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REPORT ON COLORADO RIVER WATER AVAILABLE  
AND USES IN ARIZONA IN RELATION TO PROPOSED  
SENATE BILL 56.

1939

ARIZONA. COLORADO RIVER COMMISSION.

Report on  
Colorado River Water Available  
and  
Uses in Arizona

In Relation to  
Proposed Senate Bill 56  
Providing for a Tri-State Compact



Arizona Colorado River Commission

January - 1939

## INTRODUCTION

Upon introduction of Senate Bill 56, relating to the Colorado River and providing for a compact between Arizona, California and Nevada, and providing for the approval of the Colorado River Compact, it was necessary that the Colorado River Commission review this bill in the light of factual data which had been assembled by this Commission during their term of office. The purpose of this paper is to bring together under one cover items of information which are scattered in many separate reports, and to bring about a better understanding of the water supply situation on the River, the proposed operation of the Boulder Reservoir, and the factors affecting the international situation and the relation of all of the above to the proposed bill.

It is obvious that the authors of various engineering papers dealing with the hydrological studies of the Basin may be expected to arrive at conclusions which are slightly different. One of the factors entering into this difference is that each of the divisions wish to substantiate their claim that they are able to use the water allocated to that division. In making a study of

the Colorado River Basin water supply, one soon realizes that there are two methods of approaching this subject, one being under the terms of the so-called Santa Fe Compact which is an artificial and arbitrary division of the water, and the other approach is based upon the physical and practical features which immediately present themselves in this kind of a study. In other words, although 7,500,000 acre feet is allocated to the upper division, it is obvious that if this water cannot be put to beneficial and consumptive use, it is impossible for this division to retain the water.

#### COLORADO RIVER BASIN WATER SUPPLY

In considering the water supply, under the terms of the Compact, which provides for a mean annual delivery at Lees Ferry of 7,500,000 acre feet averaged over a ten year period, or delivery of 75,000,000 acre feet over a ten year period and, assuming that the Upper Basin will use its full allocation of 7,500,000 acre feet, the following table shows the probable use of the water in the Upper Basin and the amount of water available to the Lower Basin based on the hydrograph of the river from 1897 to 1937.

Ultimate Upper Basin Consumptive Flow at Lees Ferry  
and Surpluses and Deficiencies in Deliveries

Based on Ten Year Progressive Means

Values in 1000 acre-feet

10-Year Period	Estimated Mean Upper Basin Consumption	Estimated Mean Flow at Lees Ferry	Estimated Surpluses and Deficiencies
1	2	3	4
1897-1906	7,185	8,070	570
1898-1907	7,230	8,254	754
1899-1908	7,222	8,239	739
1900-1909	7,372	8,740	1,240
1901-1910	7,410	8,867	1,367
1902-1911	7,493	9,151	1,651
1903-1912	7,740	10,011	2,511
1904-1913	7,762	10,081	2,581
1905-1914	7,972	10,801	3,301
1906-1915	7,920	10,617	3,117
1907-1916	7,935	10,652	3,152
1908-1917	7,942	10,648	3,148
1909-1918	7,995	10,839	3,339
1910-1919	7,702	9,856	2,356
1911-1920	7,882	10,467	2,967
1912-1921	7,973	10,779	3,279
1913-1922	7,935	10,652	3,152
1914-1923	8,048	11,052	3,552
1915-1924	7,860	10,422	2,922
1916-1925	7,875	10,450	2,950
1917-1926	7,745	10,040	2,540
1918-1927	7,688	9,829	2,329
1919-1928	7,710	9,929	2,429
1920-1929	7,935	10,688	3,188
1921-1930	7,748	10,032	2,532
1922-1931	7,425	8,927	1,427
1923-1932	7,403	8,841	1,341
1924-1933	7,230	8,251	751
1925-1934	7,050	7,604	104
1926-1935	7,005	7,423	- 77
1927-1936	6,992	7,325	- 175
1928-1937	6,867	6,853	- 647
Actual Mean 1897-1937	7,500	8,975	1,475

It will be seen from this analysis that, had the Compact been in effect during this period, there would have been a mean annual Upper Basin consumption of 7,500,000 acre feet. The estimated mean flow at Lees Ferry during this period would have been 8,975,000 acre feet, showing an estimated surplus of 1,475,000 acre feet. It will be noticed that in the last three years the table computed on the above basis shows a deficiency. However, it is believed consumption in the Upper Basin cannot consumptively use 7,500,000 acre feet and cannot approach this figure without considerable reservoir development. Reservoir development in the Upper Basin area would equalize the river flow to such an extent that in all probability no deficiency would occur. Or, at least, it would be greatly reduced.

In the study of the hydrology of the Boulder Canyon Reservoir, it was necessary to consider the natural physical division of the water rather than the arbitrary division as set forth in the Compact. The first step in this study was to determine the mean annual discharge at Black Canyon, the present site of Boulder Dam. The following table gives the results of this study.

Mean Annual Discharge at Black Canyon

In Acre-Feet

1897-1901, inclusive:

Bureau's 1930 estimate	- - - - -	16,200,000
LaRue 1925 estimate	- - - - -	17,700,000

1902-1922, inclusive:

Bureau's 1930 estimate from upstream		
	records - - - - -	17,600,000
Bureau's 1930 estimate from Yuma records		17,300,000
LaRue 1925 estimate	- - - - -	17,800,000

After determining this mean annual discharge, it was necessary to estimate the probable future water supply in order that the generating facilities, penstocks, and hydraulic structures might be designed to adequately serve the need as anticipated during the operating life of the structure. The study was based on the probable conditions at three dates, namely - What the conditions were as of 1928, what they would be as of 1938, and what might be expected in 1988. It is interesting to note that the estimate as set up for 1938 is very conservative, and actually the mean annual flow into Boulder Canyon is in excess of the amount of 15,900,000 as estimated.

WATER SUPPLY WITH DEVELOPMENT  
ABOVE BOULDER CANYON

	1928	1938	1988
Irrigated area, acres - - - -	1,717,000	2,040,000	3,368,000
Capacity of irrigation reservoirs, acre-feet - - -	662,000	- -	2,933,000
Capacity of power reservoirs, acre-feet -, - - - - - - -	10,000	- -	8,100,000
Transmountain diversions, acre- feet annually - - - - - - -	116,000	180,000	621,000
Surface area of irrigation reservoirs, acres - - - - -	27,800)	60,000	( 86,400
Surface area of power reservoirs, acres - - - - -	2,000)		( 172,000
Mean depletion for irrigation consumptive use, transmountain diversions and reservoir losses, acre-feet annually	2,760,000	3,481,000	6,595,000
Mean Annual inflow to Boulder Canyon acre-feet	15,730,000	15,009,000	11,895,000

It will be seen by referring to the above table that the estimated mean annual inflow into the Boulder Reservoir in 1988 is 11,895,000 acre feet annually.

In the recent studies made by Joseph Jacobs and J. C. Stevens, Consulting Engineers, U. S. Department of Interior, December 31, 1937, it was concluded that, by including all of the feasible projects for irrigation,

transmountain diversion, reservoir losses for irrigation and power, silt and flood control, and domestic use, that the depletion of the river flow due to all such developments in the upper division was not likely to exceed 6,348,000 acre feet per year. In the Lower Basin, after including the development of what is considered to be all of the feasible projects in Arizona, Nevada and California, and adding reservoir and channel losses, the result is a net total Lower Basin use of 10,049,000 acre feet per year, and the total Colorado River use in both Basins of 16,397,000 acre feet per annum (or per year).

#### SUMMARY

The foregoing shows that the Engineers of the Upper Basin have estimated that there would be 8,975,000 acre feet per year available for the Lower Basin. In the studies made by the U. S. Bureau of Reclamation in connection with the hydrology of the Boulder Reservoir it was estimated that the amount of water available for use in the Lower Basin would be 11,895,000 acre feet per year. Jacobs-Stevens, in their Report, estimated that there would be 10,049,000 acre feet per year available for use in the Lower Basin.

The Colorado River Commission, in considering the purposes for which these Reports were made and the possibility of unintentional influences creeping into

matters of decision and assumptions, have felt that a compromise figure between 11,895,000 and 10,049,000 would be the best estimate. Therefore, we have used the figure of 10,652,000 acre feet per year, arrived at as follows:

From a careful study of the Jacobs-Stevens Report we are certain that they have included all of the projects which are likely to develop in the Upper Basin and we believe that the figure of 6,348,000 acre feet for annual consumptive use in the Upper Basin is just and correct. We also believe that the long time record of mean annual discharges at Boulder Canyon is reliable and acceptable. We have taken the mean annual inflow into Boulder Canyon under virgin conditions to be 17,000,000 acre feet per year. Therefore, if we deduct the probable ultimate consumptive use of the Upper Basin from this figure, we should have the net amount of water available for use in the Lower Basin, which is 10,652,000 acre feet per year.

OPERATION OF BOULDER CANYON RESERVOIR  
WITH RESPECT TO IRRIGATION DEMANDS.

The potential power available for sale at Boulder in 1938 was 4,333,000,000 kwh of firm energy, which will be annually reduced throughout the repayment period at the rate of 8,760,000 kwh per year to allow for the increase in development in the Upper Basin. It has been estimated

that between the years of 1950 and 1960 there will be a conflict between the irrigation and power demands which will require a further reduction of the generation of firm energy. In order to meet this situation it will be necessary to construct a dam below Boulder.

The studies under way at this time indicate that this regulating dam will be constructed at what is known as Bullshead. It is estimated that within ten to fifteen years there will be a greater demand for hydro-electric power from Boulder than can be supplied. Therefore, the construction of the Bridge Canyon dam is contemplated.

The Bridge Canyon dam will provide additional power, flood control, and silt control, and will be operated in conjunction with Boulder Dam. The construction of this dam will make possible the reduction in the flood reserve of Boulder Reservoir which is now set at 9,500,000 acre feet. The placing of a part of this burden on the Bridge Canyon reservoir will enable the turbines at Boulder to work at a higher head during the flood season. Also, a dam constructed at Bridge Canyon will intercept a large percentage of the Colorado River Silt. Since the silt problem at Boulder eventually will become acute, this is a vital consideration. Likewise, it will be necessary to construct a silt control dam on the Little Colorado River, probably at the Tolchico damsite.

## RESERVOIRS WITHIN ARIZONA.

It has been assumed that, in addition to Boulder Dam and Parker Dam, the Bullshead Dam will be constructed and that the Bridge Canyon Dam will also be constructed. Such a plan will make a continuous chain of lakes starting at Parker and ending at the end of the Bridge Canyon reservoir.

Table Showing Reservoir Surface Area in Acres  
and Capacity in Acre Feet.

Reservoir	Surface Area Acres	Capacity Acre-Feet
Bridge Canyon	12,000	2,500,000
Boulder	146,500	30,500,000
Bullshead	29,000	2,125,000
Parker	25,000	700,000
Total	212,500	35,825,000

From the foregoing table it is shown that the total surface area of these reservoirs will be 212,500 acres, and that the total storage capacity will be 35,825,000 acre feet.

### EVAPORATION LOSSES FROM RESERVOIRS

The evaporation losses throughout the entire Colorado River Basin have been found to vary from 1.5 to 5.5 feet in

vertical depth per year over the exposed reservoir areas. The reason for this extreme variation is that the evaporation losses are much less in the colder climates than they are in the hot, dry, windy climate applicable to the reservoirs under consideration. Therefore, 5.0 feet has been taken as the mean evaporation loss in this system of reservoirs. Using this figure, the total evaporation loss from the system would be 1,062,500 acre feet annually.

#### FEASIBLE ARIZONA IRRIGATION PROJECTS

Arizona, in the past, has had many schemes for the use of the Colorado River water within Arizona. Some of these schemes are considered by this Commission to be fantastic and impractical. However, there are many projects which are economically feasible and should be given careful consideration and should be developed as rapidly as possible.

The Gila Project is comprised of 585,000 acres, after deducting 6% of the gross area for roads, building of canals, etc. This project is located along the lower Gila Valley, reaching from above Aztec to a point near Yuma, and the project is divided into four units. These are known as - The Desert Area, the Wellton Mesa Area, the San Cristobal Valley, and the Palomas Area. The first unit is now under construction, and detailed surveys and investigations are being made on the other units as rapidly as possible. The project designated as the Yuma Project consists of the old irrigated lands in and around Yuma and

Somerton.

The Reclamation Service is now making extensive investigations at the Bullshead damsite in order to determine the best location for a dam, and it is believed that the site will provide adequate storage and will raise the water to a sufficient height to enable the irrigation by gravity of a large portion of the Mohave Valley.

Mohave Valley consists of bottom lands extending from Fort Mohave on the north to Topock on the south, a distance of about 25 miles with a maximum width of about  $5\frac{1}{2}$  miles. Reclamation of this land has been attempted in the past. Failure of the enterprise was caused by the breaking of levees which were necessary in order to protect the lands from excessive floods. However, this condition is past due to the construction of Boulder Dam. In addition to the area that may be irrigated by gravity there is a large area of bench lands which may be irrigated by a pump lift not to exceed 150 feet.

Below Parker Dam we have the Colorado River Indian Reservation. Work is now under way to deliver water stored in Parker Reservoir to these lands from a diversion dam to be constructed at the Headgate Rock, which is a few miles below the present Parker Dam. In addition to the lands which may be irrigated by gravity, there is a portion of the Parker Mesa which may be irrigated by a pump lift not to exceed 150 feet. Below Parker is the Cibola Valley, which may be irrigated from the Colorado River by gravity.

In addition to these projects, are prospective developments along the Little Colorado River and the Williams River. Engineers of the Bureau of Reclamation are now making investigations of both of these streams. The latest reports indicate that the entire flow of the Williams River can be used in the State of Arizona. The annual discharge of this River amounts to approximately 250,000 acre feet. Since no definite plan for projects along this River has been promulgated, it has been assumed that the consumptive use of this entire River will be realized. The same condition is true of the Little Colorado River, excepting that most of the normal flow of this River is now appropriated and in use. However, there is about 200,000 acre feet of flood water flowing into the Colorado River annually which can undoubtedly be used within the State. It is reasonable to assume that this water will eventually be put to consumptive use within the State.

Arizona Projects Which Will be Irrigated  
by Colorado River Water.

Project	Acreage	Consumptive Use Acre Feet
Gila Project *#	585,000	2,047,500
Yuma Project #	45,000	157,500
Mohave Project #	24,000	84,000
Mohave Project *	9,000	27,000
Parker (Indian Lands)	104,000	364,000
Parker Mesa *	6,000	18,000
Cibola #	16,000	56,000
Williams River #	---	187,500
Little Colorado River #	---	150,000
	** 789,000	3,091,500

\*\* Total does not include lands along the Williams River and the Little Colorado River. No reliable data is available.

\* Lands receiving water by pump.

# Lands receiving water by gravity.

#### ESTIMATED LOWER BASIN USES

The Boulder Canyon Project Act provides for the possible use of 300,000 acre feet of Colorado River water per year in Nevada. However, most authorities who have made a careful study of the possibilities of use of water in Nevada concur that it will be economically impractical

for Nevada to use over 14,000 acre feet of Colorado River Water within that state. Therefore, that figure has been used in our estimates.

Lower Basin Ultimate Consumptive Use

Use	Acre Feet
Evaporation Loss - - - - -	1,062,000
Arizona Projects - - - - -	3,091,500
California (Exported from Basin) - - - - -	4,885,000
California Yuma Project - - - - -	75,000
California Palo Verde Project - - - - -	402,000
Nevada - - - - -	14,000
Total	9,529,500

From the above table it is estimated that the total consumptive use in the lower division will be 9,529,500 acre feet annually. As previously estimated, the total water available for use in the Lower Basin would amount to 10,652,000 acre feet per year. Based on the foregoing estimates there would be an available excess of 1,122,500 acre feet per year for contingencies and to supply the irrigation demands of Mexico.

WATER FOR USE IN MEXICO

The return flow from the American Projects above the Mexican Border and below the Imperial Dam will supply

water for use in Mexico as shown in the accompanying table.

Theoretical Surplus Available for use  
in Mexico.

Project	Return Water
Gila Project - - - - -	580,000
Yuma Project - - - - -	45,000
California Project - - - - -	400,000
	<hr/> 1,025,000

If desilting operations are required at the Imperial Dam, there will be approximately 350,000 acre feet released annually in this operation which will be available for use in Mexico, making the total water available for Mexico 1,375,000 acre feet. Prior to the construction of Boulder Dam, the maximum amount of water beneficially used in Mexico was 750,000 acre feet annually. In view of the foregoing, it is quite certain that there is ample water available to satisfy any just claim that Mexico might make.

OTHER COLORADO RIVER DEVELOPMENT PLANS WITHIN ARIZONA

In addition to the projects outlined in the foregoing, there has been several other plans for the diversion of water from the Colorado River into Central Arizona.

Owing to the fact that there seems to be such a popular misunderstanding in regard to these projects it might be well to mention some of the facts regarding these projects and why they have been eliminated from further consideration by the Commission.

The engineering, economic and construction features of the so-called Colorado River-Verde Tunnel Project are such that they would render this Project impractical and unfeasible. From a topographical and physical standpoint the so-called Glenn Bridge Canyon High Line Project is more feasible than the Verde-Colorado Tunnel Project, but neither of these projects is considered feasible at this time.

In the statements made by the proponents of the Glenn Bridge Canyon High Line Project, they have led many people to believe that it is possible to irrigate 6,000,000 acres of land in Central Arizona and to develop some 6,000,000 electric horsepower from the waters of the Colorado River. It is only a matter of simple deduction, from the foregoing data, to determine that there is not sufficient water to irrigate any 6,000,000 acres of land or any amount approaching this figure.

The United States Government now has invested approximately \$165,000,000 in the Boulder Canyon Project. The repayment of the majority of this investment is guaranteed by the sale of power generated at the Boulder Dam by allowing the waters of the Colorado River to pass through

the generators. It has been definitely stated by Government officials that the Government would not see fit to finance any projects above Boulder Dam which would endanger the repayment of this investment. It is for these reasons that these projects have not been mentioned in the foregoing outline.

#### BRIDGE CANYON POWER SITE

It is believed Arizona has one of its greatest undeveloped natural resources in the Bridge Canyon damsite. The proposed site for the dam, commonly referred to as the Bridge-Canyon, is located about two hundred thirty-six miles below Lees Ferry, and about two hundred sixty miles above Yuma. It is about ten miles downstream from the confluence of Diamond Creek and the Colorado River, and is at the extreme end of Lake Mead when the reservoir is full. This damsite is one of the finest on the entire River. The cross section of the damsite at Bridge-Canyon is almost identical to the cross section at Boulder Dam. The reservoir storage capacity at this damsite would be comparatively small, and would be subject to rapid depletion by silt accumulation. This dam, without upstream regulation would have a large fluctuation in power head.

However, in spite of these facts, a large amount of firm energy could be generated, with a very large percentage of secondary energy which could be converted to firm energy upon the completion of a dam upstream for regulation. As

this damsite is at a comparatively short distance from Boulder Dam, and with the City of Los Angeles constructing a third circuit to transmit that portion of the Metropolitan's unused firm energy which they (Metropolitan) are unable to take at this time and which will be a diminishing quantity for the next fifteen years, it is quite possible that, within the next fifteen years, Arizona could finance and build the Bridge-Canyon dam and install the necessary generating equipment to furnish power to be transmitted over the City of Los Angeles' third circuit which is now being built at a cost of some Twenty Million Dollars. Under such a set-up the dam and generating equipment would be paid for out of the revenue derived from the sale of power, and ultimately would produce a perpetual source of revenue and cheap power to the state of Arizona.

Our preliminary studies at this site indicate that a dam of about 570 foot height above the river surface could be built at this site. Such a dam would have a crest length of about 870 feet. Spillways would be tunnels about 400 feet long spilling into the side canyon on the south known as Spillway Canyon. A dam so constructed would create a lake about 78 miles long, with a surface area of approximately 12,000 acres, and would have a capacity of approximately 2,500,000 acre feet. A rough estimate indicates that about 330,000 horsepower would be available 90% of the time, with about 500,000 horsepower available 50%

of the time, making the installed capacity about 800,000 horsepower with provision for installation of another 300,000 horsepower when upstream storage or development would create necessary regulation.

As previously mentioned, with regulation this dam could produce a very large amount of firm energy, much more than could be used in Arizona, but could be absorbed on the Pacific Coast, owing to the fact that transmission facilities are now installed, or are being installed, which would be available for the transmission of this power. It is with this thought in mind that filings were made upon this damsite as required by the United States Federal Power Commission for the power rights at this site in the name of the state of Arizona.

In addition to power possibilities at Bridge-Canyon damsite, there will be power development in the future at Parker Dam. Also, it is quite evident that Bullshead dam will be built in the future, and at such time power will be developed which would be available for use in Arizona.

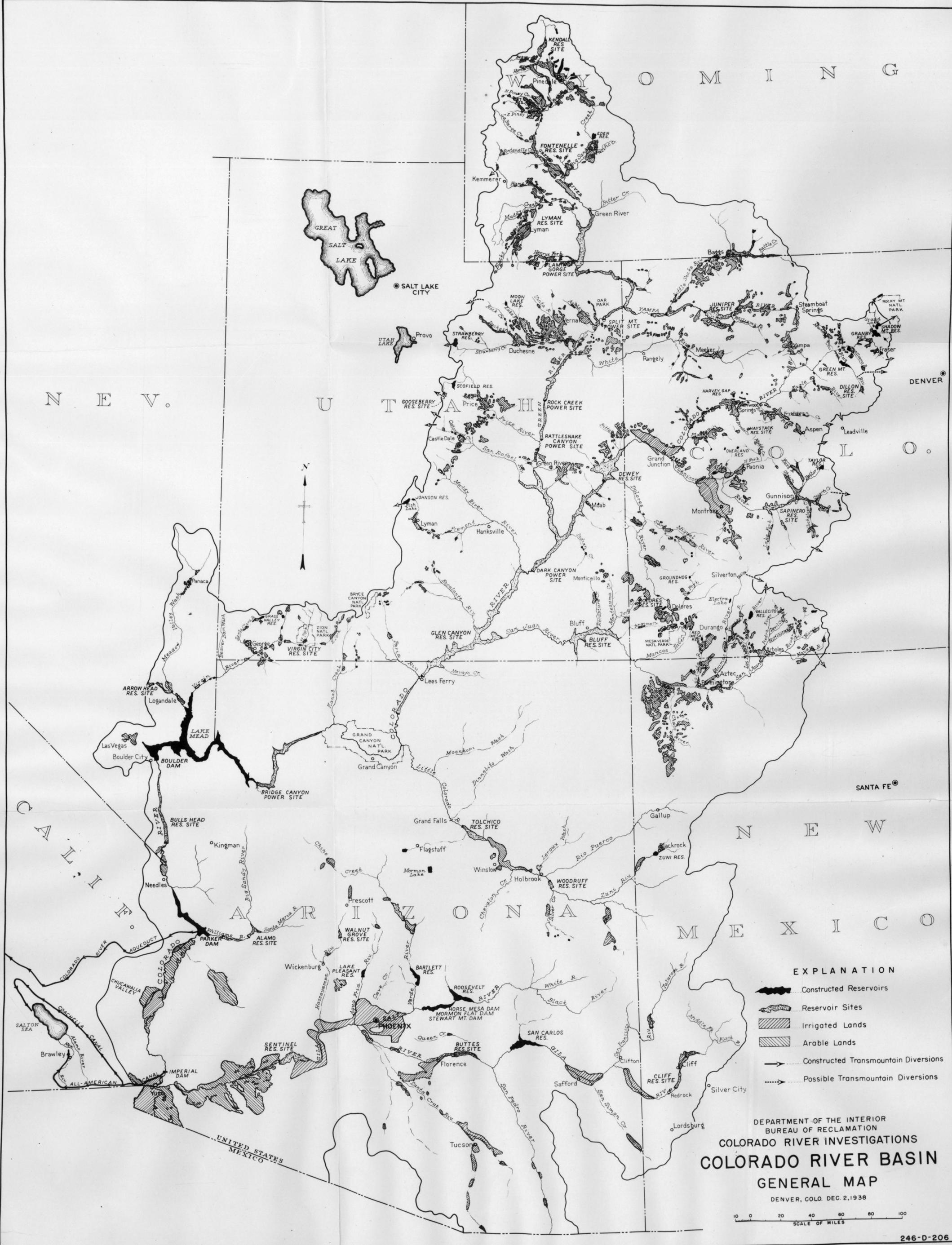
#### CONCLUSION

(1) Inasmuch as the provisions of Senate Bill 56 do not give to the state of California, or any other State, any right which they do not have under their existing contracts under the provisions of the Boulder Canyon Project Act and the Compact;

(2) No water or power may be taken from the

Colorado River without coming under the provision of the Boulder Canyon Project Act and the Compact;

(3) Inasmuch as this Act will establish a definite priority and right to the waters of the Colorado River as against Mexico, and will give Arizona the exclusive beneficial consumptive use of 2,800,000 acre feet annually from the main stream, will give the exclusive beneficial consumptive use of the waters of the Gila River and its tributaries within Arizona free from the burden of any Mexican demand and will give Arizona the right to the use of one-half of the excess or surplus waters of the Colorado River, and owing to the fact that there is sufficient water provided for under this Act for the present and future needs of the Arizona projects, we feel that there is everything to be gained by the enactment of this legislation and nothing to lose.



N E V.

U T

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M E X I C O

**EXPLANATION**

-  Constructed Reservoirs
-  Reservoir Sites
-  Irrigated Lands
-  Arable Lands
-  Constructed Transmountain Diversions
-  Possible Transmountain Diversions

DEPARTMENT OF THE INTERIOR  
 BUREAU OF RECLAMATION  
**COLORADO RIVER INVESTIGATIONS**  
**COLORADO RIVER BASIN**  
**GENERAL MAP**

DENVER, COLO. DEC. 2, 1938

