irrigated in these eleven western states has increased 1/ as follows:

	Year 1910	1920	1930	1940
Acres irrigated	13,203,000	17,401,000	17,464,000	18,553,000

The value of agricultural production calculated at the 1926 price index increased from about a billion dollars per year in the 1910-14 period to about 2¼ billion in the 1939-43 period. This trend is shown by Table 4.

Certain specialized crops have extremely high unit value. For example, lemons in some localities show a gross return of $720 per acre on the basis of 1939-44 prices.

Industrial and mining development.—During the war years, a tremendous amount of industrial expansion occurred at the various population centers of the area. This development took the form of increases in the capacity of existing plants, as well as the establishment of entirely new industries. After the cessation of hostilities, most of these industries continued to produce on an ever-increasing scale, and still other fields of industry were entered. Some idea

1/ Census of Irrigation.

of the trend can be gained from Table 6 which shows the increase in value of all mineral products of the area by states over the past decade.

There is almost no limit to the extent to which industrial development may expand in the area under consideration. Enormous quantities of various sorts of raw materials exist and the facilities needed for processing can be developed. Some of the most readily apparent fields of potential development are aluminum processing, coal hydrogenation, oil from shales, and phosphate reduction.

Plate 7 shows the geographical location of some of the more important mineral deposits. The extent of reserves, estimated from various sources including the Bureau of Mines is shown by Table 11.

National Defense

Much of the area under consideration is very strategically located from the standpoint of national defense. The Sierra-Nevada and their northern extension, the Cascades, form a natural barrier protecting the lands farther east. In this protected zone there is situated some of the area's most desirable agricultural land and a large share of its mineral resources. Equally important, a large amount of electric power could be produced. Some of the hydroelectric possibilities such as Hoover Dam already have been exploited, and many potential projects are attractive. Also, there is wide opportunity, as hereinafter described more fully, to develop large blocks of low-cost thermal energy. These could operate very advantageously

in conjunction with and in firming up the hydroelectric capacity during normal times, and in an emergency could carry essential loads without some of the more vulnerable hydroelectric stations. Furthermore, there may be opportunity to develop the fuel for thermal power as a by-product of other processing, such as the hydrogenation of coal, and derive a compound advantage.

CHAPTER 2

Water Supply

General Characteristics

Precipitation.—As indicated previously in Chapter 1, the pattern of precipitation is extremely nonuniform throughout the area under study (Plate 1). On some of the desert lands of the Southwest there is almost no precipitation at all. In some sections—for example, in the vicinity of Yuma, Arizona—rain is a rarity, and in the desert regions which extend to the north of that city an area about as large as the State of California receives an average of considerably less than 10 inches per year of total rainfall. Conversely, in the coastal belt of northern California, Oregon, and Washington, there are large areas with an annual rainfall of more than 100 inches.

Variation in rainfall from year to year is shown by Table 1, which gives the maximum, minimum, and average annual rainfall for states in the area under study. This table, together with Plate 3, shows the general trend and critical years and indicates that critically dry periods in general occur simultaneously in all sections of the area. Further pertinent information is shown in Table 2, which indicates the great variation in growing season, temperature, and precipitation within the individual states. The intensity of rainfall in the dry desert areas is often extreme, while in the areas of

greater total precipitation the fall is apt to be more gentle. Maximum intensity of rainstorms for various stations throughout the area is shown by Table 3.

Snowfall.—Precipitation in the form of snow occurs to a moderate extent in the northern sectors of the area and falls in great quantity in the higher mountains. Near the summit of the Sierra-Nevada, a direct fall in excess of sixty feet has been recorded during a single season. In these mountain areas, snow ordinarily does not melt until the following spring. The moisture of such accumulation is of tremendous importance in contribution to water supply. In many streams, far the greatest portion of annual runoff comes from the spring and early summer melting of the winter snowpack. This natural process of retarding runoff for a period of weeks or months after precipitation has occurred exerts the same practical effect as a storage reservoir in causing the resulting stream flow to synchronize more nearly with the seasonal water requirements of irrigated crops. Further, modern technique in measuring the winter's accumulation of snow enables an accurate forecast of the spring and summer runoff. This permits the residual water stocks of surface reservoirs to be adjusted accordingly and advantage to be taken of storage space so evacuated.

Evaporation.—In opposition to precipitation is evaporation, the geographical variation of which is shown by Plate 2. A comparison of this plate with that showing average annual precipitation (Plate 1),

indicates that in areas of low precipitation, drouth conditions are further aggravated by extremes of evaporation.

Rivers and Streams

General.--Rivers in the northern section of the area under consideration contribute by far the greatest portion of the area's total water supply (Plate 4 and Table 7). Of these northern rivers, the Columbia is outstanding, discharging annually some 170 million acre-feet, or about 58 percent of all the flow which enters the Pacific from northern California, Oregon, and Washington. The Columbia also may be compared to about seventeen times the present outflow from the Colorado River which latter stream has about the same size of drainage basin as the Columbia. The Willamette, Deschutes, John Day, Snake, Clarks Fork, Kootenai, and Pend Oreille are important tributaries of the Columbia River. Other significant rivers which discharge into the ocean along the coast of Oregon and northern California are the Umpqua, Rogue, Smith, Klamath, Eel, and Russian. The Sacramento and San Joaquin, which drain the Central Valley of California and discharge to the Pacific via San Francisco Bay, are important streams, but practically all of their conservable yield ultimately will be put to local use. The total of all discharge into the ocean from northern California, Oregon, and Washington is some 300 million acre-feet per year.

The Colorado River with an average annual outflow from the United States of some 10 million acre-feet (1921-45 average) is the

principal source of water for a large part of the West in California, Arizona, New Mexico, Nevada, Utah, Colorado, Wyoming, and the Republic of Mexico.

Other streams of the area are not significant contributors of water. Some are of importance because the limited yields are locally used in areas of great scarcity with correspondingly high value per unit of volume. This is especially true along the coastal plain of southern California.

Important characteristics of the principal rivers and their main tributaries are shown by Table 7 and Plate 4.

Surplus flow.—The outflow of three hundred million acre-feet per year from the north-coast streams evidently is in excess of all present consumption, since it is discharged into the sea. It is apparent, however, that present use might increase greatly, and that the foregoing quantity is not necessarily indicative of the surplus which would exist under conditions of ultimate development. In order to determine what surplus there would be under the latter conditions, estimates were made of maximum future consumption in the basins from which export might be made.

Ultimate irrigation was assumed for all lands whereon the farmer ever would go to the expense and trouble of applying an irrigation supply under any conceivable future conditions, and an inventory of potential irrigation requirements made on that basis. Pertinent existing data were utilized to the fullest possible extent. Where

data were lacking, estimates were based on map and/or field reconnaissance by technicians familiar with local conditions. Estimates were made with the advice of locally recognized authorities and were intentionally liberal, so as to indicate absolute maximum conditions. The results of this inventory were reviewed by a board of specialists during April 1950. The board recommended certain refinement in detail which had the effect of reducing the inventoried acreage by a small amount. The resulting water requirement for all lands in the Northwest, which would ever be irrigated under any future conditions, is in the order of about one-fifth of the average gross runoff. In round numbers, this leaves an ultimate excess, above maximum possible irrigation, of more than 240 million acre-feet annually for the entire Northwest, including northern California (Plate 4).

Industrial demands and those for domestic use will, in the ultimate concept, be met largely from the reserves for irrigation, since urbanization will take place mainly on those classes of land for which an irrigation supply has been reserved. A demand of 200 gallons per day per capita is generally considered abundant for both industrial and domestic use under the humid conditions which apply to most population centers of the Northwest. Therefore, a substantial population density (about 5700 persons per square mile) must be reached before the consumptive demand per unit of area exceeds that for irrigation. Moreover, at 200 gallons per day per capita,

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about four and a half million persons and their attendant industry can be sustained on an annual supply of a million acre-feet. From this, it is evident that even with maximum industrial expansion and population growth, including that on areas for which no irrigation supply would be reserved, such consumption would not exceed a few million acre-feet per year.

Analysis has been made of those natural resources in the Northwest that might, in their future exploitation, call for quantities of water above those of ordinary industry which have been included with municipal demands. Statistics of the Bureau of Mines as to mineral deposits indicate that future mining and milling operations would be of a type for which large quantities of water would not be required. The processing of wood products might call for considerable water, but in relation to the quantities under discussion, the amount is of minor consequence: It has been estimated that only 50 to 75 thousand acre-feet per year might ultimately be required in the entire Columbia Basin for this purpose; demands in other basins would be much less. No other potential consumptive requirements meriting special consideration were disclosed. The total of all demands in this category, therefore, would be very small.

From the foregoing it is evident that after reserves have been made for all conceivable future use in irrigation, industry, and domestic use throughout the Northwest, the remaining surplus would be some four times as great as the reserves, or almost

240 million acre-feet per year. Such a quantity of water is more than treble the amount which would be consumed in irrigation of the entire acreage susceptible to irrigation encountered in all the rest of the area under investigation. It is certainly enormous in comparison with any amount which is likely ever to be exported.

Specific estimates.—For those particular points where diversions are contemplated, as described in subsequent chapters, reserves have been calculated on a specific and not a general basis; that is, all of the ultimate consumption for the particular basin under consideration has been estimated, both above and below the point of diversion. Reserves have been made for satisfaction of those potential demands with an ample factor of safety, and only surpluses thereto have been considered for export.

Power Water

It is recognized that a large part of the flow which is here designated "surplus" would be used for power production in the basins of origin. Evidently, any United Western diversion above hydroelectric power plants would cause the power output thereof to be diminished in proportion to the quantity diverted. As explained in more detail later, it is assumed in this report that any such energy losses to then existing plants would be offset in kind with energy provided by the United Western project.

Other Non-Consumptive Uses

It is probable that none of the plans here contemplated would have any appreciable effect on navigation or stream pollution. Fish

and wildlife, and recreation would be adversely affected by certain of the contemplated works, and a solution of the problems so introduced will require further study and collaboration with appropriate state and federal agencies.

Local Supplies in Area Served by Import

In areas to which importation is contemplated, future demands would, of course, exceed local supplies. In much of the deficit area, local sources already have been extensively exploited. The portion of any stream which remains available for new uses is likely to be only the extreme flash floods, which waters are very expensive or impossible to conserve. In estimating demands for imported water, any local supplies have been assumed to be utilized to the maximum practicable extent; that is, it has been considered that there would be either full utilization, or utilization up to the point where the cost of developing an additional increment of the local supply might exceed that of United Western import. This comparison of the relative advantages of importation with those of additional works to conserve more water locally has been made on a highly preliminary basis. Much more study is necessary to determine the exact amount of additional local conservation which is warranted in comparison with importation. However, in the area to which importation is contemplated in this report, the total amount of local water which will remain undeveloped after completion of all the local works now proposed will be very small. Any difference between the degree of its ultimate use, as

contemplated in this report, and that finally computed by detailed study, would be of minor importance.

Quality of Water

All of the streams from which export is contemplated have an excellent quality of water.

CHAPTER 3

Water Requirements

Deficit Area

In the general area of Region 1 and the northern part of Region 2 of the Bureau of Reclamation, the over-all water supply exceeds the total of all possible future consumption. The general area is shown by Figure 1. As indicated in the previous chapter, it is this section which would provide the basic water supply for the plans here contemplated. There are, of course, large sections therein where the water supply is inadequate, but such shortages tend to be localized, and are a problem beyond the scope of this investigation.

In the remainder of the area under study the over-all demand exceeds the supply and deficiencies must be satisfied by importation. There is, therefore, a general deficiency and that portion of the territory under investigation has been designated the "Deficit Area."

Existing Deficiencies

In many sections, critical deficiencies exist at the present time, and in some areas formerly irrigated acreage with its accessory development has become idle for this reason. In the Lahontan Basin of Nevada, more than twenty thousand acres under existing canals have never been afforded a water supply. In the Escalante Valley of Utah, several thousand acres of developed land are now idle due to the failure of surface and ground water supplies. In central Arizona,

more than seventy thousand acres which were formerly irrigated are now idle because of failing ground water and inadequate surface supply. These are examples of localized conditions which already exist or which are imminent in other sections of the deficit area.

Demand for Water

Land susceptible to irrigation.—In the deficit area an inventory of land susceptible to irrigation was conducted in a manner similar to that in the basins of surplus water, but under criteria less liberal. Instead of maximum possible use of water, as contemplated in the Northwest, normal use was assumed, restricted largely to those soil types which have been proved performers under irrigation practice. On this basis, a total of some 26 million acres were found to be susceptible to irrigation (Plate 5 and Table 10).

Irrigation Water Markets.—In the analysis conducted to date, only one major area has been studied from the standpoint of definite markets. This has been in connection with the Northern California Diversion (Part II). The procedure described below was employed for those studies, and is applicable to any other definite market which may be examined in continuing investigation.

Market areas for irrigation water were established by use of "Storie" soil rating maps 1/; Soils Surveys of the Department of Agriculture; United Western Inventory data; and various maps showing presently irrigated lands.

The general practice was to determine first the gross irrigable acreage not now served with water. This gross irrigable acreage

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1/ Rating of California Soils, by Walter W. Weir and R. Earl Storie, University of California, Berkeley, California, Bulletin 599, Jan. 1936.

then was reduced to net irrigable area by a factor averaging about 10 percent to account for buildings, roads, right-of-way, etc. The net irrigable acreage was further reduced by varying percentages (averaging about 20 percent) to account for the acreage not irrigated in any particular year because of fallowing, discontinuous tenancy, weed control, etc. This determination was then checked to verify that the deliveries were practical from an engineering standpoint. In some cases, consideration of engineering feasibility sharply reduced or entirely eliminated areas of known arability.

The next step was to reduce the so-called water market acreage in each area by the amount which undeveloped local water supplies would justifiably serve. The result is the net acreage for which there is no supply except by importation (Table 10).

Municipalities.—Potential requirements of municipalities in the deficit area have been inventoried on the basis of population forecasts to the year 2000. Future per capita consumption has been estimated at 200 to 300 gallons per day, depending on the factors which influence individual cities. This amount includes allowance for industries which are normally served by municipal systems.

Population will undoubtedly increase in subsequent years beyond the figures shown for the year 2000. Forecasts of the degree of increase through such distant future trends are difficult, and it has been considered preferable, and certainly conservative, to employ the estimate for year 2000.

In the areas from which export is anticipated, the estimated year-2000 population arbitrarily has been increased by 400 percent, and reserves made for satisfaction of its demand.

Special industrial demands.--In most of the deficit area it is expected that industrial demands will be met in conjunction with ordinary municipal service. There will no doubt be some exceptions, but, in most cases, the quantity of water involved therein will be negligible in relation to the over-all demand.

In the sparsely settled region of the Upper Colorado River Basin, however, a heavy potential water demand by industries has been disclosed, and service of this demand may be largely independent of municipal systems. It cannot be determined at this time whether such demands would be met through exchanges made possible by a United Western project, or whether they would be served entirely independent of any such project. Estimates (Table 11) indicate that the requirements for production of synthetic fuel from oil shales, hydrogenation of coal, and mining and milling of minerals ultimately might approach two million acre-feet per year. Because of the speed with which research and technical developments are moving, especially in the reduction of oil shale, estimates presented in Table 11 are subject to radical change.

The total potential demands for all purposes in the Colorado River Basin are several million acre-feet per year in excess of the

supply which can be practicably developed in that Basin. The possibility of meeting a part of these demands by exchange is discussed more fully later.

CHAPTER 4

Power

Present Power Development

General.—The present magnitude of power development in the western states with which the United Western Investigation is primarily concerned, and the relative importance of hydroelectric generation therein are illustrated by the following tabulation:

Generating capacity and generation—1949.
All plants contributing to the public supply*

State	Capacity 1000 kw Total	Capacity 1000 kw Hydro	Percent Hydro	Generation 1,000,000 kw-hrs. Total	Generation 1,000,000 kw-hrs. Hydro	Percent Hydro
Arizona	737	541	74	3,429	2,603	76
California	4,775	2,419	51	22,099	11,687	53
Colorado	400	87	22	1,628	329	20
Idaho	382	377	98	1,840	1,836	99
Montana	449	433	96	2,916	2,888	99
Nevada	596	586	98	3,591	3,582	99
New Mexico	261	25	9.5	911	89	9.7
Oregon	916	718	78	5,301	4,967	94
Texas	2,258	245	11	10,666	615	5.8
Utah	180	93	52	614	359	58
Washington	2,400	2,195	91	15,071	14,739	98
Wyoming	116	55	47	508	327	65
Total	13,470	7,774	59	68,574	44,021	64

*Statistical Bulletin, Year 1949, The Electric Light and Power Industry in the United States, published by the Edison Electric Institute.

Hydroelectric component.—It will be noted that hydroelectric lants furnish the major portion of both the capacity and energy vailable in the above twelve-state area; that is, 59 percent and 4 percent, respectively. Comparable figures for the total United tates power industry are 26 percent and 31 percent.

Trend in development.—Comparable data to those tabulated above, nd compiled by the Edison Electric Institute for 1939, indicate hat in the ten-year period 1939-49 there was a growth of 7,062,000 ilowatts in generating capacity and 46,661,000,000 kilowatt-hours n total generation. These growths, which are equivalent to 110 ercent and 213 percent, respectively, of the 1939 figures, and to ompounded annual growths of 7.7 percent and 12 percent, respectively, re indicative of the unprecedented expansion of industry and population in this area. For the entire United States within the same tenar period the over-all increases in electric generating capacity and kilowatt-hours generated totaled 68 percent and 138 percent, spectively.

tential Power Resources

Table 24 shows that there is a somewhat limited remaining droelectric potential available to the states of the western ea. Column 2 of this table was obtained by adding Federal Power mmission data on generation by industries for their own use to ose contained in the preceding tabulation showing generation for lic use. Although undoubtedly containing some approximations,

the data so derived are representative of present energy consumption in the individual states.

The data contained in Table 24, Column 3, pertaining to undeveloped hydroelectric potential, compiled from Bureau of Reclamation sources, present an estimate of the power potential of feasible developments. The hydroelectric projects summarized in these data include those presently proposed by the Bureau of Reclamation and other federal and private agencies. The remaining columns of the referenced table are either self-explanatory or are clarified by footnotes to the table.

In Table 24, the periods of years shown as required to absorb the remaining hydroelectric potential are probably high; that is, the assumed 5 percent annually compounded future rate of load growth is probably low. Although the table indicates that the remaining hydroelectric potential in the four Northwestern States (Oregon, Washington, Idaho, and Montana) would be absorbed in a period not to exceed fifty years, some estimates from authoritative sources indicate that the potential, even in this area which is generally considered to have "unlimited" hydroelectric capability, will be absorbed in as short a period as twenty years.

In view of the limited hydroelectric potential remaining to be developed, it is evident that the West must turn in a relatively few years to another source to satisfy its growing power requirements. Nuclear sources are often suggested, but many improvements and

simplifications will be necessary before these sources will be proved economical. It is likely that thermoelectric generation will continue to be used to meet growing power requirements for a long time after hydroelectric resources are utilized fully.

Computations of thermal power costs in connection with this report have assumed steam-electric generation. It is probable, however, that large gas turbines will eventually be perfected to operate at even higher over-all economy than such steam turbines. In England and Switzerland at the present time they are considered competitive in capacities ranging from 500 to about 20,000 kilowatts. This type turbine would have an advantage over a steam turbine, particularly in arid areas, in that it requires no water. Furthermore, it would lend itself as a direct means of utilizing the products of in-place gasification of low-grade coals.

Consideration is given in this report to the utilization of a part of vast deposits of low-grade western coals as a source of energy for thermoelectric generating stations. As will be explained in subsequent text, power values are based on the estimated costs of utilizing these fuels. The location of reserves and the types of coal contained in each are indicated on Plate 8. A determination of the relative favorability of the deposits will require a large amount of additional study. A number of deposits lie within a 500-mile radius of United Western load centers (Plate 8), and there is no doubt that the development of some of these sources would be

practicable. The transmission distance would be in excess of any present examples in the United States, but no greater than that for which there is precedent in successful European practice.

The quantities of available fuel are so vast that project needs are relatively insignificant in comparison thereto. In round numbers, a million kilowatts generated continuously for a hundred years would consume about a half billion tons of the lower grade coal. However, almost none of the indicated deposits are rated in less than tens of billions of tons, and it is apparent that their total reserves would not only supply any United Western project, but all other needs of the West for a long time in the future. It may be safely assumed that after full development of hydroelectric potential (Table 24), these thermal possibilities will be exploited to meet general load growth, and that the thermal power needs for operation of a United Western project would be only a part of the general demand.

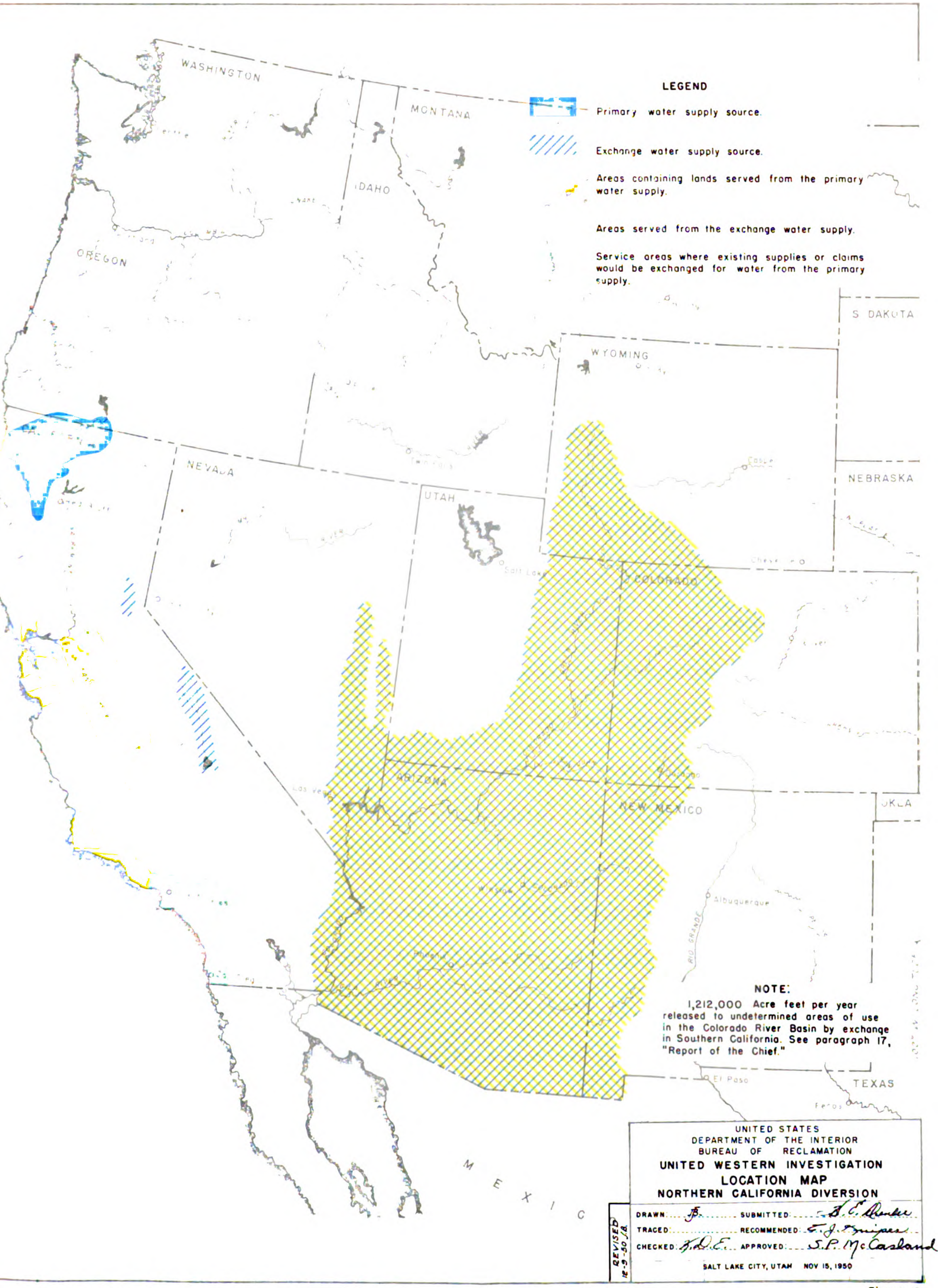

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Figure 2

PART II

NORTHERN CALIFORNIA DIVERSION

INTRODUCTION

The inventories described in Part I have indicated the geographical pattern and magnitude of both supply and demand. This definition has, in turn, suggested the general course of the investigation. Initially, the major effort has been toward a plan to serve the Southwest, where existing shortages and imminent potential demands are accentuated. Numerous schemes were examined, in varying degrees of thoroughness, and one plan, designated the Northern California Diversion, was selected as an example and subjected to complete reconnaissance analysis. Further study and enunciation of local desires may dictate certain modifications or even indicate a substantially different plan to be preferable. At this time the Northern California Diversion has been selected to afford a model for analysis of project cost and benefits. That analysis has indicated reasonable probability that detailed studies will demonstrate the economic justification and physical feasibility of satisfying a part of the demands in the Southwest by importation under a plan such as that suggested.

The plan as contemplated would be the initial stage of development. It would meet the most imminent demands and could stand as a complete and final project, but might more probably serve as the initial stage of a larger plan to meet greater demands as future economy may dictate.

PART II

CHAPTER 1

Water Supply

General

The water supply for the Northern California Diversion is divided into two classes--primary supply and exchange supply. The primary supply would be collected by the potential Ah Pah Reservoir on the Klamath River near its mouth. A diversion therefrom would serve areas in Central Valley and the south- and central-coastal areas in California. In these areas, a part of the primary supply could replace existing use or claims to other sources of water, and thus make the replaced water available for new uses on the basis of "exchanges." Exchanges assumed for purposes of analysis are:

(a) About 100,000 acre-feet per year from the Rubicon River and Caples Creek (tributaries of American River) above elevation 6000 on the east side of Central Valley, to be transferred into the Lahontan Basin of Nevada and replaced on the floor of Central Valley.

(b) About a million and a quarter acre-feet per year (under the assumptions discussed later) in the Lower Colorado River, to be used in that basin and replaced in the present service area of the Metropolitan Water District in southern California.

(c) About three hundred thousand acre-feet per year from Owens Valley to be used on the Mojave Desert and replaced in the City of Los Angeles.

Numerous other possibilities exist and will be explored in the ourse of continuing investigation.

h Pah Reservoir

General.—Geological Survey runoff records are available on the lamath River at Requa and Somesbar and on the Trinity River at Hoopa nd Lewiston. The period of record at these stations is shown in able 7. Inspection of the Lewiston discharge hydrograph (Plate 11), ontinuous since 1895, reveals that the critical period of record s embraced by the years 1920 through 1945. Accordingly, the monthly istorical runoff at the Ah Pah Dam site was computed for the period 920 through 1945 on the basis of records for Requa, Somesbar and oopa. Evidently, whatever is concluded from an analysis of this eriod can also be considered applicable with greater conservatism o the longer period 1895-1945, fifty years.

The computed historical monthly runoff at the dam site was educed in anticipation of (a) ultimate local demand upstream as escribed in Chapter 2, Part I; and (b) the Upper Trinity diversion nto the Sacramento River, which is proposed as an integral part f the Central Valley Plan. For analysis, average annual ultimate epletions were as follows:

	Acre-feet
To serve 292,000 acres and also provide 16,000 acre-feet for municipal and industrial demand—736,000 acre-feet, of which 148,000 acre-feet would return to the river above the dam site	588,000
For the proposed Upper Trinity Diversion from which there would be no return flow	706,000
Total net depletion	1,294,000 acre-feet per year

Ultimate requirements downstream from the reservoir were calculated to be as follows: 1,000 acre-feet per month from May through September to irrigate land in the coastal area where the average annual precipitation is some 76 inches per year, with good distribution and 85 percent of the fall in the period from October through April; 1,000 acre-feet per month, throughout the year, for municipal and industrial use. An additional release would be made to maintain downstream flow for aesthetic reasons and to permit migratory fish to gain access to those tributaries entering the river below Ah Pah Dam. The magnitude of this release would be determined in the course of further study in collaboration with appropriate state and federal agencies. It has been tentatively assumed at 19,000 acre-feet per month.

As indicated by Table 8 and Plate 16, the required Ah Pah Reservoir yield for export to the Sacramento Valley would be

6,094,000 acre-feet per year. This would be on an eleven-month basis, or 554,000 acre-feet per month, from February through December. It is estimated that the total inoperative period of export facilities, due to unforeseen interruption for emergency repairs and for routine maintenance of the main aqueduct and associated facilities, would amount to approximately one month each year. For this study the entire shut-down period is assumed to occur during the month of January and although actual operation may not be in complete accord with this assumption, the net effect of deviation from such a plan would be negligible.

On the basis of ultimate monthly depleted inflow at the Ah Pah Dam site, a detailed reservoir operation study, which includes losses from evaporation, was made to determine the conservation storage necessary to develop the yield required for United Western export and also to satisfy requirements downstream. This study showed that these requirements would be satisfied by storage in the amount of 9,050,000 acre-feet. Economic studies have indicated that this amount of storage probably can be provided most cheaply between elevation 600 for the export tunnel inlet and elevation 817 for normal water surface (Table 8). This corresponds to a height of dam about 813 feet above stream bed. Should subsequent investigation indicate the desirability of greater flow in the downstream channel, the firm yield of the reservoir could be augmented by

ncreasing net storage capacity, either through a higher dam or a lower inlet elevation for the export tunnel.

Conservation storage of 9,050,000 acre-feet would have resulted in satisfaction of all demands throughout the fifty years of record except in October 1935, when the export would have been deficient by 340,000 acre-feet. This is equal to an annual deficit of 5.6 percent and a monthly deficit of 60 percent. The deficit in monthly export does not imply a comparable shortage in meeting demands, inasmuch as October export would be very largely for November demands, which are light. The effect of the shortage could have been alleviated materially or eliminated entirely by runoff forecasts, tie-in with other river systems, and manipulation of terminal storage. Also, had Ah Pah Reservoir been operated so that annual shutdown would have been made in October instead of the following January, as probably would have been the case in actual practice, there would have been no shortage. It is concluded, therefore, that no shortage of consequence would have occurred during the entire period 1895-1945. The results of the reservoir operation study as well as other pertinent hydraulic properties of the dam and reservoir are shown by Table 8 and Plate 14.

Spillway design flood.—Ah Pah Reservoir has a flood contributing drainage area of 7,980 square miles. For conditions pertinent to this area, a spillway design flood inflow hydrograph was estimated. The hydrograph represents a total volume of 3,450,000 acre-feet with

a peak inflow of 884,000 cubic feet per second. The flood routing through the reservoir, with conservation storage full, was such as to retain 1,389,000 acre-feet of the total volume in surcharge storage and yield a maximum discharge of 400,000 cubic feet per second.

Power.—Power would be generated at Ah Pah Dam from that water which would flow into the lower river; water exported by the Trinity Tunnel would not pass through the turbines. No power storage beyond a few hundred acre-feet for the needs of daily peaking is contemplated.

Between the time the dam would be completed and full development of the water market, there would be a diminishing portion of the export yield available for power generation. After full development of the water market, only 228,000 acre-feet per year would be available. This would be utilized for "peak" generation and would be re-regulated by a small dam to "smooth out" the downstream flow. Dump power also would be generated at times of reservoir "spill." Should it be decided, on the basis of further investigation, that it is advisable to augment ultimate downstream releases, power production would, of course, be greater.

Sedimentation.—Sediment records do not exist for the Klamath River Basin. That portion of the drainage area above the Ah Pah Dam site which might contribute sediment has an area of 7,256 square miles. In general, it is heavily forested and probably would not contribute more than 0.2 acre-feet of sediment per square mile per

year. Inasmuch as the dead storage in the reservoir is 6,200,000 acre-feet, the reservoir would have a sediment life of several thousand years. The inlet of the tunnel from the reservoir to Sacramento Valley is on the Trinity River arm at the top of dead storage, elevation 600. The tunnel intake was located so that there would be a 25-foot differential between the invert of the tunnel inlet and the adjacent river bed elevation, thus ensuring no sediment deposition problem at the tunnel intake.

River pollution.—Stream pollution upstream from the reservoir is not anticipated; neither is it expected that conditions below the dam would be materially changed with respect to pollution or salt water intrusion.

Quality of water.—On the basis of existing uses and characteristics of drainage area, the quality of the water is judged to be excellent for any use.

Navigation.—The navigation of Klamath River above Ah Pah Dam site is not practical at the present time, and consequently construction of the dam has not been considered to cause navigation impairment.

American River Exchange

As indicated earlier, a part of the exchange water supply of the Northern California Diversion would consist of two diversions from tributaries of the American River in California. Numerous possibilities exist for the transfer of water from the west slope of the Sierra Nevada into the Lahontan Basin, by the type of exchange

here discussed. It may be possible to tap other streams and perhaps transfer much more water than the quantity here indicated. The plan presented is intended to serve as an example suggesting what might be accomplished. Additional possibilities will be investigated in the course of continuing investigation.

In the plan outlined below, one diversion would be at elevation 6400 from the Rubicon River into Lake Tahoe via a tunnel; the other at elevation 7700 from Caples Creek (an arm of the Silver Fork of the South Fork) into Lake Tahoe via a tunnel and the Upper Truckee River. No additional storage space would be required in Lake Tahoe.

Geological Survey runoff data for the export area under consideration are shown by Table 9. Computed runoff is shown by Plates 12 and 13.

Regulation.—For this typical plan, the average unregulated Rubicon diversion to Lake Tahoe would amount to 62,300 acre-feet per year while the diversion from the Caples Creek would be 37,300 acre-feet per year, or a total of 99,600 acre-feet. In order to translate the Rubicon diversions into a uniform continuous flow, approximately 155,000 acre-feet of storage would be required; for the Caples Creek diversions, approximately 75,000 acre-feet would be required; or total storage of 230,000 acre-feet. That capacity is contemplated at Meyers Reservoir on the Upper Truckee River near the town of Meyers. The above described Caples Creek diversion would enter the reservoir via Upper Truckee River and be regulated to uniform flow.

n addition, the reservoir would regulate the natural runoff from pper Truckee River which now enters Lake Tahoe without control. he natural drainage area above the dam site is approximately 50 square iles, and the runoff therefrom which may be controlled is in excess f that for the Rubicon diversions. By an exchange of storage with ake Tahoe, the reservoir would in effect control the diversions from he Rubicon.

The plan here suggested would have to be compatible with the nterests of lake front property owners. The control exerted by eyers Reservoir probably would improve the stability of the water urface elevation in the lake. However, should subsequent study ail to demonstrate conclusively that no disadvantage to lake shore roperty would ensue, the plan could be modified quite readily so as o by-pass Lake Tahoe entirely. Such modification would not be a ajor factor in the plan's feasibility.

olorado River Exchange

In view of the specific reference to the Colorado River Basin ncluded in House Resolution 244, 80th Congress, First Session, dopted by the House Committee on Public Lands (See Authority, page ive), the Investigation has examined the possibility of making dditional water available in that Basin. From an engineering stand-point, the most efficient method of providing such an additional supply ould be by the exchange of water from the Northwest for Colorado iver water now being used or planned for use in California areas.

r study purposes, such an exchange was assumed in the case of the tropolitan Water District of Southern California. It is recog- zed, of course, that the claims of that entity, dependent as they e upon an ultimate disposition of the Arizona-California contro- rsy in the Lower Colorado River, may be open to dispute, and that e outcome cannot be forecast with certainty.

A representative 1/ of the State of California has stated that lifornia asserts an entitlement to Colorado River water in an ount not less than 5,362,000 acre-feet per annum, and that if izona's views as to Arizona's entitlements were to prevail, Cali- rnia would receive 3,600,000 acre-feet. Under the California system priorities for Colorado River water, the Metropolitan Water strict's claims of about 1,212,000 acre-feet may be junior to 850,000 acre-feet of irrigation priorities. The ultimate entitle- nt of the Metropolitan Water District, as indicated by the regoing, may be as much as 1,212,000 acre-feet or as little as ro. As in the case of all such controversy, the outcome is known. However, unless some assumptions are made, engineering alysis cannot proceed. Accordingly, for the purpose of such alysis, various possibilities are assumed below and in succeeding apters. These assumptions are made without any attempt to analyze e legal problems involved and without intent to express or imply

1/ See testimony of Mr. Raymond Mathew, Chief Engineer, Colorado ver Board of California, at page 272 of printed hearings of Committee Interior and Insular Affairs, United States Senate, 81st Congress, t Session, on S. 75.

In addition, the reservoir would regulate the natural runoff from Upper Truckee River which now enters Lake Tahoe without control. The natural drainage area above the dam site is approximately 50 square miles, and the runoff therefrom which may be controlled is in excess of that for the Rubicon diversions. By an exchange of storage with Lake Tahoe, the reservoir would in effect control the diversions from the Rubicon.

The plan here suggested would have to be compatible with the interests of lake front property owners. The control exerted by Meyers Reservoir probably would improve the stability of the water surface elevation in the lake. However, should subsequent study fail to demonstrate conclusively that no disadvantage to lake shore property would ensue, the plan could be modified quite readily so as to by-pass Lake Tahoe entirely. Such modification would not be a major factor in the plan's feasibility.

Colorado River Exchange

In view of the specific reference to the Colorado River Basin included in House Resolution 244, 80th Congress, First Session, adopted by the House Committee on Public Lands (See Authority, page five), the Investigation has examined the possibility of making additional water available in that Basin. From an engineering standpoint, the most efficient method of providing such an additional supply would be by the exchange of water from the Northwest for Colorado River water now being used or planned for use in California areas.

'or study purposes, such an exchange was assumed in the case of the letropolitan Water District of Southern California. It is recog- ized, of course, that the claims of that entity, dependent as they .re upon an ultimate disposition of the Arizona-California contro- 'ersy in the Lower Colorado River, may be open to dispute, and that he outcome cannot be forecast with certainty.

A representative 1/ of the State of California has stated that alifornia asserts an entitlement to Colorado River water in an mount not less than 5,362,000 acre-feet per annum, and that if rizona's views as to Arizona's entitlements were to prevail, Cali- ornia would receive 3,600,000 acre-feet. Under the California system f priorities for Colorado River water, the Metropolitan Water istrict's claims of about 1,212,000 acre-feet may be junior to ,850,000 acre-feet of irrigation priorities. The ultimate entitle- ent of the Metropolitan Water District, as indicated by the :regoing, may be as much as 1,212,000 acre-feet or as little as ero. As in the case of all such controversy, the outcome is aknown. However, unless some assumptions are made, engineering aalysis cannot proceed. Accordingly, for the purpose of such aalysis, various possibilities are assumed below and in succeeding aapters. These assumptions are made without any attempt to analyze ae legal problems involved and without intent to express or imply

1/ See testimony of Mr. Raymond Mathew, Chief Engineer, Colorado iver Board of California, at page 272 of printed hearings of Committee a Interior and Insular Affairs, United States Senate, 81st Congress, st Session, on S. 75.

any opinion concerning the merits of any aspects of the controversy.

For purposes of analysis, the Northern California Diversion is assumed to deliver somewhat more than a million acre-feet to the general region of the Metropolitan Water District service area. This could be used through direct exchange to supply potential demands (Chapter 2) in the Colorado River Basin if the claims of southern California prevail; or in contrary event, import by the Northern California Diversion could be used in southern California as a direct supply. If the claims of southern California are sustained in part, part of the United Western import could be exchanged and part used as a direct supply.

Regardless of the outcome of the present controversy, the plan here discussed would permit the Colorado River Aqueduct to be placed on a stand-by status and its diversion from the Colorado River to be released, while insuring, at the same time, a full supply for all needs anticipated by that aqueduct in southern California.

The Colorado River Aqueduct would deliver 1,080,000 acre-feet per year from a Colorado River diversion of 1,212,000 acre-feet at Lake Havasu; losses en route evidently account for the difference. It has been verified by hydrologic studies 1/ that a release in the latter amount at Lake Havasu could be delivered elsewhere in the Colorado River Basin to offset deficiencies which would remain

1/ Made by Hydrology Division, Region 4, Bureau of Reclamation.

after full utilization of the remainder of the Colorado River flow.

In the following chapter the general subject of the Metropolitan Water District's diversion is discussed further, from the standpoint of demand for the supply provided by the Northern California Diversion.

Los Angeles Aqueduct Exchange

It is possible that the City of Los Angeles might be willing to release claim to water which it imports from the Owens River and Mono Basin, if it received an equal amount from United Western import. The Los Angeles Aqueduct sources so released could then be utilized on the Mojave Desert. For purposes of illustration, such an exchange is herein assumed.

The "Official Statement" of the Department of Water and Power, City of Los Angeles, dated November 15, 1950, indicates that the safe yield of the system is 440 cubic feet a second, which is equal to 318,560 acre-feet per year. Utilization of 300,000 acre-feet of this amount is discussed subsequently under Water Requirements. Impairment of power production through discontinuance of water supply to plants on the lower aqueduct is discussed under the Power Chapter of this Part of the report.

CHAPTER 2

Water Requirements

General

Two principal classes of water market would be served under the Northern California Diversion: Irrigation and municipal. The latter includes residential use and ordinary industrial use which is served by municipal systems. Both classes of demand exist in nearly all sections of the service area.

Characteristics of Water Markets

General.—Great precision in the data here presented has not been the objective. As in the case of other components of the over-all result, it is the intent that approximations should suffice. For most of the areas to be served by the Northern California Diversion, detailed data have existed and made possible substantial accuracy. In some cases, however, data have been meager and lesser precision has been considered acceptable.

The markets here indicated probably include only a part of the entire potential demand which ultimately will exist in the territory served by the Northern California Diversion. Whereas in the Northwest all lands were classified as susceptible to irrigation if any remote possibility of such practice existed, in the service area of the Northern California Diversion, only highly probable demands could be included in the potential market. An accurate estimate of

the extent and type of all the various demands which may develop can be made only after a detailed survey of the area. Studies made thus far serve to demonstrate that there is a probable potential market for at least the quantity of water which would be developed by the contemplated plan. The markets which are shown should be regarded as representative examples of larger demands which may exist. It will probably be shown by subsequent study that in some instances other demands than those indicated could be served more advantageously, or that service to other areas than those contemplated would be more beneficial. The plan of marketing here outlined is intended to be typical, and to afford a vehicle for the computation of benefits and costs.

The length of time which might be required for full development of individual water markets after service would become available thereto has been estimated as 25 years (Figure 3). The project would be completed in four 5-year steps over 20 years and water would first be available at the completion of the second step. The total development period would thus be 35 years from the date water first would become available, or 45 years from the start of construction. This is discussed in greater detail in Chapters 3 and 5.

Although the above estimate defines the probable length of time for market development after water would become available, no accurate estimate can be made as to when initiation of project construction would be warranted. In some sections demands for

imported water exist at the present time. In those areas and elsewhere, increasing needs can be foreseen. However, the future rate of increase is, to some extent, a matter of conjecture. As indicated elsewhere in this report, full investigation, design and construction of the project might require a period of decades, and demands could well increase more rapidly than they could be met by the facilities here discussed.

Table 14 shows characteristics of the irrigation market in detail, and Table 15 presents a summary of the total market. The general service area is shown by Plate 17; sections thereof are described below. Components of these sections are indicated by the description of project works contained in Chapter 3, Part II.

San Francisco Bay area.--The municipal demand of the San Francisco Bay area for the year 2000 is anticipated by the City of San Francisco and the East Bay Municipal Utility District in claims to about 672,500 acre-feet per year in the Sierra Nevada streams. It is assumed for this study that about 447,500 acre-feet per year of the demand could be met by exchanges with the Central Valley Project or otherwise, but that possibly 225,000 acre-feet would be served by the Northern California Diversion which probably would be a cheaper source than that now contemplated.

In addition to the foregoing municipal supply, about 208,000 acres would be irrigated each year.

Central Valley.--In the San Joaquin division of the Central Valley of California, the preliminary data now available indicate a potential annual irrigation demand by some $1\frac{1}{4}$ million acres of net irrigable area, in excess of the area to be served by the Central Valley Plan. This market includes irrigable area disclosed through studies made since evolution of the Central Valley Project Plan. It has been found that farmers tend to irrigate the irrigable area more intensively than expected, and also modern farming methods now enable the irrigation of land formerly considered to be non-irrigable.

The complexity of integrating the United Western supply with the manifold sources and intricate storage and distribution system of the Central Valley Plan makes it impossible to delineate a definite United Western service area. In fact, it is probable that no such area ever would be separable, because refinement of studies and changing conditions would make it advantageous from time to time to exchange or shift the supplies. It is considered, therefore, that on an average basis the area to be served by a United Western supply would have exactly the same characteristics as the area to be served by the Central Valley Project. Since the Sacramento Valley is fundamentally an area of surplus water, all demands therein would be served from local sources and the market for water imported by the Northern California Diversion would thus be in the San Joaquin Valley.

Pajaro-San Benito area.--No special considerations apply to the markets anticipated in the Pajaro-San Benito area (See Table 14).

Mojave Desert.--The plan of the Northern California Diversion suggests the possibility of service to about 81,000 acres each year in the Mojave Desert through release of the Owens River and Mono Basin diversions now exported to the City of Los Angeles. There would be numerous opportunities for utilization of the released water since it constitutes only about a tenth of the total potential need in the Mojave Desert area. Computations of this report are based on irrigation use in Antelope Valley as indicated in Table 14. It is emphasized that the entire plan for service in the Mojave Desert is tentative and that it is suggested in this report only as a typical possibility.

South-Central Coastal area.--No special considerations affect the South-Central Coastal area. See Table 14 and Chapter 3, Part II.

Service area of Metropolitan Water District.--As indicated in Chapter 1, Part II, the delivery of about 1,080,000 acre-feet per year is proposed by the Metropolitan Water District to serve municipal, industrial, and irrigation needs of southern California. For purposes of this report it is assumed that, if the District's claims to that quantity are established, the entire market for the corresponding United Western import would lie in the Colorado River Basin through the processes of exchange. If some part, or all of the claims fail to gain recognition, a proportionate part or all of the United Western market would lie in southern California. Moreover, it is possible that further study will disclose markets in the southern

California area, particularly for irrigation water, which are in excess of those comprehended by the full Metropolitan Water District supply. It is possible also that it would prove advantageous to dedicate United Western water to these wider markets in such volume that there would be insufficient United Western water for a full exchange with Metropolitan Water District. In such event, at least partial utilization of the Colorado River Aqueduct might continue, and release of Colorado River water would be something less than the full Metropolitan Water District diversion; or, it is possible that more water than the supply contemplated by the Northern California Diversion could be imported to southern California by one of the Supplements described in Part III of this report.

The foregoing questions require a great deal of detailed study for the development of accurate conclusions. At this time, however, estimates can be made for extremes of conditions which probably encompass the range within which future possibilities will fall. Thus, in order to provide a basis for estimating these extremes of costs and benefits, two marketing assumptions have been made as follows:

(1) United Western water to the extent of 1,080,000 acre-feet per year would be used in southern California to serve a direct and primary market; or

(2) United Western water to the extent of 1,080,000 acre-feet per year would release 1,212,000 acre-feet per

year of Colorado River water which would be marketed as indicated below.

Colorado River Basin Demands

The Bureau of Reclamation's 1946 report on the Colorado River Basin indicates that there is a potential demand in that Basin for 3,977,000 acre-feet per year in excess of needs which could be served by full development of the Basin's water resources. Since the date of that report, additional potential demands in the Upper Colorado River Basin have been disclosed in the amount of about 2 million acre-feet per year for the production of synthetic fuels and other use (Table 11). As indicated in Part I, various fuel production processes are currently under study. Some of these require much more water than others, and consequently, a precise estimate of future water requirements cannot be made at this time. It seems probable, however, that the ultimate deficiency indicated in the 1946 report would be increased to some 6 million acre-feet per year by subsequently disclosed potential demands. This is about five times the amount of the water which could be released to the Colorado River Basin by the Northern California Diversion.

It is not possible to determine at the present stage of this reconnaissance the use which might be made of any water released as suggested in the preceding section. Considerable study of this question will be necessary in the course of continuing investigation. It is assumed that the released water would be applied in general

atisfaction of the Colorado River Basin's over-all water require-ents.

evada market for American River Water

Water could be imported into Nevada from the headwaters of the merican River as indicated in the preceding chapter. The potential emand is many times greater than the contemplated importation of 6,000 acre-feet per year, and numerous possibilities for its utili-ation exist. The following plan is one of many which might be evolved.

A part of the foregoing import could be utilized to advantage n Pyramid Lake and in the entrance channel thereto, for the improve-ent of the environment of fish. The appropriate quantity and the enefits which might result should be determined in the course of rther study with the assistance of other agencies. In the meantime, provide a basis for evaluating at least minimum benefits, the antity of water which would ultimately be dedicated to this pur-se has been included with the contemplated delivery to the Newlands rigation District.

A part of the area in that District is unirrigated because insufficient water supply. For study purposes it was assumed at the Northern California Diversion would afford service each ar to about 17,500 acres in a section where major and minor works ready have been built.

Ten thousand acre-feet per year would serve municipal demands the Reno-Sparks area.

Characteristics of Demand

A flow diagram showing annual releases from the system appears on Plate 16.

Seasonal variation.—The aqueduct has been designed to carry water through most of its length at a uniform rate in order to transport the maximum quantity with the minimum size of carrier. Demand, on the other hand, will vary sharply with the season. Some seasonal variation occurs in the case of municipal and industrial demands, but such variation is not excessive and can be partially compensated by distribution reservoirs. However, the variation in irrigation demand from month to month is substantial. Furthermore, this variation will take different forms, depending on locality, type of crop, and other factors. On the basis of actual practice in areas adjacent or similar to those which would be served, monthly irrigation and municipal demands have been computed, and are shown on a percentage basis for each major service area in Table 12. In order to utilize the uniform flow of the aqueduct for these variable demands, it must be regulated by terminal storage as discussed later. Table 12 shows, in addition to variation in demand, the required amount of this storage per unit of aqueduct release.

Recovery of ground water.—In most of the areas where irrigation service is contemplated, a portion of the surface delivery would seep into the ground and increase the stock of ground water. Only a part of the surface delivery would actually be consumed by vegetation

and, although a part of the remainder would be "irrecoverably lost," most of it could be withdrawn by pumping at some future date and used on lands not served directly by the aqueduct. In this way, the quantity of water actually delivered in the combined surface and pumping system is greater than the total quantity released from the aqueduct, as shown in Table 14.

The amount of water which can be recovered by pumping depends on characteristics of the soil, topography, geology, and other factors. In some areas, no pumping at all would be practicable; in other areas, re-use of seepage losses would permit the irrigation of as much as 75 percent more land than would be possible by only surface deliveries. Pertinent factors have been evaluated for major subdivisions of the various service areas, and a determination made of the number of acres which could be irrigated, as well as the proportion thereof which would be pump-irrigated (Table 13).

Seepage and Evaporation Losses

Significant losses in the collection system probably would result from reservoir evaporation only. Losses in the conveyance system are summarized on Plate 16. Canal, lateral, and farm losses were computed as shown by Table 13. More detailed discussion of the computation of these losses follows.

Evaporation.--Evaporation losses from the surface of the main reservoir behind Ah Pah Dam were calculated at a rate of 2.6 feet per year as a part of the reservoir operation study. Evaporation

also has been estimated for all other reservoirs of the system and for the water surface in the main aqueduct. All evaporation except that for Ah Pah Reservoir has been calculated at a rate of 5 feet per year (Plate 2).

Seepage from terminal regulating reservoirs.--Seepage from reservoirs for terminal regulation of the main aqueduct's flow has been allowed in the amount of 50 percent of the evaporation computed for such reservoirs. Some part of any seepage loss probably would be recoverable, although no such recovery is evaluated herein.

Tunnels.--In the outlet tunnel from Ah Pah Reservoir to Sacramento Valley, and in all other tunnels, the tendency toward infiltration would be greater than for effluent leakage and no loss has been considered.

Sacramento River channel.--In the channel for the Sacramento River between the tunnel outlet and the delta, losses have been allowed in the amount of 25,000 acre-feet per year which would not be recovered. An additional seepage loss as great as 500,000 acre-feet per year might occur. This is considered to be recovered by drainage pumps. Costs for this recovery are included in the estimate.

Main aqueduct.--The main aqueduct would be concrete lined. Seepage through the lining probably would occur at a rate of about 0.08 of a cubic foot per square foot of wetted perimeter per day.

Leakage through gates, wasteways, etc., has been estimated in relation to the flow as follows:

Flow	Acre-feet per mile per year
500 second feet or more	50
100-500 " " " "	25
0-100 " " " "	0

For the section of the aqueduct in the San Joaquin Valley, most of the annual transit losses would appear as return flow in the San Joaquin River, or would act to reduce demands on other water sources. It is assumed that 35,000 acre-feet per year or 50 percent of the total loss could be recovered by repumping at the delta. For all other sections of the aqueduct, transit losses are considered irrecoverable.

Areas with no recovery of ground water.—In areas where no pumping is anticipated, the following irrecoverable losses have been allowed: Main canal - 5 percent of aqueduct system release; lateral loss and operating waste - 25 percent of main canal release; and percolation and farm waste - 30 percent of farm delivery. On the foregoing basis, the annual aqueduct release must be 1.4 times the farm delivery demand. Areas to which the above conditions are applicable are indicated in Table 13, together with data covering areas discussed below.

Areas permitting pump recovery.—In all areas where the recovery of ground water is possible—with the exception of San Joaquin Valley, Conejo Valley and Mojave Desert which are given special consideration below—35 percent of canal, lateral, and farm losses, computed as in the above paragraph are considered irrecoverable with 65 percent available for re-use by pumping. On this basis, net irrigation use would be 85 percent of the farm delivery demand which varies somewhat with the area served; about 61 percent of the area would be irrigated by a surface supply, and 39 percent by pumped recovery.

San Joaquin and Conejo Valleys.—For the San Joaquin and Conejo Valleys, canal, lateral, and farm losses would be the same as above, but 75 percent thereof is considered recoverable by pumping. Net irrigation use would be 2.59 and 1.60 feet, respectively, or 80 percent of farm delivery demand. Of the total area, 43 percent would be served by pump recovery.

Mojave Desert.—For Antelope Valley and the remainder of the service area in the Mojave Desert, canal, lateral, and farm losses would be the same as above, but only about 50 percent would be recoverable by pumping. Net irrigation use (3.71 feet) would be 104 percent of farm delivery demand (3.57 feet), and 26 percent of the area would be irrigated by pumps.

Terminal Regulating Reservoirs

As indicated earlier, inflow-outflow computations were made for each service area to determine the percentage of regulation

needed per unit of annual aqueduct release (Table 12). These factors, when multiplied by the total demand, indicate the total net storage required.

Losses due to evaporation and seepage were computed as indicated earlier. The terminal regulating reservoirs can be considered as part of the main aqueduct system and hence these are losses of the system. Releases from terminal storage are thus synonymous with "releases from the aqueduct" or "releases from the aqueduct system."

CHAPTER 3

Plan of Development

General Plan

The principal features of the Northern California Diversion are shown on Plates 15 and 18.

Main aqueduct system.—The primary water supply for the project would be developed by Ah Pah Reservoir, as described in Chapter 1. Diversion from the reservoir would be accomplished through the Trinity Tunnel, which would originate about four miles upstream from the village of Salyer and extend about sixty miles southeast to the Sacramento River Basin where it would discharge into the proposed Table Mountain Reservoir (Central Valley Project feature)* at approximately maximum water surface elevation. United Western water would be routed through an addition to the Table Mountain Power Plant with resultant power generation. An alternative to the latter possibility would be to route the United Western water by aqueduct to a location slightly beyond Table Mountain Dam site and drop it to the Sacramento River through an independent power plant. Releases from Table Mountain Reservoir would enter the proposed Iron Canyon Afterbay (Central Valley Project feature) where power benefits could be derived by an enlargement of the Iron Canyon Power Plant. An independent power plant might be employed at this site also, should this prove necessary or advantageous. Below

*In text and all drawings, the reference to "Central Valley Project" feature contemplates the ultimate Central Valley Basin development.

Iron Canyon, conveyance would be accomplished in the Sacramento River Channel to the Sacramento-San Joaquin Delta. Imported water reaching the delta would be lifted to the headworks of an aqueduct extending southward along the west side of the San Joaquin Valley. A location of the pumping plant near the city of Antioch has been tentatively adopted as a basis for cost estimates, but it is recognized that use of this pumping site would be contingent upon construction of a salt water barrier which has long been considered. Such a structure would prevent the intrusion of salt water which now penetrates upstream beyond Antioch. Should a salt water barrier not be constructed, the pumping plant would be relocated to a point further south near the town of Bethany, California, and a cross-delta channel constructed from the Sacramento River. Under this eventuality, additional construction costs would be incurred and are estimated to be equal to an increase of about 1 percent in the over-all project costs.

Four pumping plants would be required in the reach of the aqueduct in the San Joaquin Valley to deliver water to the vicinity of Buena Vista Lake, and thereafter two additional pumping plants would lift the canal flow to the inlet portal of a tunnel through the Tehachapi Mountains.

The Tehachapi Tunnel would extend southward some forty miles to daylight in the Santa Clara River 1/ system near Fillmore, California.

1/ Two different rivers discussed herein are named "Santa Clara." See Plate 15.

Thereafter, the aqueduct, consisting of canal sections and relatively short tunnels, would proceed southeasterly to the Santa Ana River about four miles west of Corona, and thence meander eastward to a pumping plant just south of Corona. Beyond the pump lift the aqueduct would extend to Lake Mathews and a smaller branch line would connect to the San Diego Aqueduct near the town of San Jacinto.

San Francisco Bay unit.--Under the plan here discussed, irrigation water markets to be served within the San Francisco Bay unit comprise 208,000 acres lying in the Napa, Sonoma, and Petaluma Valleys to the north of San Pablo Bay, and in the Santa Clara and Livermore Valleys to the south of San Francisco Bay. Separate branch aqueducts would be required to serve each sector. In addition to the foregoing service, 225,000 acre-feet each year of municipal and industrial water could be released immediately above the Antioch Pumping Plant for use in the San Francisco Bay area.

Service to the sector north of San Pablo Bay would be provided by pumping annually about 145,000 acre-feet from the Sacramento River near Rio Vista into a branch aqueduct which would extend westward through a second pump lift to connect with the potential Putah South Canal (Central Valley Project feature). A continuation from that canal would command 56,000 acres in Napa, Sonoma, and Petaluma Valleys. Aqueduct deliveries to such markets would vary in accordance with demands and it is assumed that about 71,000 acre-feet of regulatory storage, required to firm up these releases,

could be provided in existing or future Central Valley Project reservoirs. Typical costs therefor have been included in the estimate.

The branch aqueduct carrying the southern sector supply would originate at the headworks of the main aqueduct near Antioch Pumping Plant. From that point the line would skirt the foothills south of Suisun Bay to Port Chicago, and thence meander south to Ramon Valley. Near Shell Ridge a pumping plant would lift water approximately 220 feet for delivery into a side canal leading to the contemplated Alamo Reservoir north of Livermore Valley. Storage amounting to about 65,000 acre-feet could be provided in Alamo Reservoir to regulate 156,000 acre-feet annually for service to 60,000 acres in Livermore Valley.

From Shell Ridge the branch aqueduct would continue southwest to existing Lake Chabot (East Bay Municipal Utilities District feature) which reservoir could be enlarged to provide 104,200 acre-feet of additional storage for needed regulation. From Lake Chabot the conduit would loop around the south end of San Francisco Bay to the contemplated Redwood Reservoir located three miles west of Palo Alto, California. Approximately 16,600 acre-feet annually would be pumped 40 feet into storage in this reservoir. About 92,000 acres each year would be irrigated in Ramon and Santa Clara Valleys.

Central Valley.—As indicated earlier, there is a potential market in the San Joaquin division of Central Valley of some

$1\frac{1}{4}$ million acres each year. In addition, about a hundred thousand acre-feet per year of United Western water would be delivered to lands in the American River service area in exchange for a like amount of American River water which would be diverted, at a higher elevation, to the Lahontan Basin of Nevada. Neither the "exchange" area, nor the general service area for the Northern California Diversion can be accurately delineated at the present time. To provide a basis for estimating distribution and other costs in a realistic manner, all these lands have been assumed to have the same characteristics, on the average, as those included in the Central Valley Project plan. Estimates have been based on typical areas which, in combination, reflect these average conditions. Separate estimates have been made for a portion of the United Western service area (82,000 acres), which would lie in the foothills and thus have characteristics differing from those of Central Valley Project lands.

Under the typical plan of service outlined below, some 1,366,000 acre-feet would be pumped from the Sacramento River, at a point about 14 miles below Sacramento, to the head of a canal which would extend southward along the east side of San Joaquin Valley to serve about a half million acres of new land and replace the hundred thousand acre-feet of American River water. It has been estimated that an average pump lift of 100 feet would be required to command this area. The location of approximately 500,000 acre-feet of regulatory

storage required for this and other supplies is indeterminate prior to final definition of service areas. However, a typical cost of storage therefor has been estimated on the basis of average unit costs in the foothills of the Sierra Nevada.

In the vicinity of San Luis Reservoir (Central Valley Project feature), on the west side of San Joaquin Valley, 850,000 acre-feet would be released from the main aqueduct. With pump recovery of ground water, this release would provide an annual irrigation supply for 328,000 acres. Water would be pumped to San Luis Reservoir in sufficient amount to accomplish regulation of this supply. The incremental cost of enlarging this reservoir for the above and subsequently indicated purposes is incorporated in the project estimate.

In the vicinity of Avenal Gap, 847,000 acre-feet would be released from the aqueduct and, with pump recovery of ground water, would provide an annual irrigation supply for about 327,000 acres. Storage regulation for this water also would be provided in San Luis Reservoir into which the necessary portion of the supply would be pumped. Some enlargement of the main aqueduct between the San Luis Reservoir and the Avenal Gap release points would be required to accommodate peak irrigation demands met by San Luis Reservoir storage.

Near Avenal Gap, 212,000 acre-feet could be pumped to a canal which would provide an irrigation supply to some 82,000 acres of foothill lands. Regulatory storage and aqueduct capacity for

this supply would be obtained in the same manner as indicated above.

Pajaro-San Benito unit.—The area served under the Pajaro-San Benito segment of the plan lies in the Upper Santa Clara, San Benito, and Pajaro Valleys located east of Monterey Bay. A release of 143,000 acre-feet per year would be made from the aqueduct at the same pumping plant which would deliver to San Luis Reservoir. However, this portion of the pumpage would by-pass the reservoir and be delivered by means of canal sections and a tunnel to the potential Pacheco Reservoir on Pacheco Creek. Here, regulation would be provided for the full annual irrigation demands of 44,500 acres of new land. No re-use of ground water is contemplated.

Lahontan Basin unit.—Earlier (Chapter 1) an exchange has been suggested which would permit the transfer of American River water to Nevada. Service to Nevada probably could be effected in various ways. For this analysis the following plan is considered:

Runoff from Rock Bound Lake and the Rubicon River at a point approximately seven miles west of Rubicon Point on Lake Tahoe would supply an estimated 62,300 acre-feet annually (Chapter 1). Small diversion structures at the outlet of Rock Bound Lake and on the Rubicon River would be constructed and a 4.7-mile tunnel would lead from the Rubicon River to Lake Tahoe.

Seasonal runoff from Caples Creek, another tributary of the American River, would be diverted by a small diversion dam and

through a 3.8-mile tunnel to the Upper Truckee River.. The point of diversion would be approximately 16 miles south of Lake Tahoe. Approximately 37,300 acre-feet of yield annually would be developed here.

Regulation of these flows would be afforded by the contemplated Meyers Reservoir located on the Upper Truckee River approximately four miles from its outlet into Lake Tahoe (Chapter 1).

The new supply of water reaching Lake Tahoe would be released therefrom through Washoe Aqueduct which originates at the northeast extremity of the Lake and extends through Washoe Valley to Meadow Valley; thence the flow would return, via Galena Creek to the (lower) Truckee River near Reno. Washoe and Steamboat Power Plants would utilize a hydrostatic head of some 1600 feet in the drop between the surface of the lake and Galena Creek.

Of the 96,000 acre-feet of new water annually arriving at the mouth of Galena Creek, 10,000 acre-feet would be utilized in the Reno-Sparks area for municipal and industrial purposes and the remaining 86,000 acre-feet would be diverted downstream into the existing Truckee-Carson Canal, leading to Lahontan Reservoir. This water could thereafter serve lands of the Newlands Project through existing distribution systems now unused because of insufficient water. Rehabilitation of distribution facilities probably would be required.

Mojave Desert unit.—In the preceding chapter, a possible exchange was suggested between the City of Los Angeles supply

originating in Owens River and Mono Lake, and an equivalent amount of water from the Northern California Diversion. This could release some 300,000 acre-feet for use on the Mojave Desert.

Service to lands in Antelope Valley could be effected by utilizing the Los Angeles Aqueduct system for collection and conveyance, existing Fairmont Reservoir for regulatory storage, and new facilities for conveyance and distribution below Fairmont Reservoir. With ground water recovery, a full supply could be made available to 81,000 acres each year.

South-Central Coastal unit.—The areas served in the South-Central Coastal unit comprise numerous small non-contiguous bodies of land in the Lower Santa Clara River Valley and adjacent coastal valleys, and in the Valleys of the Santa Ynez and Santa Maria Rivers to the north. Each year a total of about 48,000 acres in the Santa Ynez Valley and 28,000 acres in the Santa Maria Valley would be served a supply of about 197,000 acre-feet by releases from the aqueduct and ground water recovery. In Ventura and Los Angeles Counties about 56,000 acres each year would receive a supply of about 112,000 acre-feet in a like manner. In addition, 51,000 acre-feet would be delivered each year in the Santa Clara Valley for municipal and industrial use.

The Santa Ynez and Santa Maria areas would be served by an aqueduct approximately 223 miles long originating in Sespe Creek at the outlet of the Tehachapi Tunnel. This aqueduct would meander generally westward along and through the coastal foothills to a

point near Galeta, thence via a 13.8-mile tunnel piercing the Santa Ynez Mountains to the Santa Ynez Valley. Regulatory storage amounting to 20,400 acre-feet would be afforded by the potential Zaca Reservoir north of Santa Ynez which could be supplied by gravity releases from the aqueduct. The aqueduct would pass north of Lompoc to enter the Santa Maria Valley near Orcut. Regulatory storage of 11,800 acre-feet needed for this area would be provided in Berros Reservoir. The foregoing plan for service to the Santa Maria and Santa Ynez Valleys represents the most conservative concept of cost. In actual practice an exchange probably would be worked out whereby United Western water would serve the Cachuma Project, and the waters originating in Santa Maria and Santa Ynez Valleys would largely be retained therein for local use. Such a plan would be more favorable than the one indicated above.

Service to other areas in Ventura County involves a somewhat complicated distribution system. Three branch canals and one pumping plant would be required to serve prospective irrigation markets. Fagan and Brea Reservoirs together would provide approximately 19,000 acre-feet of storage for full regulation of releases in this area.

Southern California unit.—In addition to the service described in preceding paragraphs, the analysis suggests that the Northern California Diversion would deliver 1,400,000 acre-feet per year to the Los Angeles area. As indicated in Chapter 2, disposition of this

supply is presented under two extremes of future possibilities. One, considered as the basic hypothesis, assumes the exchange of 1,080,000 acre-feet per year of United Western import for the full Colorado River diversion proposed by Metropolitan Water District, the exchange of 300,000 acre-feet per year of United Western water with the City of Los Angeles to permit Mojave Desert service, and the direct service in southern California of 20,000 acre-feet per year of supplemental water. The other, considered as an alternative hypothesis, assumes direct service of the United Western import of 1,080,000 acre-feet per year to southern California markets, with the Mojave Desert irrigation and supplemental water service as in the basic hypothesis. These assumptions are made to afford the means of computing extremes of benefit-cost ratio between which the economic characteristics of a project might be expected to lie under those future conditions which would actually develop. The basic hypothesis yields the lowest and most conservative benefit-cost ratio and all statements in this report are predicated thereon unless specifically qualified as pertaining to the alternative hypothesis.

Basic hypothesis.—For the basic hypothesis, strategic points at which the project could effect replacement of the other supplies and deliver supplemental water have been determined and service thereto has been planned accordingly.

Contemplated points of release are San Fernando, Burbank, Santa Anita Canyon, San Gabriel Canyon, Santa Ana River, Lake Mathews,

and the San Diego Aqueduct. The plan has included all cost of pumping, regulation, and conveyance; it is intended to be typical and provide a basis for computing the cost of the replacement.

As indicated in Chapter 2, there is a potential demand in the Colorado River Basin for several times the quantity of water which would be released in that River under the basic hypothesis. However, the most appropriate use for the released water cannot be determined without more detailed study. For the purposes of analysis, therefore, the released water is considered to be made available in Lake Havasu and beyond that point no cost has been included in the estimates. No credit has been included in benefits for the released water.

For the water released in the Mojave Desert, all costs of conveyance and distribution to the farm head gate have been included. Appropriate cost for delivery of the 20,000 acre-feet per year of supplemental water also has been included.

Alternative hypothesis.—Under the alternative hypothesis, full diversion by the Colorado River Aqueduct would become impossible due to the outcome of the Arizona-California controversy. Benefits attributable to the Northern California Diversion then would result in southern California from utilization of all or part of the 1,080,000 acre-feet per year that the Colorado River Aqueduct proposes to deliver, and it would be incumbent upon the United Western project to provide distribution, conveyance, and regulating facilities for service of a corresponding part of this quantity. In order to illustrate the most extreme

condition, costs and benefits have been computed on the basis of use of the entire 1,080,000 acre-feet as a primary supply. Benefits are discussed fully in Chapter 5.

Estimates of the costs in excess of those applicable to the conditions of a simple exchange described above have been made in the manner herein indicated for other divisions of the Northern California Diversion. They include all additional costs of pumping, power, storage, conveyance, distribution to farm head gate or wholesale delivery point, and operation and maintenance (Table 29).

The Los Angeles Aqueduct exchange and the 20,000 acre-feet per year supplemental irrigation supply would be accomplished as described above for the basic hypothesis.

Discontinuance of Colorado River Aqueduct diversion.—Under either of the foregoing hypotheses, diversion by the Colorado River Aqueduct could be discontinued. It has been assumed that discontinuance would be gradual, over a period of 25 years during which time a need in the Colorado River Basin would develop for the released water.

The Aqueduct would remain useful as a stand-by unit in the water supply system of southern California. It might be operated at rare intervals in case of emergency, on which occasions it would be obligatory to recognize any impairment to the rights of others in the diverted water.

It is assumed that the Aqueduct could be maintained on a stand-by basis for about half the cost of normal operation and maintenance exclusive of power. Therefore, half the normal operation and maintenance has been credited as a benefit to the Northern California Diversion. No benefit has been included for the "stand-by" service of the aqueduct.

Project Works

Ah Pah Dam.--Ah Pah Dam would be constructed on the Klamath River approximately 13 miles from its mouth. It would be a concrete gravity structure about 813 feet high and would create a reservoir above the elevation of the Trinity Tunnel inlet with a net capacity of 9,050,000 acre-feet for conservation (Table 8).

Maximum water surface of Ah Pah Reservoir would extend up the Klamath River approximately four miles above the town of Cottage Grove and up the Trinity River to approximately Burnt Ranch. The reservoir area would lie within the Klamath and Trinity National Forests. Only relatively minor improvements now exist in this area. The cost of lands and relocation of improvements has been included in the project estimate.

Geological conditions existing at the dam site have been appraised by preliminary examination. The site is in dense meta-sandstone formation, and probably contains minor faults. Excavation for dam foundation has been estimated to vary from 20 feet to a maximum of 40 feet in the river channel.

Preliminary design contemplates that two side-channel spillways having a total capacity of 400,000 cubic feet per second would flank the dam and empty into tunnels discharging downstream from the powerhouse. Saddles have been noted which perhaps would be more advantageously used as spillway sites, and this possibility will be explored further. Physical data are shown by Table 18.

Ah Pah Afterbay.—An afterbay would be located approximately two miles downstream from Ah Pah Dam and would serve to re-regulate the non-uniform power releases from Ah Pah Power Plant. This dam would be a concrete overflow structure approximately 15 feet high and would afford approximately 1500 acre-feet of regulatory storage.

Other dams.—Numerous other dams to provide diversion, terminal regulation or carryover storage are contemplated in connection with the Northern California Diversion, as indicated in Table 18. Explanatory remarks relative to these also are presented in various parts of the report. Analysis of these smaller dams affords a typical indication of the unit cost of storage in the area where such storage is needed. Subsequent study will undoubtedly disclose some sites which are superior to those here selected.

Sacramento River Channel.—The tunnel from Ah Pah Reservoir would daylight in the Sacramento Valley immediately upstream from Redding, and the Sacramento River Channel would be used for conveyance of the supply of the Northern California Diversion to the Sacramento-San Joaquin Delta. The river channel is already developed

to carry increments of flood flow much greater than the addition (9200 cubic feet per second) here contemplated. Since no export from Ah Pah Reservoir would be necessary during flood periods, flood conditions in the channel would not be aggravated by the addition of United Western water.

As a result of the introduction of the above amount of clear water, some minor degradation of the upper channel can be expected and, in time a change in the regimen of the river might occur. The location and extent of degradation and resulting aggradation cannot be predicted without extensive additional study, but it is probable that remedial measures would involve only routine dredging, with a nominal increment to present channel maintenance cost.

It is anticipated that the drainage problem in the valley would be aggravated somewhat by the increased flow. The degree of this aggravation cannot be evaluated accurately without further study. In this report it is arbitrarily assumed that an additional 15 million acre-feet-feet per year would have to be pumped for this purpose. The cost of this pumping is included in the estimate.

Potential power development along the river channel is discussed in Chapter 4 of this Part of the report.

Main aqueduct.—Under the plan here discussed, the main aqueduct extends from the Sacramento River Delta near Antioch to a connection with the San Diego Aqueduct at a point near San Jacinto, California. The general plan is shown on Plate 15 and the profile appears on Plate 18.

Total length of the main aqueduct from its origin near the Sacramento-San Joaquin Delta to the terminus at San Diego Aqueduct would be 545 miles. Of this length, 101 miles would be tunnel construction, 5 miles would be pressure conduits, and the remainder would consist of canals and canal structures.

The capacity of the aqueduct would diminish from a maximum of 7,000 cubic feet per second at the delta pumping plant to a minimum of 170 cubic feet per second at the point of discharge into the San Diego Aqueduct. Releases are shown diagrammatically on Plate 16.

The canal would be concrete lined throughout and concrete siphons would be utilized to cross river channels and depressions. Checks, wasteways, and drainage structures have been provided as required. Layout of the route was based upon Geological Survey quadrangle sheet topography. The slope is 0.00004 in canals and .0004 in tunnels. Additional head was provided at siphon crossings. Throughout most of its length the canal traverses level to rolling terrain. Some heavy construction would be encountered along the valley foothills, but in general topographic conditions are not adverse.

Land acquisition costs for the aqueduct would be appreciable. Approximately one-half of the length in San Joaquin Valley would pass through developed agricultural area. Less expense would be entailed in Ventura County where the area traversed would be generally

eveloped. In the vicinity of Los Angeles, tunnels have been lized throughout most of the distance to minimize right-of-way ts.

With the possible exception of the Tehachapi Tunnel portion, aqueduct location is well served by existing roads and access ing construction would be relatively easy.

Washoe Aqueduct.—The Washoe Aqueduct connecting Lake Tahoe h the Newlands Irrigation District has been described adequately a previous section of this Chapter and is also discussed in pter 4, "Power."

Major tunnels.—Longer tunnels in the main aqueduct and their gths are: Trinity, 59.8 miles; Tehachapi, 40.5 miles; Simi, 8.2 es; San Gabriel, 26.7 miles; and San Jose, 16 miles. Character- ics are shown by Table 17.

Trinity Tunnel: The Trinity Tunnel lies under heavy cover and most of its length would be constructed through four vertical shafts having heights of 1020, 1045, 1240, and 730 feet. Construction costs comprehend the additional cost of shaft construction, as well as that of the tramming and hoisting of excavation and materials. After construction, the shafts and equipment would be used for maintenance. Preliminary study has indicated that geological conditions would not be unusually adverse. Considerable ground water may be encountered during construction, and to provide for this eventuality, construction

costs have comprehended extensive drainage pumping. The tunnel bore would be a 37-foot horseshoe section, and would be concrete lined throughout. A control structure would be provided at the inlet. For approximately the first half of its length the tunnel would lie beneath the Trinity National Forest and most of the remaining length would underlie publicly owned land.

Tehachapi Tunnel: The Tehachapi Tunnel would originate at a point 23 miles south of Bakersfield and extend southward 40.5 miles through the Tehachapi Mountains to emerge in Sespe Creek, a tributary to the Santa Clara River of southern California, near Fillmore. Construction of the tunnel would involve four vertical shafts having heights of 1700, 4540, 3560, and 1880 feet. A 22-foot concrete lined horseshoe section would be employed. In a portion of the length, adverse geological conditions are anticipated and in the cost estimates the contingency factor has been increased to 37½ percent on the entire tunnel to cover unforeseen construction difficulties. Seven known faults would be crossed, and possibly others would be encountered. Six of the known faults would not pose unusual construction problems. The other is the famous San Andreas fault which would present a broken zone at least two miles wide. Extra heavy supports would be required throughout this zone. Most of the tunnel length would underlie the Los Padres

National Forest and right-of-way costs would be nominal.

Simi Tunnel: The Simi Tunnel, 8.2 miles long, would extend eastward from Simi Valley through the Simi Hills to daylight in San Fernando Valley near Canoga Park. Neither right-of-way nor geologic problems are believed to be unusual. No vertical shafts would be required.

San Gabriel Tunnels: The San Gabriel Tunnels extend 26.7 miles along the southern slope of the San Gabriel Mountains, passing in foothill country north of the highly developed Los Angeles area. In this length the tunnel would surface in Verdugo Wash, Santa Anita Canyon, and San Gabriel Canyon, and headings would exist at these points. Foothills in this area are mantled with valley fill consisting of sand, silt, and gravel, and considerable ground water would be encountered in the driving of tunnel lengths under light cover. At greater depths granitic rock would occur and contain one known fault of significance. Allowances to cover these conditions and also for appreciable right-of-way costs have been made in the estimate.

San Jose Tunnel: This tunnel would extend from San Gabriel Canyon eastward to Big Dalton Canyon, then southward through the San Jose Mountains to approximately four miles south of Pomona. The material penetrated would be chiefly

marine sediments. Most of the length would underlie urban or highly developed areas and appreciable right-of-way costs have been allowed.

Drainage.—Provision for surface and subsurface drainage facilities would be made to assure permanent and economic production from the project lands.

On-farm surface and subsurface drainage would be provided by the individual water users. The requirements would vary widely in cost, depending on the extent of facilities required to control the water table. An allowance for these expenses has been included in the general costs of farm operation in the computations of irrigation benefits.

As with on-farm drainage, the requirements for project construction of interceptor and outlet systems would vary widely over the project area. Some areas would require extensive facilities to dispose of storm water, irrigation waste water and excess subsurface water. However, many areas where ground water would be utilized for irrigation by pumping would not require significant expenses for drainage works, and some other limited areas would have natural drainage outlets.

A detailed appraisal of the drainage characteristics of project lands is beyond the scope of this reconnaissance investigation. However, a cost for the estimated average requirements for project drainage features has been included in the estimate. Operation and maintenance expenses also are included.

Irrigation distribution systems.--Irrigation distribution systems would be provided to accomplish delivery to the farm head gate in the various market areas anticipated. In the San Francisco Bay, Pajaro-San Benito, West San Joaquin foothills, South-Central Coastal Basin, and Mojave Desert areas, a map location of principal conduits was made so as to command prospective irrigable lands. In the Central Valley floor where lands to be served can be located only in a general manner, a hypothetical distribution system was employed for the development of conveyance and pumping costs. Lateral distribution and drainage systems would be provided for all new lands served. Concrete lining of all canals and laterals is contemplated. Where advantageous, concrete pipe distribution systems would be used, and in limited areas of rough terrain, sprinkler irrigation systems are contemplated. New irrigation water supplied the Lahontan Basin would utilize existing distribution facilities now unused because of insufficient water supply. Rehabilitation of these works is contemplated under the project development.

Canals and laterals would be provided for areas to be served by ground water recovery, as well as those to receive a surface supply direct from the aqueduct. The cost of these works has been included in the estimate.

Power transmission systems.--Facilities for the transmission of energy generated by the project power plants to irrigation pumping plants and to power market areas would be provided. No layout has

been made of the lines, and cost estimates have been based upon unit costs per kilowatt of installed capacity for similar installations.

Pumping plants.—The locations of pumping plants are shown symbolically on Plate 15, and pertinent data on such plants appear in Table 19. For convenience, pumping plants have been grouped into three classes: Those required for conveyance of the water in the main aqueduct; those required for servicing branch conduits and pumping into terminal reservoirs; and those for recovery of ground water.

Main aqueduct: Nine pumping plants would be required to convey water from the Sacramento River Delta to the ultimate delivery point at the connection with the San Diego Aqueduct. These plants are designated: Antioch, Byron, Volta, Avenal, Buena Vista, Tehachapi, Sulphur, Lake Mathews, and Riverside. Locations and characteristics appear in Table 19.

Auxiliary pumping plants: Fifteen pumping plants would be required to deliver water to market areas through branch conduits from the main aqueduct or to pump into terminal reservoirs. Locations and characteristics are shown in Table 19.

Pumps to recover ground water: A substantial part of the irrigated area encompassed by the Northern California Diversion would be served by the recovery of ground water. It cannot

be anticipated what portion of this recovery would be accomplished in practice by individual farm pumps and what portion might be pumped by project pumps. In either case, the net result would be the same insofar as water utilization is concerned, and for the purposes of estimating costs, it has been assumed that pumps would be installed and operated by the project.

Schedule of Project Development

The project construction schedule appears on Plate 19, which shows the order of the various steps, annual expenditures for construction, annual operating costs, and water export.

This schedule contemplates construction at a rate not exceeding that of water demand and at a rate calculated to effect greatest economies in investment costs. After the completion of each facility for the delivery of water, it has been assumed that each market would develop at a uniform rate from zero to 100 percent in a period of 25 years. Following complete development of each market area, service would continue undiminished throughout the period of analysis.

Construction of the project has been assumed to occur in four distinct steps, each of which bring into service increments of the market. The first step of the development occupies the first five years. During that period Ah Pah Dam and Power Plant would be completed and the Trinity Tunnel about half completed.

Step 2 would occupy the interval between year 5 and the end of year 10. During Step 2, the Trinity Tunnel would be completed and features constructed for the initiation of service to market areas in Central Valley, San Francisco Bay area, Pajaro-San Benito area and Lahontan Basin. Approximately 1½ million acres would be comprehended in these market areas, corresponding to a farm delivery of approximately 4½ million acre-feet under conditions of full development. Included also would be 235,000 acre-feet of municipal and industrial supply.

The third step would occupy the five-year period after year 10, and during this interval, conveyance and distribution facilities would be completed for the initiation of service to the South-Central Coastal area. This would provide for the final annual delivery of 308,000 acre-feet of irrigation water to approximately 132,000 acres, and the delivery of 51,000 acre-feet of municipal and industrial water.

The fourth step occurring in the five years after year 15 would permit completion of all main project features. Features constructed during that step would permit irrigation service to Antelope Valley in the Mojave Desert unit, the release of 20,000 acre-feet per year for supplemental irrigation, replacement of 300,000 acre-feet per year now supplied by the Los Angeles Aqueduct, and replacement of 1,080,000 acre-feet proposed for delivery from the Colorado River by the Metropolitan Water District.

Cost Estimates

The estimated construction costs of all features of the Northern California Diversion appear on Table 21. Simple addition of the estimated construction costs of the project totals about three and a third billion dollars. Annual costs of operation and maintenance and of replacement reserve are shown on Tables 22 and 23, respectively. Estimated costs are based upon price levels as of June 1, 1950. Costs have also been prepared on the basis of average prices prevailing during the period 1939-44, corresponding to the period employed for benefit analysis. However, all costs presented in this report relate to the June 1, 1950, level unless otherwise qualified.

Estimates include a minimum of 25 percent allowance for contingencies, and 15 percent allowance for engineering and overhead. Annual costs include operation and maintenance, replacement reserve, and amortization of construction costs over 100 years at $2\frac{1}{2}$ percent interest (Plate 19). No salvage has been considered. As indicated later, the project hydroelectric power generation early in the life of the project would be such as to build up a monetary surplus which would more than offset the value of the power deficit in the later years of project operation.

Project Evaluation

Construction costs would be incurred chiefly in the four distinct steps indicated above, with minor additional costs for pumping plant enlargements during the succeeding 25-year market development periods.

For the purpose of analysis, it has been assumed that the project would continue in operation from the inception of service of initially constructed features until 100 years after completion of the last or fourth construction step. Thus, it will be observed that those features constructed during Steps 1, 2, and 3 would continue in operation 115, 110, and 105 years, respectively. All costs during the entire 120-year period of project construction and operation have been discounted to capitalized value at 2½ percent as of the beginning of construction, and this value expressed as an annual equivalent by amortization at 2½ percent interest over a period of 100 years beyond the start of construction. Project costs are summarized in Table 29. A further discussion of the computation of cost on the basis of project year zero appears in Chapter 5.

The total of all project costs amortized over a 100-year period at 2½ percent interest, on the foregoing basis, is equivalent to $89,000,000 annually.

PART II

CHAPTER 4

Power

General

If the Northern California Diversion were to be placed in operation, an influence would be exerted on the then existent hydroelectric stations of certain other projects by reason of changed conditions of water supply. These influences would be both beneficial and detrimental. The beneficial results can be estimated with reasonable certainty, but the detriments depend upon the number of hydroelectric potentialities which would have been developed between the present and the time the Northern California Diversion might be constructed. On the assumption that detrimental influence would be confined to present projects and those now authorized, the Northern California Diversion would generate sufficient power in the early years of operation to offset, on a financial basis, the energy deficit in the later years of operation (Plate 21). The net monetary balance between the energy produced as a result of the Northern California Diversion during its assumed life, and the energy required by that project during the same period for its own operation, and to offset the foregoing degree of interference, would be such as to yield a surplus equivalent to $4,180,000 per year. Under the most unfavorable conditions of interference with all other projects which it would be physically possible to develop between now and the time of the

Northern California Diversion, the net monetary deficit would be equivalent to $12,950,000 per year.

Costs and benefits applicable to power features are presented in this Chapter to afford an indication of their relative financial magnitude. However, all such values have been comprehended in the over-all project estimate previously discussed and in over-all project benefits subsequently discussed.

For the analysis here discussed, the principal objectives of the power studies were the determination of the quantities and values of energy in the following categories:

(a) Pumping: The energy required for lifting water in the main aqueduct, to branches and terminal reservoirs, and to points of use. The latter category includes ground water recovery. Also included is the energy required for pumping Sacramento River seepage back into the channel and the energy required for land drainage pumps.

(b) Generation: The energy made available at hydroelectric generating stations constructed as a part of the Northern California Diversion and at other existing and proposed hydroelectric generating stations which receive additional water made available by the United Western project; and the amount of energy in addition to the foregoing which ultimately would have to be produced at thermal plants to sustain project requirements.

(c) Impairments: The energy losses as a result of the diversion of United Western water from other hydroelectric generating stations; and the possible inundation of certain proposed stations as a result of the Northern California Diversion.

(d) Other: The energy gained as a result of eliminating the necessity for the pumping of water in the Colorado River Aqueduct under the assumptions of this analysis.

Further objectives were the determination of the scope and costs of structures and equipment required for pumping and generation, and the possible reduced costs resulting from the elimination of generating and pumping equipment, rendered unnecessary as the result of United Western water diversion or import. The matter of cost reductions is discussed in connection with "Impairments," in subsequent paragraphs.

Pumping Requirements

The studies of pumping energy requirements were concerned with twenty-four individual pumping stations, as well as with certain general pumping requirements. Some of the individual plants would be located on the main aqueduct, and others utilized for the purpose of lifting water into regulatory reservoirs where it could be released in accordance with the pattern of demands.

It is estimated that the export of water from the Ah Pah Reservoir would start ten years after initiation of construction of

the Northern California Diversion and that the full water market contemplated would not be completely developed until year 45. The pumping installations contemplated have therefore been designed in accordance with the requirements imposed by the increasing demand for water over this 35-year period. The following tabulation lists the names of the individual pumping plants, the termini to which their discharge is lifted, energy required, and other physical data.

Pumping Stations

Name	Point of delivery	Dynamic head (ft)	Installed capacity (kw)	Ultimate average annual power demand (kw)
ioch	Aqueduct	104	91,000	65,500
on	"	80	63,000	44,000
ta	"	158	119,000	66,600
nal Gap	"	151	72,000	41,700
na Vista	"	80	27,000	19,100
achapi	"	226	84,000	55,600
phur Canyon	"	245	72,000	50,400
e Mathews	Regulatory storage	681	100,000	36,200
erside	Use area	251	7,800	3,860
Vista	Branch	56	4,500	1,080
den	Use area	78	6,000	1,550
t Chicago	Branch	131	10,200	7,100
ll Ridge	"	226	6,300	4,350
e Ridge	"	144	11,400	7,860
wood	Regulatory storage	39	275	90
Luis	Regulatory storage	197	78,000	20,700
tleman	Branch	93	9,000	2,710
tooth	Use area	294	30,000	8,580
ramento #1	Branch	25	6,900	4,740
ramento #2	"	76	21,000	14,200
i	Use area	253	300	105
Antonio	Branch	161	240	93
a	Use area	171	2,100	765
Fernando	Regulatory storage	317	10,800	5,100
und water mping	Use areas		40,000	15,600
ramento River epage	Sacramento River	30	---	2,930
	Totals		873,000	481,000

It will be noted that in addition to the twenty-four individual pumping plants listed in the above tabulation there is a twenty-fifth item covering the pumping of ground water. The energy evaluation in this instance applies to pumping plants which would be utilized in recovering United Western water which has percolated into ground water reservoirs after application to irrigated lands, and also in small part for pumping in sprinkler irrigation. The energy allowance thus made is assumed adequate to include farm drainage pumping since most of the water so pumped could be re-used.

The last item in the preceding tabulation further contemplates the removal of approximately 500,000 acre-feet annually of seepage from behind Sacramento River levees.

The 481,000 kilowatt ultimate average annual power input to all pump stations would be used at an over-all pump-system annual load factor of approximately 75 percent.

Generation

General.—The following three generating plants would be constructed as an integral part of the project under discussion:

Potential United Western hydroelectric generating stations

Name	Stream	Rated head-ft.	Installed capacity-kw
Ah Pah	Klamath	660	540,000
Washoe	Lake Tahoe Diversion	975	18,600
Steamboat	Lake Tahoe Diversion	574	11,000

In addition to the above plants, there is a possibility for the development of at least two generating stations on canal drops. Inasmuch as these features would be of relatively minor importance they have been ignored in this report.

In the plan under discussion, the output of the following hydroelectric generating stations, not a part of the Northern California Diversion, would be augmented as a result of an increase in the water made available to them by United Western diversions:

Potential independent hydroelectric generating stations

Name	River	Rated head-ft.	Installed capacity-kw Before UW diversion	After UW diversion
Table Mountain	Sacramento	152	200,000	415,000
Iron Canyon	Sacramento	42	45,000	100,000

Ah Pah Generating Station.—The Ah Pah Generating Station would be the largest hydroelectric plant constructed as a part of the Northern California Diversion. In accordance with the adopted schedule of project development, this generating station would be placed in service in year 5, utilizing the complete water yield made available by Ah Pah storage. After the end of year 10, which would mark completion of the diversion tunnel to the Sacramento River and the start of diversions for irrigation purposes, the yield available for power production at Ah Pah Dam would gradually decrease until

the end of year 45 when the water available for power would be limited to that required for downstream releases. This results from the fact that the exported water diverted to the Sacramento River would not pass through the power turbines at Ah Pah Dam. The average annual power draft available initially at Ah Pah Dam, if initiation of that station happened to coincide with a recurrence of the 10-year critically dry period between 1928 and 1938, would total 8700 cubic feet per second and would yield a resultant average power output of 413,000 kilowatts. Assuming recurrence of the same critical period with the maximum export in effect after project year 45, the power draft would average 316 cubic feet per second and the power output 15,000 kilowatts. Plates 22 an[illegible]how reservoir water surface elevations, power draft, and power output for the 1920-1945 adopted period of record for initial and ultimate conditions, respectively.

The power installation at Ah Pah Generating Station would consist of six units rated at 90,000 kilowatts each. The turbines would be designed to permit average power output during the aforementioned critical power period to be produced at the minimum head resulting during maximum reservoir drawdown. Gross head at this plant would vary between 777 feet and 560 feet.

Under initial conditions, with all of the storage yield (6,094,000 acre-feet per year) discharged through the turbines, the generating station would operate at 76.5 percent plant factor.

Under ultimate conditions one of the generating units, operated at 16.7 percent plant factor, would be adequate to utilize the water available for firm power production, and the other five units might be removed from service. However, transmission lines into the power plant necessarily would be designed for the initial installation and it is possible that the five units not required after year 45 for power generation could be retained in service. These units could serve for emergency stand-by particularly during periods of system peak load. Further, in the event of major interconnection between the Northwest and California transmission systems, these units might serve as a source of system power factor correction and stability.

As indicated earlier, the foregoing values for ultimate releases from Ah Pah Dam are tentative. Subsequent study may disclose the desirability of increasing the releases to satisfy other purposes downstream.

Washoe and Steamboat Power Plants.—In the plan under discussion, Washoe Power Plant would operate on an average discharge of 133 cubic feet per second. This water would be dropped through a net head of 974 feet to develop approximately 9300 kilowatts average power output. The generating station would consist of two 9300-kilowatt generating units which would permit operation at 50 percent weekly plant factor. From Washoe tailwater the power draft would be conducted to the Steamboat Plant. This generating station would consist of two, 5500-kilowatt generating units operated under a net head of 574 feet to develop

approximately 5500 kilowatts total average power output at 50 percent weekly plant factor.

Independent generating plants benefited.—In the plan under analysis, the authorized Table Mountain and Iron Canyon power developments on the Sacramento River would ultimately receive 6,094,000 acre-feet of additional water annually via the diversion tunnel from Ah Pah Reservoir. It is assumed herein that Table Mountain Dam would be constructed to provide conservation storage to the presently proposed elevation of 494. Should future studies indicate the desirability of constructing this dam to a lesser height, it would be possible to convey the Ah Pah Tunnel outflow in a canal to an independent power plant which would discharge into Iron Canyon Reservoir. The latter plan would eliminate the loss of head which would result from the drawdown of Table Mountain storage but would entail an additional expenditure for construction of the power canal.

The costs of this alternative canal and generating plant have not been investigated fully, and computations are based on the assumptions that United Western water would be dropped through the presently proposed Table Mountain Power Plant and the power development at Iron Canyon Dam. The latter provides for re-regulation of Table Mountain water releases. Rated heads at these plants are 152 feet and 42 feet, respectively.

There would be an increase of water at these two generating stations during United Western project years 10 through 45 which

would parallel the decrease in water available at the Ah Pah Generating Station. Under the ultimate stage of export from Ah Pah Reservoir, the increase in prime power output of Table Mountain and Iron Canyon Generating Stations would average 92,600 kilowatts and 25,600 kilowatts, respectively. The contemplated power plant expansion at these two dams, based upon the 43 percent and 47 percent plant factors presently proposed for their design as a part of the Central Valley Project, would increase their total installed capacities by 215,000 kilowatts and 55,000 kilowatts, respectively.

Power Impairment

General.--Energy losses resulting from the diversion of United Western water from existing and potential hydroelectric generating stations and from inundating any such plants were computed for two hypotheses, designated Case 1 and Case 2. The Case 1 evaluation included those hydroelectric plants now existing and now authorized. The Case 2 impairment evaluation included in addition to Case 1 generating stations, all potential hydroelectric plants which it would ever be physically feasible to develop.

Although all Case 1 plants might be in operation at the time construction of the Northern California Diversion was initiated, it is impossible to estimate the extent to which the potential hydroelectric projects might be developed by that time. Many of the developments included in Case 2 are without economic justification at the present time. Also, if detailed investigation confirms the over-all

advantages here suggested for the Northern California Diversion, its ultimate construction could be foreseen, and in consequence most of the Case 2 projects would never be undertaken. It is considered unlikely, therefore, that any great number of the potential projects would have been constructed prior to the United Western project. However, evaluation of this extreme has been presented to illustrate the most unfavorable conditions which could occur. A close approach to Case 1 is a much more probable future condition and all values in this report are based on Case 1 unless specifically qualified as pertaining to Case 2.

Case 1.—The tabulation on the following page lists existing and authorized generating plants, their gross energy generation before any United Western water diversion, and the impairment to energy generation which would result from such diversion.

The last listed four existing plants located on the Los Angeles Aqueduct are owned by the City of Los Angeles. Two other City of Los Angeles plants on the Aqueduct, namely, Haiwee and River, would be unaffected by the United Western development.

The Northern California Diversion has been credited with a saving in annual costs of operation, maintenance, and replacement for the discontinued Los Angeles Aqueduct hydroelectric projects estimated at approximately $80,000 (one-half of the estimated total annual operating cost).

Case 1.--Existing and authorized hydroelectric plants

Plant affected	Stream	Gross energy generation kw-yrs. Before UW diversion	Impairment
American River (E)	South Fork American	3,730	2,100
Eldorado (E)	" " "	9,540	7,100
Folsom (A)	American River	57,400	2,600
Nimbus (A)	" "	3,080	300
San Francisquito No. 1 (E)	Los Angeles Aqueduct	28,000	28,000
San Francisquito No. 2 (E)	" " "	16,200	16,200
San Fernando (E)	" " "	7,500	7,500
Franklin Canyon (E)	" " "	8,550	8,550
	Total	134,000	72,000

(E)-Existing.
(A)-Authorized.

No credit was taken for possible reductions in annual costs of American River hydroelectric plants: In the analysis of impairment, Folsom and Nimbus are affected by the Northern California Diversion to but a minor degree, and although the capabilities of the existing "American River" and "Eldorado" Plants would be reduced drastically, it was assumed that they would be kept in full operation to produce peak load power at lower plant factors.

Case 2.—The following tabulation lists the hydroelectric stations, in addition to those included in Case 1, which could conceivably be affected by the Northern California Diversion, with their gross energy generation before United Western diversions, and the impairment resulting therefrom. To the bottom of this table are added the total figures covering power impairment resulting in Case 1 as a means of indicating the total power impairment which would result under the Case 2 conditions of complete hydroelectric development.

Case 2.—Potential hydroelectric plants

Plant affected	Stream	Gross energy generation kw-yrs. Before UW diversion	Impairment
Wooley Creek	Salmon	6,250	6,250
Ishi Pishi	Klamath	69,800	69,800
Slate Creek	"	68,300	68,300
Jackman	"	103,000	103,000
Dillon Creek	"	31,200	31,200
Horse Linto	Trinity	37,200	37,200
Ironside	"	32,000	32,000
China Flat	Silver Fork	11,300	4,000
Slab Creek	South Fork American	9,100	466
Kelsey	" " "	12,900	786
Coloma	" " "	14,800	1,100
Salmon Falls	" " "	6,300	300
Parsley Bar	Rubicon	64,100	3,360
Rubicon	"	66,400	10,400
Middle Fork	Rubicon Diversion	54,300	8,400
Oregon Bar	North Fork American	20,800	1,560
	Subtotal	608,000	378,000
	Case 1 Total	134,000	72,000
	GRAND TOTAL	742,000	450,000

The first seven power plants listed in the above tabulation and shown as proposed for future construction on the Salmon, Klamath, and Trinity Rivers would be inundated by backwater from the Ah Pah Dam. It has been assumed that with Case 2 conditions prevailing, it would be necessary for the Northern California Diversion to make repayment in kind for the 347,750 kilowatt average annual power potential of these seven hydroelectric developments.

Partially offsetting this cost to the Northern California Diversion would be the elimination of operation and maintenance costs and annual replacement reserve investments for the seven inundated projects. This credit is estimated at $2,685,000 annually. No salvage value has been assumed for any of the property thus retired from service. Inasmuch as it has been arbitrarily assumed that replacement of the total energy losses would continue over the 120-year life of the project, it has been assumed that the annual savings would be realized over a like period.

The energy output of the proposed China Flat hydroelectric development on the Silver Fork of the American River would be nearly eliminated in low water years by reason of the suggested diversion into the Lahontan Basin of practically all the flow available to it. However, it is considered probable that sufficient water would remain at all times in the Silver Fork to permit operation of this particular project for peaking purposes, and no credit has been taken for possible savings in operation and maintenance and replacement reserve costs.

The remaining hydroelectric projects in the Case 2 list are affected to but a minor degree by the United Western diversion. It is assumed, therefore, that they would continue operation on a full scale, and that although the Northern California Diversion would offset in kind the loss in energy, no credit would be taken for reduction of their annual costs.

Colorado River Aqueduct pumping.—Of opposite effect to the above tabulated power impairments for Case 1 and Case 2 is a large credit which, in this analysis, is attributed to the Northern California Diversion as a result of eliminating the necessity for lifting Colorado River water from Lake Havasu to the high point on the Colorado River Aqueduct. Five pumping plants are employed to lift the water 1617 feet. The present pumping installations operate at an over-all average efficiency of approximately 88 percent. The total ultimate average pumping requirement computed on this basis is 272,500 kilowatts. In computations, this maximum credit for release of pumping energy has been assumed to develop gradually over project years 21 to 46 in accordance with the water demand growth schedule.

Inasmuch as the Colorado River Aqueduct would be retained as a stand-by source of water for southern California, it has been assumed that the Northern California Diversion could claim credit for eliminating only one-half the annual costs involved in operation (excluding pumping energy), maintenance, and replacement. This

saving has been estimated in the course of the analysis on the same basis as that employed in determining annual costs for features of the Northern California Diversion. The maximum annual saving thus realized would total approximately $950,000 apart from energy saving.

Economic Analyses

Evaluation of power generation and power requirements.—Plate 21 shows the growth and decline, over the 35-year development period (year 10 to year 46), of Case 1 total power requirements and power made available. Energy generation was computed for each of the Northern California Diversion hydroelectric projects, previously discussed, during each year of development and for the succeeding period after year 45. This is shown by Plate 21 on an average annual basis, decreased by 5 percent to account for transmission losses.

The figures for energy made available (Plate 21) include a credit for the energy saved by elimination of the previously discussed pumping of 1,212,000 acre-feet of water annually in the Colorado River Aqueduct. This energy saving has been reduced by 5 percent to compensate for added transmission losses between the pumping stations and the Los Angeles load area to which it is assumed the power thus released would be diverted.

Pumping energy requirements were determined for each year of the growth period, and during the succeeding period between year 46 and year 120, for the individual pumping stations in accordance with

their individual water supply schedules, and determined also for the small amount of miscellaneous pumping required. The power requirements indicated on the referenced Plate also include the necessary energy reimbursements which would be made by the Northern California Diversion to offset the power impairment at the assumed existing Case 1 hydroelectric generating stations.

With the exception of the hydroelectric plants on the Los Angeles Aqueduct, average annual power impairments measured at the generating stations have also been reduced by 5 percent to account for normal losses in transmission. The Los Angeles Aqueduct plants were ignored in this computation for the reason that they are situated relatively close to their load centers.

The average power made available and the average power requirements measured at major substations having thus been computed by years, net annual values for energy surplus or energy deficit were determined by subtraction. Under Case 1 conditions, a gradually decreasing energy surplus from the start of year 6 through about year 31 of the project life would be followed by a gradually increasing energy deficit up to year 46, after which the deficit would remain constant until the end of project life in year 120. In Case 2, the energy surplus would disappear at the end of year 14; energy deficits would start in the following year and increase to year 46, after which it would remain constant.

The net annual values (at six mills per kilowatt-hour) for both energy surplus and energy deficit were discounted to present worth as of project year zero, at $2\frac{1}{2}$ percent. The results of these computations are recapitulated in the following tabulation:

Present worth (capitalized value)
Project Year 0

Case 1

Energy Surplus	$270,500,000
Energy Deficit	117,400,000
Net Surplus	$153,100,000

Case 2

Energy Deficit	$508,100,000
Energy Surplus	33,700,000
Net Deficit	$474,400,000

Amortized over 100 years at $2\frac{1}{2}$ percent interest, the above net values are equivalent to an annual surplus of $4,180,000 and an annual deficit of $12,950,000.

It may be noted that the hydroelectric power output which could be generated by the project would, in general, have characteristics superior to those of the power requirements of the project. As indicated earlier, most of the project energy demands would be at a load factor of 75 percent, whereas much of the project output could

be at an output factor less than 50 percent. The project output, therefore, would have greater value per kilowatt-hour than the project demand. However, to adhere to a conservative basis for analysis, the project surplus was evaluated at the same rate as the project deficit.

Substantial quantities of dump hydroelectric power also could be produced, but due to the difficulty of computing the monetary advantage which might be derived, these also have been disregarded.

Credits from reduced operating costs.—The credit from cessation or reduction in cost of operation, maintenance, and replacement reserve investment, under Case 1 and Case 2, for the Colorado River Aqueduct, the Los Angeles Aqueduct, and the seven potential plants which would be inundated on the Klamath-Trinity-Salmon Rivers systems are summarized in Table 28b.

Derivation of energy value.—By the time a United Western project would commence operation, the low-cost hydroelectric projects which now are undeveloped probably would have been constructed. The most likely source of further large-scale power supply lies in the Western low-grade coal fields, as described in Chapter 5 of Part I. If, by the time of a United Western development, these are the lowest cost remaining means of producing new increments of required power, the cost of such production would govern the kilowatt-hour value of surplus power which a United Western project could market, as well as the value of any energy required to meet a project power deficit.

For the purposes of this analysis, therefore, it has been assumed that the energy deficit of the Northern California Diversion would be met by steam-electric plants situated about 500 miles from Bakersfield in one of the low-grade coal deposits shown on Plate 8. Although high efficiency steam-electric generation costs have been employed as typical, it is considered probable that, in actual practice, future improvements in gas turbine design would make their use more advantageous. The characteristics of the load which established theoretical generating station requirements have been considered to be those of the ultimate Northern California Diversion pump load. Transmission costs and losses were included in the over-all energy cost determination. On the above basis, the cost of energy at Bakersfield has been estimated to be about 6 mills per kilowatt-hour.

In this report, the foregoing thermoelectric generating stations are not considered to be a part of the United Western project and no capital or operating cost therefor is included in the estimate. All project power requirements, which could not be met by project hydroelectric generation or by the release of Colorado River Aqueduct pumping energy, are evaluated on a unit basis of 6 mills per kilowatt-hour.

As indicated earlier, hydroelectric energy generated by the United Western project would have a higher value than that required to supply the United Western pump load. However, it is impracticable to evaluate this increment of advantage in money at this time and,

consequently, the value for both surplus and deficit energy has been rounded off at 6 mills per kilowatt-hour. It may be noted that, with the hydroelectric energy generation and energy requirements so nearly balanced on a financial basis, a precise power rate is not of profound importance in the over-all economic analysis of the project.

PART II

CHAPTER 5

Project Justification

Classes of Benefits

General.--Measurable benefits attributable to the plan under study would result from new supplies of water for irrigation, domestic use and industry; from the generation of hydroelectric power; and from the discontinuance of certain expenses rendered unnecessary on other projects.

Benefits from power would be a maximum at the initiation of project operation and thereafter would gradually decrease; benefits from water would commence to accrue as each new market area was successively brought under service, and in each area they would increase as the market developed. Thus, the total project benefit would be highly variable (Figure 3) from year to year. To express these benefits on a uniform annual basis of equivalent value, the year to year benefits during the life of the project were first discounted (at $2\frac{1}{2}\%$) to their capitalized value as of the year in which construction of the project would be initiated. This amount (about $6\frac{1}{4}$ billion dollars) was then amortized over a hundred years at the same rate ($2\frac{1}{2}\%$). The resulting annual equivalent value, between project year zero and year 100, is about $170,000,000.

Benefits also might result from flood control, recreation, fish propagation, wildlife refuges, and national defense. These are

not evaluated in terms of money in this report. Detriments could result from power impairment, interference with natural fish propagation, and perhaps some depreciation of recreational facilities. Power detriments have been evaluated on a monetary basis, but the monetary disadvantage from interference with fish and recreation can be evaluated only by extensive further study in collaboration with the interested agencies.

Characteristics of the various classes of benefits are indicated in more detail below.

Irrigation.—Gross income from irrigation was computed on the basis of the net acreage to be irrigated annually (Chapter 2, Part I), the estimated future crop pattern, normal yields and average 1939-44 farm prices. From this gross figure all expenses except those of irrigation water and family living were deducted. Production costs were determined by the detailed development of 19 representative farm budgets covering the selected major types of farming expected to occur within the service areas. Further, the present annual net return was calculated in a like manner to show pre-project conditions, and this amount also deducted. The resulting figure is the direct net benefit from irrigation.

Indirect irrigation benefits were evaluated in accordance with procedure prescribed by the Bureau of Reclamation. In general, they are slightly more than the net direct benefit (Table 28a).

Municipal water.—The total direct and indirect benefit from new water destined for domestic use and the industries served by municipal systems has been evaluated at $100 per acre-foot at the point of wholesale delivery.

Table 27 shows wholesale water costs in 25 American cities, varying from $121 per acre-foot to $41 per acre-foot.

Table 26 shows additional data on the retail rates for 40 cities in the United States. These rates vary between $200 and $81 per acre-foot to the consumer. Values at the point of wholesale delivery would be reduced by a maximum decrement of some $30 to $60 per acre-foot —or perhaps more in isolated cases—for the cost of distribution and treatment; ordinarily such costs are much less.

Many of the indicated systems are subsidized by taxes which really are water charges. Also, in nearly all cases a part of the capital cost covering elements still in operation has been fully retired; and even more important, much of the capital cost which remains outstanding was incurred in past decades at lower cost levels than the 1939-44 average.

For many of the existing municipal water supply systems, therefore, the cost would be more than $100 per acre-foot at the point of wholesale delivery, if development works were to be provided at the 1939-44 cost level. There is no apparent means by which the supplies herein contemplated could be provided at cheaper cost

in the absence of the Northern California Diversion. Consequently, it is concluded that benefits would equal at least that amount.

The portion of any municipal supply used for industrial purposes would also be productive of indirect benefits, but these have not been measured separately; they are assumed to be included in the value of $100 per acre-foot indicated above.

Electric power.—As indicated in the preceding chapter, there would be a surplus of electric energy during the first years of project operation. The monetary value of surplus energy would more than offset the cost of the project's later power deficit. Benefits, in addition to those attributable to the value of the actual energy, would result from the cessation or reduction of operation and maintenance at the stations rendered wholly or partially inoperative by the Northern California Diversion (Table 28b).

Benefits would accrue from the generation of dump power, but these have not been evaluated (Chapter 4, Part II).

A substantial benefit would accrue to the general power system of the Southwest by the existence of the thermal capacity required for the United Western load. This thermal capacity could exert a significant "firming" effect on the hydroelectric potential of the entire system. The net effect would be of considerable financial significance, but any evaluation will require more detailed study.

Apart from the purely commercial significance of the firming capabilities of the thermal potential, such capacity would be of

even greater importance in a case of a war emergency or national catastrophe. The United Western system has a certain amount of flexibility in operation, and in the event of vital necessity, the pumps could be shut down while the power supply therefor might be temporarily diverted to other more critical needs.

Colorado River Basin Benefits

As indicated in Chapter 2, potential demands in the Colorado River Basin, as contemplated in the Bureau of Reclamation's 1946 report, are some 4 million acre-feet per year in excess of those which could be met by available supplies in that basin. An additional potential demand for water in production of synthetic fuels and mineral processing, disclosed since that report, amounts to possibly 2 million acre-feet per year. Utilization of water in these newly disclosed avenues would result in benefits much greater than contemplated in the 1946 report. In fact, an annual increment equivalent to some 40 to 50 million dollars might be added to the value anticipated in that document.

It is not practical at this time to assign a separable value to the benefits which might accrue from Colorado River water released through exchange in southern California, as described in Chapter 2, since it would be difficult or impossible to segregate the purpose served by that particular water. At this stage of these investigations, it can be assumed only that the released water would be used in connection with the remainder of the Colorado River flow,

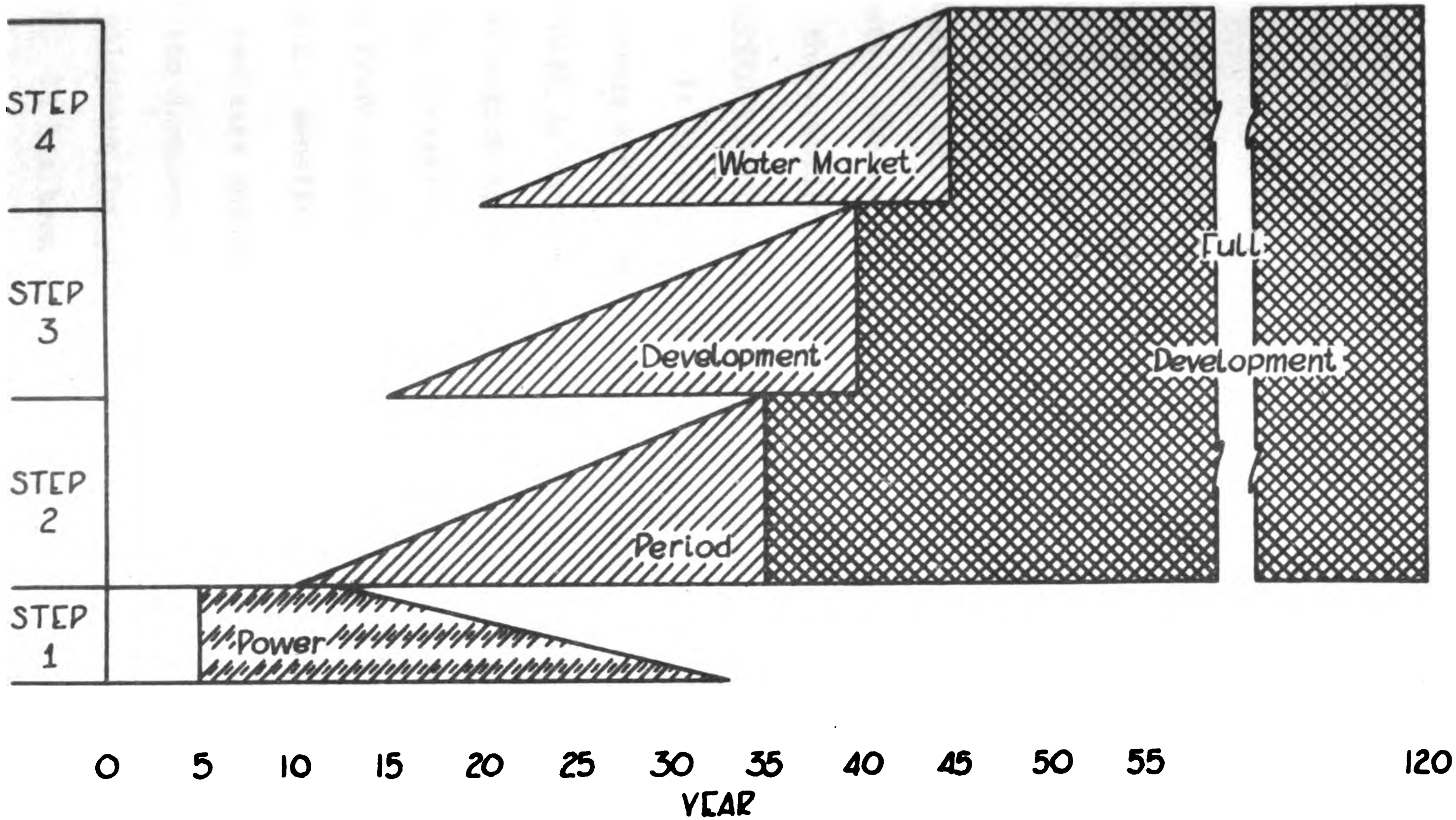


Figure 3

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UNITED WESTERN INVESTIGATION

SCHEMATIC REPRESENTATION OF BENEFIT ACCRUAL

DRAWN...	SUBMITTED...
TRACED...	RECOMMENDED...
CHECKED...	APPROVED...

SALT LAKE CITY, UTAH. 11/15/50 595-907-161

in general satisfaction of the Basin's demands. It has not been possible to compute the effect which this release would exert on the over-all Colorado Basin development, but it is probable that the net benefits to that project would be substantial. Due to uncertainty of the figures, however, these benefits are not claimed in economic justification of the Northern California Diversion.

If diversion by the Colorado River Aqueduct were discontinued, benefits would result from the cessation of operation and maintenance costs. The amount of these costs has been estimated as indicated in the preceding Chapter.

Emergency Municipal Supplies

It is anticipated that the Los Angeles Aqueduct and the Colorado River Aqueduct would be maintained on a stand-by basis to furnish an emergency water supply to the Los Angeles area in event of destruction of other sources of supply as a result of war or other major catastrophe. Similarly, the present aqueducts serving the San Francisco Bay area probably would be retained on a stand-by basis. Benefits attributable to these stand-by supplies are difficult to evaluate and they have been disregarded in economic justification of the Northern California Diversion.

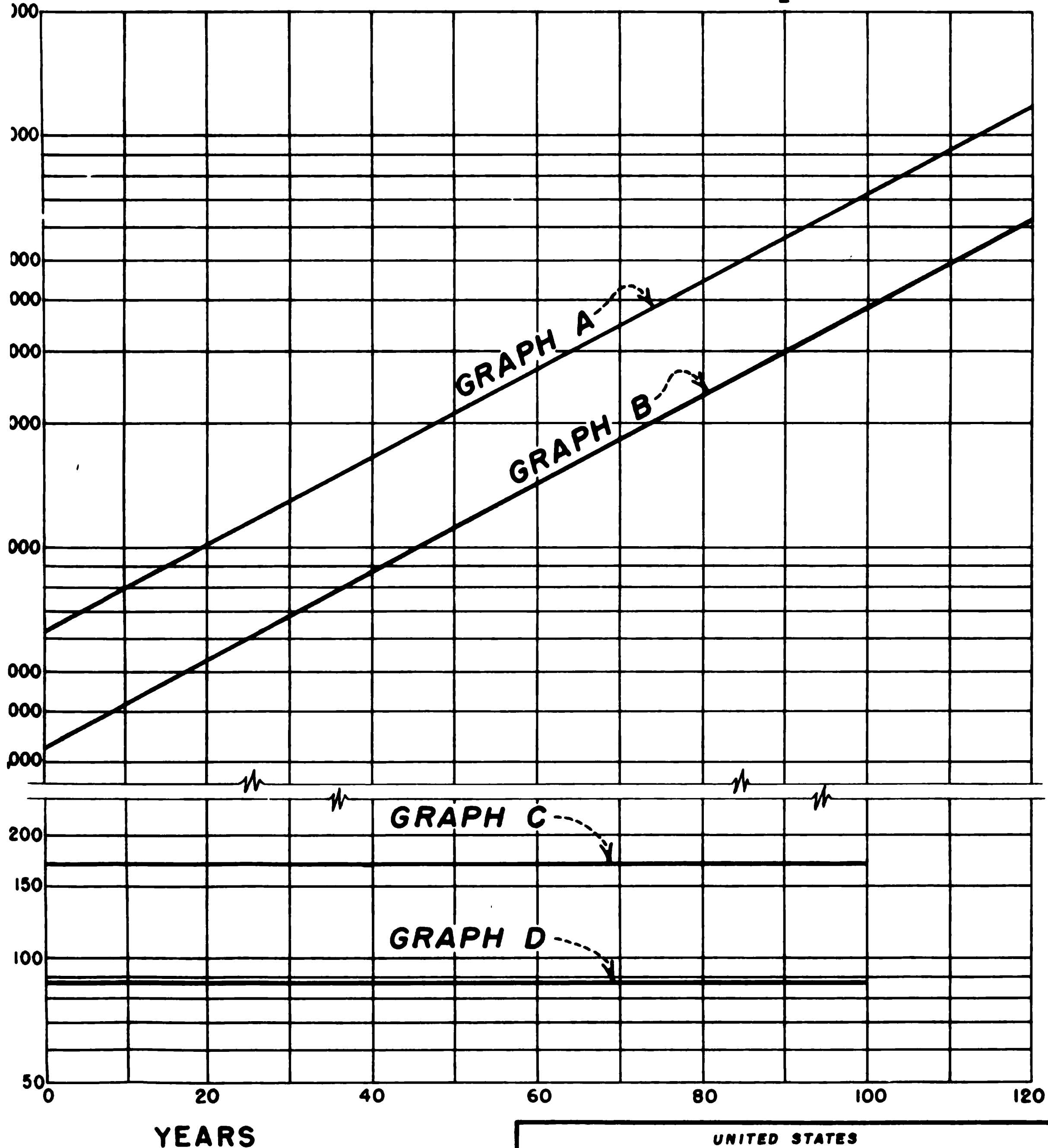
Development Period

It has been assumed that surplus firm electric energy would be marketable as soon as it would become available.

NOTES

RAPH A - Capitalized value of all benefits in any year.
RAPH B Capitalized value of all project costs in any year.
RAPH C - Uniform annual benefits from year zero to year 100, equal to capitalized value of all project benefits (Curve A) at any point in time.
RAPH D - Uniform annual costs from year zero to year 100, equal to capitalized value of all project costs (Curve B) at any point in time.

All values based on interest or discount at rate of $2\frac{1}{2}$ %



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

UNITED WESTERN INVESTIGATION

CAPITALIZATION & AMORTIZATION

NORTHERN CALIFORNIA DIVERSION

DRAWN: A.F.W. SUBMITTED: A. F. Wilber
TRACED: R.M.W. RECOMMENDED:
CHECKED: A.F.W. APPROVED: E. J. [illegible]

SALT LAKE CITY, UTAH - JAN. 5, 1951
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FIGURE - 4

For water of all classes, it has been assumed that the market would develop as explained in detail in Chapter 3, Part II.

Capitalization and Amortization

As indicated earlier, the Northern California Diversion is a typical plan, which might well be modified by further investigation. The object at this time is to determine whether such further investigation is warranted. The index of the degree to which that study may be justified is the estimated ratio of benefit to cost for the plan here analyzed.

Thus, the principal objective of project analysis has been the determination of project benefit and cost, and their expression in a manner such that they can be compared as a ratio. For the project under consideration, the determination of these values on a comparable basis is complicated. Commonly in project analysis there is a date where construction terminates and where project use (and benefits) commences. It is usual practice to compute the construction cost with interest which would have accumulated up to such a date, to add to it the value of operating cost capitalized for that date, and to compare the sum with the value of benefits capitalized for the same date. For the Northern California Diversion, major and minor construction extends over a period of 45 years, and benefits overlap 40 years of that construction period. To accumulate construction costs as an unretired, interest-bearing debt until the end of the 45th year would not yield a realistic indication of cost.

No intermediate year of the construction period is a more appropriate time index. Hence, the start of construction, or year zero, was selected as the time index for both cost and benefit. Both construction and operating cost, and benefits, have been discounted (at $2\frac{1}{2}\%$) to their capitalized value (present worth) at this initial project year. Those capitalized values, for both cost and benefit, are less than the simple addition of all the annual amounts, by reason of the discount factor.

The cost, so capitalized, may be considered as the "cash in advance" price of doing all the work. For illustration, let it be supposed that there might be contracting firms which could undertake construction of the project and its subsequent maintenance and operation; let it be supposed also that such firms can lend or utilize idle funds so as to gain $2\frac{1}{2}$ percent interest. Then, in return for a lump sum payment of $3,246,000,000, received at the start of construction, it would be good business for such a firm to construct and operate and maintain the project for 120 years as herein described.

By the laws of compound interest, the above amount of $3,246,000,000 can be converted to equivalent capitalized project cost in any other year. For illustration this has been done (Figure 4). The indicated values for years subsequent to year zero include "interest during construction" up to that date, and the capitalized value of subsequent operation and maintenance.

To determine equivalent annual cost, the capitalized value of project cost has been amortized over a period of 100 years subsequent to year zero, although the life of the project has been assumed at 120 years. This shorter period for amortization yields $89,000,000 per year, a more conservative equivalent annual cost than would have been the case for 120 years of amortization. In this amount, a reserve fund is accumulated to carry the cost of operation and maintenance between year 100 and year 120. From Figure 4 it is evident that no matter what year of capitalized cost may be selected, the equivalent annual project cost corresponding thereto will be the same: $89,000,000 for the period of 100 years following the start of construction. It is logical that equivalent annual project cost should be considered to commence in the first year of construction, because actual construction cost would start to accrue in that year, in an amount comparable to or greater than the computed "equivalent annual cost."

The same general reasoning applies to benefits. The capitalized value of benefit for year zero, $6,212,000,000, is equivalent to an annual value of about $170,000,000 when amortized at 2½ percent interest over 100 years. The 100-year period of amortization results in slightly higher equivalent annual benefit than amortization over 120 years. However, the ratio between benefit and cost is fixed by the ratio of the capitalized values. This ratio of these values is constant, regardless of the year in which the comparison may be made;

the same ratio exists for equivalent annual benefit and cost, regardless of the period of amortization and regardless of the date beyond which the values may be amortized.

Benefit-Cost Ratio

The ratio of benefit to cost for the basic concept 1/ of the Northern California Diversion is 1.9 to 1 ($170,000,000/$89,000,000).

Certain possible variations in the Northern California Diversion are discussed in earlier text. The effect of these on the benefit-cost ratio is indicated below and summarized in Table 29.

(1) If the water which is assumed to be used in the Colorado River Basin by exchange were considered as supplying a direct market in southern California, and no consideration given to use in the Colorado Basin (Chapter 2), the ratio of benefits to cost would be 2.6 to 1.

(2) If all of the potential hydroelectric capabilities indicated in Case 2 (Chapter 4) had been constructed by the time of initiation of the Northern California Diversion, the cost would have been greater and the benefits-cost ratio would be 1.6 to 1.

The foregoing examples of extremes of conditions are illustrative of the effect which modifications would be likely to exert on the aspects of the over-all project, and indicate that substantial changes in plan could occur without jeopardy to project justification.

1/ Basic hypothesis, Chapter 3, with Case 1, Chapter 4.

Unit Cost of Water

As indicated above, if all construction and annual costs of the project are discounted at 2½ percent to capitalized value as of year zero, they total $3,246,000,000. If this entire amount were to be amortized (with 2½ percent interest on the outstanding balance) in accordance with the schedule of water deliveries herein contemplated, considering both the time and quantity of delivery, the cost per acre-foot would be about $25. The $25 per acre-foot represents all out-of-pocket costs which would be sustained by the Government (including all interest) in providing, maintaining, and operating all the works of the Northern California Diversion. In other words, $25 per acre-foot would completely liquidate the entire financial obligation by the end of the 120th year. Project benefits have been computed on an entirely separate basis, and have not been applied as a reduction in the computations of the above project cost.

The foregoing cost of $25 per acre-foot should not be confused with the price which the consumer might pay for water. Repayment by the consumer is dependent on the allocation of project cost among the purposes of irrigation, municipal use, power, and perhaps others. Studies of such allocation and the succeeding repayment analysis are beyond the scope of this reconnaissance investigation. It may be noted, however, that the foregoing factors would reduce the amount to be paid by irrigators. Furthermore, in accordance with Reclamation law and policy, irrigators would not be required to

repay interest charges on the project cost allocated to irrigation. The amount to be paid by the consumer for irrigation water, to repay fully on an interest-free basis, thus would be materially lower than the $25 per acre-foot indicated above; it might well be as low as $10 per acre-foot.

It is significant that in the area where the project contemplates delivery, certain organizations are currently sustaining a cost comparable to that herein anticipated in the development of water supply. Table 25 indicates examples of high development cost ranging from $11.16 per acre-foot to $64.82 per acre-foot with a weighted average of about $29 per acre-foot. Although in the same areas, many projects endowed with favorable characteristics are able to develop water at much lower costs, such costs are not a criterion, since they result mainly from favorable natural conditions. Such cheap sources of water are becoming fully exploited as evidenced by the fact that more costly supplies are coming into use. By the time of a United Western project, the cheap sources probably would have been completely developed. The examples in Table 25 demonstrate that, even at the present time, irrigation is practical under costs comparable to those anticipated for the Northern California Diversion.

Care should be exercised in comparing the $25 per acre-foot cost under the Northern California Diversion with other unit water costs which may have been computed without regard to the financial effects of the carrying charges during the initial period before the

full water delivery could be marketed. The simple division of the total of all annual costs of the Northern California Diversion by its final annual water delivery ($\frac{\$89,000,000}{6,657,000 \text{ a.f.}}$) indicates a cost per acre-foot of less than \$14.

It is important to note that the above indicated value of cost per acre-foot (\$25), like the benefit-cost ratio, is independent of the year for which project cost may be capitalized. The same \$25 value would result from computations referred to any other year in project life (Figure 4).

1939-44 Price Level

Under ordinary circumstances, costs are estimated for engineering works at the price levels which prevail at the time of the estimate because it is usually expected that actual expenditure will follow within a short or at least a predictable time interval; in the case of the Bureau of Reclamation, this procedure has been required by law. Under ordinary circumstances also it is expected that benefits will accrue over a long period after project construction and be influenced by the changing price levels which prevail during the project life. It is customary, therefore, to compare costs pertinent to the price level at the time of the estimate with benefits calculated to another price level which reflects an average of expected fluctuations and future trends throughout the life of the project. At the present time it is considered by the Bureau of Reclamation that agricultural prices are high, and it is, therefore, the policy to

use the 1939-44 average price for benefits in comparison with the 1950 level for construction cost.

In order to conform to this standard practice, the costs and benefits hereinbefore presented have been computed in the above manner, comparing the 1939-44 level of benefit with the higher 1950 construction cost. However, an unjustifiable depreciation of project merit is reflected in this way because, in the case of the Northern California Diversion, no actual construction expenditures are presently proposed. For this reason, an alternative evaluation is presented, as described below, with both costs and benefits at the average 1939-44 level (Table 29).

When the actual construction costs would be incurred, they would extend over a long period—20 years or more—and consequently sharp peaks and depressions would tend to average out in much the same way as anticipated in the case of benefits. By the time the expenditures actually would be made, both the cost index and benefit index probably would have changed. The date at which the project would be undertaken is unknown, and any attempt to predict future levels of construction cost or agricultural prices would be futile. The purpose of estimates at this time is mainly to establish the relation between benefits and costs. Although it cannot be predicted what the proper index would be for either, there is no justification for anticipating that the cost all would be incurred in a peak period at a higher index than that for the resulting benefits.

Benefits from any project continue to accrue long after the capital investment has been incurred. If the upward trend of prices which has prevailed during the period of record continues, the benefits would accrue at a later, and consequently higher, index than the capital cost, no matter when the project might be undertaken. In the case of the Northern California Diversion, it is, therefore, conservative to assume the same index for both costs and benefits; and certainly, there is no justification for assuming a lower index on benefits than on costs.

It would be difficult to adjust the benefits index to the 1950 level because of the transient influences which affect the current market for agricultural products. It is preferable, therefore, to adjust the 1950 cost index to the 1939-44 level. On that basis costs would be 37 percent lower than those hereinbefore indicated. The benefit-cost ratios would, therefore, be increased accordingly. For the basic concept of the Northern California Diversion the ratio would be 3.0 to 1.0.

Fish and Wildlife

As indicated earlier, neither benefits nor detriments from the influences of the Northern California Diversion on fish and wildlife can be evaluated without further study.

Benefits would accrue if water were introduced into Pyramid Lake in Nevada, as suggested in Part II, Chapter 2.

Under the assumptions of this study, detriments would result from elimination of migratory fish by Ah Pah Dam. Such detriments might be offset wholly or in part by the introduction and fostering of non-migratory species above the dam. It might be desirable also to adopt additional means of offsetting the detriments, as indicated in the course of future study. Other streams probably exist where the environment for migratory fish could be improved to an extent compensating for the effects of Ah Pah Dam. The cost of such measures is, of course, not known at this time, but it is not conceivable that it would be of sufficient magnitude to be a major factor in project justification.

Recreation

As in the case of fish and wildlife, influences of the project would be both beneficial and detrimental from the standpoint of recreation. The large area of dead storage at Ah Pah Reservoir would maintain an extensive lake at all times. Improvement of recreational potentialities at Pyramid Lake also might result. Some disadvantage might ensue to sportsmen who fish particularly for migratory species, and to specialized local interests which cater to them. These disadvantages would have to be offset by remedial measures yet to be planned.

National Defense

As indicated in Part I of this report, the Northern California Diversion would contribute a substantial benefit toward the long-range

aspects of national defense. These possibilities will receive detailed study in the course of succeeding investigations. At this time, it is possible only to enumerate some of the avenues which can be investigated:

Additional water might be made available to the Colorado River Basin, possibly facilitating dispersal of war industries to lower basin states;

Thermal power for the Northern California Diversion might serve as stand-by and firm-up for war power;

Early development of indicated fuel resources, for power production on a partial or pilot basis, might be stimulated in anticipation of later heavy demands of the Northern California Diversion; and

Alternative emergency water supplies could be made available to the Cities of San Francisco and Los Angeles.

PART III

SUCCEEDING STAGES OF DEVELOPMENT

INTRODUCTION

As stated earlier, the Northern California Diversion would be susceptible of enlargement in succeeding stages to serve an expanding water market in the Southwest. The major sources which might be utilized for additional supplies are the Eel, Mad, Van Duzen, and Smith Rivers in northern California, and the Rogue, Umpqua, Willamette, and Columbia Rivers in Oregon. These rivers could be tapped by progressive supplements to the initial stage in an orderly and efficient manner.

Land inventories have revealed the existence of much land susceptible to irrigation in the Southwest for which a local supply is not available and for which no supply is anticipated under the Northern California Diversion. Much of this land is so situated that service would be unjustifiable under present economic standards; the portion which could be economically served by an imported supply at some future time would depend upon economic conditions prevailing at that time. It is also probable that continuing study will disclose much additional area which could be justifiably served under existing economic standards. Although the delineation of all these potential units of additional service area has not yet been accomplished, an estimate has been made as to the availability of additional water supplies, on the

basis described in Part I, and rough computations have been made of the cost of transferring such additional supplies to a common point, the Sacramento Valley. These opportunities for additional stages of project development, as described subsequently, have been evaluated in terms of the quantities of water which could be delivered, and the cost per acre-foot of delivery into the Sacramento River. All costs are computed at the June 1950 index and assume immediate delivery of the entire supply; that is, no carrying charges have been allowed for the period of market development. Likewise, it should be noted that costs hereinafter indicated cover only delivery to the Sacramento River, with no allowance for further conveyance to the point of use. Therefore, they are not comparable to the cost of delivery estimated for the Northern California Diversion.

Yields for succeeding stages of development have been computed in a manner similar to that employed for the Northern California Diversion described earlier; that is, no shortage would occur even during periods of critically low runoff.

Supplements to the initial stage of development which have been examined are:

1. Willamette High-Line Route
2. Eel-Sacramento Diversion
3. Willamette Pump Route
4. Van Duzen-Mad-Trinity Diversion
5. Coast Range Gravity Interception Route (upper elements)

6. Salt Water Barrier at the Sacramento-San Joaquin Delta

Various overlapping possibilities are included among the foregoing plans and it would not be physically possible to construct all the features of all the plans indicated. Some of the plans might be considered as alternatives as well as supplements to the Northern California Diversion and thus, wholly or in part, also fall within the category discussed in Part IV.

WILLAMETTE HIGH-LINE ROUTE 1/

The so-called Willamette High-Line Route involves a coordinated system of diversion, storage reservoirs, pumping plants, and other features beginning at Clackamas River in northern Oregon and extending southward along the west slope of the Cascade Range to the Klamath River in northern California. The initial diversion is at approximate elevation 380 and the first pump diversion from Willamette River near Oregon City is approximately at sea level. Further study may disclose problems in water quality and stream pollution which would result if diversion were made on the Willamette as contemplated. In such event, the point of diversion might be shifted to the Columbia River below Bonneville Dam. This modification would not be a major factor with respect to the economic justification of the plan. The water supply from the initial diversion plus that collected incrementally along the route would be in excess of 10 million acre-feet per year. However, various operational problems would reduce the average annual supply to about 9,200,000 acre-feet for the base period studied, 1920-1946. At the first and second pumping plants, lifts are constant with variable discharges. The remaining six pumping plants would operate with both varying heads and discharges. The average total lifts would vary from a minimum of 1,746 feet during October to a maximum of 1,910 feet during April.

1/ Developed by the Salem Area Planning Office, Bureau of Reclamation.

)uring years of excess stream flow the total pump lifts would be 'educed materially.

The route would cover a total distance of about 375 miles, .ncluding some 170 miles of canals and 165 miles of tunnels, with :he remainder consisting of pipelines, siphons, and reservoirs. :anal capacities would vary from 7,000 to 15,000 second-feet and :unnel capacities from 9,000 to 15,000 second-feet. There would be .4 tunnels ranging from 1.3 to 33.0 miles in length.

The system would include eight reservoirs on the route and 'ive supplementary reservoirs. All but three of the reservoirs are :urrently proposed or under construction by other agencies and could erve dual purposes with no appreciable added investment.

Further study of this route would examine the possibility of eveloping electrical energy. It is possible that an average of ome 84,000 kilowatts could be developed.

Delivery of water from the Willamette to the Sacramento via his route is estimated to cost between $20 and $30 per acre-foot. s in other supplements contemplating Ah Pah Reservoir for conveyance, his figure is exclusive of construction costs for Ah Pah Dam on the remise that that feature would have been previously completed; owever, the cost of a second Trinity-Sacramento Tunnel is included.

EEL-SACRAMENTO DIVERSION

An exportable annual yield of about 1,500,000 acre-feet probably could be developed by the construction of a 500-foot dam on the Eel River immediately downstream from its junction with the North Fork.

The plan contemplates the dam and a 43½-mile free-flow tunnel to transfer the water eastward to the Sacramento Valley. The tunnel inlet would be located about five miles downstream from Dos Rios, California, and the outlet on Grindstone Creek, approximately 5½ miles northwest of the town of Elk Creek, California. From there, the water would follow existing natural channels to the Sacramento River.

By this plan water could be transferred from the Eel to the Sacramento drainage basins at an estimated cost of between $5 and $10 per acre-foot.

WILLAMETTE PUMP ROUTE

The Willamette Pump Route contemplates the diversion of 10 million acre-feet per year from the Columbia River Basin and the delivery of that amount, less transit losses, to the Sacramento River above Redding, California. This amount has been arbitrarily selected; the quantity of surplus water at the contemplated point of diversion is much greater.

The route would start with a pumping plant on the Willamette River near Oregon City or on the Columbia River below Bonneville Dam. From that point the aqueduct would extend south along the east side of the Willamette Valley, using short tunnel or siphon sections where necessary. The first pumping plant, and additional pumping plants near Silverton and Coburg, would lift the water a total of 660 feet.

After the third pump lift, the flow would enter a nine-mile tunnel which would daylight about four miles west of Eugene. Thereafter, the conduit would siphon across both the McKenzie River and Middle Fork of the Willamette, and continue south along the Coast Fork of the Willamette to a point two miles northeast of Cottage Grove, Oregon. There it would enter a 30-mile tunnel, heading in a southwest direction to daylight on Cabin Creek north of Oakland, Oregon. The route would then continue south to about five miles south of Roseburg, and the fourth pumping plant, which would have a 306-foot lift.

After that lift, the route would cross the South Umpqua River and follow the west bank of that stream to the site of the fifth

pumping plant, approximately four miles west of Riddle. Here, the water would be raised 187 feet to a short canal and 17-mile tunnel which would daylight on Grave Creek, tributary of the Rogue River.

The route would continue along the east bank of the Rogue to a siphon crossing of that river six miles west of Grants Pass. Then it would follow the Applegate River to Wilderville, Oregon, where it would enter a 55-mile tunnel to the Klamath River. Total aqueduct distance from the Willamette to the Klamath would be 381 miles.

The Rogue-Klamath Tunnel would empty into the upper limits of the proposed Ah Pah Reservoir, which would convey the water to a 60-mile Trinity-Sacramento Tunnel for delivery above Redding, California.

Delivery of water from the Willamette to the Sacramento via this route is estimated to cost between $18 and $23 per acre-foot. As in other supplements contemplating Ah Pah Reservoir for conveyance, this figure is exclusive of construction costs for Ah Pah Dam on the premise that that feature would have been previously completed; however, the cost of a second Trinity-Sacramento Tunnel is included.

VAN DUZEN-MAD-TRINITY DIVERSION

By the combination of storage on both the Mad and Van Duzen Rivers, it would be possible to divert an annual yield of about 420,000 acre-feet to the Trinity Basin.

Of this amount, approximately 170,000 acre-feet might be developed from the Van Duzen River by construction of Dinsmore Dam, 325 feet high, at a site two miles upstream from Dinsmore, California. From the reservoir thus formed, water could be diverted via a one-mile tunnel which would empty into the potential Pilot Creek Reservoir on the Mad River. Pilot Creek Dam would conserve the combined Mad and Van Duzen yield. The dam would be constructed immediately below the mouth of Pilot Creek and would have a height of 345 feet above stream bed.

An eight-mile tunnel would transfer water eastward from the Pilot Creek site to the point where Cold Springs Creek enters the South Fork of the Trinity. At this outlet there is a potential power drop of 600 feet to the river water surface.

The water would then follow the existing river channel and reach Ah Pah Reservoir. It could be delivered to the Sacramento Valley through a Trinity-Sacramento Tunnel.

With a credit of $1.50 per acre-foot for development of potential power, a net amount of $10 to $15 per acre-foot is estimated as the unit cost of delivery to the Sacramento Valley. Incremental tunnel cost between Ah Pah Reservoir and the Sacramento Valley is included.

COAST RANGE GRAVITY INTERCEPTION ROUTE
(Upper Elements)

The upper elements of the so-called Coast Range Gravity Interception Route probably could develop an exportable yield of about 2,330,000 acre-feet per year from the Rogue River Basin by Lewis Creek Dam on the Rogue River, and Eight Dollar Dam on the Illinois River.

Lewis Creek Dam would have a height of about 486 feet; it would provide about 1,550,000 acre-feet of conservation storage and develop a yield of 1,400,000 acre-feet per year. The installation of a power plant would permit the average generation of about 60,000 kilowatts.

Releases from Lewis Creek Reservoir would follow the natural channel of the Rogue River to the Jones Creek Diversion Dam, a concrete structure about 25 feet high. This dam would divert the Lewis Creek Reservoir yield to a canal, ten miles long, which would skirt Grants Pass, Oregon, and lead to the Applegate Diversion Pool. The latter would be formed by a 20-foot high concrete dam across the Applegate River.

Eight Dollar Dam on the Illinois River would have a height of about 291 feet; it would provide 1,200,000 acre-feet of conservation storage and develop a yield of 970,000 acre-feet per year of which a part to be determined later would be released for fish culture. The remainder would be diverted to the Applegate Diversion Pool through an 18-foot free-flow horseshoe tunnel 5.3 miles long.

The combined exportable yields of Lewis Creek and Eight Dollar Reservoirs would be raised by a 50-foot pump lift from Applegate Diversion Pool to the inlet of a 25-foot free-flow tunnel which would extend 55 miles to the Klamath River above Ah Pah Reservoir. It is assumed that Ah Pah Dam would have been completed and that it would be necessary only to construct a second bore paralleling the 60-mile tunnel from Ah Pah to the Sacramento River above Redding, California.

With power benefits deducted, a net annual cost of $12 to $16 per acre-foot is estimated for delivering this water to the Sacramento Valley.

This supplement is identical with the upper elements of the basic plan of the same title which is described in Part IV. For the sake of clarity, the title is here preserved. However, considered as a supplement to the Northern California Diversion, a pump lift into Ah Pah Reservoir is necessary, and the supplement thus is not strictly a "gravity" route.

PART III

SALT WATER BARRIER AT THE SACRAMENTO-SAN JOAQUIN DELTA

The possibility of preventing salinity intrusion into the Sacramento-San Joaquin Delta by means of a barrier dam has been studied at various times in the past. Such a barrier might consist primarily of navigation locks and a low dam across the combined rivers near Antioch. The Central Valley Project proposes to accomplish salinity control by maintaining a minimum flow of 3,300 cubic feet per second, totaling 2,400,000 acre-feet annually, through the delta region toward San Francisco Bay. It is possible that the necessity for discharging this quantity to the ocean could be obviated by a barrier dam. If such a barrier were feasible, perhaps 2,000,000 acre-feet of water could become available at a comparatively low cost.

COLORADO RIVER REPLACEMENTS

As discussed earlier in this report, the Northern California Diversion in its initial stage would replace 1,212,000 acre-feet of Colorado River water. Should it prove desirable to release additional Colorado River water for within-basin use, this could be achieved by replacement of present use in the Imperial Valley of California. An additional primary water supply could be provided by one or more of the previously described supplements to the Northern California Diversion.

United Western water consigned to use in Imperial Valley would reach the Santa Ana River by the main aqueduct (enlarged accordingly) as described for Part II. From this point a branch aqueduct would extend southward on the coastal side of the Santa Ana Mountains to the San Luis Rey Valley near the town of Bonsall. At this point the aqueduct would veer eastward and continue via a 46-mile tunnel to the Imperial Valley at Borego. From that point a short canal would provide service to lands under the existing All American Canal.

The cost of constructing this aqueduct extension beyond the Santa Ana River has been estimated at $10 to $15 per acre-foot of water carried therein; to this would be added the cost of conveyance from the source to the Santa Ana River. Should it be possible to incorporate the coastal segment with other facilities to be constructed for service to the coastal area, the resultant saving in construction cost would be appreciable.

It also would be possible to make delivery of water to Baja California, by enlargement and extension of the branch of the aqueduct which would serve San Jacinto Reservoir under the Northern California Diversion. Still another method of delivering water to Mexico would be by extension of the Imperial Valley Aqueduct to also serve Mexican lands to the south. The common interest which the United States and the Republic of Mexico might have in such possibilities remains to be explored in the course of further investigation.

P A R T IV

VARIOUS PLANS CONSIDERED

GENERAL

Various other plans of development proposed to deliver new water to the Southwest have been examined in the course of reconnaissance studies to date. Some possibilities have been shown to have very little merit after only brief study. Others have been subjected to more careful examination before being deferred. In a few cases, alternatives have been attractive and certain features thereof may still receive consideration. Various of these alternatives, including some of rather low priority, are described briefly in succeeding paragraphs. Some of these present possibilities as alternatives to the Northern California Diversion.

The general layout of these routes is presented on Plate 25. They are:

1. Coast Range Gravity Interception Route (Alternate)
2. Albeni Falls Diversion
3. Willamette Pump Route (Alternate)
4. Coast Range Low-Level Route
5. Snake River Diversion

Costs are based on the 1950 index and computed as explained in Part III.

COAST RANGE GRAVITY INTERCEPTION ROUTE (ALTERNATE)

The Coast Range Gravity Interception Route would develop an exportable yield of about 6,000,000 acre-feet per year from the Rogue and Klamath Basins by means of the following dams:

Lewis Creek on the Rogue River

Eight Dollar on the Illinois River

Benjamin and Redcap on the Klamath River

Burnt Ranch, Gaynor Peak, and Horse Linto on the Trinity River

The upper elements of this plan, Lewis Creek and Eight Dollar Dams, and the adjacent aqueducts, would be the same under this alternative as under the Supplemental Stage of Development of the same name described earlier, producing a yield of 2,332,000 acre-feet annually for export. The Rogue-Klamath Tunnel would have substantially the same alignment, but the pumping plant at the tunnel inlet would be eliminated and the tunnel dropped approximately 50 feet to divert by gravity from the Applegate Diversion Pool. Lowering of this tunnel would become possible because the maximum elevation of Redcap Reservoir would be somewhat lower than that of the supplanted Ah Pah Reservoir.

Benjamin Dam on the Klamath River would have a maximum height of about 487 feet; it would provide some 1,900,000 acre-feet of conservation storage and develop a yield of about 1,982,000 acre-feet

per year. All of the yield would be released from the dam to follow the natural channel to Redcap Reservoir. The average annual power potential at Benjamin Dam is estimated at 85,000 kilowatts.

Redcap Dam on the Klamath River would have a maximum height of about 550 feet; it would provide some 1,000,000 acre-feet of conservation storage and develop an annual yield of about 1,074,000 acre-feet from the drainage basin below Benjamin Dam. The combined Benjamin and Redcap Reservoir yields are, therefore, about 3,056,000 acre-feet per year, of which a part would be released from Redcap Dam for fish propagation. The remainder of the supply, combined with the Lewis Creek-Eight Dollar Reservoir yields, totals about 4,328,000 acre-feet per year. This would be diverted through a 32-foot horseshoe free-flow tunnel, 20.7 miles long, to the Horse Linto Diversion pool.

Burnt Ranch Dam on the Trinity River would have a height of about 553 feet; it would provide some 955,000 acre-feet of conservation storage and develop a yield of 830,000 acre-feet per year. All of this would be released from the dam to follow the natural channel to Horse Linto Diversion pool. Potential benefits from hydroelectric generation were not evaluated.

Gaynor Peak Dam on the South Fork of the Trinity River would have a neight of about 600 feet; it would provide some 1,085,000 acre-feet of conservation storage and develop a yield of 944,000 acre-feet per year. All of this would be released from the dam to

follow the natural channel to Horse Linto Diversion pool. The average annual power potential at Gaynor Peak Dam is estimated at 50,000 kilowatts.

Horse Linto Dam on the Trinity River below the South Fork would have a maximum height of 297 feet. No conservation storage would be provided; its function would be solely to form a diversion pool. From this pool a net export of 5,997,000 acre-feet per year would be diverted into the Sacramento River through a 37-foot free-flow tunnel, 60 miles long, which would daylight near Redding.

The cost under this plan, neglecting the aforementioned potential hydroelectric power benefits, is estimated to be about $10 to $15 per acre-foot delivered to the Sacramento River.

ALBENI FALLS DIVERSION

The Albeni Falls Route would divert water from Pend Oreille River, a tributary of the Columbia, at the Albeni Falls Dam site. The initial diversion would be at elevation 2028 and probably could be carried by gravity flow to the Klamath River above the Ah Pah Reservoir. The total length of aqueduct to the Klamath River would be about 1020 miles, of which about 290 miles would be tunnel and 40 miles in siphon. No estimates of cost or exportable yield were made for this plan because the necessary length of aqueduct causes it to appear unattractive, and also because inspection of ultimate local water requirements indicates a lack of any substantial exportable surplus.

WILLAMETTE PUMP ROUTE (ALTERNATE)

The Willamette Pump Route here outlined is an alternate to the Willamette Pump Route described earlier as a possible succeeding stage to the Northern California Diversion.

The annual diversion of 10 million acre-feet would be the same as in the supplementary plan, and the route would also be identical from the initial pumping plant to the inlet of the Rogue-Klamath Tunnel near Wilderville, Oregon. At this point the alternative plan would convey the water directly to the Sacramento River below Keswick Dam via a 133-mile tunnel. The center line of this tunnel would diverge from a straight line route in order to pass under terrain where excavating shafts could be located more favorably.

The delivery of water to the Sacramento Valley via this route is estimated to cost from $20 to $25 per acre-foot, including pumping power costs.

COAST RANGE LOW-LEVEL ROUTE (ALTERNATE)

The Coast Range Low-Level Route would develop an exportable yield of approximately twelve million acre-feet per year. The surplus flows of the Rogue, Smith, and Klamath Rivers would be collected and diverted at the furthest downstream location which would permit gravity delivery to the Sacramento.

The Rogue River yield would be developed by three dams:

Lewis Creek, Eight Dollar, and Copper Canyon.

Lewis Creek Dam would have a height of about 486 feet; it would provide about 1,550,000 acre-feet of conservation storage and develop a yield of some 1,400,000 acre-feet per year.

Eight Dollar Dam would have a height of about 291 feet; it would provide about 1,200,000 acre-feet of conservation storage and develop a yield of some 970,000 acre-feet per year.

Copper Canyon Dam would have a height of about 802 feet; it would provide about 2,905,000 acre-feet of conservation storage which, combined with that provided at Lewis Creek and Eight Dollar, would develop an exportable yield from the Rogue River Basin of about 5,292,000 acre-feet per year

This Rogue River yield would be diverted to Junction Reservoir on the Smith River through a 40.5-foot pressure tunnel, 31 miles long.

The Smith River Basin yield would be developed by one dam, Junction Dam, which would have a height of about 700 feet; about 1,432,000 acre-feet of conservation storage would develop an exportable yield of some 1,716,000 acre-feet per year.

The combined Rogue and Smith yields, some 7,000,000 acre-feet per year, would be diverted to the Ah Pah Reservoir on the Klamath River, through a 44-foot pressure tunnel, 15 miles long.

The Klamath Basin yield would be developed by one dam, Ah Pah, which would have a height of about 732 feet; some 4,800,000 acre-feet of conservation storage would develop an exportable yield of about 5,000,000 acre-feet per year.

The combined Rogue-Smith-Klamath yields, 12,000,000 acre-feet per year would be diverted to the Sacramento River through a 47-foot free-flow horseshoe tunnel, 60 miles long, daylighting near Redding, California.

The annual cost per acre-foot delivered to the Sacramento River is estimated at $8 to $10, disregarding certain possible benefits from power not evaluated under this plan.

This route might also be considered as a supplementary plan to the Northern California Diversion. Considered thus, the Rogue and Smith Rivers yields, 7,000,000 acre-feet per year, would be developed for export but the Klamath yield would be reduced by about 1,100,000 acre-feet per year below the export indicated in Part II, due to the restrictions as to normal water surface elevation at Ah Pah Reservoir. The total exportable quantity made available would be about 12,000,000 acre-feet per year, as indicated above.

SNAKE RIVER DIVERSION

The so-called Snake River Diversion plan, although not favorably considered in this report, has been discussed widely by certain local interests. It would deliver water from the Snake River to lands in Nevada and possibly to southern California.

By means of a series of pump lifts located near Twin Falls, Idaho, water from the Snake River would be lifted approximately 2,000 feet to an aqueduct which would extend in a southerly direction to the Humboldt River in Nevada. The river would serve as a conveyance channel until the water reached the vicinity of the town of Lovelock. A low dam would then divert the water into an aqueduct extending in a southerly direction through Carson Sink and terminating in Owens Valley, California.

Total pump lifts would be about 2,640 feet. The conveyance system would include 366 miles of canal, 280 miles of river channel, and 35 miles of tunnel. Very approximate estimates indicate an annual canal-side cost of $20 to $25 per acre-foot for water delivered into the Humboldt River Basin, $30 to $35 per acre-foot for water delivered to the Hawthorne, Nevada, area, and $40 to $45 per acre-foot for water delivered into Owens Valley.

The cost of delivery of water from Owens Valley to southern California has not been evaluated; however, the terrain would be generally favorable for a conduit following the approximate alignment of the existing Los Angeles Aqueduct.

PART IV
Snake River Diversion

The cost of transferring water from the Snake River into Nevada and southern California appears to exceed that which would obtain under other plans outlined in this report. Moreover, studies indicate that under conditions of ultimate development, there would be no exportable surplus in the Snake River at appropriate diversion points. Unless these fundamental disadvantages can be mitigated in some way, this route will remain unattractive.

P A R T V

PROJECT INVENTORY

The area under study by the United Western Investigation includes the entire Western United States. The Investigation, therefore, is concerned with all possibilities for inter-regional water transfer which exist in that area.

Numerous such opportunities exist in addition to those mentioned earlier in this report. Many of these are under consideration at the present time and still others will be explored in the course of continuing reconnaissance. Interim data on the general characteristics of some of these potentialities are shown by Table 30, but as yet no definite statements can be made as to their probable merit.

In the above mentioned Table there are enumerated, according to states, the various water supply projects to which this investigation is giving, or plans to give, consideration. The character of benefits which might accrue to the individual western states as result of developing any project which may be found favorable is indicated. Shown also are both the direct and indirect sources of the water which would be utilized by the individual projects, and their relation to the broader inter-regional development of which each would be a part.

Information available at this time is simply an enumeration of readily discernable characteristics. No evaluation of projects other than those indicated in the preceding Parts of this report has yet been made. Future studies will undoubtedly indicate the desirability for both deleting from and adding to the foregoing inventory. As of the present date of compilation, and as indicated in referenced Table 30, twenty-six individual state projects and eleven related inter-regional developments have been listed.

Benefits to the individual states may accrue in one or more of several ways: through use of surface waters conveyed by canals into designated areas for agricultural, municipal, or industrial purposes; secondly, through the exchange of a new source of water supply for claims or entitlements to the Colorado River or other rivers, thus permitting reassignments of the formerly claimed water for new use, possibly even to areas east of the Rocky Mountains; and further, through surplus energy from United Western generating stations which could be employed for the pumping of ground water or similar uses. As studies on these additional projects are completed, favorable possibilities will be reported fully, in a document similar to that here attached for the Northern California Diversion.

Continuing studies will undoubtedly show the desirability of coordinating projects and structures which eventually may be proposed by the United Western Investigation, with certain developments proposed by other Bureau of Reclamation offices or other

federal or private agencies. In fact, the disclosure and reconciliation of the conflicts which may exist between projects ultimately to be necessary on an inter-regional scale and those interim projects which are proposed for development on a more local basis is one of the most important objectives of the Investigation.

PART VI

WATER SOURCES OTHER THAN RIVER DIVERSION

INTRODUCTION

The problem of adjusting the water supply of the Western States to better satisfy present and future demands has, in the foregoing sections of this report, been subjected to solution by the conventional means of developing exportable yields in areas of surplus, and conveying such yields many miles through conduits to the ultimate destination where a new water supply is required. Because the total cost and scope of such proposals go beyond present experience, it has been deemed advisable to consider other basic means of augmenting water supply.

Those other means which have been considered are:

A. Artificial Precipitation.

B. Rendering Sea Water Potable.

C. Transportation of Water by Boat.

D. Sewage Reclamation.

Artificial precipitation remains to be proved as a practical means of water supply on any scale. The other three processes have been demonstrated to be practical on a small scale, but only at high cost. Estimates indicate that such cost would be reduced somewhat for large volumes comparable to the needs of a city for domestic use, but the reduction probably would not be sufficient to place these

processes in a competitive position with conventional means of water supply. However, the indicated costs are no higher than the maximum costs now paid for water by certain communities, and it is possible that any of these methods might have merit under special circumstances for limited areas. For large water supplies comparable to those hereinbefore contemplated, however, they appear at this time to be impractical for purely physical reasons as well as from economic considerations.

PART VI

ARTIFICIAL PRECIPITATION

Various agencies have conducted cloud seeding programs over specific areas during the past several years, and apparent results indicate that total rainfall has been increased significantly in those areas. However, these somewhat startling results have not been compared with long-time weather records or with rainfall conditions which might have prevailed naturally in the area of operation and, therefore, a defensible statistical foundation is not available. Hence, these data are incomplete and unproved for general application.

Experience to date also has disclosed the possibility of adverse effects resulting from the chemicals used in the artificial induction of rainfall. It is possible that certain atmospheric conditions might arise which would allow chemicals generated during a seeding operation in one area to be transferred over long distances with a resultant unintended effect on the weather or even the climate in a totally different area. Seeding of clouds at high elevation is at times futile, as the rainfall evaporates before reaching the ground; excessive seeding may cause water clouds to turn to ice crystal clouds prematurely and then dissipate into the atmosphere without going through the process of precipitation.

There are also legal complications to be resolved: Artificially induced precipitation in one area may be at the expense of some other area where rain would have fallen naturally,

PART VI
Artificial Precipitation

It appears that artificial induction of rainfall as a dependable supplemental water supply will not be possible until the fundamental chemistry and physics of cloud formation and precipitation are more clearly understood and the prevailing weather conditions favorable for artificial nucleation have been thoroughly studied and catalogued for any given locality. At this time, extensive research and experimentation are being conducted in an effort to solve the aforementioned problems and many scientists working with the studies believe that, in the future, artificial induction of rainfall will prove to be a practical means of supplementing water supplies in some areas. On a scale comparable with that generally contemplated in this report, there is as yet no evidence that the process would be a substitute for the conventional means of water diversion and conveyance.

RENDERING SEA WATER POTABLE

Several methods of rendering sea water potable have been known for years. Many ocean liners of today distill sea water en route rather than carry large supplies of fresh water. The process is warranted under these special conditions but, in spite of continuous research, no cheap, large-volume process has yet been developed.

In addition to distillation, chemical-deionization, electrolysis, freezing, and other methods have been tried. However, greatest progress had been made with distillation. By compression processes, efficiencies have increased to the point where 200 pounds of water are produced per pound of fuel. Such efficiencies are very high and no great margin for improvement remains. Cost is about $0.50 per 1,000 gallons, or $165 per acre-foot at sea level, without storage, pumping, conveyance, or distribution. For large quantities of water certain residual salts would exceed the quantity which the market could absorb; disposal cost of waste might more than offset the value of any useable bi-products.

French engineers propose a process utilizing electrical energy generated by means of the difference in temperature between the ocean surface and the ocean at great depths. If the experiment proves successful, very little cost other than the capital cost may ensue. As in the case of artificial precipitation, the possibility remains to be proved.

PART VI
Rendering Sea Water Potable

In summary, it can be said that on the basis of experience to date, no process of sea water conversion appears to be as advantageous as conventional means of water supply, but more attractive aspects may be revealed by future studies.

TRANSPORTATION OF WATER BY BOAT

Conveyance of water by means other than conduits has long been practiced, especially in desert regions or as an emergency measure in drought-stricken areas. Because of the relatively small quantities of water involved and the haphazard management that has accompanied such undertakings, it has been a very expensive practice in terms of cost per unit volume of water delivered.

It was believed possible that the cost of such water supply could be greatly reduced if undertaken on a large scale and operated over a long period of time in a manner comparable to conventional methods of water supply. A study of the possibility of transporting water by boat shows an estimated cost of $115 per acre-foot for water taken from the Klamath River, transported in large tank ships to the Los Angeles area, and pumped into an existing reservoir at the end of the Metropolitan Water District distribution system. The estimated costs included in this study comprehend amortization of the total investment at 2½ percent over a period of fifty years, replacement of machinery and other features whose life would be less than fifty years, operation and maintenance of the ships and the shore installations, and over-all supervision of the entire undertaking.

Water transported by boat must necessarily be unloaded at sea level, so it could be most advantageously used in coastal areas at low elevation. Its estimated unit cost when so delivered, although many times greater than that under the Northern California Diversion,

is no more than the maximum prices now being paid at certain points in such areas, and appears to be cheaper than conversion of sea water.

Boat transportation would be well adapted to supplementing or extending the water supply for a seaboard municipality that has outgrown its accessible local sources, and faces a long interim period before it can negotiate for and construct a new aqueduct to tap distant sources. In such a situation, boat transportation might make new water available quickly and with low total investment, and could increase deliveries gradually with growing demand until such time as an overland aqueduct could be justified and constructed. The saving in carrying charges on an aqueduct system, during the time before the water market had developed to a point requiring heavy aqueduct use, might well justify the employment of this means of interim water supply. For supplies of the magnitude herein contemplated, however, boat transportation appears to be unattractive.

SEWAGE RECLAMATION

The scientific and engineering principles relating to the reclamation from sewage of a water suitable for useful purposes are well established. A few small sewage treatment plants have been designed and operated for the recovery and re-use of water. Each of these plants produces re-usable water which is better for the purpose intended or more economical than could be obtained from other available sources. Substantial quantities of sewage and industrial wastes are now being discharged into the ocean from population centers on the coast. In the Los Angeles area alone approximately 150,000 acre-feet per year of physically reclaimable water is now being discharged into the ocean, and this quantity is expected to at least double by the year 2000.

The water reclamation process comprises the following steps: collection, treatment, spreading, filtration to ground water stocks, recovery from underground reservoirs, and conveyance to points of use. Preliminary estimates indicate that the cost of these operations probably would exceed the cost of importation under a plan similar to the Northern California Diversion. In addition, public prejudice and legal restrictions would have to be overcome. In summary, it may be said that although the reclamation of sewage appears to offer a practical means of gaining relatively small additions to water supply, it cannot provide large increments, and even in small amounts,

the cost probably would be higher than that of the suggested Northern California Diversion.

Table 1.—Precipitation data - western states

Year	Washington	Oregon	Idaho	Montana	Wyoming	California	Nevada	Utah	Colorado	Arizona	New Mexico
	Mean Annual Precipitation in inches										
1886	41.33	33.75	16.70	12.45	9.79	19.48	7.53	9.67	17.58	9.89	15.97
87	43.93	42.31	16.03	15.95	8.02	18.59	5.21	6.35	14.21	11.42	15.32
88	41.43	32.65	16.41	13.50	13.03	21.35	7.67	8.83	12.00	12.30	14.63
89	31.83	29.79	14.76	8.94	12.93	33.25	12.41	12.67	13.73	13.29	10.97
90	33.66	22.24	19.03	9.86	14.81	25.29	13.34	8.44	11.97	15.49	12.83
91	43.32	29.16	15.93	17.17	15.99	22.23	14.06	13.52	19.88	8.28	14.69
92	32.97	22.87	19.99	15.52	11.92	25.98	10.54	9.68	15.56	9.85	9.51
93	41.23	29.57	20.13	15.65	10.67	23.24	9.32	11.56	12.89	10.41	12.40
94	43.47	32.52	20.01	15.18	11.87	25.84	11.33	11.43	14.37	11.09	10.47
95	35.55	25.17	13.89	11.82	16.90	22.24	7.39	10.66	18.33	13.19	15.56
96	46.20	33.13	20.91	16.21	15.00	28.59	9.92	11.20	15.07	12.88	13.23
97	43.18	28.60	20.19	15.80	12.86	18.99	9.94	14.55	19.46	12.47	16.52
98	33.04	21.02	14.92	16.44	12.50	10.35	6.93	10.61	15.61	12.20	14.03
99	45.07	31.06	18.96	14.92	13.99	22.47	8.61	11.83	14.67	8.61	10.98
1900	36.67	24.57	16.39	13.81	10.95	19.34	7.55	8.38	14.43	7.83	13.52
01	34.41	24.75	15.13	15.23	12.09	22.12	11.39	10.05	14.14	10.65	14.50
02	40.24	29.88	16.96	15.37	9.81	24.22	7.29	9.17	13.88	10.23	9.97
03	31.53	24.96	17.58	15.58	12.87	20.69	6.79	10.21	13.80	8.93	11.25
04	32.38	32.46	17.74	11.09	14.29	30.39	11.26	11.43	16.30	9.45	14.41
05	28.96	21.05	15.63	13.62	16.23	21.59	7.97	13.58	18.09	27.83	20.95
06	35.64	29.50	21.01	18.64	17.82	38.70	13.01	18.34	19.71	16.48	15.89
07	31.93	31.71	20.63	17.65	14.62	32.49	11.77	16.07	16.33	15.41	16.13
08	32.23	20.90	16.97	19.25	17.22	18.78	6.58	14.82	17.09	16.16	12.68
09	35.87	32.85	22.83	19.92	16.36	42.13	10.00	19.31	20.96	14.48	12.83
10	33.43	26.96	17.62	16.12	12.12	16.77	5.81	11.16	14.35	10.08	9.46
11	26.68	22.76	18.15	18.53	13.98	29.39	8.58	13.02	19.24	16.29	17.92
12	34.99	32.50	22.19	17.35	18.40	22.27	7.83	14.15	18.84	13.10	13.92
13	31.50	27.48	20.44	15.41	16.88	25.20	10.99	13.02	17.78	12.52	15.36
14	33.05	26.40	17.13	15.15	12.32	31.13	9.43	13.60	19.26	17.06	19.45
15	34.39	26.09	19.35	18.92	19.21	33.82	7.97	13.33	19.44	16.39	17.64
16	33.93	28.64	21.02	18.58	13.50	34.84	9.76	15.93	18.70	17.24	15.95
17	33.80	24.33	19.67	14.43	13.78	16.48	6.72	11.88	14.74	13.04	9.49
18	30.12	20.61	17.46	13.83	16.13	24.47	9.28	14.12	18.75	15.18	15.08
19	31.00	26.21	15.96	10.88	10.99	21.29	7.08	11.83	17.22	20.70	20.95
20	34.19	26.48	19.20	14.59	14.18	26.71	8.89	16.57	17.75	13.65	14.87
21	36.80	27.26	18.93	14.64	12.58	25.89	8.30	15.49	19.37	15.17	16.46
22	24.67	23.85	16.01	15.12	14.16	28.96	9.56	14.83	15.60	13.16	10.86
23	29.64	23.37	19.33	18.12	19.31	14.13	8.70	13.60	21.23	17.80	19.46
24	27.70	21.76	13.49	13.71	12.69	17.05	5.49	10.57	13.75	9.12	10.65
25	28.09	23.71	19.51	16.34	15.62	21.13	10.16	14.50	16.96	13.33	13.86
26	32.12	25.49	18.24	13.79	14.58	27.06	6.39	12.43	16.98	16.55	17.44
27	42.02	31.12	24.04	20.63	18.16	27.50	7.84	16.58	20.32	16.64	13.94
28	31.93	22.42	13.90	13.06	14.23	18.64	4.87	10.07	17.05	9.91	15.09
29	23.74	19.93	13.94	13.08	15.06	15.00	5.83	13.60	18.16	11.29	16.48
30	27.28	19.22	17.03	12.38	14.70	18.38	9.77	15.14	17.32	15.55	14.64
31	42.17	24.52	15.02	10.09	11.57	24.37	7.98	10.06	14.03	19.60	18.32
32	44.22	26.69	19.71	16.17	13.31	15.60	8.24	13.36	14.17	13.64	16.20
33	47.28	28.16	18.67	15.69	12.16	20.18	6.67	10.57	15.16	11.90	12.83
34	38.27	25.87	16.10	11.22	10.85	18.01	7.12	9.52	10.89	10.47	10.08
35	29.19	20.42	12.40	10.89	12.28	22.06	8.61	10.83	15.81	15.45	14.85
36	32.62	23.77	16.49	11.32	13.13	26.20	10.26	16.97	16.06	14.33	13.50
37	43.32	34.70	20.03	12.93	15.53	29.06	8.89	14.74	14.59	13.01	15.00
38	29.35	26.31	19.57	16.60	15.26	30.06	11.79	15.19	19.35	12.90	14.62
Maximum	47.28	34.70	24.04	20.63	19.21	42.13	14.06	16.58	20.96	27.83	20.95
Minimum	23.74	20.42	13.49	8.94	8.02	10.35	4.87	6.35	10.89	7.83	9.46
Month	Mean monthly precipitation in inches										
Jan.	5.04	4.11	2.22	0.87	0.78	4.80	1.20	1.19	0.77	1.26	0.58
Feb.	3.67	3.10	1.70	.70	.78	4.29	1.05	1.25	.96	1.33	.72
Mar.	3.43	2.85	1.80	.94	1.14	3.66	.97	1.40	1.30	1.06	.75
Apr.	2.42	2.06	1.44	1.13	1.54	1.73	.76	1.16	1.80	.57	.87
May	1.97	1.75	1.64	2.09	2.07	1.01	.85	1.16	1.86	.32	1.15
June	1.69	1.30	1.35	2.56	1.58	.31	.50	.57	1.41	.33	1.26
July	.67	.43	.64	1.42	1.36	.07	.38	.88	2.23	2.13	2.48
Aug.	.77	.40	.62	1.08	1.10	.10	.48	.99	1.98	2.28	2.41
Sept.	1.80	1.18	.98	1.30	1.09	.44	.39	.94	1.34	1.20	1.73
Oct.	2.98	1.97	1.44	1.02	1.07	1.21	.58	1.06	1.14	.81	1.12
Nov.	5.08	3.67	1.97	.91	.69	2.36	.65	.91	.79	.93	.64
Dec.	5.66	4.10	2.11	.86	.73	4.01	1.00	1.12	.91	1.23	.70
Total	35.18	26.92	17.91	14.88	13.93	23.99	8.81	12.63	16.49	13.45	14.41

Source: Adapted from Department of Agriculture, 1941 Yearbook of Agriculture, Climate and Man

Table 2.--Climatic summary for representative stations

State	County	Station: Name	Station: Elevation M.S.L. (Feet)	Temperature: Length Record (Yrs.)	Temperature: January Average (°F)	Temperature: July Average (°F)	Temperature: Maximum (°F)	Temperature: Minimum (°F)	Killing frost avg. dates: Length Record (Yrs.)	Killing frost avg. dates: Growing Season (Days)	Killing frost avg. dates: Last in Spring	Killing frost avg. dates: First in Fall	Precipitation: Length Record (Yrs.)	Precipitation: Average annual depth (Inches)
Washington	Clellan	Tatoosh Island	101	40	41.2	55.1	88	7	40	311	Feb 8	Dec 16	40	77.28
	Grays Harbor	Quinault	220	27	38.4	63.5	104	11	26	208	Apr 13	Nov 7	29	128.58
	Spokane	Spokane	2357	40	27.5	69.0	108	-30	40	184	Apr 12	Oct 13	40	14.62
	Okanogan	Conconully	2270	39	20.8	66.6	109	-29	30	130	May 19	Sep 26	39	14.36
Oregon	Baker	Baker	3446	39	24.9	65.6	104	-24	39	144	May 12	Oct 3	40	10.69
	Deschutes	Bend	3599	37	30.8	65.1	105	-26	34	91	Jan 8	Sep 7	35	12.64
	Tillamook	Glenora	--	18	36.6	62.5	106	3	19	140	May 18	Oct 5	19	129.47
	Lincoln	Newport	148	40	43.7	56.8	100	1	29	248	Mar 23	Nov 26	39	66.19
California	Del Norte	Crescent City	50	35	45.9	59.3	102	19	35	230	Apr 2	Nov 18	36	75.87
	Sacramento	Sacramento	25	40	45.6	73.9	114	17	40	307	Feb 6	Dec 10	40	15.88
	Kern	Bakersfield	489	38	47.0	83.5	118	13	36	277	Feb 21	Nov 25	40	6.12
	Monterey	Salinas	74	40	49.7	63.3	110	18	32	250	Mar 17	Nov 22	40	13.37
	Riverside	Riverside	1050	40	52.0	75.6	118	21	38	265	Mar 6	Nov 26	40	11.53
	San Diego	San Diego	19	40	55.1	67.5	110	25	40	365	None	None	40	10.11
	Imperial	Brawley	-119	28	52.7	91.1	121	19	28	303	Feb 5	Dec 5	30	2.43
Nevada	Elko	Elko	5075	40	24.4	69.8	107	-43	39	103	Jun 1	Sep 12	40	9.46
	Mineral	Mina	4350	40	32.4	78.0	110	-22	31	148	May 9	Oct 4	39	3.45
	Clark	Las Vegas	2006	28	44.6	86.1	118	8	32	239	Mar 16	Nov 10	31	4.84
Idaho	Ada	Boise	2844	40	30.4	74.2	121	-28	40	177	Apr 23	Oct 17	40	12.47
	Bannock	Pocatello	4453	38	25.5	72.2	105	-28	40	161	Apr 28	Oct 6	39	13.34
	Clearwater	Orofino	1027	33	29.3	73.0	118	-24	34	165	Apr 30	Oct 12	34	26.41
Utah	Salt Lake	Salt Lake City	4222	40	30.1	77.0	105	-20	40	192	Apr 13	Oct 22	40	15.79
	Beaver	Milford	5029	30	25.4	73.4	104	-34	30	126	May 20	Sep 23	30	8.65
	San Juan	Blanding	6036	32	26.2	71.7	110	-23	32	147	May 12	Oct 6	33	14.54
	Emery	Green River	4087	37	22.2	79.6	112	-42	34	156	May 3	Oct 6	37	6.13

Table 2.--Climatic summary for representative stations--Continued

State	County	Station: Name	Station: Elevation M.S.L.	Temperature: Length Record	Temperature: January Average	Temperature: July Average	Temperature: Maximum	Temperature: Minimum	Killing frost avg. dates: Length Record	Killing frost avg. dates: Growing Season	Killing frost avg. dates: Last in Spring	Killing frost avg. dates: First in Fall	Precipitation: Length Record	Precipitation: Average annual depth
			Feet	Yrs.	°F	°F	°F	°F	Yrs.	Days			Yrs.	Inches
Arizona	Mojave	Kingman	3333	35	43.3	82.3	117	6	33	212	Apr 12	Nov 10	35	10.94
	Yuma	Yuma	138	40	54.6	91.0	120	22	40	348	Jan 12	Dec 26	40	3.58
	Pima	Tucson, University of Arizona	2423	40	49.6	85.1	111	6	40	245	Mar 19	Nov 19	40	11.16
	Cocinino	Flagstaff	6903	40	27.2	65.2	99	-30	40	118	Jun 3	Sep 29	40	20.92
New Mexico	San Juan	Aztec	5800	27	26.8	73.7	104	-27	29	155	May 5	Oct 7	33	9.17
	Socarro	Socarro	4618	40	37.4	79.7	108	-16	40	196	Apr 9	Oct 22	39	10.34
	Grant	Ft. Bayard	6152	39	38.7	72.6	103	-12	40	194	Apr 19	Oct 30	40	16.38
Wyoming	Lincoln	Bedford	6221	38	16.7	60.4	97	-46	39	64	Jun 27	Aug 30	38	18.37
	Sweetwater	Green River	6083	33	18.6	69.3	103	-40	34	100	Jun 3	Sep 11	34	7.42
Colorado	Mesa	Grand Junction	4849	40	25.0	77.9	105	-21	40	191	Apr 16	Oct 24	40	8.76
	San Miguel	Telluride	8756	30	20.7	58.4	96	-36	31	65	Jun 27	Aug 31	30	23.16
Montana	Lewis & Clark	Helena	3893	40	20.2	65.7	103	-42	40	153	May 2	Oct 2	40	12.54
	Missoula	Missoula	3201	40	22.3	67.6	105	-42	40	128	May 18	Sep 23	40	14.01

Adapted from U. S. Department of Agriculture, 1941 Yearbook of Agriculture, Climate and Man.

Table 3 .--Maximum intensity of rainfall

State	Station	Maximum observed precipitation					
		5 Mins.	10 Mins.	20 Mins.	30 Mins.	60 Mins.	120 Mins.
Washington	Tatoosh Island	.33	.50	.88	--	1.42	1.89
	North Head	.27	.32	.43	.53	.88	.94
	Port Angeles	.27	.30	--	--	--	--
	Seattle	.29	.46	.57	.58	--	--
	Tacoma	.15	.29	.38	.56	--	--
	Spokane	.23	.36	--	--	--	--
	Walla Walla	.21	.29	.46	.57	--	--
Oregon	Portland	.33	.63	1.00	1.10	--	--
	Roseburg	.55	.80	1.14	--	--	--
	Baker	.30	.44	.58	.78	--	--
California	Eureka	.21	.37	--	.63	--	--
	Point Reyes	.24	.36	.51	.53	.98	--
	Mt. Tamalpais	.19	.34	.45	.53	--	--
	San Francisco	.33	.50	.72	.81	--	--
	San Luis Obispo	.28	.43	.59	.71	1.07	--
	Los Angeles	.42	.53	.87	1.10	1.44	--
	San Diego	.29	.47	.75	.93	1.15	2.09
	Red Bluff	.39	.51	.89	1.21	2.07	3.72
	Sacramento	.27	.45	.66	.79	--	--
	Fresno	.34	.58	1.06	1.16	--	--
Nevada	Winnemucca	.27	.53	.79	--	--	--
	Reno	.30	.54	.76	--	--	.91
	Tonopah	.21	.34	--	--	--	--
Idaho	Lewiston	.30	.50	.80	1.05	--	--
	Boise	.17	.33	.55	--	.95	--
	Pocatello	.35	.48	.69	.95	--	--
Utah	Salt Lake City	.36	.66	.87	1.05	--	--
	Modena	.38	.68	1.06	1.12	1.41	--
Arizona	Flagstaff	.35	.64	.96	1.15	--	--
	Phoenix	.36	.60	.99	1.16	1.30	1.79
Montana	Kalispell	.44	.70	.95	--	--	--
	Helena	.47	.60	--	--	--	--
	Havre	.37	.67	.88	--	1.19	--
	Miles City	.38	.62	.98	--	--	--
Wyoming	Yellowstone Park	.17	.30	.39	.50	--	--
	Sheridan	.48	.69	.99	1.30	1.39	2.68
	Lander	.45	.75	1.16	1.31	1.43	1.46
	Cheyenne	.48	.90	1.63	2.04	--	--
Colorado	Grand Junction	.30	.54	.61	.64	--	--
	Denver	.87	1.20	1.62	1.72	2.20	--
	Pueblo	.44	.80	1.20	1.59	--	--
New Mexico	Santa Fe	.41	.55	.90	--	1.16	1.60
	Roswell	.55	.86	1.33	1.46	2.21	2.78

Adapted from Table 2 of USDA Bulletin #204 (Yarnell)

Table 4.--Farm income trend (1926 price level)

ɔdity group	Average annual cash farm income (eleven western states 1/) 1910-14	1939-43	Percentage increase 1910-14 to 1939-43
ts and nuts	$ 170,200,000	$ 423,500,000	150
tables	71,200,000	264,500,000	270
r crops	311,200,000	533,000,000	70
animals	319,300,000	512,700,000	60
r livestock	177,300,000	516,500,000	192
Total	$1,049,200,000	$2,250,200,000	114

leven western states: Washington, Oregon, Idaho, Montana, Utah, ɔlorado, Wyoming, New Mexico, Arizona, Nevada, California.

Table 5.--Cash farm income by groups of commodities in 1939 for eleven western states 1/

modity group	Cash income Total	Wholly irrigated 2/	Partly irrigated 2/	Non-irrigated
grains	$ 110,863,000	$ 7,848,000		$103,015,000
grains and hay	58,778,000	35,000,000		0
n lint and seed	50,529,000	50,529,000		23,778,000
eed	3,759,000	3,008,000		751,000
oes (incl. sweet)	34,104,000	31,158,000		2,946,000
crops	119,643,000	107,889,000		11,754,000
vegetables	24,491,000	15,118,000		9,373,000
s	29,050,000	25,641,000		3,409,000
es	15,111,000	14,289,000		822,000
	13,455,000	11,740,000		1,715,000
s	30,783,000	25,743,000		5,040,000
berries	6,958,000	3,859,000		3,099,000
s	73,838,000	73,838,000		0
fruit	42,474,000	31,561,000		10,913,000
crops	96,417,000	77,489,000		18,928,000
ops: subtotal	$ 710,253,000	$514,710,000		$195,543,000
	38,625,000	650,000	$ 12,556,000	25,419,000
products	176,682,000	70,636,000	29,363,000	76,683,000
	56,925,000	11,859,000	4,718,000	40,348,000
ens	15,485,000	4,277,000	1,221,000	9,987,000
rs	19,889,000	4,369,000	11,078,000	4,442,000
and calves	218,166,000	25,200,000	95,653,000	97,313,000
	37,822,000	16,238,000	3,000,000	18,584,000
and lambs	82,251,000	11,550,000	25,423,000	45,278,000
estock and live-ck products: total 3/	$ 645,845,000	$144,779,000	$183,012,000	$318,054,000
nd total	$1,356,098,000	$659,489,000	$183,012,000	$513,597,000

tes included: Washington, Oregon, Idaho, Montana, Utah, Colorado, Wyoming, Mexico, Arizona, Nevada, and California.
land receiving any irrigation water is considered "irrigated," and pro-tion from such land listed as "wholly irrigated." Where livestock obtain t of their feed from irrigated crop or pasture lands, value of their ducts is listed as "partly irrigated."
tting minor livestock products such as honey.

: Long Term Outlook for Western Agriculture--USDA and USDI, by Marion n and Wendell Calhoun.

Table 6.--Value of mineral products

State	1937	1944	1947
Arizona	$ 94,564,494	$ 115,600,000	$ 186,751,000
California	476,974,925	606,754,000	855,553,000
Colorado	67,338,548	79,555,000	105,135,000
Idaho	40,633,119	51,321,000	67,786,000
Montana	82,086,815	89,479,000	87,167,000
Nevada	38,871,816	51,799,000	42,639,000
New Mexico	72,855,745	126,218,000	156,554,000
Oregon	6,609,710	9,668,000	16,658,000
Texas	813,270,605	1,319,260,000	1,926,699,000
Utah	105,652,422	150,103,000	206,639,000
Washington	26,658,257	36,234,000	40,027,000
Wyoming	41,087,908	73,031,000	118,422,000

Source of Data: World Almanac.

Table 7. Runoff data, Pacific Coast rivers, San Francisco Bay to Columbia River

Principal river	Tributary	U.S.G.S. gaging station	Period of record	Drainage area sq. miles	Runoff in 1000 acre-feet Mean for period	Maximum year	Minimum year
Russian		near Healdsburg	1941-1946	791	1,079	1,834	455
		at Guerneville	1941-1946	1,346	1,756	3,201	730
Eel		at Scotia	1910-1915)				
			1916-1946)	3,070	4,574	10,400	885
Mad		at Arcata 1/	1894-1946	452	921	1,522	152
Klamath		at Requa	1910-1926	12,040	10,876	16,800	3,740
		at Somesbar	1927-1946	8,480	4,826	9,590	2,238
	Trinity River	at Hoopa	1911-1913)				
			1931-1946)	2,840	3,876	7,601	1,903
		at Lewiston	1895-1946	731	1,237	2,547	266
	Salmon River	at Somesbar	1911-1913)				
			1927-1946)	737	1,126	2,234	473
Smith (Calif.)		at Crescent City	1931-1946	613	2,435	3,567	1,550
Chetco			No runoff data available				
Rogue		at Raygold	1905-1946	2,020	1,983	3,176	839
	Applegate	near Wilderville	1939-1946	767	487	725	192
	Illinois	at Kerby	1926-1946	367	782	1,348	389
Coquille	South Fork	at Powers	1928-1946	169	518	951	287
	Middle Fork	near Myrtle Point	1930-1946	305	538	905	263
	North Fork	near Myrtle Point	1929-1946	276	660	990	374
Umpqua		near Elkton	1905-1946	3,680	5,095	8,770	2,280
	South Umpqua	near Brockway	1905-1911)				
			1924-1926)				
			1942-1946)	1,640	1,773	2,994	761
	North Umpqua	at Toketee Falls	1908-1909)				
			1914-1917)				
			1924-1946)	337	624	903	459

1/ California State Records.

Table 7.--Runoff data, Pacific Coast rivers, San Francisco Bay to Columbia River--Continued

Principal river	Tributary	U.S.G.S. gaging stations	Period of record	Drainage area sq. miles	Runoff in 1000 acre-feet Mean for period	Maximum year	Minimum year
Columbia		Birch Bank	1913-1946	34,000	49,700	62,800	34,900
		Grand Coulee Dam	1913-1946	74,100	76,400	101,400	50,900
		The Dalles	1879-1946	237,000	140,500	225,000	85,500
		at Cascade Locks	1879-1946	240,000	148,200	239,700	90,500
	Willamette River	Salem	1909-1916)				
			1927-1946)	7,280	15,700	25,600	9,900
	Deschutes	Moody	1906-1946	10,500	4,130	5,700	3,000
	John Day	McDonald Ferry	1904-1946	7,580	1,400	2,600	460
	Snake	Clarkston	1915-1922)				
			1928-1946)	103,200	31,200	49,000	20,600
		Weiser	1911-1946		12,700	19,100	7,900
		Milner	1909-1946		2,400	5,800	113
		Heise	1910-1946	5,740	4,900	6,600	3,000
	Clearwater	Spalding	1926-1946	9,570	10,000	17,600	6,200
	Salmon	Whitebird	1910-1946	13,550	7,500	11,500	4,200
	Spokane	Spokane	1891-1946	4,350	4,800	7,400	2,100
	Pend Orielle	Z-Canyon	1912-1946	25,200	18,100	27,900	10,000
	Clark Fork	Priest River	1903-1941	24,200	18,000	27,400	9,400
	Kootenai	Port Hill	1928-1946	13,700	10,100	15,400	6,000

Table 8.--Physical properties of Ah Pah Reservoir

Feature	
levation top of dam	848 feet M.S.L.
levation maximum surcharge water surface 1/	840 do.
lormal water surface elevation	817 do.
linimum pool elevation	600 do.
levation tailwater	40 do.
levation stream bed	35 do.
otal storage	15,250,000 acre-feet
onservation storage	9,050,000 acre-feet
otal yield from reservoir	6,322,000 acre-feet per year
ield for export to Sacramento Valley	6,094,000 acre-feet (554,000 acre-feet per month, Feb. 1 - Dec. 31)
elease to downstream channel 2/	228,000 acre-feet per year

1/ Determined by routing spillway design flood: total runoff ,450,000 acre-feet, peak inflow 884,000 c.f.s.; peak discharge 00,000 c.f.s.

2/ Releases made through power plant.

Table 9.--Runoff data, Trans-Sierra Nevada diversions

Stream	Station	Period of record	Elevation of gage in feet	Drainage area in square miles	Unit runoff for period of record in A.F./sq.mi./year
Rubicon 1/	Georgetown	1943-1946	3,500	198	1,860
Cold Creek 2/	Mokelumne Peak	1927-1946	6,000	23	1,826
South Fork 2/ Silver Creek	Ice House	1924-1946	5,300	28	1,797
Silver Creek 2/	Union Valley	1924-1946	4,530	83	1,733
Medley Lakes Outlet 3/	Valde	1922-1946	8,100	6	1,975
Twin Lakes Outlet 3/	Kirkwood	1922-1946	7,900	12	1,944

1/ Minor storage regulation upstream and diversion from basin for which there are no records.

2/ No storage or diversion above station.

3/ Storage above station but no diversion.

Source of data: U.S.G.S. Water Supply Papers.

Table 10.--Estimated acreage susceptible to irrigation

Elevation zone (feet)	USBR Region 1 (acres)	USBR Region 2 (acres)	USBR Region 3 (acres)	USBR Region 4 (acres)	Total all Regions (acres)
0-1000		4,054,400	2,155,000		6,209,400
1000-2000		67,300	1,655,000		1,722,300
2000-3000		189,500	1,883,000		2,072,500
3000-4000		10,200	319,000	141,000	470,200
4000-5000		645,500	69,000	4,420,200	5,134,700
5000-6000		99,700		8,243,300	8,343,000
6000-7000				1,894,000	1,894,000
Over 7000				449,000	449,000
0-8000	1/ 25,166,000				25,166,000
Total	1/ 25,166,000	2/ 5,066,600	6,081,000	3/ 15,147,500	51,461,000
Estimate of acreage under authorized development					3,000,000
Net acreage					48,000,000

1/ Total all elevation zones.
2/ Includes 40,600 acres requiring a supplemental water supply.
3/ Includes 1,875,900 acres requiring a supplemental water supply.

Note: These figures include presently irrigated land needing a supplemental supply.

Source of data: United Western Inventory.

Table 11.--Estimated water and power requirements for mineral processing

A	B	C	D		E	F	G	
Mineral	Reserves	Unit Water Requirements	Possible Requirements for Water by Reserves (Acre-Feet/Year)		Life of Reserve (Years)	Unit Power Requirements	Possible Requirements for Power by Reserves (Thousands of Kwh/Year)	
			By Hydrogenation(1)	By Gas Synthesis (1)			Minimum(1)	Maximum (1)
COAL (1) (Bituminous only)		Hydrogenation of bituminous coal: 7,367 ac.-ft./year for 10,000 B/D plant (5) Gas synthesis of bituminous coal: 9,766 ac.-ft./year for 10,000 B/D plant (5)				91,670,000 to 167,000,000 kwh/ year for a 10,000 B/D plant (9)		
Northwest Colorado (2)								
Twenty mile Park	3,920,000,000 tons (±7,840,000,000 bbl.)		73,670 (6)	97,660 (6)	220		916,700 (6)	1,670,000 (6)
Axial and Monument Butte Quadrangles	20,000,000,000 tons (±40,000,000,000 bbl.)		73,670 (6)	97,660 (6)	1,110		916,700 (6)	1,670,000 (6)
Meeker Quadrangle	10,600,000,000 tons (±21,200,000,000 bbl.)		73,670 (6)	97,660 (6)	600		916,700 (6)	1,670,000 (6)
Rollins and Somerset Districts Grand Mesa Field	7,760,000,000 ton (±15,520,000,000 bbl.)		73,670 (6)	97,660 (6)	430		916,700 (6)	1,670,000 (6)
Palisade District, Grand Mesa Field and parts of Book Cliffs Field	6,390,000,000 tons (±12,780,000,000 bbl.)		73,670 (6)	97,660 (6)	360		916,700 (6)	1,670,000 (6)
Utah	93,100,000,000 tons (±93,100,000,000 bbl.)(4)		368,350 (7)	488,300 (7)	520		4,583,500 (7)	8,350,000 (7)
Arizona	15,000,000,000 tons (±15,000,000,000 bbl.)(4)		73,670 (8)	97,660 (8)	420		916,700 (8)	1,670,000 (8)
Wyoming (3)	±93,000,000,000 tons (±93,000,000,000 bbl.)(4)		368,350 (7)	488,300 (7)	520		4,583,500 (7)	8,350,000 (7)
Total Coal			1,178,720	1,562,560			14,667,200	26,720,000
OIL SHALE (1) (15 gals. per ton or higher)		1,450 ac.-ft./year for 10,000 B/D (12)				161,740,800 kwh/ year for a 10,000 B/D plant (16)		
Colorado (10)	756,000,000,000 tons (270,000,000,000 bbl.)		435,000 (13)(1)		250		48,522,240 (13)(1)	
Utah (11)	92,000,000,000 tons (33,000,000,000 bbl.)		145,000 (14)		90		16,174,080 (14)	
Wyoming (11)	7,176,000,000 tons (2,560,000,000 bbl.)		14,500 (15)		70		1,617,410 (15)	
Nevada (11)	7,219,000 tons (6,039,000 bbl.)							
Total Oil Shale			594,500				66,313,730	
CRUDE OIL AND NATURAL GAS LIQUIDS	(bbl.)	A 10,000 B/D complete lubricating refinery (18) utilizes 6600 ac.-ft.-yr. of which 760 ac.-ft. of good quality water is consumed.				20 to 75 kwh per 10,000 gallon production (9)	Depends on type and amount of refinery product.	
California	4,143,026,000							
Colorado	369,002,000							
New Mexico	677,941,000							
Utah	16,039,000							
Wyoming (17)								
NATURAL GAS	(MCF)	No data available				No data available		
California	9,991,635,000							
Colorado	1,227,095,000							
New Mexico	6,241,003,000							
Utah	65,577,000							
Wyoming (17)								
PHOSPHATE ROCK (23)	(tons of rock)	Phosphoric acid requires 7,500 to 75,000 gallons of water per ton for process and cooling	Depends on product			Phosphoric acid from phosphorus or phosphate rock requires 3,460 kwh per ton. Elemental phosphorus requires 12,000 to 14,000 kwh/ton	Depends on product	
Idaho	5,736,335,000							
Montana	391,323,000							
Utah	1,741,480,000							
Wyoming	115,754,000							
POTASH	(tons of K_2O)							
Brines		No data available						
California, Searles Lake	10,000,000 to 12,000,000							
California, Owens Lake	6,000,000						No data available	
Utah, Salduro Marsh	50,000,000						No data available	
Alunite Utah, Marysvale	934,600	No data available					No data available	
Sylvite and Carnallite Utah, Thompsons	No data available	No data available						
Leucite Rock Wyoming	No data available	No data available					No data available	
MAGNESIUM (23)		Water requirements are minor for the electrolytic or electrothermic processing of magnesium chloride or oxide.	(23)			Salts require ± (23)(25) 10/kwh/pound magnesium		
Salts Utah	No data available							
Magnesite and Brucite	(tons of ore)					Magnesite requires (23)(26) 9½ to 11 kwh/pound magnesium		
Nevada, Gabbs	74,348,000							
Nevada, Overton	35,730,000							
Nevada, St. Thomas	500,000							
California	± 2,000,000							
ALUMINUM (23)	(tons of pure alunite and equivalent)	(Bayer process for bauxite requires 6,300 gallons water per ton alumina produced)	(23)			(180 kwh/ton alumina (23)(25) from bauxite)		
Alunite								
Utah, Marysvale	11,682,500							
Arizona, Yuma County	141,000							
Colorado, Custer County	210,700							
Colorado, Dolores County	1,026,000							
Nevada, Railroad Pass	10,600							
Nevada, Cactus Range	8,075							
Nevada, Sulfur	39,000							
Nevada, Boyd	82,800							
MANGANESE ORES	(tons of ore)	6 tons water per ton ore (24)	Total acre-feet			silico manganese: (23)(25) 4,500 to 6,500 kwh/ton ferromanganese: 6,000 to 7,000 kwh/ton		
Western States (Arizona) California, Colorado, Idaho, Montana, Nevada, Utah Washington)								
Ore containing less than 25% Mn	8,000,000 to 12,000,000		39,600 to 59,400					
Ore containing 25 to 50% Mn	5,000,000		24,750					
CHROMIUM		6 tons water per ton ore (24)	Total acre-feet			ferrochrome: (23)(25) 4,000 to 6,000 kwh/ton		
Chromite	(tons of ore)							
California (11-43% Cr_2O_3)	185,300		920					
Oregon (5-22% Cr_2O_3)	2,980,000		14,750					
Montana (21.6% Cr_2O_3)	5,525,000		27,350					
VANADIUM	(tons of ore or rock)	No data available	---			milling of carnotite: (23) 820 kw/ton V_2O_5 electrothermic production (23) of 30-35% ferrovanadium (25) from vanadium ores: 6,800 kw/ton		
Carnotite ore Colorado and Utah (1 to 5% V_2O_5)	500,000 (measured and indicated)							
Phosphate rock Idaho and Wyoming (0.2 to 1% V_2O_5)	1,100,000 (measured) 7,500,000 (indicated) 300,000,000 (inferred) to 437,000,000 (includes measured and indicated)							
URANIUM								
Carnotite ore Colorado and Utah	No data available	---	---			No data available		
Pitchblende Colorado (2 to 3% V_3O_8)	No data available	---	---			No data available		

(1) At present the U. S. consumes about 5,000,000 B/D of petroleum; consumption will undoubtedly be greater by the time synthetic liquid fuels are used to supply the demand. In this estimate the possible future production requirement of synthetic liquid fuel has been split with coal supplying an estimated 1,600,000 B/D and oil shale, 4,100,000 B/D. The estimate has been made by straight line extrapolation from pilot plant data; it is for illustrative purposes only and is a forecast of levels which may actually be reached.

(2) Including only coal suitable for manufacturing synthetic fuel.

(3) Including only those reserves lying in the Colorado River Basin.

(4) Assuming that 50 percent of reserves might be utilized for synthetic fuel production.

(5) Adapted from figures in USBM Report of Investigations 44.56 Oil from Coal, January 1949.

(6) Assuming an arbitrary 100,000 B/D production in each of the five Northwest Colorado areas.

(7) Assuming an arbitrary 500,000 B/D production in Utah and in Wyoming.

(8) Assuming an arbitrary 100,000 B/D production in Arizona.

(9) Adapted from figures in <u>Water for Utah</u>, Utah Water & Power Board, July 1, 1948, p. 80.

(10) Including only a 900 square mile area of Piceance Creek Basin, with all beds averaging over 15 gallons per ton.

(11) 15 gallon per ton shale.

(12) Average of five estimates, all of which include refining.

(13) Assuming an arbitrary 3,000,000 B/D production.

(14) Assuming an arbitrary 1,000,000 B/D production.

(15) Assuming an arbitrary 100,000 B/D production.

(16) Requirements for mining, crushing, and Union Oil Company retorting and refining, assuming continuous process. Adapted from figures in USBM Report of Investigations 4652. Oil from Shale, February, 1950.

(17) Only a small part of Wyoming's oil and gas reserves lie in the Colorado River Basin.

(18) Adapted From figures in American Petroleum Refining, H. S. Bell, 1945, page 552.

(19) Assuming an arbitrary 1,000,000 B/D crude oil throughput.

(20) Assuming an arbitrary 100,000 B/D crude oil throughput.

(21) Assuming an arbitrary 150,000 B/D crude oil throughput.

(22) Assuming an arbitrary 1,000 B/D crude oil throughput.

(23) Water requirements in acre-feet per year and power requirements in kilowatt-hours per year depend on the products of the refining process and the amount to be produced per year.

(24) Six tons of water per ton of ore is an average calculated from the requirements of 31 plants listed in Arthur F. Taggart's Handbook of Mineral Dressing, 1945, page 20 et. seq.

(25) Adapted from figures in Power Requirements in Electrochemical, Electro-metallurgical and Allied Industries, Federal Power Commission, 1938.

(26) Our Magnesium Resources, Mining Congress Journal, August 1941, pp. 16-22.

NOTE: The estimate of possible annual water and power requirements required for processing coal and oil shale contained in this table are included for illustrative purposes. They do not purport to be forecasts of what may actually be attained. See Note 1.

B/D = barrels per day

Table 12.--Monthly demand schedules and unit terminal storage requirements

Month	Monthly demand in percent of annual total						
	Municipal	Irrigation					
	All areas served	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
January	6.2	1.4	1.9	1.0	0	0	0
February	5.6	1.0	1.5	2.0	1.1	0	0
March	7.0	2.8	4.5	5.0	5.4	0	2.0
April	7.7	7.8	7.6	9.0	9.7	3.9	11.0
May	9.4	8.8	9.7	12.0	16.1	13.0	18.0
June	10.2	10.8	11.7	14.0	18.2	22.2	19.0
July	11.3	13.8	14.1	19.0	19.3	25.0	18.0
August	11.0	14.8	14.3	18.0	15.1	22.9	16.0
September	9.6	13.8	13.6	12.0	9.7	10.9	11.0
October	8.5	10.8	11.6	5.0	4.3	2.1	3.0
November	7.3	9.8	7.5	2.0	1.1	0	2.0
December	6.2	4.4	2.0	1.0	0	0	0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Storage required in percent of total annual demand	7.0	19.3	20.5	29.6	33.6	48.6	43.0

Area: 1 Southern California south of Tehachapi Mountains.
2 San Luis Obispo County, California.
3 Friant--Kern Canal, California.
4 Delta--Mendota Canal, California.
5 American River Area, California.
6 Reno--Newlands Area, Nevada.

Table 13.--Characteristics of annual irrigation demand

Area served	Acre-feet per acre or feet of depth					
	Net irrigation use or aqueduct system release	Farm delivery demand	Net consumptive use	Irrecoverable loss	Percent of area served by pump recovery	Percent of area served by direct application
1	2.45	1.75	1.22	1.23	0	100
2	2.52	1.80	1.26	1.26	0	100
3	2.66	1.90	1.33	1.33	0	100
4	2.70	1.93	1.35	1.35	0	100
5	2.73	1.95	1.36	1.37	0	100
6	2.80	2.00	1.40	1.40	0	100
7	2.94	2.10	1.47	1.47	0	100
8	3.72	2.66	1.86	1.86	0	100
9	4.90	3.50	2.45	2.45	0	100
10*	1.60	2.00	1.40	.20	43	57
11*	2.59	3.24	2.27	.32	43	57
12**	1.70	2.00	1.40	.30	39	61

Table 13.--Characteristics of annual irrigation demand--Continued

Area served	Acre-feet per acre or feet of depth					
	Net irrigation use or aqueduct system release	Farm delivery demand	Net consumptive use	Irrecoverable loss	Percent of area served by pump recovery	Percent of area served by direct application
13**	2.19	2.58	1.81	.38	39	61
14**	2.21	2.60	1.82	.39	39	61
15***	3.71	3.57	2.50	1.21	26	74

General area: (all in California except No. 9)

1: Redwood City
2: Nampa Valley
3: Alameda County
4: Watsonville, Santa Cruz
5: Marin County, Sonoma Creek
6: Santa Clara Valley, Oxnard Plain, Lower Ventura, Capistrano, Oceanside, El Cajon
7: Gilroy
8: Hollister
9: Newlands Project, Nevada
10: Conejo Valley
11: San Joaquin Basin
12: Simi Valley, Las Virgenes, Oxnard, Las Posas Ojai, Ventura, Canada Larga, Los Angeles Metropolitan, Anaheim, Capistrano, Oceanside, El Cajon
13: Berros-Nipomo, Santa Maria, Santa Ynez
14: Livermore
15: Mojave Desert

Note:

Transit loss for all areas
- Canal loss -- 5% of aqueduct release
- Lateral loss -- 25% of canal release
- Farm loss -- 30% of farm delivery

* Recovery of losses 75%
** Recovery of losses 65%
*** Recovery of losses 50%

	Acres served			Farm	Demand	Demand
		By	By			

Table 14.--Irrigation water markets

Market area	Acres served: Gross	Acres served: Net each year	Acres served: By surface supply	Acres served: By pumped recovery	Farm delivery demand AF/yr.	Demand met by surface supply AF/yr.	Demand met by pumped supply AF/yr.	Imported supply AF/yr.
Central Valley	1,518,000	1,217,000	693,700	523,300	3,941,000	2,245,000	1,696,000	3,152,000
San Francisco Bay	260,000	208,000	184,300	23,700	436,700	375,100	61,600	527,000
Pajaro-San Benito	55,700	44,600	44,600	0	102,100	102,100	0	143,000
Lahontan Basin	21,900	17,500	17,500	0	61,500	61,500	0	86,000
South Central Coast	165,000	132,100	81,200	50,900	308,200	188,800	119,400	266,000
Mojave Desert	101,000	81,000	60,000	21,000	289,000	213,800	75,200	300,000
Los Angeles vicinity 1/					20,000			20,000
Totals	2,121,600	1,700,200	1,081,300	618,900	5,158,500	3,186,300	1,952,200	4,494,000

1/ Supplemental irrigation supply.

Colorado River replacement	1,080,000
Municipal releases	286,000
Total aqueduct releases	5,860,000

Table 15.--Water market summary (full development)

Area	Irrigation demand AF/yr.	Municipal and industrial demand AF/yr.	Total demand AF/yr.
Central Valley	3,941,000	None	3,941,000
San Francisco	436,700	225,000	661,700
Pajaro-San Benito	102,100	None	102,100
Lahontan Basin	61,500	10,000	71,500
Total Step 2	4,541,300	235,000	4,776,300
South Central Coast	308,200	51,000	359,200
Total Step 3	308,200	51,000	359,200
Mojave Desert	289,000	None	289,000
Southern California	1/ 20,000	None	20,000
Colorado River Exchange		2/ 1,212,000	2/ 1,212,000
Total Step 4	309,000	1,212,000	1,521,000
Grand Total	5,158,500	1,498,000	6,656,500

1/ Supplemental supply.
2/ Use not determined. See Paragraph 17, "Report of the Chief."

Table 16.--Aqueduct lengths in miles

Segment	Step 1/	Canal	Tunnel	Total
rinity Tunnel	1 & 2	0	60	60
ain Aqueduct	2	214	0	214
an Francisco Branch-North	2	145	2	147
an Francisco Branch-South	2	164	8	172
ajaro-San Benito Branch	2	123	6	129
an Joaquin Foothills Branch	2	82	1	83
ahontan Unit	2	12	12	24
Subtotal	1 & 2	740	89	829
ehachapi Tunnel	3	0	40	40
ain Aqueduct	3	132	5	137
outh Central Coastal Basin and Santa Clara Basin Branches	3	251	32	283
Subtotal	3	383	77	460
imi Tunnel	4	0	8	8
an Gabriel Tunnels	4	0	27	27
an Jose Tunnels	4	0	16	16
ain Aqueduct	4	98	5	103
ojave Unit	4	20	0	20
Subtotal	4	118	56	174
Grand Total		1,241	222	1,463

/ See Plate 19 for explanation of steps.

Table 17.--Major Tunnels

Name	Length (miles)	Diameter (ft.)	Lining thickness (in.)	Invert elevation		Capacity (c.f.s.)
				Inlet	Outlet	
·inity	59.8	37	25	570	465	9,175
›hachapi	40.5	22	17	680	592	2,700
ımi	8.2	20.5	16	810	791	2,150
ın Gabriel	26.7	19.5	16	785	727	1,770
ın Jose	16.0	17.75	16	727	693	1,380

Table 18.--Dams

Dam	River	Type	Crest length (ft.)	Elev. top of dam	Elev. streambed	Elev. normal water surface	Gross reservoir capacity (acre-feet)	Spillway capacity (c.f.s.)	Location
Storage Dams									
Ah Pah	Klamath	Concrete	2,890	848	35	817	15,250,000	400,000	8 mi. SE of Klamath, Calif.
Meyers	Upper Truckee	Earthfill	3,000	6,460	6,300	6,445	230,000	17,000	4 mi. S of Lake Tahoe.
Diversion Dams									
Kirkwood	Caples Creek	Concrete	600		(Diversion dam, 20 ft. high)				16 mi. S of Lake Tahoe.
Rubicon	Rubicon	Concrete	380		(Diversion dam, 35 ft. high)				7 mi. W of Lake Tahoe.
Terminal Storage and Regulatory Dams									
Ah Pah Afterbay	Klamath	Concrete	850	55	30	55	2,000	400,000	7 mi. SE of Klamath, Calif.
Alamo	Alamo Creek	Earthfill	2,510	587	425	577	64,600	10,000	9 mi. NW of Livermore, Calif.
Redwood	(unnamed)	Earthfill	1,370	243	125	233	16,600	1,500	3 mi. W of Palo Alto, Calif.
Lake Chabot (Replacement) 1/	San Leandro Creek	Earthfill	2,280	356	200	346	104,200	20,000	2 mi. E of San Leandro, Calif.
San Luis (Enlargement) 2/	San Luis Creek	Earthfill	7,900	493	245	485	568,000	5,000	13 mi. W of Los Banos, Calif.
Pacheco	Pacheco Creek	Earthfill	1,170	490	345	481	29,300	51,000	14 mi. NE of Hollister, Calif.
Fagan	Fagan Canyon	Earthfill	1,620	526	340	516	17,700	3,700	1 mi. NW of Santa Paula, Calif.
San Antonio	San Antonio Creek	Earthfill	900	560	470	550	5,000	4,500	9 mi. N of Ventura, Calif.
Zaca	Zaca Creek	Earthfill	2,230	498	390	480	20,400	18,000	15 mi. E. of Lompoc, Calif.
Berros	Los Berros Canyon	Earthfill	1,830	422	290	410	11,800	9,000	4 mi. SW of Arroyo Grande, Calif.
Brea	La Brea Canyon	Earthfill	850	840	740	830	3,200	2,000	16 mi. SE of Santa Paula, Calif.

1/ Existing features of Eastbay Municipal Utilities District to be replaced by larger dam.
2/ Proposed Central Valley feature.

Table 15.--Pump plants

Name	Location	Static pump lift (feet)	Ultimate installed capacity (kilowatts)	Required hydraulic capacity 1/ (c.f.s.)
	Main aqueduct plants			
Antioch	2 mi. SE of Antioch, Calif.	100	91,000	7,000
Byron	8 mi. NW of Tracy, Calif.	79	63,000	6,100
Volta	5 mi. SW of Volta, Calif.	151	119,000	6,000
Avenal	15 mi. S of Kettleman City, Calif	140	72,000	3,500
Buena Vista	3 mi. SE of Buena Vista Lake	77	27,000	2,750
Tehachapi	23 mi. S of Bakersfield, Calif.	222	84,000	2,750
Sulphur	5 mi. E of Santa Paula, Calif.	242	72,000	2,350
Lake Mathews	3 mi. SE of Corona, Calif.	2/ 667	100,000	1,120
Riverside	4 mi. E of Riverside, Calif.	248	7,800	240
	Service plants			
Rio Vista	1 mi. N of Rio Vista, Calif.	55	4,500	670
Vanden	4 mi. NE of Fairfield, Calif.	78	6,000	670
Port Chicago	1 mi. S of Port Chicago, Calif.	130	10,200	610
Lime Ridge	3 mi. SE of Concord, Calif.	143	11,400	610
Shell Ridge	7 mi. S of Concord, Calif.	222	6,300	220
Redwood	3 mi. W of Palo Alto, Calif.	39	275	53
San Luis	8 mi. W of Los Banos, Calif.	188	78,000	3,000
Kettleman	16 mi. S of Kettleman, Calif.	92	9,000	760
Sawtooth	5 mi. SW of Devils Den, Calif.	288	30,000	760
Sacramento Valley #1	(hypothetical)	25	6,900	2,100
Sacramento Valley #2	(hypothetical)	75	21,000	2,100
Ojai	1 mi. S of Ojai, Calif.	252	300	9
San Antonio	2½ mi. SW of Ojai, Calif.	160	240	12
Brea	17 mi. SE of Santa Paula, Calif.	170	2,100	90
San Fernando	3 mi. S of San Fernando Reservoir	294	10,800	270

1/ Pumping installations, in general, provide for an additional 20% standby capacity.
2/ Accomplished in two lifts--50,000 kw. pumping installation at each station.

Table 20.--Power plants

Plant	Location	Rated head (feet)	Installed capacity (kilowatts)
Pah	8 mi. SE of Klamath, Calif.	660	540,000
shoe	2 mi. S of Franktown, Nev.	975	18,600
eamboat	11 mi. S of Reno, Nev.	574	11,000
ble Mountain 1/	10 mi. NE of Red Bluff, Calif.	152	215,000
on Canyon 1/	6 mi. NE of Red Bluff, Calif.	42	55,000

Additions to Central Valley Project Plants.

	(0-5 yrs.)	(5-10 yrs.)	(10-15 yrs.)	(15-20 yrs.)	[illegible]
Ah Pah Dam and Afterbay	$ 605,500,000	$ ---	$ ---	$ ---	$ 605,500,000
Alamo Dam	---	8,800,000	---	---	8,800,000
Lake Chabot Dam	---	9,300,000	---	---	9,300,000
Redwood Dam	---	3,000,000	---	---	3,000,000
San Luis Dam (Enlargement)	---	38,300,000	---	---	38,300,000
Pacheco Dam	---	7,000,000	---	---	7,000,000
			7,900,000	---	7,900,000
					2,000,000

Feature	Cost increments by steps				Total
	Step 1 (0-5 yrs.)	Step 2 (5-10 yrs.)	Step 3 (10-15 yrs.)	Step 4 (15-20 yrs	
Ah Pah Dam and Afterbay	$ 605,500,000	$ ---	$ ---	$ ---	$ 605,500,000
Alamo Dam	---	8,800,000	---	---	8,800,000
Lake Chabot Dam	---	9,300,000	---	---	9,300,000
Redwood Dam	---	3,000,000	---	---	3,000,000
San Luis Dam (Enlargement)	---	38,300,000	---	---	38,300,000
Pacheco Dam	---	7,000,000	---	---	7,000,000
Fagan Dam	---	---	7,900,000	---	7,900,000
San Antonio Dam	---	---	2,000,000	---	2,000,000
Zaca Dam	---	---	6,300,000	---	6,300,000
Berros Dam	---	---	4,200,000	---	4,200,000
Brea Dam	---	---	2,200,000	---	2,200,000
Meyers Dam	---	15,800,000	---	---	15,800,000
Regulatory Storage in Central Valley	---	21,300,000	---	---	21,300,000
Main Aqueduct	---	139,000,000	86,000,000	47,000,000	272,000,000
Washoe Aqueduct	---	5,400,000	---	---	5,400,000
Lahontan Diversion Works	---	13,700,000	---	---	13,700,000
Major Tunnels	400,000,000	401,200,000	261,200,000	201,600,000	1,264,000,000
Irrigation Distribution Systems	---	448,400,000	95,700,000	20,100,000	564,200,000
Project Drainage	---	93,700,000	9,400,000	5,100,000	108,200,000
Aqueduct Pumping Plants 1/	---	30,000,000	19,900,000	55,100,000	105,000,000
Service Pumping Plants 1/	---	15,800,000	7,300,000	17,400,000	40,500,000
Ah Pah Power Plant	46,500,000	---	---	---	46,500,000
Table Mountain Power Plant 1/	---	7,900,000	4,100,000	7,600,000	19,600,000
Iron Canyon Power Plant 1/	---	4,700,000	2,500,000	4,600,000	11,800,000
Washoe Power Plant	---	3,200,000	---	---	3,200,000
Steamboat Power Plant	---	1,600,000	---	---	1,600,000
Transmission Lines	65,500,000	36,400,000	---	---	101,900,000
Ground Water Pumping Power Distrib. 1/	---	1,600,000	200,000	2,100,000	3,900,000
Total	$1,117,500,000	$1,306,100,000	$ 508,900,000	$ 360,600,000	$3,293,100,000

1/ Pumping and Power Plant costs following Step 4 have been included in Step 4.

Feature	Cost increments by steps				Total
	Step 1 (5-120 yrs)	Step 2 (10-120 yrs)	Step 3 (15-120 yrs)	Step 4 (20-120 yrs)	
Ah Pah Dam and After Bay	$ 48,500	$ ---	$ ---	$ ---	$ 48,500
Alamo Dam	---	2,800	---	---	2,800
Lake Chabot Dam	---	3,600	---	---	3,600
Redwood Dam	---	1,400	---	---	1,400
San Luis Dam (Enlargement)	---	8,000	---	---	8,000
Pacheco Dam	---	2,000	---	---	2,000
Fagan Dam	---	---	1,300	---	1,300
San Antonio Dam	---	---	700	---	700
Zaca Dam	---	---	1,600	---	1,600
Berros Dam	---	---	1,200	---	1,200
Brea Dam	---	---	700	---	700
Meyers Dam	---	5,600	---	---	5,600
Regulatory Storage in Central Valley	---	8,700	---	---	8,700
Main Aqueduct	---	1,560,000	735,400	311,000	2,606,400
Washoe Aqueduct	---	12,300	---	---	12,300
Lahontan Diversion Works	---	11,900	---	---	11,900
Major Tunnels	---	404,000	132,100	103,000	639,100
Irrigation Distribution Systems	---	4,829,000	1,045,800	210,000	6,084,800
Project Drainage	---	937,900	94,000	51,000	1,082,900
Aqueduct Pumping Plants 1/	---	365,000	248,000	697,000	1,310,000
Service Pumping Plants 1/	---	195,000	98,000	230,000	523,000
Ah Pah Power Plant	582,000	---	---	---	2/ 582,000
Table Mountain Power Plant 1/	---	99,000	52,000	96,000	247,000
Iron Canyon Power Plant 1/	---	59,000	31,000	58,000	148,000
Washoe Power Plant	---	40,000	---	---	40,000
Steamboat Power Plant	---	20,000	---	---	20,000
Transmission Lines	840,000	614,000	---	---	1,454,000
Ground Water Pumping Power Distrib. 1/	---	20,000	3,000	27,000	50,000
Sacramento River Maintenance	---	150,000	---	---	150,000
Total	$1,470,500	$9,349,200	$2,444,800	$1,783,000	$15,047,500

1/ Pumping and Power Plant costs following Step 4 have been included in Step 4.

2/ Following year 40 operation and maintenance for Ah Pah Power Plant decreases to $194,000 annually.

Feature	Cost increments by steps				Total
	Step 1 (5-120 yrs)	Step 2 (10-120 yrs)	Step 3 (15-120 yrs)	Step 4 (20-120 yrs)	
Ah Pah Dam and After Bay	$ 109,300	$ ---	$ ---	$ ---	$ 109,300
Alamo Dam	---	1,800	---	---	1,800
Lake Chabot	---	1,900	---	---	1,900
Redwood Dam	---	600	---	---	600
San Luis Dam (Enlargement)	---	8,000	---	---	8,000
Pacheco Dam	---	1,400	---	---	1,400
Fagan Dam	---	---	1,600	---	1,600
San Antonio Dam	---	---	400	---	400
Zaca Dam	---	---	1,300	---	1,300
Berros Dam	---	---	900	---	900
Brea Dam	---	---	500	---	500
Meyers Dam	---	3,300	---	---	3,300
Regulatory Storage in Central Valley	---	---	---	---	---
Main Aqueduct	---	220,000	96,200	56,000	372,200
Washoe Aqueduct	---	1,700	---	---	1,700
Lahontan Diversion Works	---	2,800	---	---	2,800
Major Tunnels	---	4,200	1,300	---	5,500
Irrigation Distribution Systems	---	147,800	39,900	8,000	195,700
Project Drainage	---	---	---	---	---
Aqueduct Pumping Plants 1/	---	110,000	74,000	215,000	399,000
Service Pumping Plants 1/	---	54,400	29,000	75,600	159,000
Ah Pah Power Plant	177,000	---	---	---	2/ 177,000
Table Mountain Power Plant 1/	---	30,000	16,000	28,000	74,000
Iron Canyon Power Plant 1/	---	18,000	9,000	18,000	45,000
Washoe Power Plant	---	12,000	---	---	12,000
Steamboat Power Plant	---	6,000	---	---	6,000
Transmission Lines	1,000,000	743,000	---	---	1,743,000
Ground Water Pumping Power Distrib. 1/	---	24,000	4,000	32,000	60,000
Total	$1,286,300	$1,390,900	$ 274,100	$ 432,600	$3,383,900

1/ Pumping and Power Plant costs following Step 4 have been included in Step 4.
2/ Following year 40 the replacement reserve for Ah Pah Power Plant decreases to $59,000 annually.

State	Annual energy requirements 1949 in millions of Kw. hrs.	Undeveloped average annual hydroelectric potential in millions of Kw. hrs. 1/	Approx. No. yrs. to absorb all hydroelectric potential 2/	Estimated tons of undeveloped bituminous and sub-bituminous coal reserves in millions of tons	Approximate No. yrs. one million Kw. could be generated continuously with estimated coal reserves 3/
Arizona	4/ 900	14,335	58	15,660	3,000
California	4/ 29,600	35,000	16	(5/)	---
Colorado	2,010	4,900	25	317,000	60,000
Idaho	1,890	49,000	65	(5/)	---
Montana	2,950	20,000	42	65,500	13,000
Nevada	4/ 300	1,135	32	(5/)	---
New Mexico	1,130	815	11	20,000	4,000
Oregon	5,670	37,000	42	1,500	300
Texas	14,930	2,300	3	8,000	1,600
Utah	2,000	5,950	28	93,000	18,000
Washington	15,980	84,000	38	63,600	12,000
Wyoming	640	4,350	42	670,000	120,000
Total	78,000	258,785	30 (Avg.)	1,253,060	231,900

1/ Physically feasible, but not necessarily economical in comparison with thermal power development.
2/ Assuming a 5% compounded rate of load growth and load increases met entirely by hydroelectric power.
3/ Assuming reserves used entirely for generation of electrical energy. Plant conversion efficiency assumed 26.5%
4/ Estimate based on combined generation in Arizona, California and Nevada.
5/ Known reserves inadequate to justify their development for power generation.

Table 25.--Average acres irrigated, water deliveries, total disbursements and cost per acre-foot in selected California water users organizations, 1945-47 1/

Water users organization	Average No. acres irrigated 3/	Total acre-feet delivered	Total disbursements 2/	Average cost per acre-foot
Beaumont	2,238	11,492	$ 275,524	$23.98
Carpenter	1,200	5,560	105,370	18.95
Carmichael	No record	13,407	163,199	12.17
Hollister	15,500	2,596	35,391	13.63
Lindsay-Strathmore	10,479	50,493	737,749	14.61
Newport Heights	200	3,428	85,182	24.85
Oroville-Wyandotte	4,326	14,355	358,949	25.01
Paradise	3,207	8,140	496,108	60.95
Ramona	160	1,100	58,095	30.09
San Dieguito	1,759	8,092	524,546	64.82
Santa Fe	2,472	8,758	501,922	57.31
San Ysidro	500	1,784	35,572	19.94
Serrano	1,305	6,176	68,904	11.16
Terra Bella	2,283	22,158	601,451	27.14
Vandalia	1,120	6,070	203,367	33.50
Vista	7,764	31,206	1,307,924	41.91
Total	54,513	194,815	$5,559,253	$28.54

1/ Computed from unpublished data compiled by individual water users organizations and filed with the California State Division of Water Resources.
2/ Items included are: administration, operation and maintenance, debt retirement, capital outlays, and miscellaneous.
3/ Annually.

Table 26.--Retail municipal water rate in 40 cities

City and state	Population	Percent metered	Gallons per capita per day	Cost per acre-foot dollars
Beckley W. Va.	35,000	96	486	202
Mt. Pleasant, Mich.	12,000	100	83	174
Cedartown, Ga.	11,000	100	136	174
Boonville, Mo.	7,000	100	114	163
Grand Forks, N. D.	25,000	100	90	163
Tyler, Texas	43,500	100	78	163
Newark, New Jersey	440,000	98	184	152
Schuylkill Haven, Pa.	9,000	100	78	147
Roanoke, Virginia	72,000	100	104	139
Austin, Texas	140,000	100	118	131
Niles, Ohio	20,000	100	240	131
Chanute, Kansas	11,000	100	102	131
Petersburg, Va.	40,000	100	100	131
Hamilton, Ohio	60,000	100	93	131
Perth Amboy, N. J.	60,000	95	158	130
Oak Park, Illinois	72,000	100	76	130
Wichita Falls, Texas	70,000	100	100	124
Mason City, Iowa	30,000	100	67	122
Oklahoma City, Okla.	260,000	100	82	121
Ossining, New York	14,000	100	79	118
San Francisco, Calif.	800,000	100	128	113
Galveston, Texas	81,000	99	140	109
Herkimer, New York	12,000	1	167	109
Milford, Connecticut	30,000	52	133	109
Dallas, Texas	450,000	100	107	108
Gaffney, S. C.	12,000	94	67	107
Augusta, Georgia	110,000	100	109	98
Bartlesville, Okla.	20,000	98	63	98
Lincoln, Illinois	12,752	100	274	96
New Kensington, Pa.	40,000	100	118	91
Tuscaloosa, Ala.	50,000	100	120	91
Bellevue, Ohio	6,969	100	215	87
East Orange, N. J.	75,000	99	83	87
Ashland, Wisconsin	11,000	62	159	87
Mt. Vernon, New York	75,000	100	75	87
Fairburg, Nebraska	7,000	100	229	87
Jackson, Miss.	100,000	100	90	87
Covington, Kentucky	99,000	90	96	87
Monrovia, California	18,000	100	222	83
Paris, Tennessee	10,000	86	75	81

Data taken from Modern Water Rates and Sewer Service Charges, issued June, 1949 by the American City Magazine.

Table 27.--Cost of wholesale water for various
U. S. towns and cities
(Arranged by price per acre-foot)

City	Price
1. Lake Side, California	1/ $121
2. San Diego, California	93
3. Elizabeth, New Jersey	89
4. La Canada, California	1/ 79
5. Caldwell, New Jersey	75
6. North Brunswick, New Jersey	60
7. Oklahoma City, Oklahoma	59
8. Yonkers, New York	56
9. Dallas, Texas	55
10. Akron, Ohio	54
11. Des Moines, Iowa	52
12. Omaha, Nebraska	52
13. Fort Wayne, Indiana	50
14. Portland, Oregon	49
15. Tulsa, Oklahoma	47
16. Houston, Texas	45
17. New Bedford, Massachusetts	45
18. Long Beach, California	43
19. Memphis, Tennessee	43
20. St. Paul, Minnesota	41

Source: 1/ Statistical Data, California Division Water Resources Average 1944, 1945, and 1946.

All other data taken from--Report North Jersey Water Supply Commission, Newark, New Jersey, No. 7, Volume 31, 1939, Journal American Water Works Association.

Table 28.--Summary of measured benefits

Item	Annual equivalent benefits 1/
·igation and municipal water	
·an Francisco	$ 42,997,000
·ajaro-San Benito	7,125,000
·entral Valley	85,000,000
·ahontan Basin	1,150,000
Subtotal Step 2	$136,000,000
·outh Central Coast	21,600,000
Subtotal Step 3	$ 21,600,000
·ojave Desert	4,600,000
·upplemental Supply	1,556,000
Subtotal Step 4	$ 6,200,000
Total irrigation and municipal	$164,000,000
·er and pumping	
·et energy	$ 4,180,000
·peration and maintenance savings	2/ 168,000
Total power benefits	$ 4,348,000
·er	
·olorado River and Los Angeles Aqueduct maintenance savings on canals and tunnels	413,000
Grand total	3/$170,000,000

·All anticipated benefits to project year 120 capitalized as of project year 0 and amortized over 100 years with 2½ percent.
·On discontinuance of Colorado River and Los Angeles Aqueduct pumping equipment. Energy saving included in "Net energy."
·Rounded.

Table 28a.--Summary of direct and indirect irrigation benefits by areas
(Project fully developed)

	Annual benefits 1/		
	Direct	Indirect	Total
tep 2			
San Francisco	$ 16,486,000	$ 36,448,000	$ 52,934,000
Pajaro-San Benito	2,840,000	9,279,000	12,119,000
San Joaquin	78,944,000	65,796,000	144,740,000
Newlands	553,000	408,000	961,000
Subtotal	$ 98,823,000	$111,931,000	$210,754,000
tep 3			
South Central Coastal	11,903,000	25,400,000	37,300,000
Subtotal	$ 11,903,000	$ 25,400,000	$ 37,300,000
tep 4			
Southern California	1,025,000	2,512,000	3,537,000
Antelope Valley	4,560,000	5,891,000	10,451,000
Subtotal	$ 5,585,009	$ 8,403,000	$ 13,988,000
Grand total	$116,311,000	$145,734,000	2/$262,000,000

' Does not include municipal water benefits, nor benefits from use of 1,212,000 acre-feet per year released in Colorado River Basin.
' Rounded.

Project	Case 1		Case 2	
	Present worth	Annual equivalent	Present worth	Annual equivalent
Colorado River Aqueduct	[illegible]	($6,023,000)	($220,618,000) [illegible]	($6,023,000) 132,000 [illegible]

Table 28b.--Credits from reduced operation, maintenance, and replacement reserve on projects affected by Northern California Diversion 1/

Project	Case 1		Case 2	
	Present worth	Annual equivalent	Present worth	Annual equivalent
Colorado River Aqueduct				
Pumping energy 2/	($220,618,000)	($6,023,000)	($220,618,000)	($6,023,000)
Pumping stations	4,830,000	132,000	4,830,000	132,000
Canals and tunnels	10,289,000	281,000	10,289,000	281,000
Subtotal	$ 15,119,000	$ 413,000	$ 15,119,000	$ 413,000
Los Angeles Aqueduct				
Power plants	1,219,000	33,000	1,219,000	33,000
Canals and tunnels	4,943,000	135,000	4,943,000	135,000
Subtotal	$ 6,162,000	$ 168,000	$ 6,162,000	$ 168,000
Silver Fork-Rubicon-American Rivers (13 projects affected)	0	0	0	0
Klamath-Salmon-Trinity Rivers (7 inundated projects)				
Power plants	0	0	27,700,000	756,000
Dams and reservoirs	0	0	61,700,000	1,685,000
Subtotal	0	0	$ 89,400,000	$2,441,000
Grand Total	$ 21,281,000	$ 581,000	$110,681,000	$3,022,000

1/ Computed on basis of 1950 cost level.
2/ Deducted from required generation and not evaluated as a separate benefit.

Item	Basic assumption No. Calif. Diversion	Alternative possible conditions - No. Calif. Diversion		
		Primary market southern California	Case 2 power impairment	1939-1944 price level
Costs:				
Grand total construction costs (simple addition)	$3,293,000,000	$3,413,000,000	$3,293,000,000	$2,106,000,000
Capitalized construction cost (discounted at 2½% to present worth, year 0)	2,705,000,000	2,782,000,000	2,705,000,000	1,733,000,000
Capitalized operation, maintenance, and replacement costs (discounted at 2½% to present worth, year 0)	541,000,000	562,000,000	905,000,000	332,000,000
Capitalized total, all project costs (discounted at 2½% to present worth, year 0)	3,246,000,000	3,344,000,000	3,610,000,000	2,065,000,000
Total uniform annual equivalent cost (amortized at 2½% over 100 years)	89,000,000	91,000,000	99,000,000	56,000,000
Cost per acre-foot to amortize capitalized total cost in accordance with the time and quantity of scheduled water deliveries (2½% interest)	$25	$25	$27	$16
Benefits:				
Capitalized values all project benefits (discounted at 2½% to present worth, year 0)	6,212,000,000	8,500,000,000	5,495,000,000	6,212,000,000
Total uniform annual equivalent benefit (amortized at 2½% interest over 100 years)	170,000,000	233,000,000	164,000,000	170,000,000
Ratio of benefits to costs	1.9 to 1	2.6 to 1	1.6 to 1	3.0 to 1

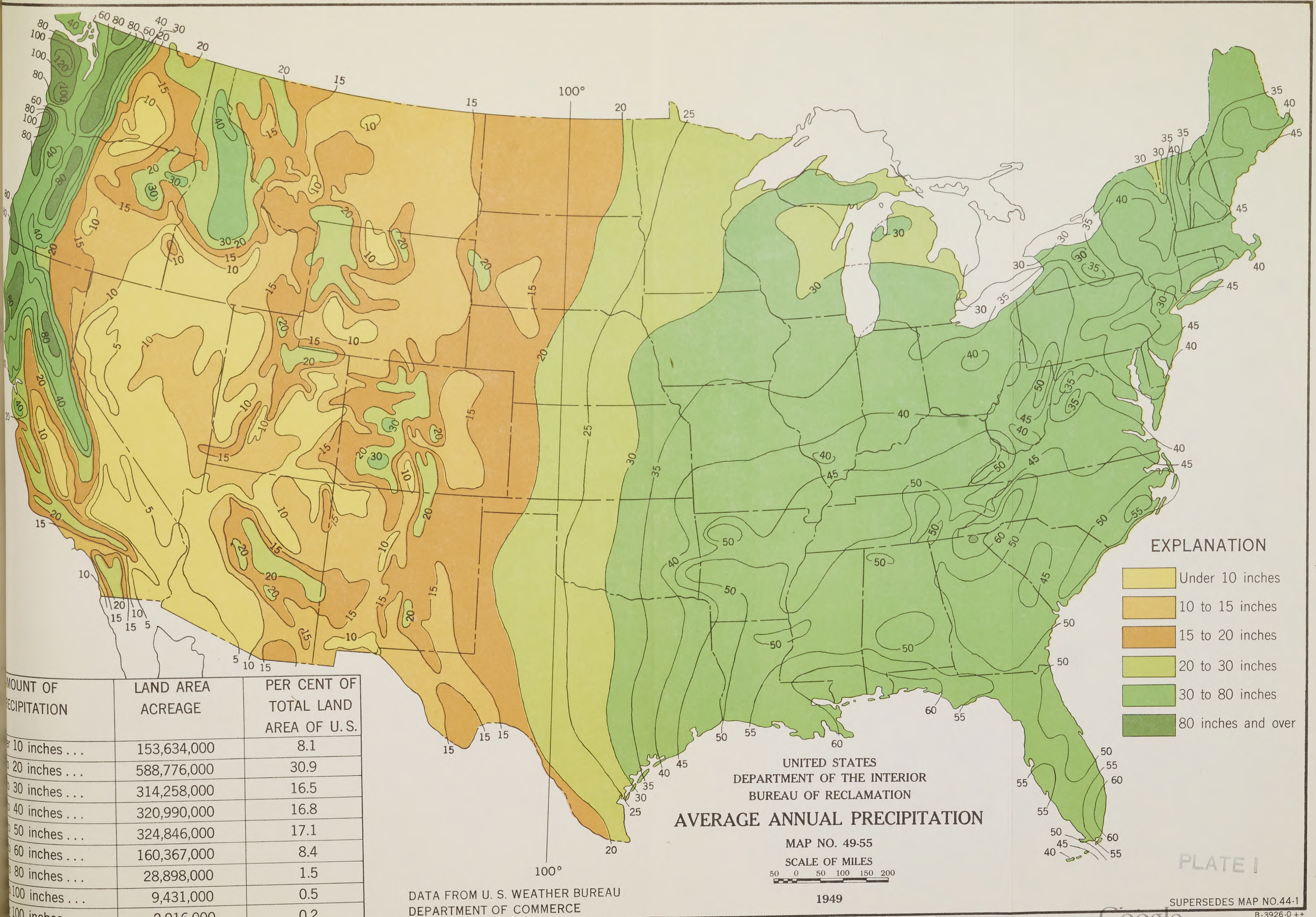
Note: Costs based on 1950 level, except as indicated. Benefits based on 1939-44 level in all cases.

TABLE 30 - POSSIBLE PROJECTS

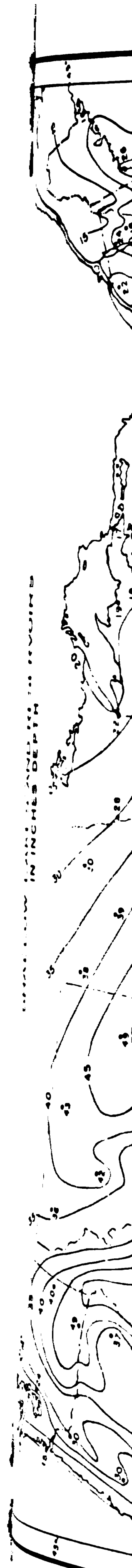
State benefited	State plan No. 1/	Made possible by U. W. I. General Project No. 2/	Area benefited	Water use	Source of water: Direct	Source of water: Indirect 4/	Remarks
ARIZONA	AR-1	I, II, & III	Maricopa & Yuma Counties	Irrig., Municip., & Ind.	Colorado River)	Northwest streams 5/	Exchange in So. California
"	AR-2	I, II, & III	Headwaters Gila River	Mining, milling, & mfg.	Colorado River)		
CALIFORNIA	CAL-1	I, II, & III	Owens, Panamint, & Death Valleys	Irrig., Municip., & Ind.	San Joaquin, Kings &) Kern Rivers)	Northwest streams 5/	(Exchange in Central (Valley and Trans-Sierra (Diversion of Direct (Source.
"	CAL-2	I, II, & III	Honey Lake Basin	Primarily Irrig.	Pacific slope Sierra) Nevada streams)		
COLORADO	COLO-GEN.	I, II, & III	To be determined	Irrig., Municip., & Ind.	Upper Colorado tributaries	Northwest streams 5/	Exchange in So. California
IDAHO	IDA-1	IV 3/	Snake & Bear River Basins	Irrig., Municip., & Ind.	Snake & Bear Rivers	Salmon River	
"	IDA-2	VII	Snake River Basin	Irrig., Municip., & Ind.	Snake River	S. Fk. Yellowstone River	(Water replacement to (Missouri River Basin from (Clark's Fork or Clearwater (tributaries.
MONTANA	MONT-GEN.	X	Missouri River Basin	Irrig., Municip., & Ind.	Missouri River and tributaries	West slope Montana Rivers	(U. W. I. would compensate (for Columbia River power (impairment.
NEVADA	NEV-1	I, II, & III	Truckee River Basin	Irrig., Municip., & Ind.	N. Fork American & Yuba) Rivers)		
"	NEV-2	I, II, & III	Truckee and Carson Rivers	Irrig., Municip., & Ind.	Tributaries of South &) Middle Forks American) River)	Northwest streams 5/	(Exchange in Central Valley (and Trans-Sierra Diversion (of Direct Source.
"	NEV-3	I, II, & III	Carson River Basin	Primarily Irrig., incidental Municip. & Industrial	Mokelumne & Stanislaus) Rivers)		
"	NEV-4	I, II, & III	Carson River Basin	Primarily Irrig., incidental Municip. & Industrial	South Fork of American) River & tributaries)		
"	NEV-5		Statewide - scattered	Irrigation	Pumped underground water)		(Power for pumping would (be furnished by U.W.I.
"	NEV-6	V 3/	Humboldt River Basin	Primarily Irrig., incidental Municip. & Industrial	Owyhee & Bruneau Rivers) in Nevada	Salmon River via Snake River	
NEW MEXICO	NM-1	I, II, & III	N.W. & Central New Mexico	Irrig., Municip., & Ind.	High altitude Colorado) River tributaries)	Northwest streams 5/	Multiple Exchange
OREGON	ORE-1	I	John Day River Basin	Irrigation	Pend Oreille) River at Albeni Falls)		
"	ORE-2	VI	Lake County	Irrigation	Klamath River		(Klamath River power im- (pairment would be offset (by U. W. I. power
TEXAS	TEXAS-GEN.	I, II, & III	Rio Grande Basin	Irrig., Municip., & Ind.	Mexican tributaries of) Rio Grande)	Northwest streams 5/	(Exchange for U.W.I. water (delivered to northern Baja (California.
UTAH	UTAH-1	VII	Great Basin	Irrig., Municip., & Ind.	Bear River	(S. Fk. Yellowstone River (via Snake River	(Water replacement to (Missouri River Basin (from Clark Fork or Clear- (water River tributaries.
"	UTAH-2	VIII	Great Basin	Irrig., Municip., & Ind.	Bear River		(Bear River power loss (would be replaced by U.W.I.
"	UTAH-3	IV 3/	Great Basin	Irrig., Municip., & Ind.	Bear River	Salmon River via Snake River	
"	UTAH-4	IX 3/	Green River Basin	Irrig., Municip., & Ind.	Green River	Salmon River via Snake River	
"	UTAH-GEN.	I, II, & III	To be determined	Irrig., Municip., & Ind.	Upper Colorado River) tributaries)	Northwest streams 5/	Exchange in So. California
WASHINGTON	WASH-1	I	Grand Coulee, Dayton, Umatilla areas	Irrigation	Pend Oreille) River at Albeni Falls)		
WYOMING	WYO-GEN.	I, II, & III	To be determined	Irrig., Municip., & Ind.	Upper Colorado River) tributaries)	Northwest streams 5/	Exchange in So. California

1/ Designation and order in which individual project descriptions are arranged in Appendix V-"A".
2/ Indicates general U.W.I. Projects, usually applicable to more than one state, which make the individual state plans possible. Refer to Appendix V-"B" for description of General Projects. Where more than one general project number is listed adjacent to a state plan, the general projects are alternative.
3/ Inter-Regional study of these projects has been deferred because it appears that neither the Snake River nor the Salmon River could provide a surplus to the ultimate needs of the Snake River Basin at appropriate elevations for export. Further study of these projects will be warranted only if future investigations indicate that surplus water can be made available.
4/ Where "Indirect" source is shown, it would make possible exchanges which would release "Direct" source for the use proposed.
5/ Includes the source streams for U.W.I. Projects I, II, or III.

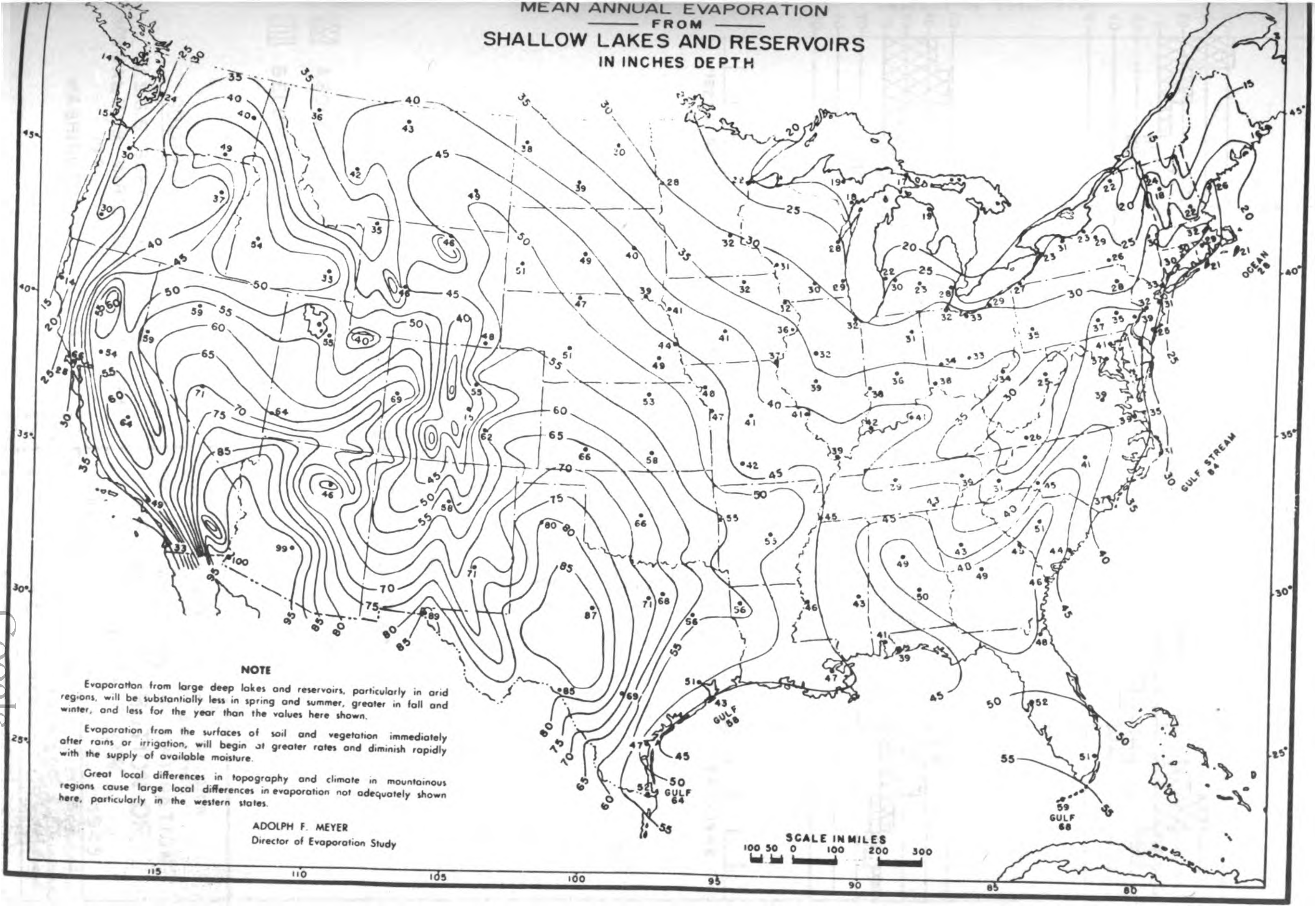
Source for I: Pend Oreille River at Albeni Falls.
Source for II: Columbia River below Bonneville Dam.
Source for III: One or more of Klamath, Rogue, Umpqua, Chetco, Smith Rivers, and their tributaries, and possibly other streams of the North Coast Range.



MOUNT OF ECIPITATION	LAND AREA ACREAGE	PER CENT OF TOTAL LAND AREA OF U.S.
r 10 inches . . .	153,634,000	8.1
20 inches . . .	588,776,000	30.9
30 inches . . .	314,258,000	16.5
40 inches . . .	320,990,000	16.8
50 inches . . .	324,846,000	17.1
60 inches . . .	160,367,000	8.4
80 inches . . .	28,898,000	1.5
100 inches . . .	9,431,000	0.5
100 inches . . .	2,916,000	0.2


IN INCHES DEPTH

MEAN ANNUAL EVAPORATION
FROM
SHALLOW LAKES AND RESERVOIRS
IN INCHES DEPTH



NOTE

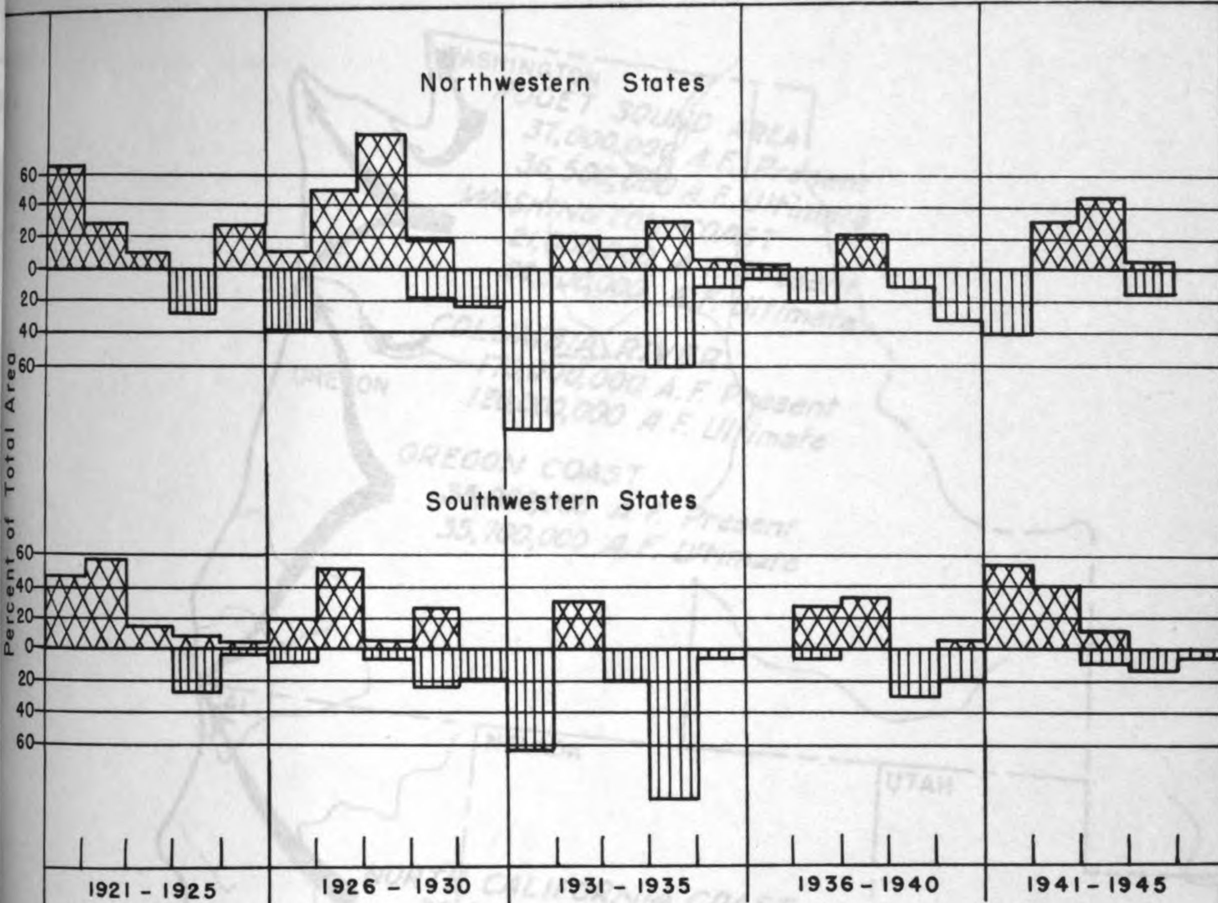
Evaporation from large deep lakes and reservoirs, particularly in arid regions, will be substantially less in spring and summer, greater in fall and winter, and less for the year than the values here shown.

Evaporation from the surfaces of soil and vegetation immediately after rains or irrigation, will begin at greater rates and diminish rapidly with the supply of available moisture.

Great local differences in topography and climate in mountainous regions cause large local differences in evaporation not adequately shown here, particularly in the western states.

ADOLPH F. MEYER
Director of Evaporation Study

Plate 2



Geographic divisions of United States

ABOVE NORMAL

BELOW NORMAL

SOURCE OF DATA

U.S.G.S. SUPPLEMENT NO.2
NORMALS & VARIATIONS IN RUNOFF
1921 – 1945
WASHINGTON, D.C. : 1949

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UNITED WESTERN INVESTIGATION

AREAL DISTRIBUTION OF STREAM FLOW

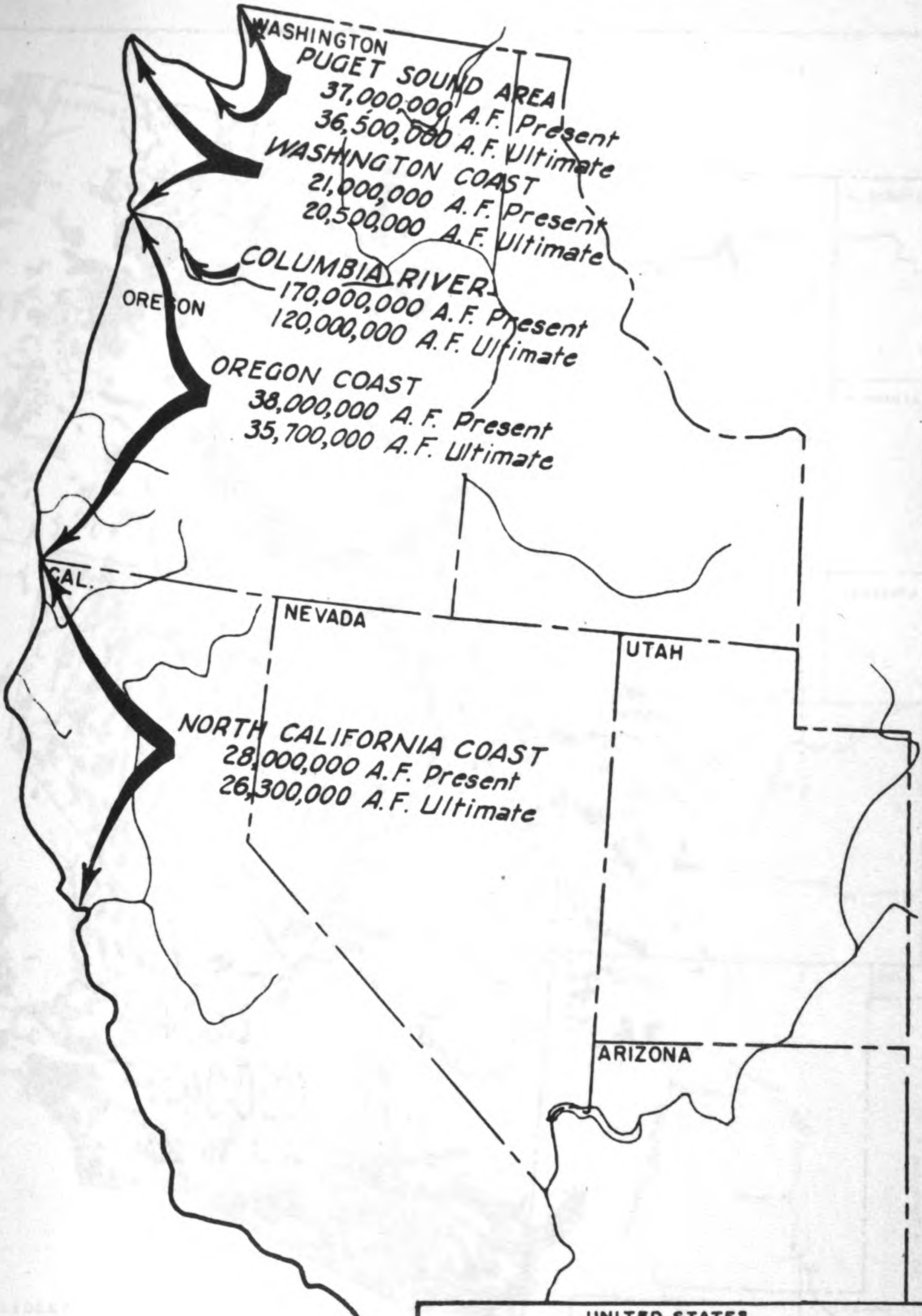
Western United States, 1921 – 1945

DRAWN D.R.K. ..... SUBMITTED
TRACED .... RECOMMENDED
CHECKED K.D.E. .. APPROVED

REVISED 12-3-50 JA

SALT LAKE CITY, UTAH 11/15/50

595-907-156



NOTES

All values are approximate.
"Ultimate" refers to conditions without U. W. project development.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UNITED WESTERN INVESTIGATION

ESTIMATED ANNUAL OUTFLOW TO OCEAN

REVISED 12-6-50 LB	DRAWN J.B.	SUBMITTED Kenneth D. Eak
	TRACED	RECOMMENDED J. M. Schaser
	CHECKED J.D.E.	APPROVED S.T. McCasland

SALT LAKE CITY, UTAH NOV 15, 1950 595-907-139

PLATE 4

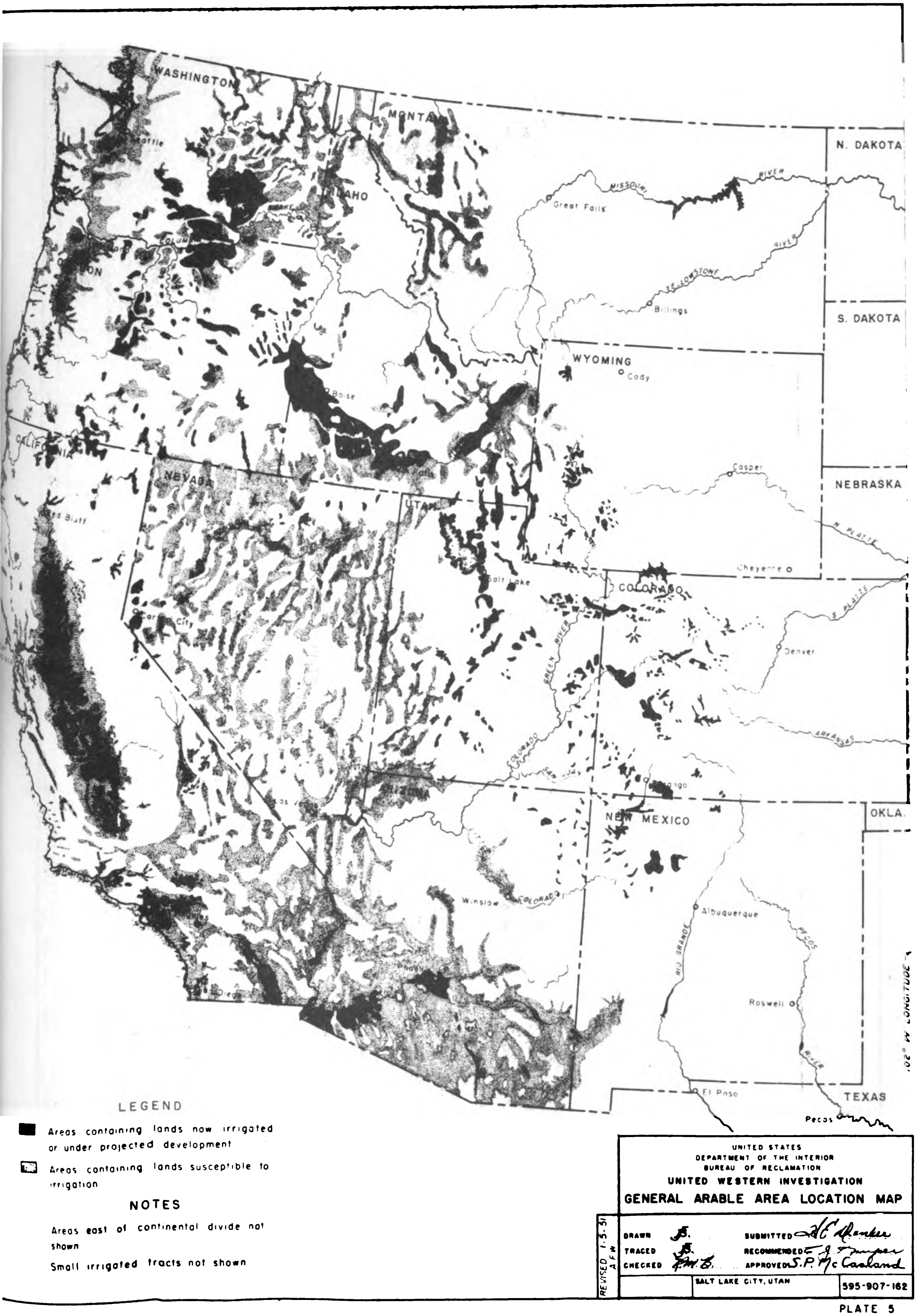

WASHINGTON
MONTANA
N. DAKOTA
IDAHO
Great Falls
MISSOURI RIVER
YELLOWSTONE RIVER
Billings
OREGON
S. DAKOTA
WYOMING
Cody
Boise
CALIFORNIA
NEVADA
Casper
NEBRASKA
UTAH
N. PLATTE
Cheyenne
Salt Lake
COLORADO
S. PLATTE
GREEN RIVER
Denver
ARKANSAS
COLORADO
SAN JUAN
ARIZONA
Durango
OKLA.
NEW MEXICO
Winslow
COLORADO
Albuquerque
RIO GRANDE
PECOS
Roswell
RIVER
El Paso
TEXAS
Pecos
102° W LONGITUDE
LEGEND
Areas containing lands now irrigated or under projected development
Areas containing lands susceptible to irrigation
NOTES
Areas east of continental divide not shown
Small irrigated tracts not shown
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UNITED WESTERN INVESTIGATION
GENERAL ARABLE AREA LOCATION MAP
REVISED 1-5-51 A.F.W.
DRAWN
TRACED
CHECKED
SUBMITTED
RECOMMENDED
APPROVED S.P. McCasland
SALT LAKE CITY, UTAH
595-907-162

PLATE 5

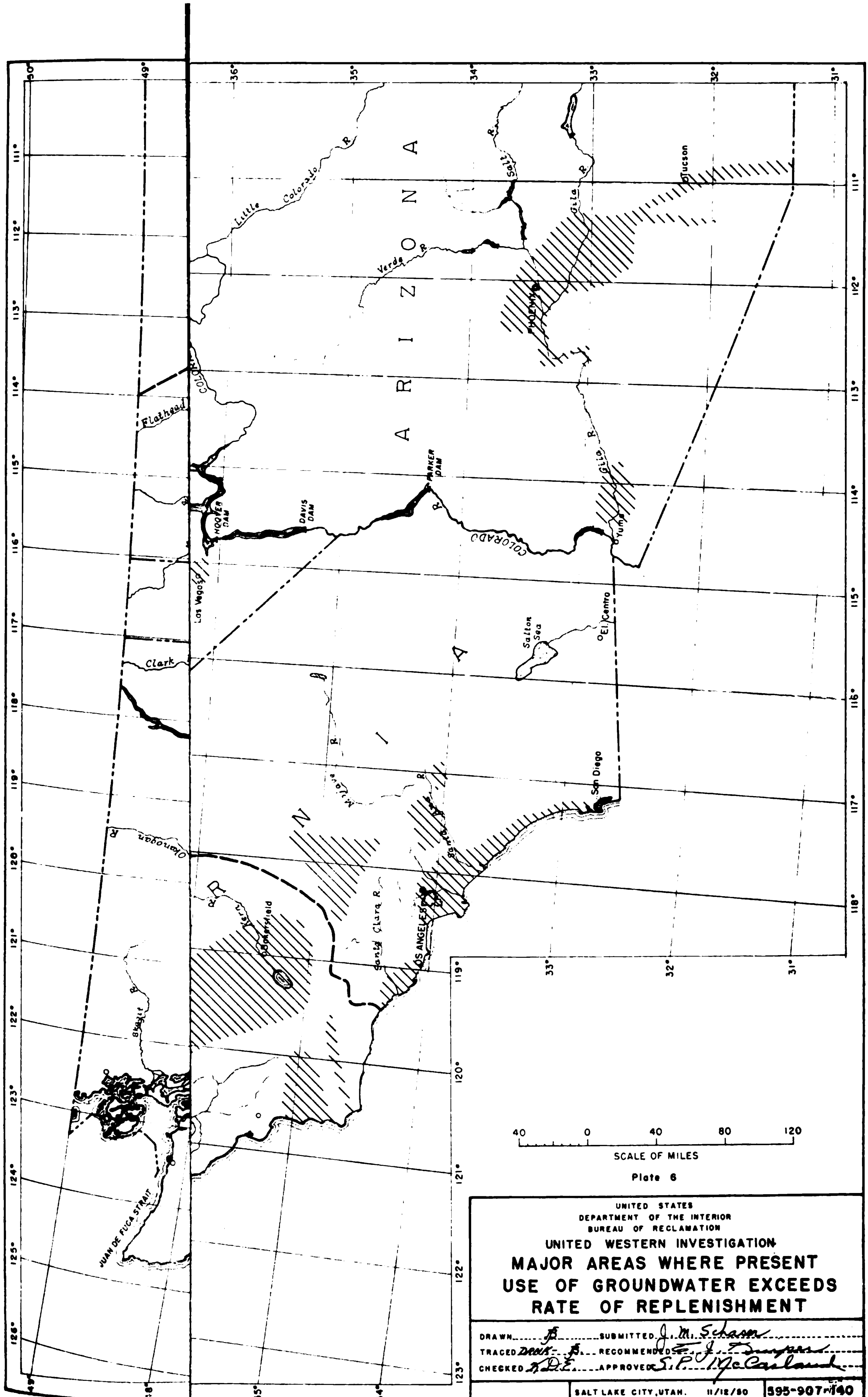


Plate 6

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

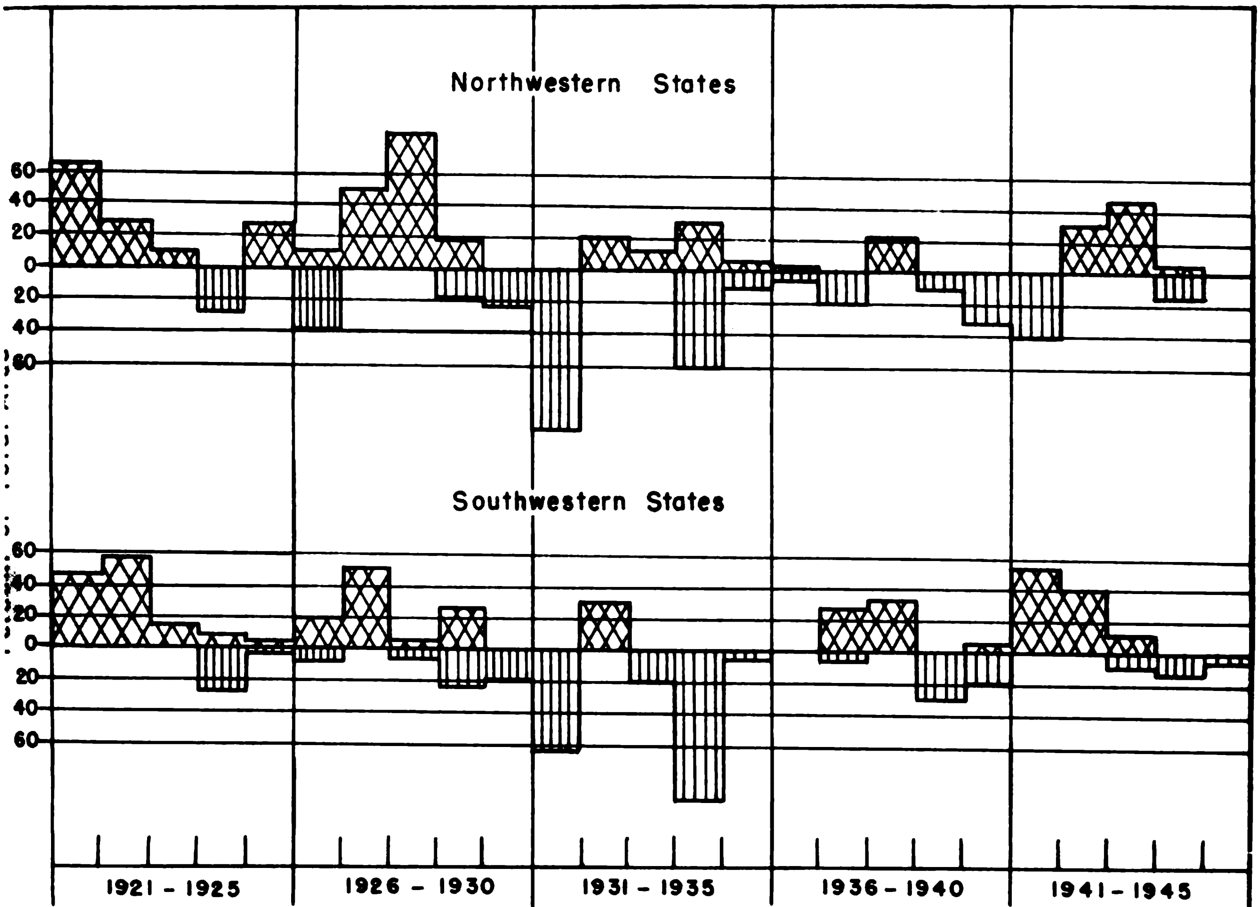
UNITED WESTERN INVESTIGATION

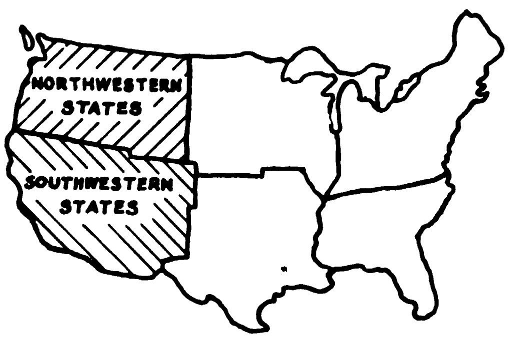
MAJOR AREAS WHERE PRESENT USE OF GROUNDWATER EXCEEDS RATE OF REPLENISHMENT

DRAWN B SUBMITTED J. M. Schaser
TRACED DWK B. RECOMMENDED E. J. Burger
CHECKED K.D.E. APPROVED S. P. McCasland

SALT LAKE CITY, UTAH. 11/12/50 595-907-140

U.B.N. S.L.C.U.- 1M -1-51





Geographic divisions of United States

ABOVE NORMAL

BELOW NORMAL

SOURCE OF DATA

U.S.G.S. SUPPLEMENT NO.2
NORMALS & VARIATIONS IN RUNOFF
1921 – 1945
WASHINGTON, D.C. ; 1949

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UNITED WESTERN INVESTIGATION

AREAL DISTRIBUTION OF STREAM FLOW

Western United States, 1921 – 1945

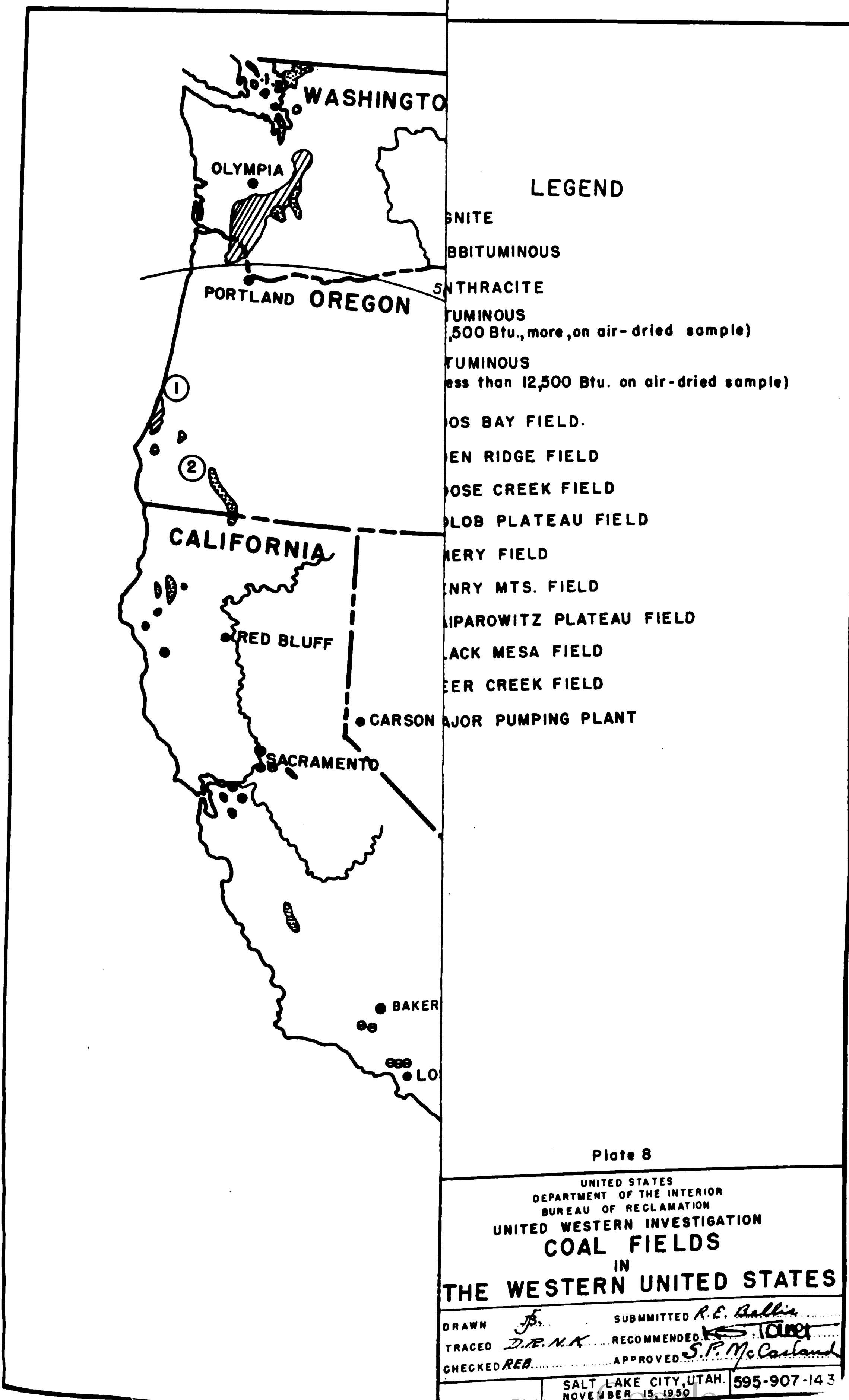
DRAWN D.R.K. ...... SUBMITTED ....
TRACED .... RECOMMENDED ....
CHECKED K.D.E. ... APPROVED ....

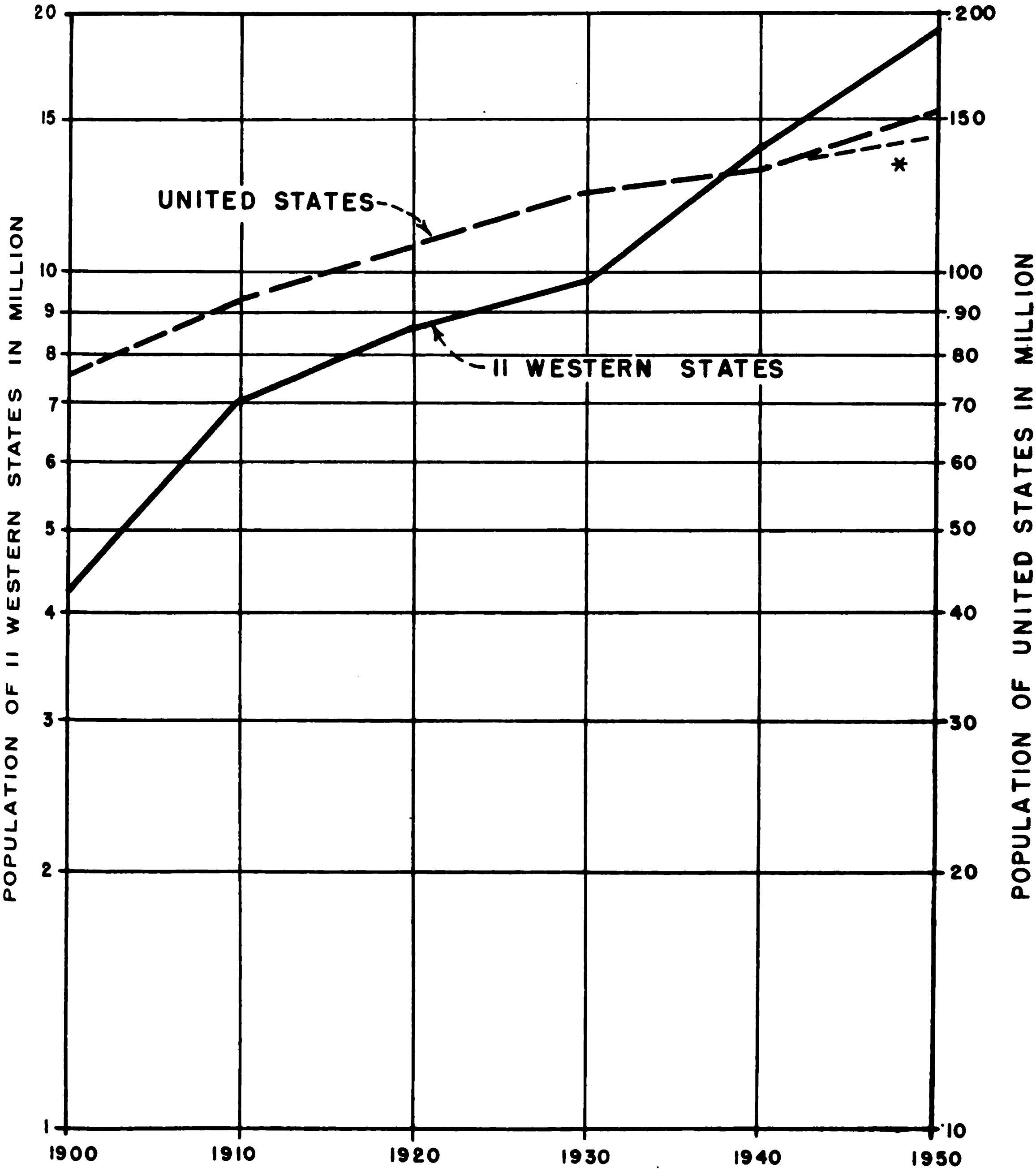
REVISED

SALT LAKE CITY, UTAH 11/15/50

595-907-156

Plate 3


WASHINGTO
OLYMPIA
PORTLAND
OREGON
CALIFORNIA
RED BLUFF
CARSON
SACRAMENTO
BAKER
LO
LEGEND
GNITE
BBITUMINOUS
NTHRACITE
TUMINOUS
,500 Btu., more, on air-dried sample)
TUMINOUS
ess than 12,500 Btu. on air-dried sample)
OS BAY FIELD.
EN RIDGE FIELD
OSE CREEK FIELD
LOB PLATEAU FIELD
IERY FIELD
NRY MTS. FIELD
IPAROWITZ PLATEAU FIELD
ACK MESA FIELD
EER CREEK FIELD
AJOR PUMPING PLANT
Plate 8
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UNITED WESTERN INVESTIGATION
COAL FIELDS
IN
THE WESTERN UNITED STATES
DRAWN
TRACED D.R.N.K.
CHECKED REB
SUBMITTED R.E. Ballis
RECOMMENDED
APPROVED S.P. McCasland
SALT LAKE CITY, UTAH.
NOVEMBER 15, 1950
595-907-143



* Forecast for 1950, taken from "Estimates of Future Population of the United States, 1940 - 2000." National Resources Planning Board, August 1943.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

UNITED WESTERN INVESTIGATION

POPULATION TREND

UNITED STATES & 11 WESTERN STATES

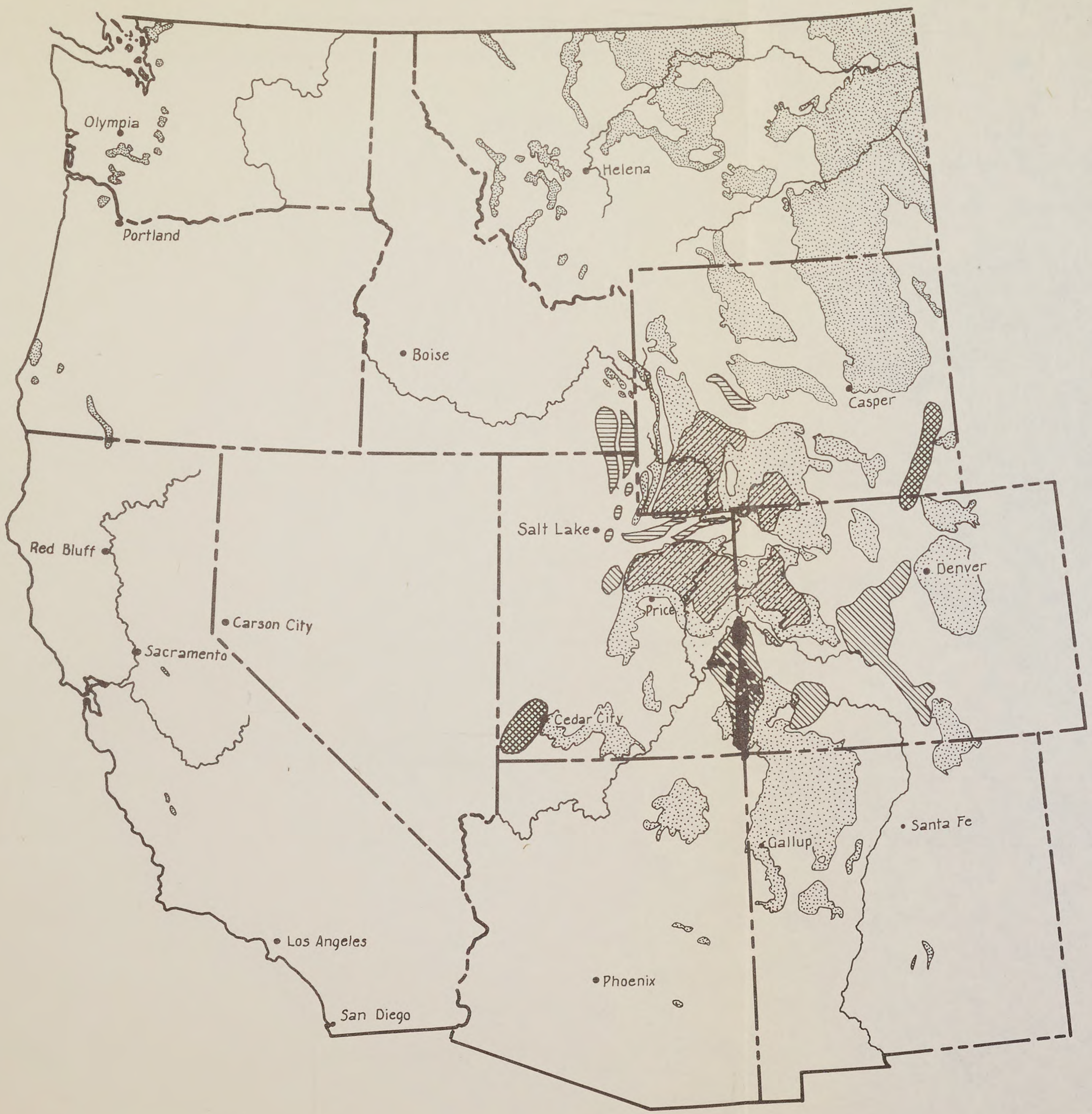
1900 - 1950

DRAWN............ SUBMITTED
TRACED DRVK RECOMMENDED
CHECKED .... APPROVED S.P. Mc Casland

Plate 9

595-907-144


WYOMING
MONT.
IDAHO
UTAH
NEVADA
ARIZONA
WASHINGTON
OREGON
CALIFORNIA
Great Falls
HELENA
Butte
Kalispell
Flathead Lake
Spokane
Lewiston
Pendleton
SEATTLE
Tacoma
OLYMPIA
PORTLAND
SALEM
Bend
Medford
Klamath Falls
Idaho Falls
BOISE
Twin Falls
Ogden
SALT LAKE CITY
Provo
Utah Lake
GREAT SALT LAKE
Sevier Lake
St George
Elko
CARSON CITY
SACRAMENTO
SAN FRANCISCO
San Jose
Fresno
Bakersfield
LOS ANGELES
San Diego
El Centro
Salton Sea
Las Vegas
HOOVER DAM
DAVIS DAM
PARKER DAM
PHOENIX
Tucson
Yuma
Owens Lake
GRAND COULEE DAM
SHASTA DAM
Clear Lake
JUAN DE FUCA STRAIT
40 0 40 80 120
SCALE OF MILES
Plate 6
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UNITED WESTERN INVESTIGATION
MAJOR AREAS WHERE PRESENT
USE OF GROUNDWATER EXCEEDS
RATE OF REPLENISHMENT
DRAWN
SUBMITTED J. M. Schaser
TRACED
RECOMMENDED
CHECKED
APPROVED S. P. McCasland
SALT LAKE CITY, UTAH. 11/12/50
595-907-140
U.B.N. S.L.C., U.-1M-1-51



LEGEND

- COAL
- OIL SHALE
- METALS AREA
- IRON
- MAGNESIUM
- VANADIUM - URANIUM
- PHOSPHATES

NOTE

This map shows major western coal deposits and major mineral Reserves of the upper Colorado River Basin & adjacent areas.

100 50 0 100 200 300

SCALE OF MILES

Plate 7

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UNITED WESTERN INVESTIGATION

MINERAL RESOURCES REQUIRING A SIGNIFICANT WATER SUPPLY FOR DEVELOPMENT

DRAWN:	SUBMITTED:
TRACED: EMB JB.	RECOMMENDED: E. J. Kuiper
CHECKED: HED	APPROVED: S. P. McCasland
SALT LAKE, UTAH	595-907-142

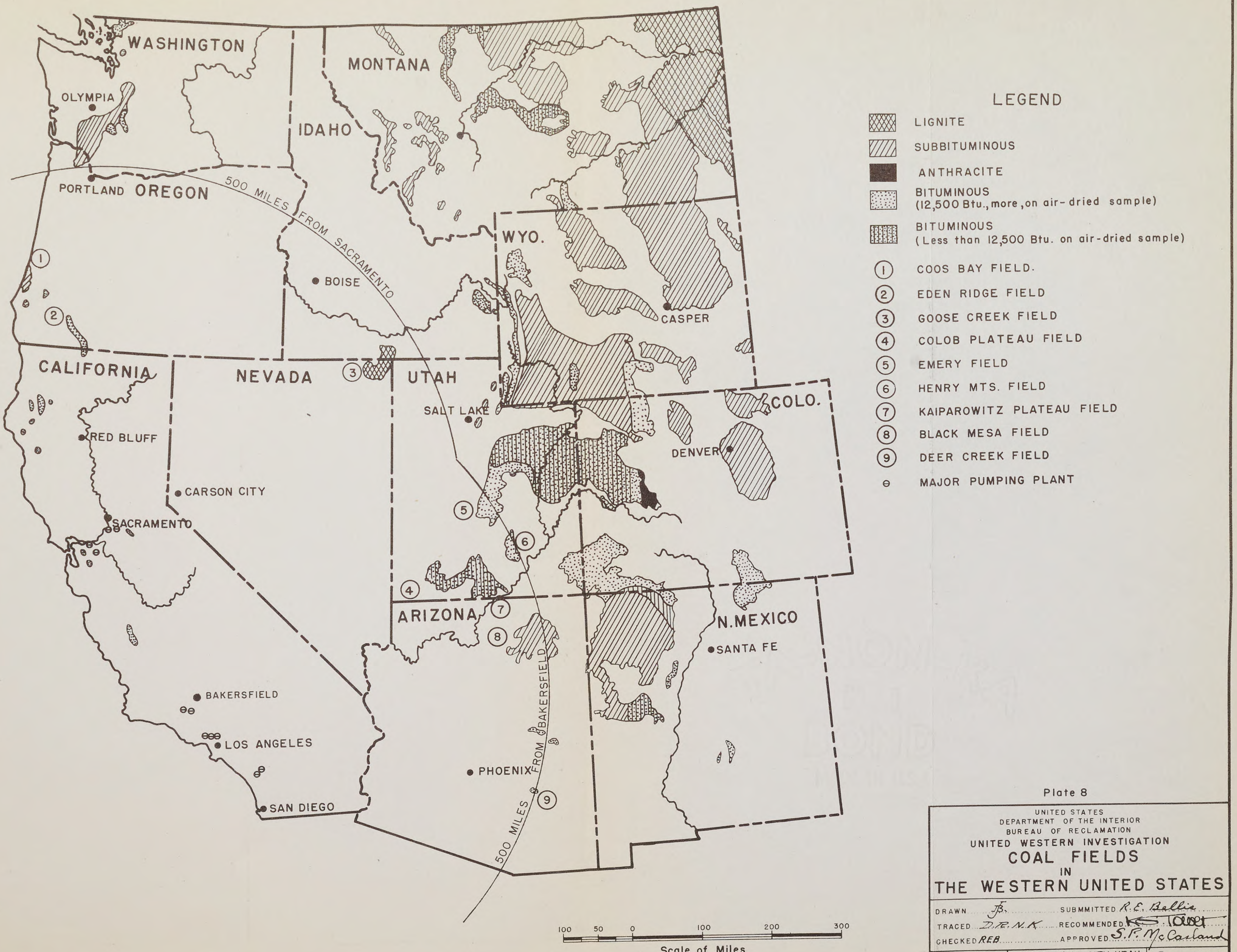


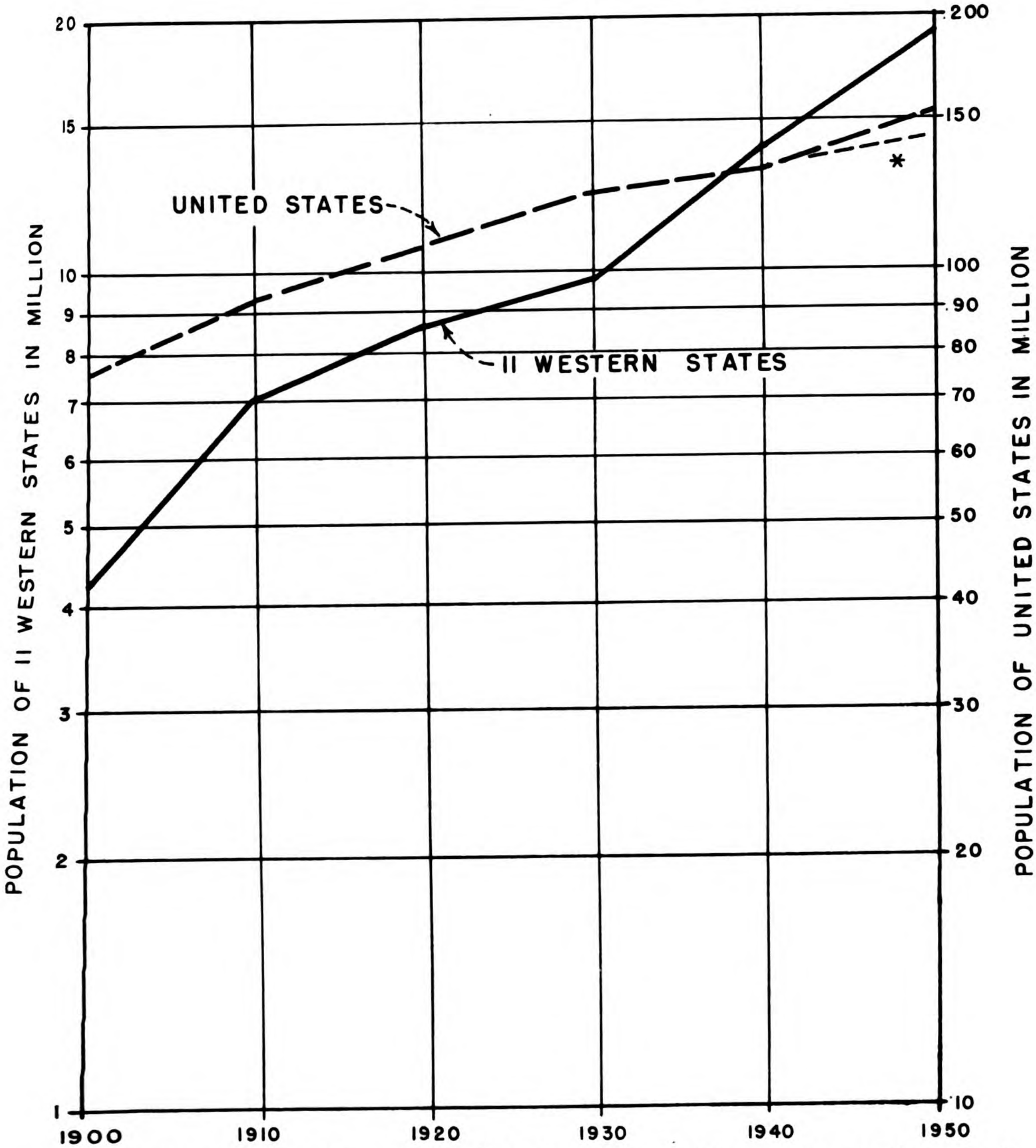
Plate 8

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UNITED WESTERN INVESTIGATION

COAL FIELDS IN THE WESTERN UNITED STATES

DRAWN J.B. SUBMITTED R.E. Bellis
TRACED D.R.N.K. RECOMMENDED K.S. Tower
CHECKED REB APPROVED S.P. McCasland

SALT LAKE CITY, UTAH. NOVEMBER 15, 1950 595-907-143



* Forecast for 1950, taken from "Estimates of Future Population of the United States, 1940 - 2000." National Resources Planning Board, August 1943.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

UNITED WESTERN INVESTIGATION

POPULATION TREND

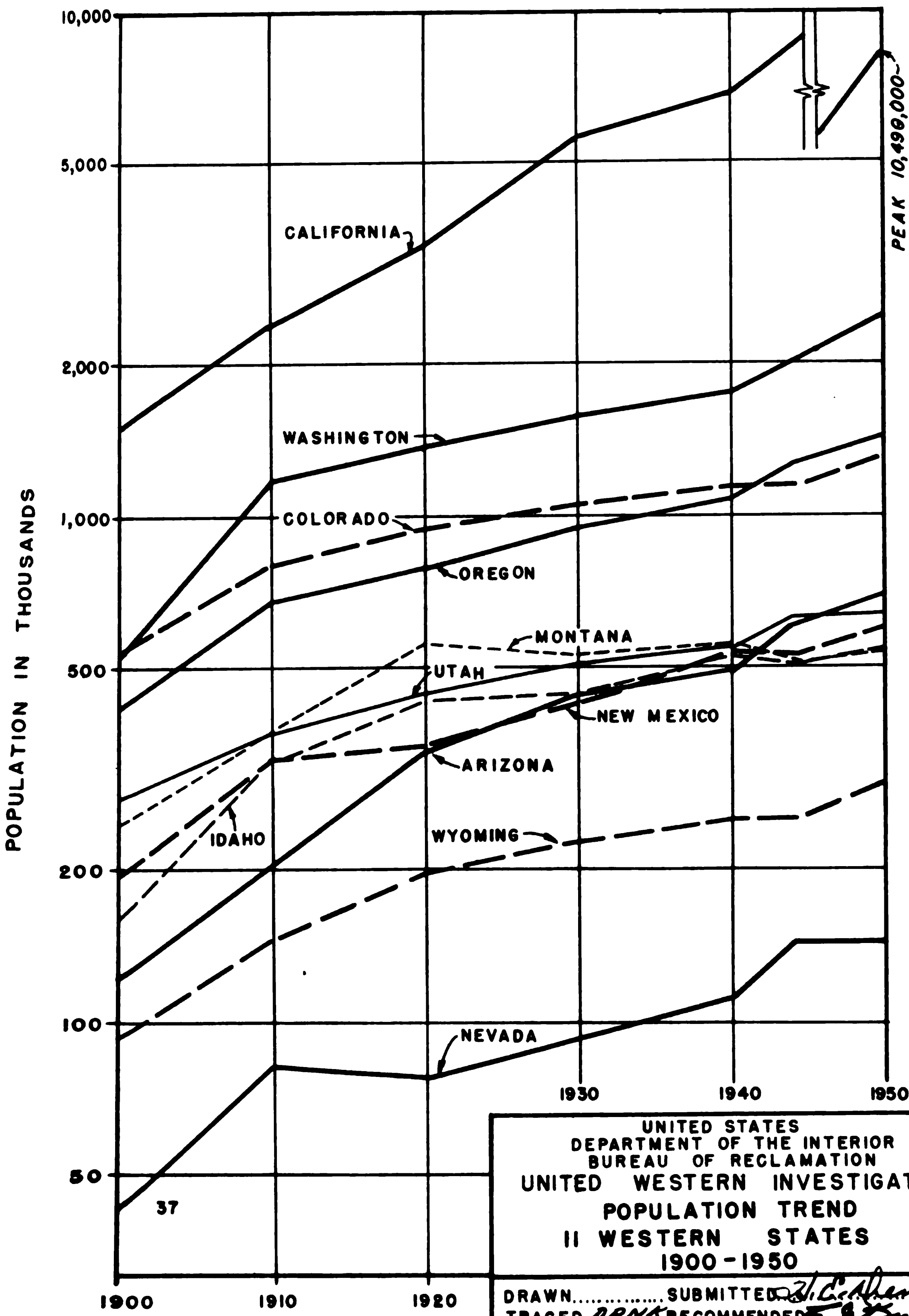
UNITED STATES & 11 WESTERN STATES

1900 - 1950

DRAWN.................SUBMITTED
TRACED DRNK...RECOMMENDED
CHECKED.........APPROVED S.P.Mc Casland

Plate 9

595-907-144

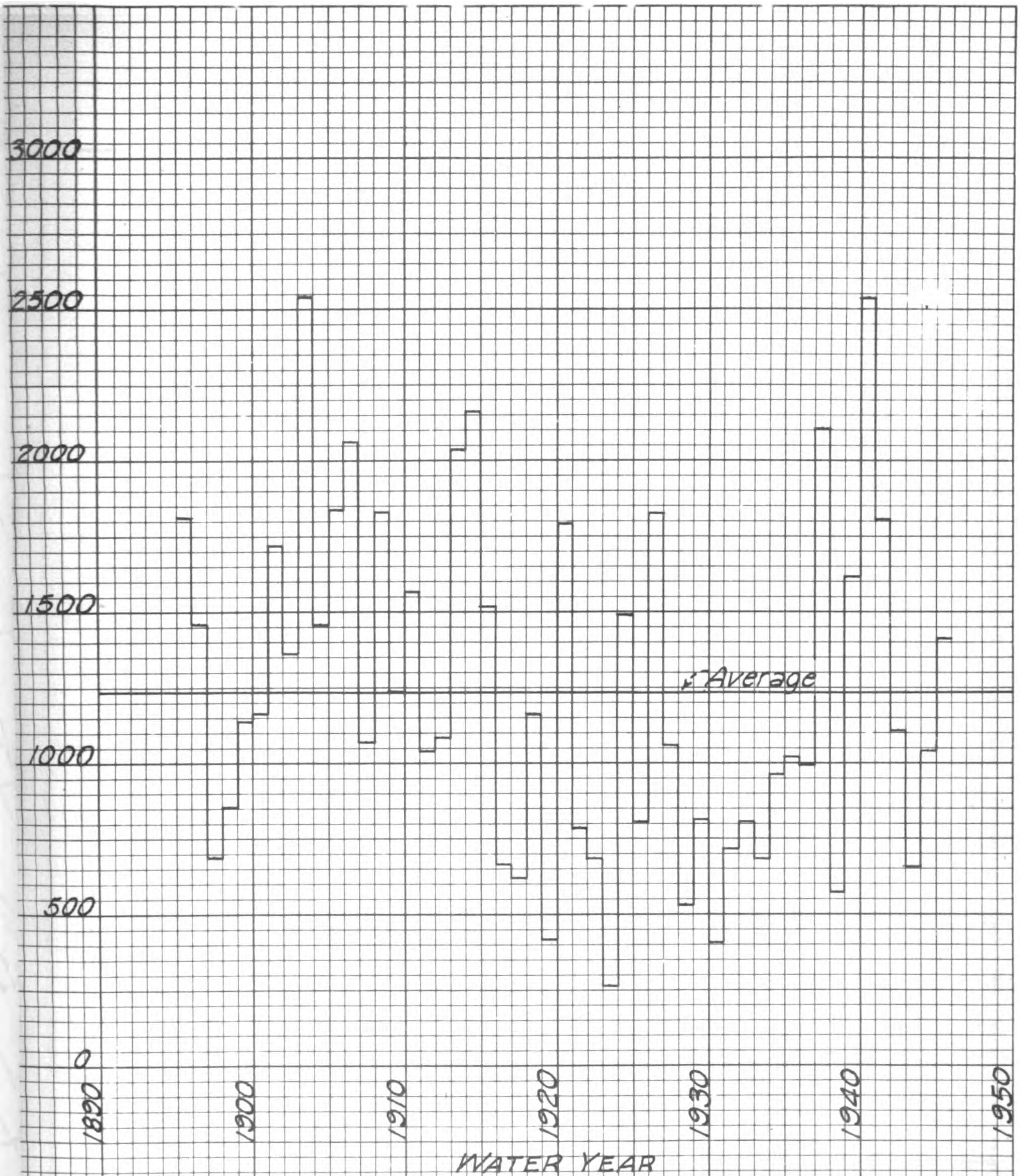


UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UNITED WESTERN INVESTIGATION
POPULATION TREND
11 WESTERN STATES
1900 - 1950

DRAWN............ SUBMITTED
TRACED .... RECOMMENDED
CHECKED .... APPROVED S. P. McCasland

595-907-145

Plate 10



NOTE

ecord computed for period 1895
911 from comparison with Sac-
nento River at Red Bluff.

Plate II

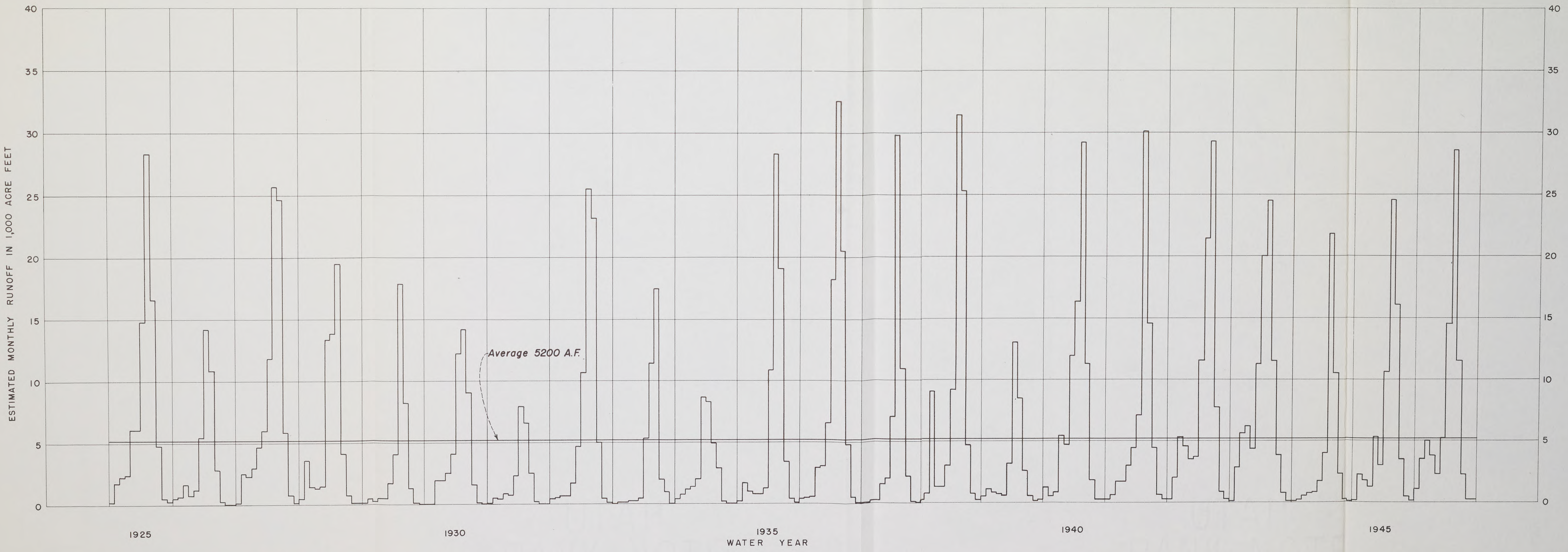
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UNITED WESTERN INVESTIGATION

UNIMPAIRED RUNOFF
TRINITY RIVER

LEWISTON, CALIFORNIA

DRAWN K.D.E.	SUBMITTED J. M. Schaser
TRACED B.	RECOMMENDED E. J. Burger
CHECKED K.D.E.	APPROVED S.P. McCasland

SALT LAKE CITY, UT. 1/6/50 535-907-146



NOTES

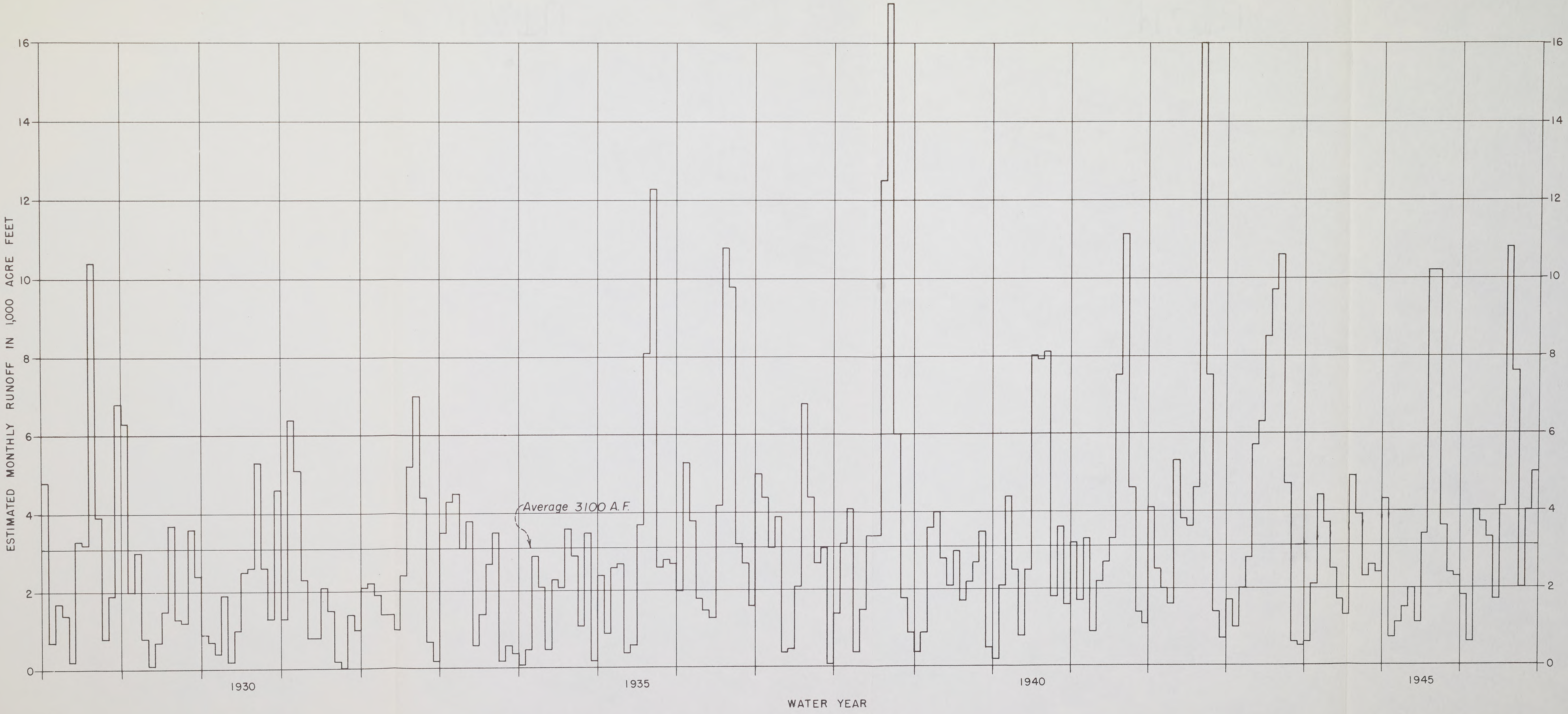
Point of diversion at Elevation 6400' M.S.L.
Drainage area = 34 square miles.
Computed from U.S.G.S. records, South Fork of Silver Creek at Ice House.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UNITED WESTERN INVESTIGATION

RUBICON RIVER – CALIF.
RUNOFF

DRAWN . . K.D.E. . . .	SUBMITTED J.M. Schaser
TRACED . . J.K.A. . . .	RECOMMENDED C.J. Kuiper
CHECKED . K.D.E. . . .	APPROVED S.P. Mc Casland
SALT LAKE CITY, UTAH JAN. 51 ONE SHEET	595-907-147

U.B.N. S.L.C.,U.-600-1-51 PLATE 12



NOTES:

Point of diversion at Elevation 7700 M. S. L.

Drainage area = 19 square miles.

Computed from U. S. G. S. records for Cold Creek near Mokelumne Peak and for Twin Lakes outlet at Kirkwood.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

UNITED WESTERN INVESTIGATION

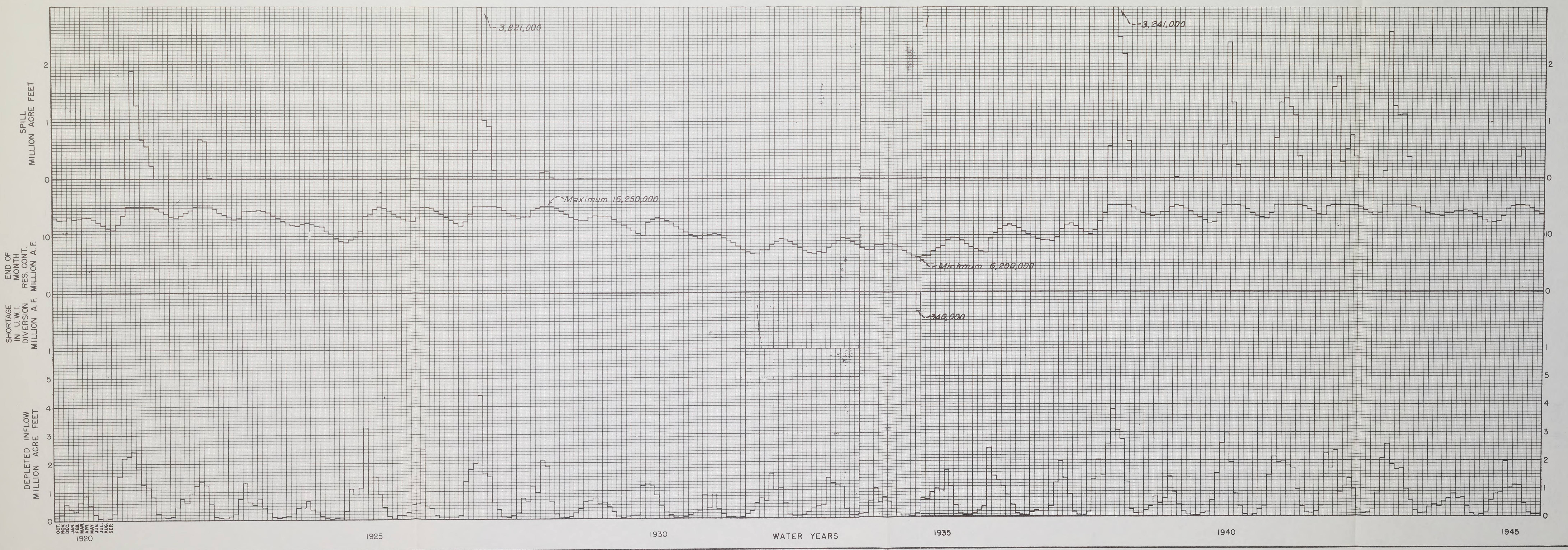
RUNOFF

CAPLES CREEK CALIFORNIA

DRAWN: K. D. E. SUBMITTED: J. M. Schoser
TRACED: J. B. L. E. RECOMMENDED: C. J. Kuiper
CHECKED: K. D. E. APPROVED: S. P. McCasland

SALT LAKE CITY, UTAH. 1-2-51 | 595-907-148

U.B.N. S.L.C. U.-600-1-51



NOTE:

TOTAL RESERVOIR YIELD = 6,322,000 Acre Feet/year
United Western Diversion:
February thru December 554,000 Acre Feet/month
January = none
Total = 6,094,000 Acre Feet/year

Release for downstream use:
12 month basis = 19,000 Acre Feet/month
Total = 228,000 Acre Feet/year

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UNITED WESTERN INVESTIGATION

AH PAH RESERVOIR

OPERATION STUDY 1920-1945

DRAWN: K.D.E. SUBMITTED: J.M. Schaser
TRACED: L.E. RECOMMENDED: C.J. Kuiper
CHECKED: K.D.E. APPROVED: S.P. McCasland
SALT LAKE CITY, UTAH 1-5-51 595-907-149

U.B.N. S.L.C.,U.- 600-1-51 PLATE 14

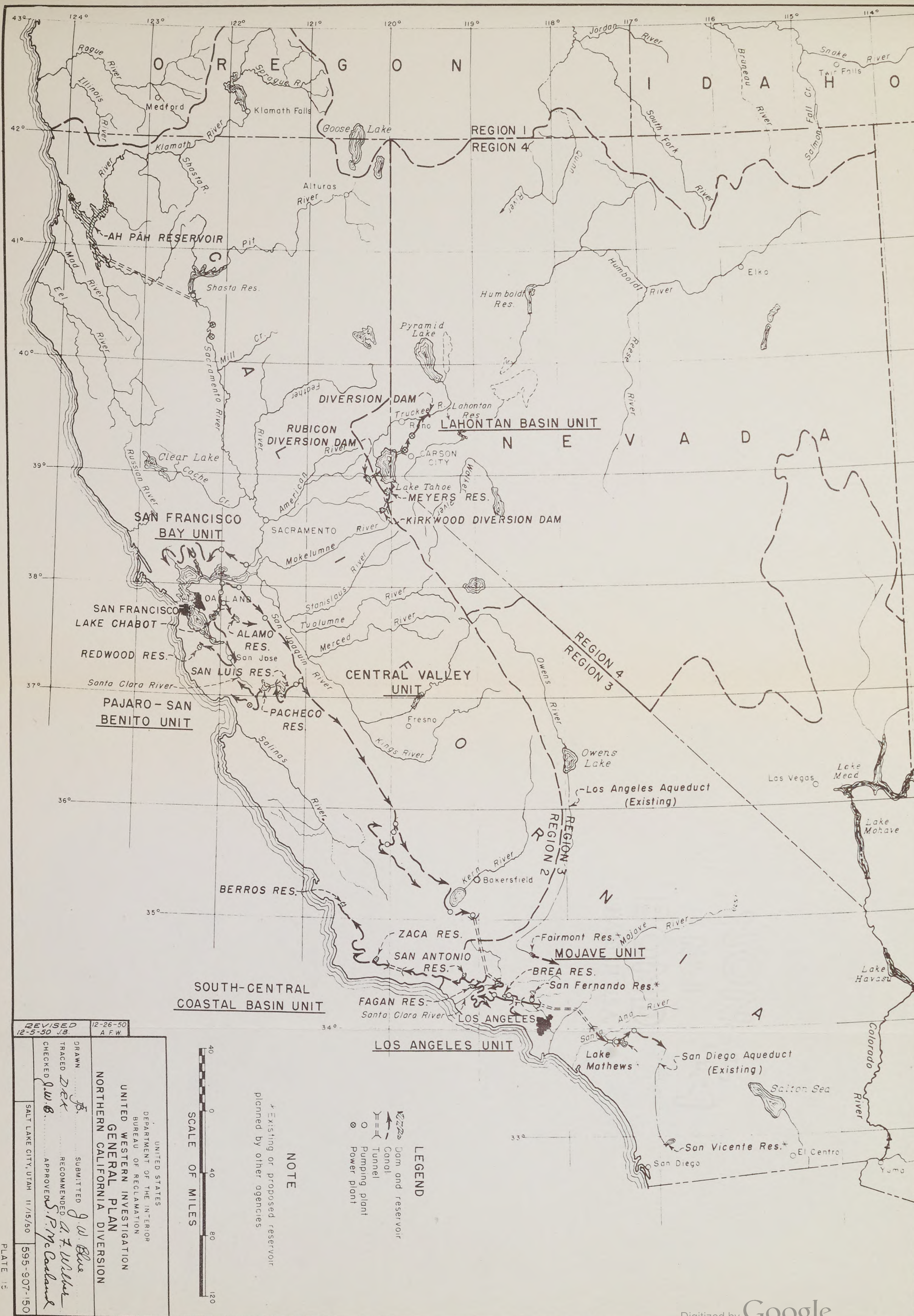
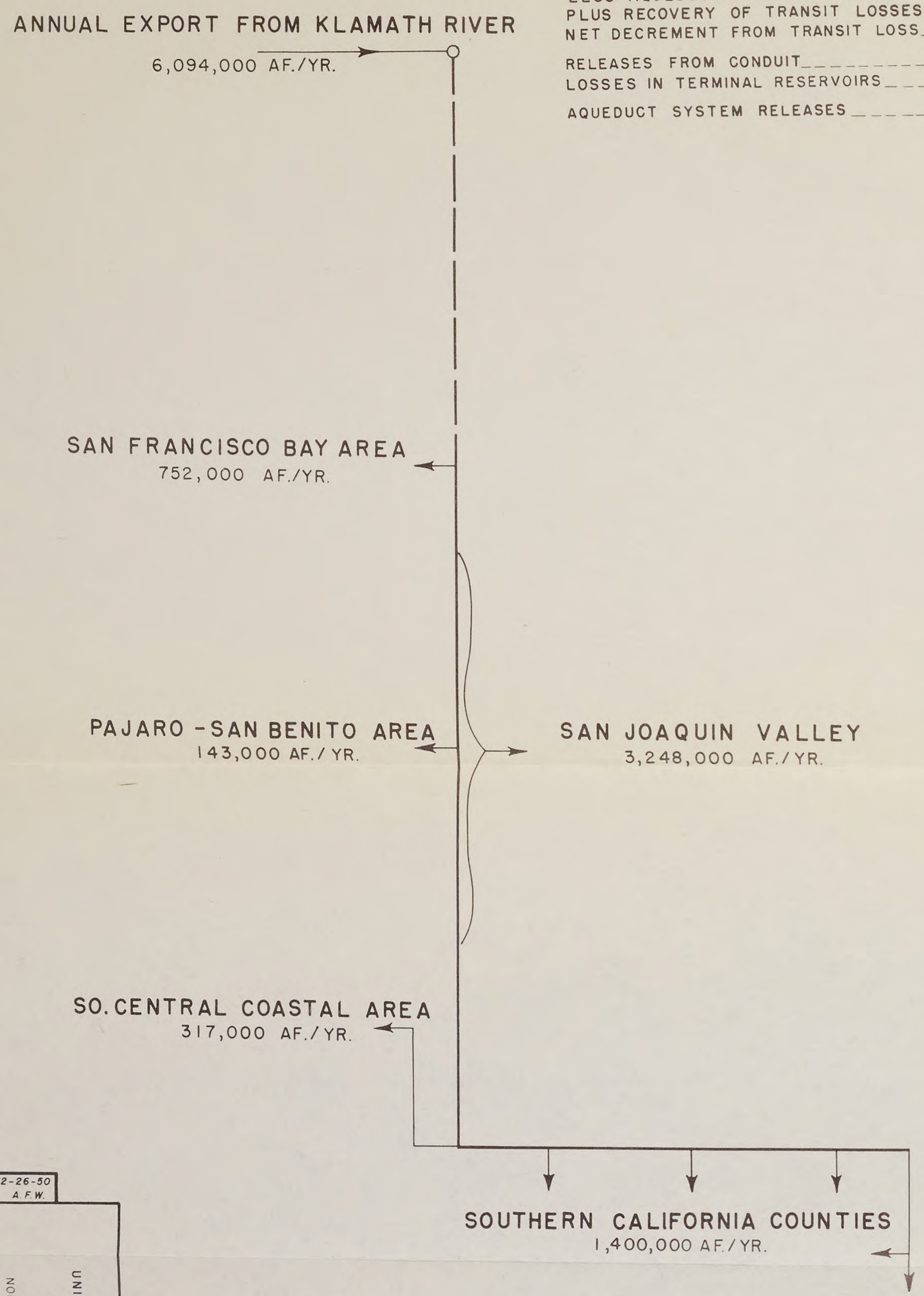

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UNITED WESTERN INVESTIGATION
GENERAL PLAN
NORTHERN CALIFORNIA DIVERSION
DRAWN
TRACED
CHECKED
SUBMITTED
RECOMMENDED
APPROVED
SALT LAKE CITY, UTAH 11/15/50
595-907-150
REVISED 12-5-50 J.B.
12-26-50 A.F.W.
SCALE OF MILES
40 0 40 80 120
NOTE
* Existing or proposed reservoir planned by other agencies
LEGEND
Dam and reservoir
Canal
Tunnel
Pumping plant
Power plant
OREGON
IDAHO
NEVADA
CALIFORNIA
REGION 1
REGION 4
REGION 3
REGION 2
AH PAH RESERVOIR
Shasta Res.
DIVERSION DAM
RUBICON DIVERSION DAM
LAHONTAN BASIN UNIT
MEYERS RES.
KIRKWOOD DIVERSION DAM
SAN FRANCISCO BAY UNIT
SACRAMENTO
OAKLAND
SAN FRANCISCO
LAKE CHABOT
ALAMO RES.
REDWOOD RES.
San Jose
SAN LUIS RES.
Santa Clara River
PAJARO-SAN BENITO UNIT
PACHECO RES.
CENTRAL VALLEY UNIT
Fresno
Bakersfield
Owens Lake
Los Angeles Aqueduct (Existing)
BERROS RES.
ZACA RES.
SAN ANTONIO RES.
Fairmont Res.*
MOJAVE UNIT
BREA RES.
San Fernando Res.*
SOUTH-CENTRAL COASTAL BASIN UNIT
FAGAN RES.
Santa Clara River
LOS ANGELES
LOS ANGELES UNIT
Lake Mathews
San Diego Aqueduct (Existing)
Salton Sea
San Vicente Res.*
San Diego
El Centro
Yuma
Los Vegas
Lake Mead
Lake Mohave
Lake Havasu
Colorado River
Medford
Klamath Falls
Goose Lake
Alturas
Pyramid Lake
Truckee R.
Reno
Lahontan Res.
CARSON CITY
Lake Tahoe
Humboldt Res.
Elko
Twin Falls
Clear Lake
Mokelumne River
Stanislaus River
Tuolumne River
Merced River
San Joaquin River
Kings River
Kern River
Salinas River
Owens River
Mojave River
Santa Ana River
Sacramento River
American River
Feather River
Rogue River
Klamath River
Eel River
Mad River
Russian River
Snake River
Humboldt River

PLATE 15

WATER DISPOSITION

EXPORT FROM KLAMATH RIVER		6,094,000 A.F.
LESS AQUEDUCT TRANSIT LOSSES	178,000 A.F.	
PLUS RECOVERY OF TRANSIT LOSSES	35,000 A.F.	
NET DECREMENT FROM TRANSIT LOSS		143,000 A.F.
RELEASES FROM CONDUIT		5,951,000 A.F.
LOSSES IN TERMINAL RESERVOIRS		91,000 A.F.
AQUEDUCT SYSTEM RELEASES		5,860,000 A.F.



REVISED 12-6-50 J.B. | 12-26-50 A.F.W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UNITED WESTERN INVESTIGATION

ANNUAL RELEASE FROM AQUEDUCT

NORTHERN CALIFORNIA DIVERSION

DRAWN A.F.W. ...... SUBMITTED A.F. Wilber
TRACED D.E.N.K. ...... RECOMMENDED
CHECKED ...... APPROVED S.P. McCasland

SALT LAKE CITY, UTAH - 11/6/50 | 595-907-151

PLATE 16

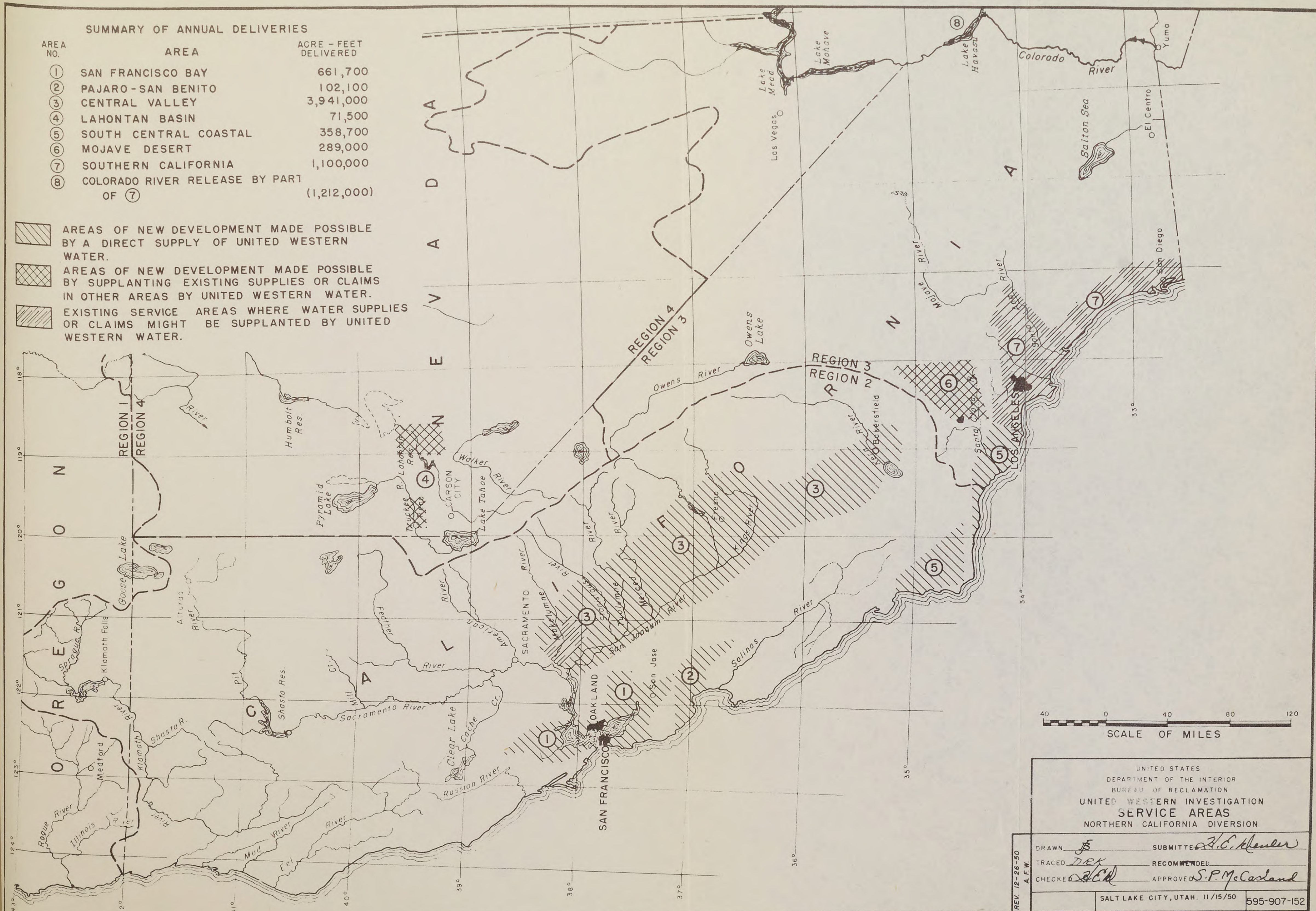
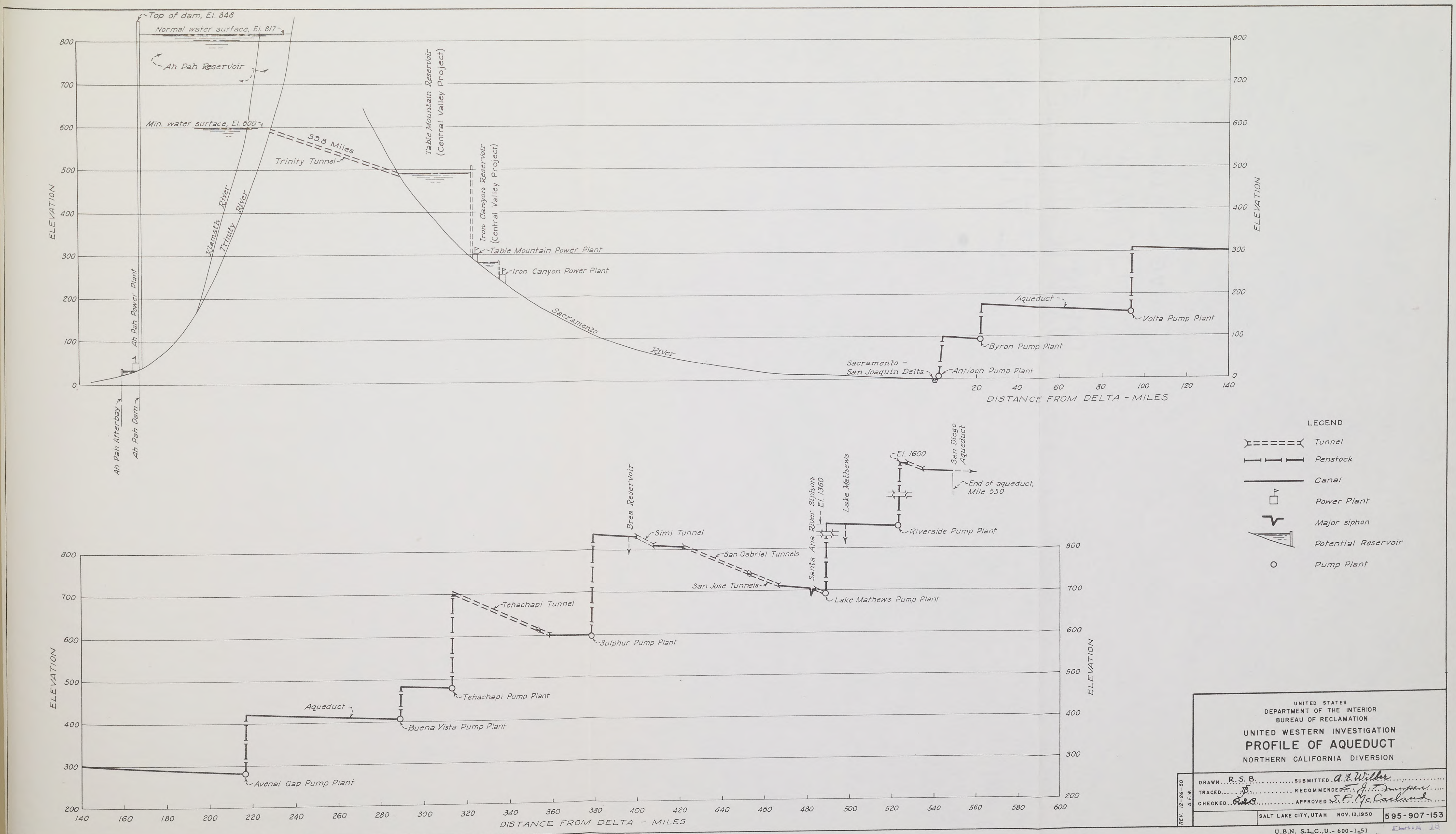

SUMMARY OF ANNUAL DELIVERIES
AREA NO.
AREA
ACRE - FEET DELIVERED
1 SAN FRANCISCO BAY 661,700
2 PAJARO - SAN BENITO 102,100
3 CENTRAL VALLEY 3,941,000
4 LAHONTAN BASIN 71,500
5 SOUTH CENTRAL COASTAL 358,700
6 MOJAVE DESERT 289,000
7 SOUTHERN CALIFORNIA 1,100,000
8 COLORADO RIVER RELEASE BY PART OF 7 (1,212,000)
AREAS OF NEW DEVELOPMENT MADE POSSIBLE BY A DIRECT SUPPLY OF UNITED WESTERN WATER.
AREAS OF NEW DEVELOPMENT MADE POSSIBLE BY SUPPLANTING EXISTING SUPPLIES OR CLAIMS IN OTHER AREAS BY UNITED WESTERN WATER.
EXISTING SERVICE AREAS WHERE WATER SUPPLIES OR CLAIMS MIGHT BE SUPPLANTED BY UNITED WESTERN WATER.
NEVADA
CALIFORNIA
OREGON
REGION 4
REGION 3
REGION 3
REGION 2
REGION 1
REGION 4
Lake Mead
Lake Mohave
Lake Havasu
Colorado River
Yuma
Las Vegas
Salton Sea
El Centro
San Diego
Owens Lake
Owens River
Mojave River
Bakersfield
Kern River
LOS ANGELES
Santa Clara
Fresno
Kings River
San Joaquin River
Merced
Tuolumne
Stanislaus
Mokelumne
Cosumnes
Salinas River
San Jose
OAKLAND
SAN FRANCISCO
SACRAMENTO
Sacramento River
American River
Feather River
Mill Cr.
Pit
Shasta Res.
Shasta R.
Clear Lake
Cache Cr.
Russian River
Eel River
Mad River
Klamath River
Klamath Falls
Medford
Rogue River
Illinois
Sprague R.
Goose Lake
Alturas
Pyramid Lake
Truckee R.
Lahontan Res.
CARSON CITY
Lake Tahoe
Walker River
Humbolt Res.
SCALE OF MILES
40 0 40 80 120
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UNITED WESTERN INVESTIGATION
SERVICE AREAS
NORTHERN CALIFORNIA DIVERSION
DRAWN JS
TRACED DRK
CHECKED
SUBMITTED
RECOMMENDED
APPROVED S. P. McCasland
REV. 12-26-50 A.F.W.
SALT LAKE CITY, UTAH. 11/15/50
595-907-152

PLATE 17



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

UNITED WESTERN INVESTIGATION

PROFILE OF AQUEDUCT

NORTHERN CALIFORNIA DIVERSION

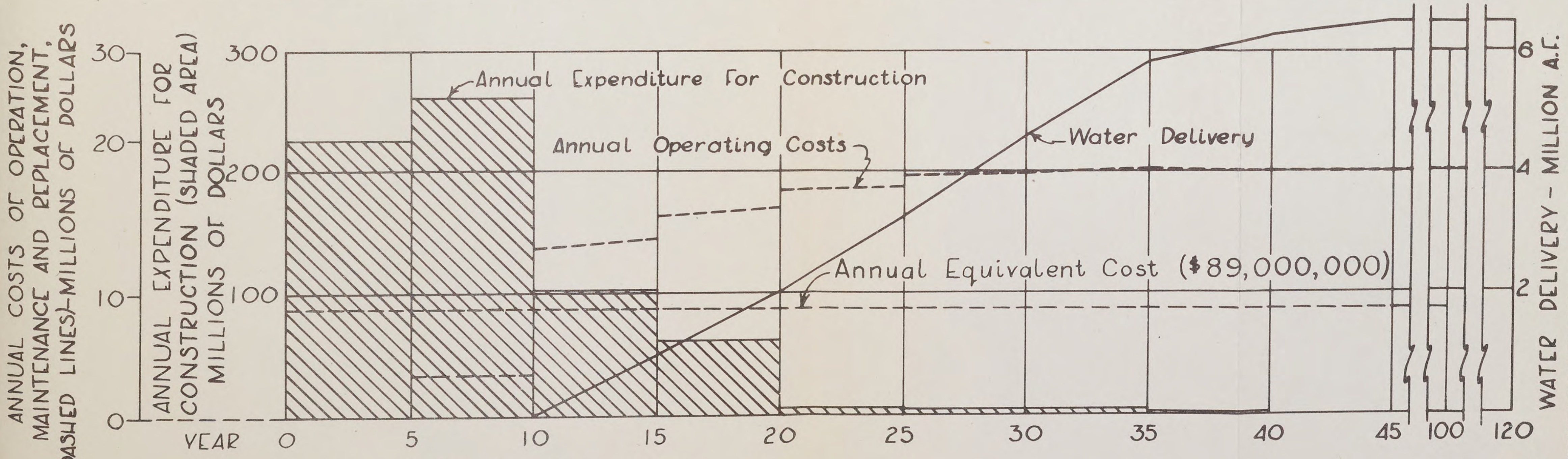
DRAWN R.S.B.	SUBMITTED A. F. Wilber
TRACED B.	RECOMMENDED J. T. [illegible]
CHECKED [illegible]	APPROVED S. P. McCasland

REV. 12-26-50 A.F.W.

SALT LAKE CITY, UTAH NOV. 13, 1950 595-907-153

U.B.N. S.L.C..U.- 600-1-51

STEP	CONSTRUCTION COST-MILLIONS OF DOLLARS
1	1,118
2	1,306
3	509
4	307
4-a	22
4-b	17
4-c	9
4-d	5



MAJOR CONSTRUCTION ITEMS

STEP 1 Ah Pah Dam & Power Plant; first half of Trinity Tunnel.
STEP 2 Second half of Trinity Tunnel.
Service facilities to San Joaquin Valley, San Francisco Bay Area, Pajaro-San Benito Area, and Lahontan Basin Area.
STEP 3 Tehachapi Tunnel.
Service facilities to South-Central Coast.
STEP 4 Service facilities to Southern California Counties.
STEP 4 a, b, c & d Enlargement of Pumping Plants.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UNITED WESTERN INVESTIGATION
EXPENDITURE AND
CONSTRUCTION SCHEDULE
NORTHERN CALIFORNIA DIVERSION

DRAWN R.M.B. SUBMITTED J.W. Blue
TRACED R.M.B. RECOMMENDED A.F. Wilfer
CHECKED J.W.B. APPROVED E.P. McCasland
SALT LAKE CITY, UTAH. 11/15/50 595-907-154

REV. 12-14-50 R.M.B. 2-26-50 A.F.W.

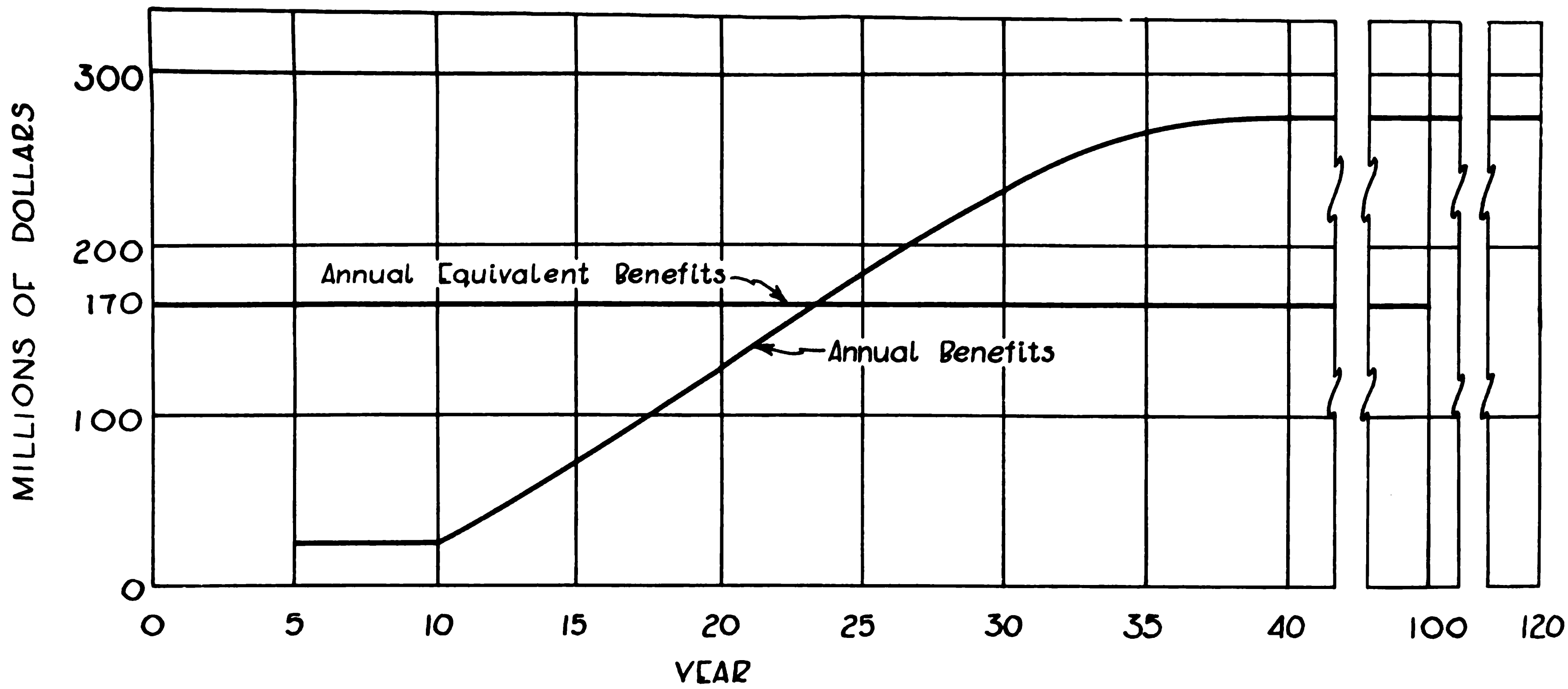


Plate 20

NOTE

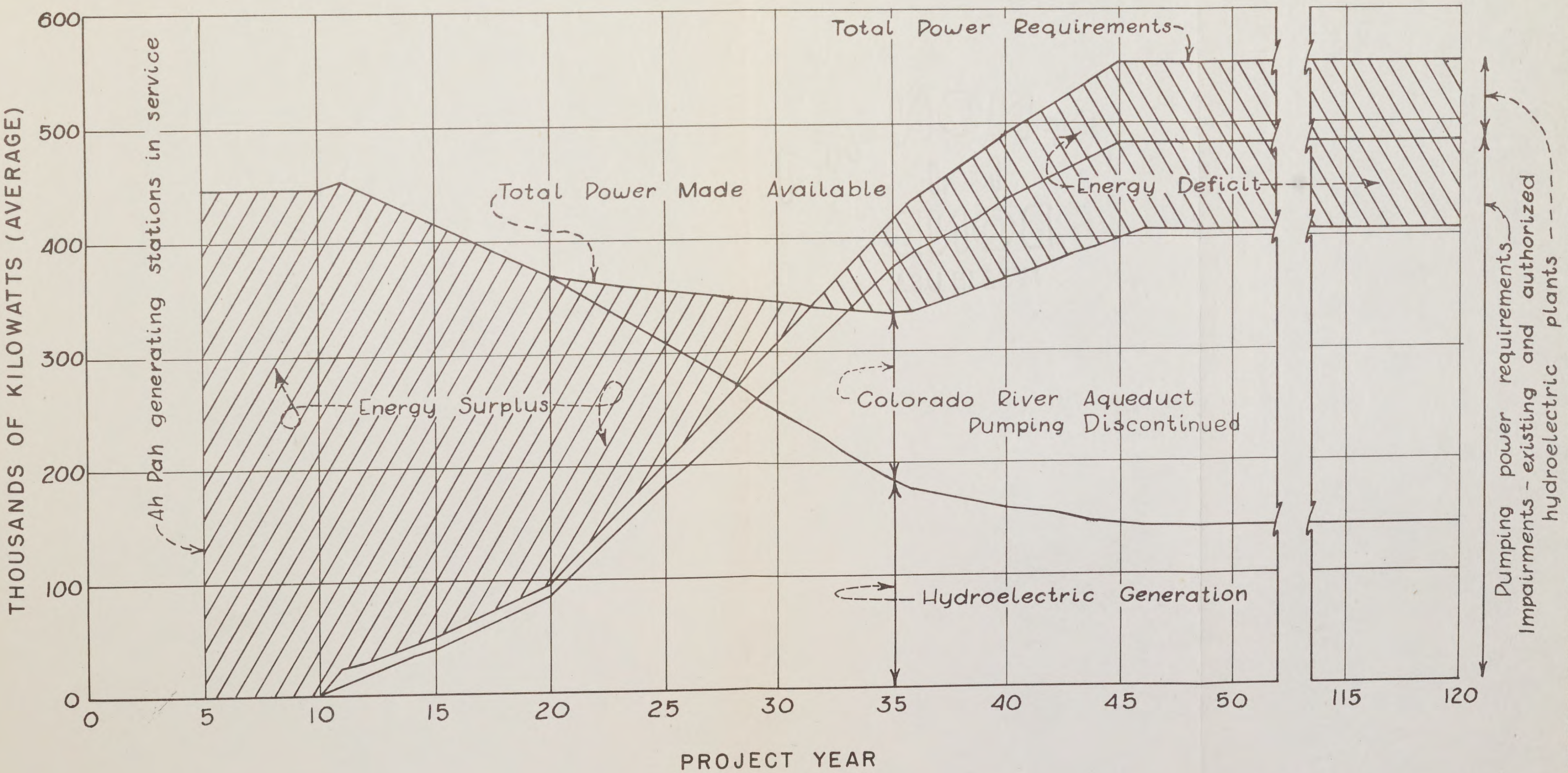
Total benefits discounted to present worth at year zero are about 6 billion dollars. Present worth amortized at 2½ % over 100 years is equivalent to 170,000,000 dollars per year.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UNITED WESTERN INVESTIGATION
COMPARISON OF TOTAL
ANNUAL BENEFITS TO
ANNUAL EQUIVALENT BENEFITS

DRAWN. RMB ...... SUBMITTED E. E. Jenks
TRACED RMB ...... RECOMMENDED E. J. Zmura
CHECKED KR ...... APPROVED S. P. McCasland

SALT LAKE CITY, UTAH. 11/15/50 | 595-907-155

REV. 12-15-50 R.M.B.



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UNITED WESTERN INVESTIGATION
NORTHERN CALIFORNIA DIVERSION
POWER REQUIREMENTS
AND GENERATION -- CASE - I

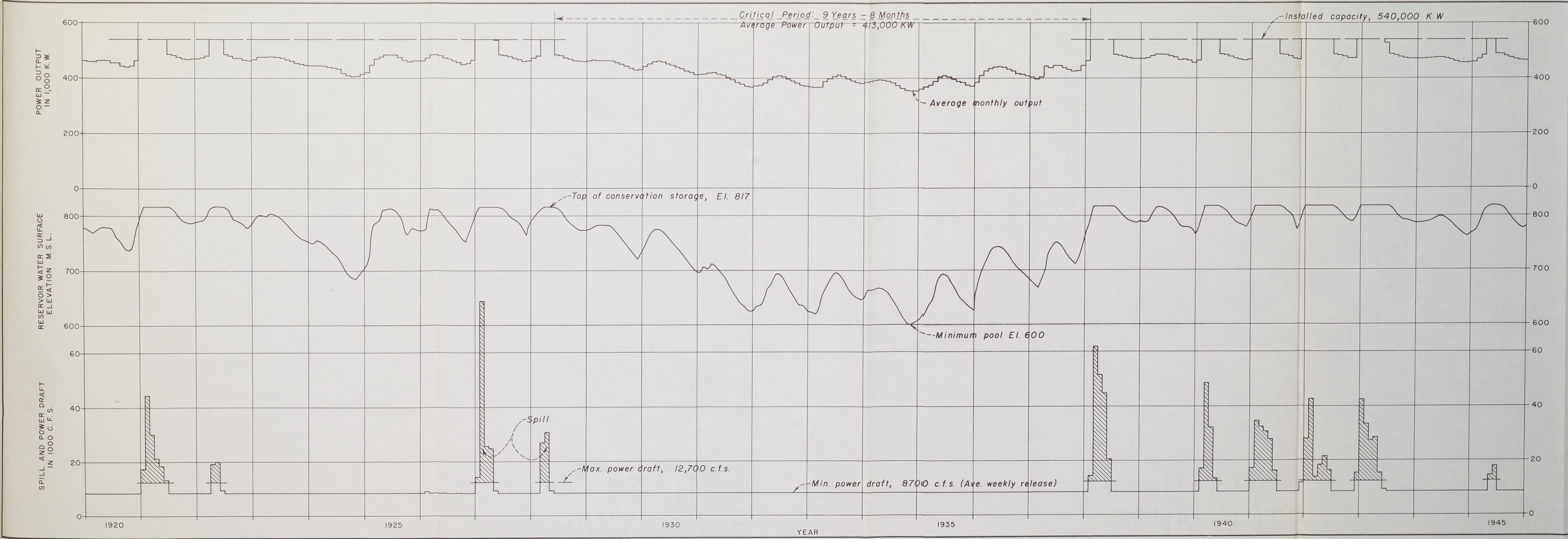
DRAWN R.E.B.	SUBMITTED R.E. Bellie
TRACED D.R.N.K.	RECOMMENDED
CHECKED	APPROVED S.P. McCasland
SALT LAKE CITY, UT. 11/15/50	595-907-157

REV. 12-19-50 R.M.B.

PLATE 21

8 Mont
3,000

draft,



NOTES:

Tail-water elevation assumed constant at 40 feet M.S.L.

Overall plant efficiency from forebay to high voltage side of transformers assumed 85%.

8700 c.f.s. average weekly power draft will be exceeded only when reservoir is filled.

Afterbay downstream from Ah Pah will permit Ah Pah generating station to be operated at 76.5% average weekly plant factor during the critical period.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UNITED WESTERN INVESTIGATION

AH PAH DISCHARGE AND POWER GRAPHS 1920-1945

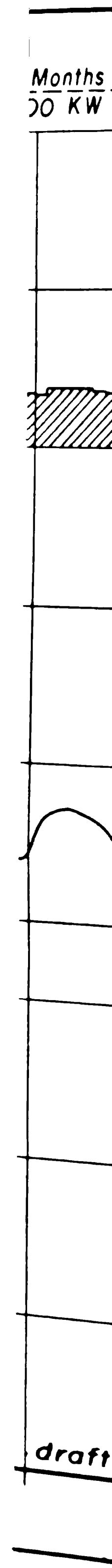
INITIAL CONDITIONS

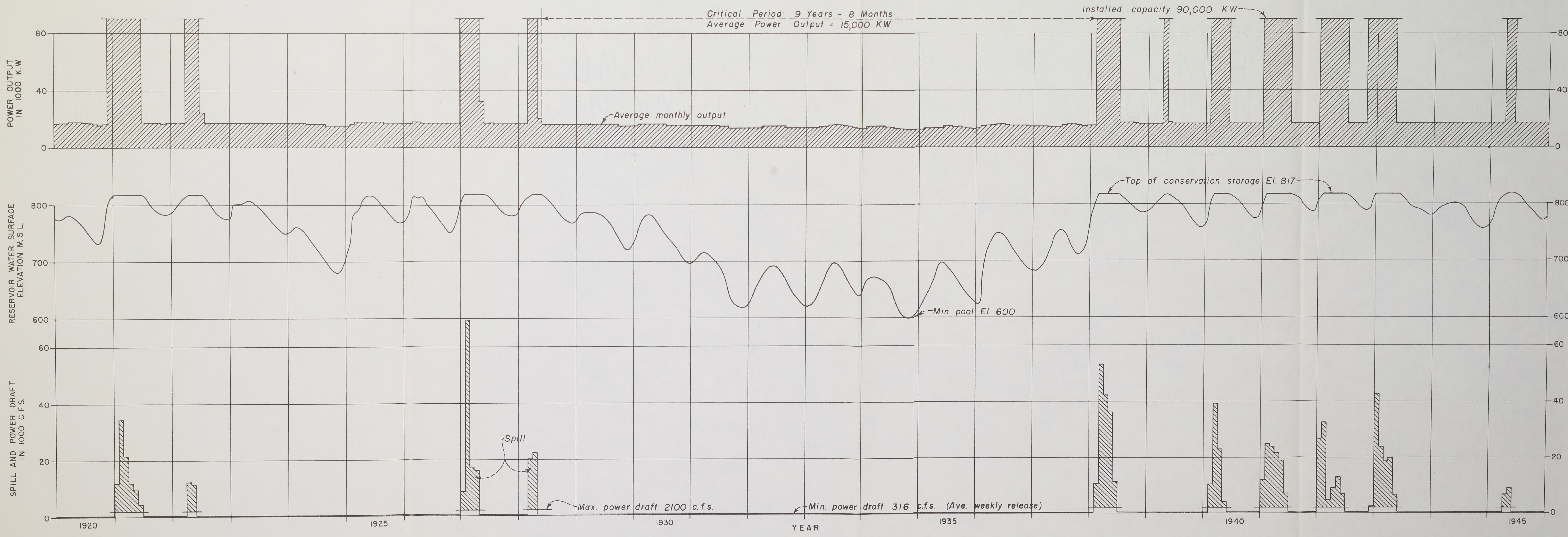
REV. 12-20-50 W.S.C.

DRAWN....R.E.B.......SUBMITTED..R.E. Bellis.....
TRACED....R.B.R.......RECOMMENDED.K.G. Tower....
CHECKED...K.G.T.......APPROVED..S.P. McCasland...

SALT LAKE CITY, UTAH 1-8-51 | **595-907-158**

U.B.N. S.L.C.,U.-600-1-51 PLATE 22


Months
KW
draft



NOTES:

Tail-water elevation assumed constant at 40 feet M.S.L.

Overall plant efficiency from forebay to high voltage side of transformers assumed 85 %.

316 c.f.s. average weekly power draft will be exceeded only when reservoir is full.

Afterbay downstream from Ah Pah will permit Ah Pah generating station to be operated at 16.7 % average weekly plant factor during the critical period.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

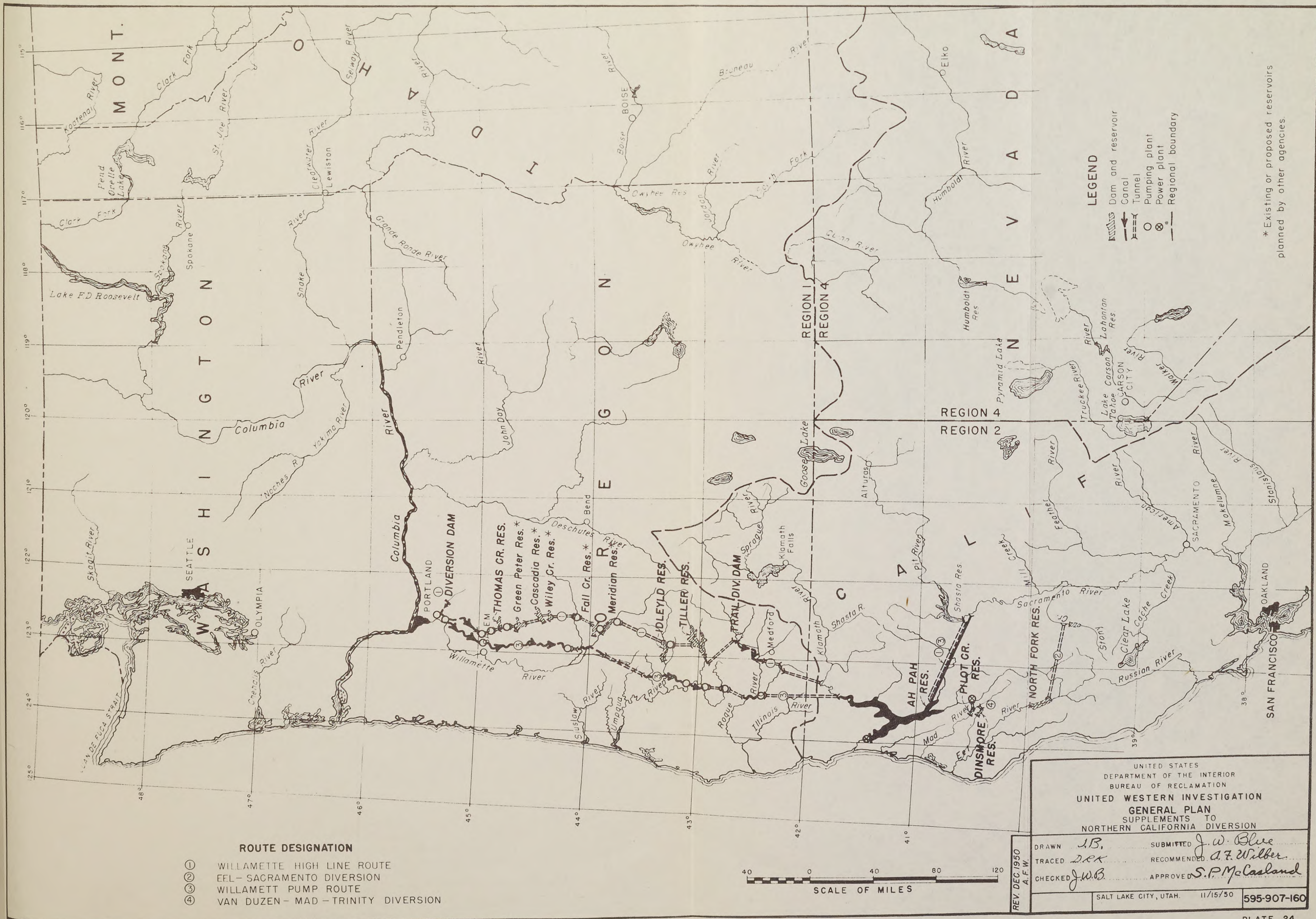
UNITED WESTERN INVESTIGATION

AH PAH DISCHARGE AND POWER GRAPHS 1920-1945

ULTIMATE CONDITIONS

DRAWN: J. B.	SUBMITTED: R.E.Bellis
TRACED: L. E.	RECOMMENDED: K.G.Tower
CHECKED: R.E.B.	APPROVED: S.P. McCasland
SALT LAKE CITY, UTAH. 1-4-51	595-907-159

U.B.N. S.L.C.,U.- 600-1-51 PLATE 23


UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UNITED WESTERN INVESTIGATION
GENERAL PLAN
SUPPLEMENTS TO
NORTHERN CALIFORNIA DIVERSION
DRAWN J.B.
TRACED D.R.K.
CHECKED J.W.B.
SUBMITTED J. W. Blue
RECOMMENDED A. F. Wilber
APPROVED S. P. McCasland
SALT LAKE CITY, UTAH. 11/15/50
595-907-160
REV. DEC. 1950 A.F.W.
ROUTE DESIGNATION
① WILLAMETTE HIGH LINE ROUTE
② EEL-SACRAMENTO DIVERSION
③ WILLAMETT PUMP ROUTE
④ VAN DUZEN - MAD - TRINITY DIVERSION
40 0 40 80 120
SCALE OF MILES
LEGEND
Dam and reservoir
Canal
Tunnel
Pumping plant
Power plant
Regional boundary
* Existing or proposed reservoirs planned by other agencies.
WASHINGTON
OREGON
IDAHO
MONT.
NEVADA
CALIF.
REGION 1
REGION 4
REGION 2
SEATTLE
OLYMPIA
PORTLAND
SALEM
Spokane
Lewiston
Pendleton
BOISE
Bend
Medford
Klamath Falls
Alturas
Elko
CARSON CITY
SACRAMENTO
OAKLAND
SAN FRANCISCO
DIVERSION DAM
THOMAS CR. RES.
Green Peter Res. *
Cascadia Res. *
Wiley Cr. Res. *
Fall Cr. Res. *
Meridian Res.
IDLEYLD RES.
TILLER RES.
TRAIL DIV. DAM
AH PAH RES.
PILOT CR. RES.
DINSMORE RES.
NORTH FORK RES.
Shasta Res.
Columbia River
Willamette River
Deschutes River
John Day River
Snake River
Rogue River
Klamath River
Sacramento River
Russian River
Eel River
Mad River
Lake F.D. Roosevelt
Goose Lake
Pyramid Lake
Lake Tahoe
Humboldt Res.
Lahontan Res.
Clear Lake
PLATE 24

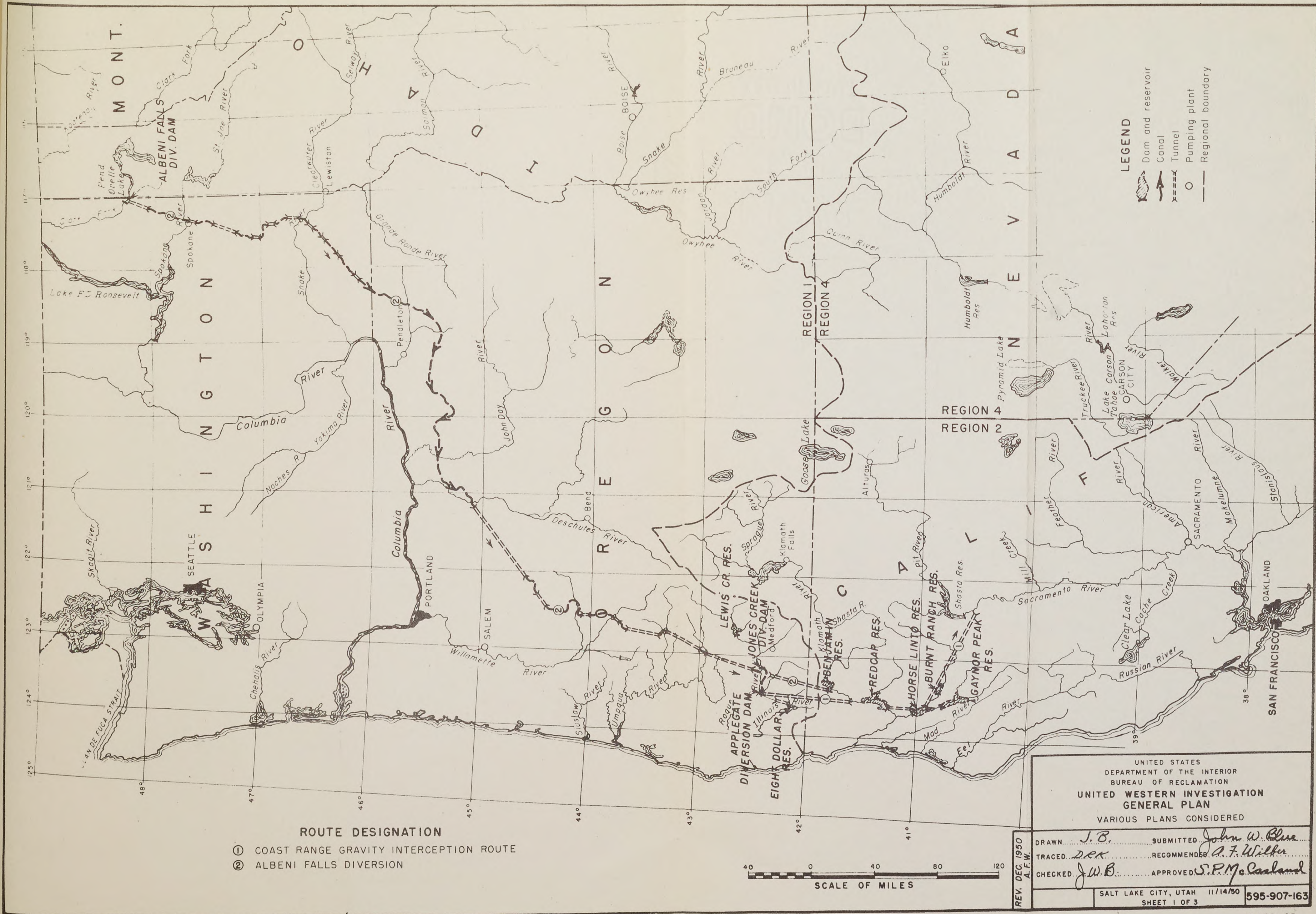

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UNITED WESTERN INVESTIGATION
GENERAL PLAN
VARIOUS PLANS CONSIDERED
DRAWN J.B.
TRACED D.R.K.
CHECKED J.W.B.
SUBMITTED John W. Bliss
RECOMMENDED A.F. Wilber
APPROVED S.P. McCasland
REV. DEC. 1950 A.F.W.
SALT LAKE CITY, UTAH 11/14/50
SHEET 1 OF 3
595-907-163
ROUTE DESIGNATION
① COAST RANGE GRAVITY INTERCEPTION ROUTE
② ALBENI FALLS DIVERSION
SCALE OF MILES
40 0 40 80 120
LEGEND
Dam and reservoir
Canal
Tunnel
Pumping plant
Regional boundary
REGION 1
REGION 4
REGION 2
MONT.
IDAHO
WASHINGTON
OREGON
NEVADA
CALIF
ALBENI FALLS DIV. DAM
LEWIS CR. RES.
JONES CREEK DIV. DAM
APPLEGATE DIVERSION DAM
EIGHT DOLLAR RES.
BENJAMIN RES.
REDCAP RES.
HORSE LINTO RES.
BURNT RANCH RES.
GAYNOR PEAK RES.
SEATTLE
OLYMPIA
PORTLAND
SALEM
SPOKANE
LEWISTON
PENDLETON
BOISE
BEND
MEDFORD
KLAMATH FALLS
ELKO
CARSON CITY
SACRAMENTO
OAKLAND
SAN FRANCISCO
Columbia River
Snake River
Willamette River
Deschutes River
John Day River
Sacramento River
Russian River
Eel River
Mad River
Klamath River
Rogue River
Lake Tahoe
Pyramid Lake
Goose Lake
Clear Lake

PLATE 25

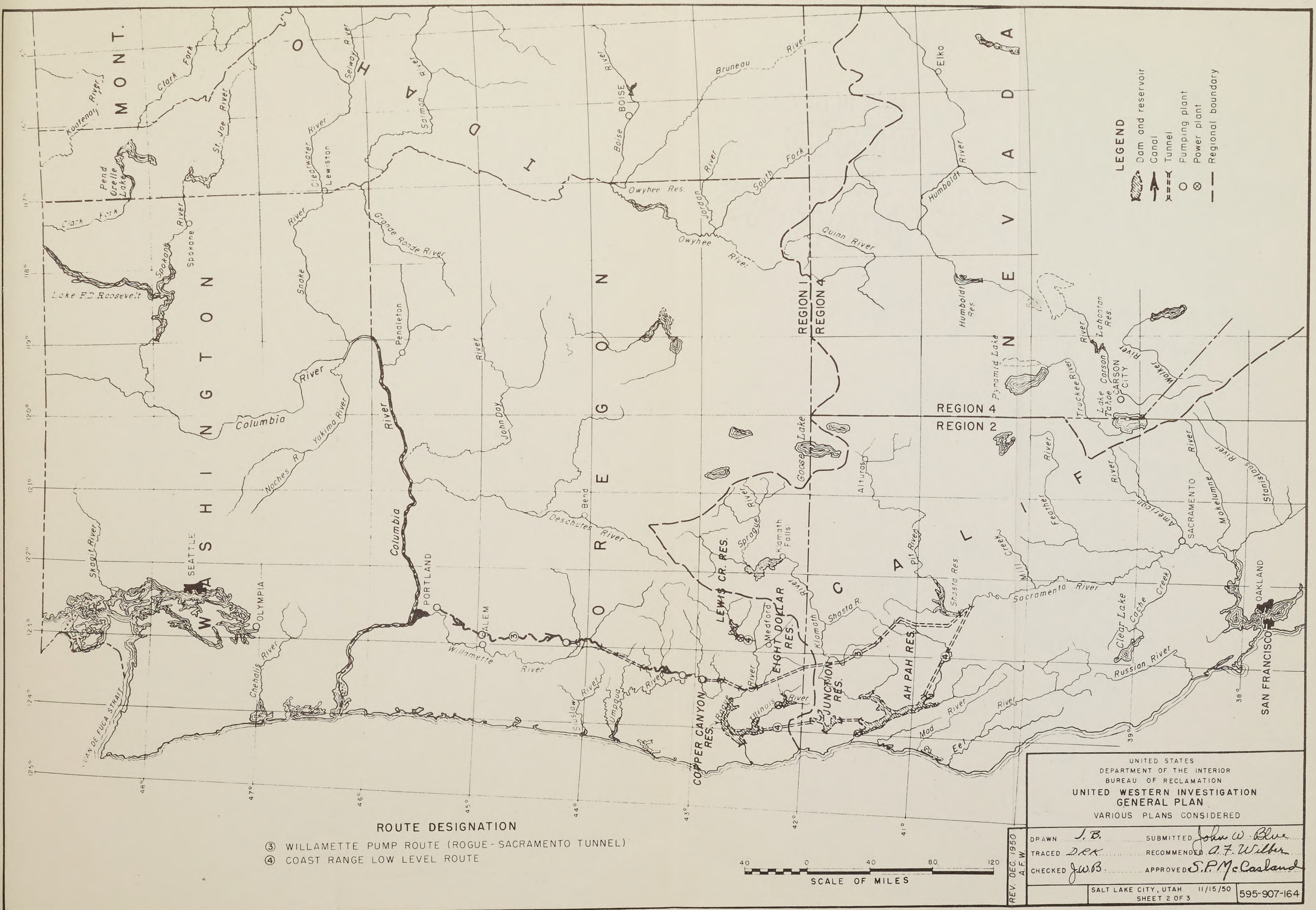

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UNITED WESTERN INVESTIGATION
GENERAL PLAN
VARIOUS PLANS CONSIDERED
DRAWN J.B.
TRACED D.R.K.
CHECKED J.W.B.
SUBMITTED John W. Blue
RECOMMENDED A.F. Wilber
APPROVED S.P. McCasland
REV. DEC. 1950 A.F.W.
SALT LAKE CITY, UTAH 11/15/50
SHEET 2 OF 3
595-907-164
LEGEND
Dam and reservoir
Canal
Tunnel
Pumping plant
Power plant
Regional boundary
ROUTE DESIGNATION
③ WILLAMETTE PUMP ROUTE (ROGUE - SACRAMENTO TUNNEL)
④ COAST RANGE LOW LEVEL ROUTE
SCALE OF MILES
40 0 40 80 120
MONT.
IDAHO
WASHINGTON
OREGON
NEVADA
CALIF.
REGION 1
REGION 4
REGION 2
SEATTLE
OLYMPIA
PORTLAND
SALEM
SPOKANE
PENDLETON
LEWISTON
BOISE
BEND
KLAMATH FALLS
MEDFORD
ALTURAS
ELKO
CARSON CITY
SACRAMENTO
OAKLAND
SAN FRANCISCO
LEWIS CR. RES.
EIGHT DOLLAR RES.
COPPER CANYON RES.
JUNCTION RES.
AH PAH RES.
Columbia River
Snake River
Willamette River
Deschutes River
John Day River
Yakima River
Rogue River
Klamath River
Sacramento River
Pit River
Feather River
American River
Owyhee Res.
Owyhee River
Humboldt River
Goose Lake
Pyramid Lake
Lake Tahoe
Clear Lake
Russian River
Eel River
Mad River
Lake F.D. Roosevelt
Pend Oreille Lake
Shasta Res.

PLATE 25

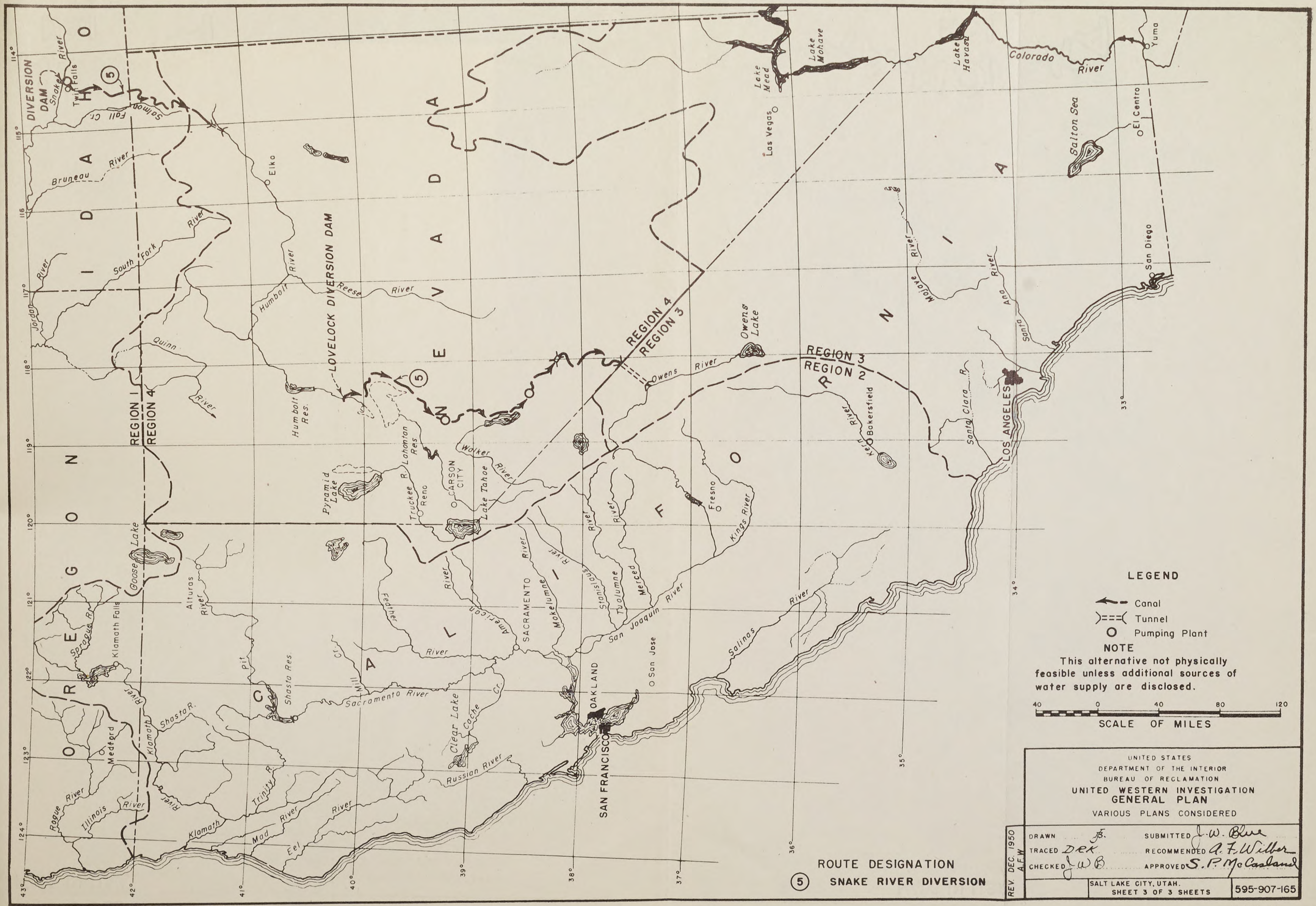

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UNITED WESTERN INVESTIGATION
GENERAL PLAN
VARIOUS PLANS CONSIDERED
DRAWN
TRACED
CHECKED
SUBMITTED J. W. Blue
RECOMMENDED A. F. Wilber
APPROVED S. P. McCasland
REV. DEC. 1950 A.F.W.
SALT LAKE CITY, UTAH.
SHEET 3 OF 3 SHEETS
595-907-165
LEGEND
Canal
Tunnel
Pumping Plant
NOTE
This alternative not physically feasible unless additional sources of water supply are disclosed.
40 0 40 80 120
SCALE OF MILES
ROUTE DESIGNATION
5 SNAKE RIVER DIVERSION
DIVERSION DAM
LOVELOCK DIVERSION DAM
REGION 1
REGION 4
REGION 3
REGION 2
IDAHO
NEVADA
OREGON
CALIFORNIA
Twin Falls
Snake River
Salmon Falls Cr.
Bruneau River
South Fork River
Jordan River
Quinn River
Elko
Humboldt River
Humboldt Res.
Reese River
Pyramid Lake
Truckee R.
Reno
Lahontan Res.
Carson City
Lake Tahoe
Walker River
Owens River
Owens Lake
Las Vegas
Lake Mead
Lake Mohave
Lake Havasu
Colorado River
Yuma
Salton Sea
El Centro
San Diego
Mojave River
Santa Ana River
Santa Clara R.
Los Angeles
Kern River
Bakersfield
Fresno
Kings River
Merced
Tuolumne River
Stanislaus River
Mokelumne River
American River
Sacramento
Feather River
Sacramento River
San Joaquin River
Salinas River
San Jose
Oakland
San Francisco
Russian River
Clear Lake
Cache Cr.
Mill Cr.
Pit River
Shasta Res.
Shasta R.
Alturas
Goose Lake
Klamath Falls
Sprague R.
Klamath River
Medford
Rogue River
Illinois River
Trinity R.
Mad River
Eel River
114° 115° 116° 117° 118° 119° 120° 121° 122° 123° 124°
43° 42° 41° 40° 39° 38° 37° 36° 35° 34° 33°

PLATE 25