UPPER COLORADO RIVER COMMISSION

SIXTH ANNUAL REPORT

APRIL 1, 1955

THE SENTINEL PRINTERS, GRAND JUNCTION, COLORADO

UPPER COLORADO RIVER COMMISSION

520 Rood Avenue

Grand Junction, Colorado

April 1, 1955

Mr. President:

Article VIII (d) (13) of the Upper Colorado River Basin Compact provides that the Upper Colorado River Commission shall make and transmit annually to the Governors of the signatory States and the President of the United States of America, with the estimated budget, a report covering the activities of the Commission for the preceding water year.

A copy of the Sixth Annual Report is enclosed. The budget is attached as Appendix A.

Respectfully yours,

/s/ IVAL V. GOSLIN

IVAL V. GOSLIN
Acting Secretary

The President
The White House
Washington 25, D. C.

Enclosure

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This report was, on the same date, transmitted to the Governors of each Upper Basin State.

FRONTISPIECE

LETTER OF TRANSMITTAL

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SIXTH ANNUAL REPORT

UPPER COLORADO RIVER COMMISSION

April 1, 1955

Article VIII (d) (13) of the Upper Colorado River Basin Compact provides that the Upper Colorado River Commission shall "make and transmit annually to the Governors of the signatory States and the President of the United States of America, with the estimated budget, a report covering the activities of the Commission for the preceding water year."

Article VIII of the By-Laws of the Upper Colorado River Commission provides as follows:

1. The Commission shall make and transmit annually on or before April 1 to the Governors of the states signatory to the Upper Colorado River Basin Compact and to the President of the United States, a report covering the activities of the Commission for the water year ending the preceding September 30.

2. The annual report shall include, among other things, the following:

   (a) The estimated budget;

   (b) All hydrologic data which the Commission deems pertinent;

   (c) Estimates, if any, of the Commission forecasting water run-off;

   (d) Statements as to cooperative studies of water supplies made during the preceding water year;

   (e) All findings of fact made by the Commission during the preceding water year;

   (f) Such other pertinent matters as the Commission may require.

For data on the activities of the Commission during that part of the preceding water year to March 25, 1954, reference is hereby made to the Commission's Fifth Annual Report. In order that a more nearly recent account of the Commission's activities may be gained, the Commission has determined to include in this report an account of the activities of the Commission through March 21, 1955.

During the period covered by this report, the Commission consisted of the following:

Robert J. Newell	—Commissioner for the United States of America and Chairman of the Commission
John R. Erickson	—Commissioner for the State of New Mexico and Vice Chairman of the Commission
John H. Bliss	—Commissioner for the State of New Mexico
E. L. Dutcher	—Commissioner for the State of Colorado
Frank Delaney	—Commissioner for the State of Colorado
George D. Clyde	—Commissioner for the State of Utah
L. C. Bishop	—Commissioner for the State of Wyoming

The following have acted as advisers to each Commissioner from time to time:

United States of America:

Legal:

E. W. Fisher, Chief Counsel, Bureau of Reclamation, Washington, D. C.

T. Richard Witmer, Assistant Chief Counsel, Bureau of Reclamation, Washington, D. C.

J. Stuart McMaster, Regional Counsel, Region IV, Bureau of Reclamation, Salt Lake City, Utah

James D. Geissinger, Regional Solicitor, Department of the Interior, Denver, Colorado

Engineering:

J. R. Riter, Chief, Hydrology Division, Bureau of Reclamation, Denver, Colorado

H. P. Dugan, Head, River Regulation Section, Hydrology Division, Bureau of Reclamation, Denver, Colorado

Cecil B. Jacobson, Area Engineer, Colorado River Storage Project, Bureau of Reclamation, Salt Lake City, Utah

Colorado:

Legal:

Hatfield Chilson, Loveland, Colorado

Omer Griffin, Deputy Attorney General, Denver, Colorado

Engineering:

Royce J. Tipton, Consultant, Colorado Water Conservation Board, Denver, Colorado

Frank C. Merriell, Engineer, Colorado River Water Conservation District, Grand Junction, Colorado

Ivan C. Crawford, Director, Colorado Water Conservation Board, Denver, Colorado

New Mexico:

Legal:

Fred E. Wilson, Attorney at Law, Albuquerque, New Mexico

R. H. Robinson, Attorney General, Santa Fe, New Mexico

Engineering:

John H. Bliss, Santa Fe, New Mexico

I. J. Coury, Member, Interstate Stream Commission, Farmington, New Mexico

Utah:

Legal:

E. R. Callister, Jr., Attorney General, Salt Lake City, Utah

J. A. Howell, Attorney at law, Ogden, Utah

Engineering:

Joseph M. Tracy, State Engineer, Salt Lake City, Utah

Jay R. Bingham, Utah Water and Power Board, Salt Lake City, Utah:

Wyoming:

Legal:

Howard Black, Attorney General, Cheyenne, Wyoming

Engineering:

H. T. Person, Dean, School of Engineering, University of Wyoming, Laramie, Wyoming

Earl Lloyd, Deputy State Engineer, Cheyenne, Wyoming

Paul Rechard, Engineer, Wyoming Natural Resources Board, Cheyenne, Wyoming

Alternates in absence of Commissioner:

Joe L. Budd, Big Piney, Wyoming

Norman W. Barlow, Cora, Wyoming

The staff of the Upper Colorado River Commission, as of the date of this report, consists of:

John Geoffrey Will, Secretary and General Counsel
R. D. Goodrich, Chief Engineer
Ival V. Goslin, Assistant Chief Engineer
Barney L. Whatley, Treasurer
Richard T. Counley, Assistant Treasurer
Mrs. Lois S. Burns, Administrative Assistant
Mrs. Lois P. Crowder, Official Reporter

During the period March 15, 1954 to March 21, 1955, the Commission held eleven meetings, as follows:

March 15, 1954	Regular Meeting Washington, D. C.
June 30, 1954	Adjourned Regular Meeting Washington, D. C.
September 20, 1954	Annual Meeting Grand Junction, Colorado
October 14, 1954	Adjourned Annual Meeting Denver, Colorado
October 30, 1954	Special Meeting Denver, Colorado
November 7, 1954	Special Meeting Portland, Oregon

December 10, 1954	Special Meeting Salt Lake City, Utah
January 8, 1955	Special Meeting Denver, Colorado
January 23-24, 1955	Special Meeting Gallup, New Mexico
February 25-March 2, 1955	Special Meeting Washington, D. C.
March 21, 1955	Regular Meeting Grand Junction, Colorado

During this period also there were meetings from time to time of the standing committees. These committees and their membership, as of the date of this report, are as follows:

Engineering Committee:

J. R. Riter, Chairman
John H. Bliss
Royce J. Tipton
George D. Clyde
Jay R. Bingham
Frank C. Merriell
H. T. Person
Joseph M. Tracy
Earl Lloyd
Ivan C. Crawford

Legal Committee:

Fred E. Wilson, Chairman
E. R. Callister, Jr.
J. Stuart McMaster
Howard Black
Omer Griffin
Hatfield Chilson

Budget Committee:

John H. Bliss, Chairman
Joseph M. Tracy
Ivan C. Crawford
J. R. Riter
Norman W. Barlow

The following special committees also met during the period of this report:

Committee on Rules and Regulations:

E. R. Callister, Jr., Chairman
R. M. Gildersleeve
Earl Lloyd
Fred E. Wilson
J. R. Riter

Finance Committee:

Norman W. Barlow, Chairman
Dan Hunter
George D. Clyde
I. J. Coury

Committee to Consider What, If Any, Changes Should be made in the Draft of Bill to Authorize the Colorado River Storage Project and Participating Projects:

E. R. Callister, Jr., Chairman
John Geoffrey Will
Howard Black
Omer Griffin
I. J. Coury

The principal activities of the Commission and its staff have consisted of: (a) the final preparation and arrangements for introduction of and hearings on legislation to authorize the Colorado River Storage Project and participating projects; and (b) research looking to improved methods for the application of the Inflow-Outflow theory of measuring the consumptive use of water.

No findings of fact, pursuant to Article VIII of the Upper Colorado River Basin Compact have been made by the Commission.

The Commission acknowledges with appreciation the assistance that it has had throughout the year from agencies of the Executive Branch of the Federal Government and the courtesies extended to it by the Legislative Branch.

Most encouraging progress has been made in connection with our efforts to secure the enactment of legislation to authorize the Colorado River Storage Project and Participating Projects. Since January 1, the Commission has maintained a temporary office at Washington, D. C. which has served as a base of operations in connection with the authorization of the Colorado River Storage Project and Participating Projects, as well as for the Upper Colorado River Basin Grass Roots, Inc. Hearings have been held by the Irrigation and Reclamation Sub-Committee of the Senate Committee on Interior and Insular Affairs. The case for the Project has been made before the House Sub-Committee. A most impressive group of witnesses appeared at the hearings in support of legislation.

The Department of the Interior has approved a large part of our program.

In his address to the Congress on the State of the Union, President Eisenhower said (House Document No. 1, 84th Congress, p. 8):

> "*** the Federal Government must shoulder its *** partnership obligations by undertaking projects of such complexity and size that their success requires Federal development. In keeping with this principle I again urge the Congress to approve the development of the Upper Colorado River Basin to conserve and assure better use of precious water essential to the future of the West."

Likewise in his Budget Message (House Document No. 16, 84th Congress, p. M65) the President said:

> "I also recommend enactment of legislation authorizing the Bureau of Reclamation to undertake construction of two comprehensive river-basin improvements which are beyond the capacity of local initiative, public or private, but which are needed for irrigation, power, flood control and municipal and industrial water supply. These are the Upper Colorado River Basin development in the States of Colorado, Utah, Wyoming, Arizona, and New Mexico, and the Fryingpan-Arkansas development in Colorado. The Colorado River development will enable the

Upper Basin States to conserve flood waters and to assure the availability of water and power necessary for the economic growth of the region. *** Sale of power generated at these developments will repay the power investment within 50 years and will make a contribution toward repayment of other investments."

In the budget itself it was pointed out (p. 830) that the Administration proposes to initiate construction of the Colorado River Storage Project during the next fiscal year if it is authorized and that the budget includes an item for funds to be requested for this purpose.

The members of the Senate and House of Representatives from the Upper Colorado River Basin States have worked valiantly and ably. We look with hope and confidence to the enactment of legislation on the project by the present Congress.

Technical work with respect to the Inflow-Outflow Method of measuring stream depletions was continued throughout the past year. Three of the larger sub-basins in the Upper Colorado River Basin have now been very thoroughly covered. Considerable investigation has also been done on inflow-outflow relationships between inner rim stations above the canyon sections of the Colorado, Green and San Juan Rivers which unite in the canyons leading to the Compact Point at Lee Ferry.

Through the cooperation of the Bureau of Reclamation the use of its electronic calculating equipment and staff made it possible to make an exhaustive investigation of the influence of numerous climatic factors, as well as stream discharge records, which are known to influence the variable annual and seasonal character of stream flow.

For the Colorado River Basin and the Gunnison River Basin above Grand Junction 55 sets of simultaneous equations using various combinations of from three to six of 22 different variables were solved in complete detail for each of these two streams. In addition, 22 sets of equations using various combinations of 11 selected variables showing the greatest significance were solved for the Green River Basin.

The adjusted coefficients of correlation (R) for all the 132 resulting equations computed were over 95%. The smallest value was 95.5% on the Green River where, however, 8 of the 22 equations had coefficients of correlation of 97%, one being 97.5%. Of the 55 equations for the Colorado River and also for the Gunnison River above Grand Junction, at least 13 equations had adjusted values of the coefficients of correlation of 98% or better. The smallest value of this coefficient for each stream was 97% while there were 4 for each stream which were 98.5% or over.

While these results are very encouraging, much remains to be done to cover all sub-basins in the four states of the Upper Division of the Colorado River Basin. Only five or six of the most significant variates may be adopted as standard for the further studies and only eight or ten sets of simultaneous equations will be solved for each sub-basin, thus saving as much time as possible in this phase of these studies.

An investigation of the inflow-outflow relations at Lee Ferry which covered several months led to the conviction that the additional information on present irrigation in each state of the Upper Basin, which information has been requested through the Commission, will be necessary before the final phase of these studies can be undertaken.

In the meantime the installation of several new gaging stations nearer state boundaries than are some of the old locations will require special correlation studies before the records for the short periods these new stations have been in operation can be substituted for those covering the much greater number of years the older stations have been in operation. On an annual basis a record of stream discharges covering four years is only half as reliable as one covering sixteen years, hence the desirability of avoiding a very short record of stream flow if possible.

A preliminary study was recently made of the available discharge records which give the flow of the Colorado River crossing the United States-Mexico boundary and the elevation of the Salton Sea. The records used are found in the U. S. Geological Survey Water Supply Papers for the Colorado River Basin and the Great Basin including the year 1952 with provisional records for the years 1953 and 1954. These studies are for the water year beginning on October first of the preceding year. The records dealing with the Salton Sea are contained in the Water Supply Papers for the Great Basin and give only the surface elevations below mean sea level for about the first of each month up to the year 1952 after which U. S. Geological Survey provisional records were obtained. Areas enclosed by three contours at elevations 250, 240 and 230 feet below mean sea level were also available. The water surface of the Lake has now risen above the -240 foot level so that the areas of the lake are obtained by interpolation between those for the -240 and -230 contours. No published records are available of the flow into the Salton Sea from any of several drainage channels or waste ditches. Hence indirect methods must be used to estimate the quantity of water from the Colorado River flowing into this sink. The data available upon which these estimates are made are very meager, to say the least.

Return surface flows as given in the U. S. Geological Survey Colorado River Basin Water Supply Papers and provisional tabulations for the period 1939 through 1953, were first tabulated for the discharge of the several channels and ditches draining the return flow from the Yuma Irrigation Project. A similar tabulation was also made of the records of the Colorado River for the gaging stations at the Mexican boundary and for the flow carried by the Alamo Canal. The discharge of the river as recorded at the Yuma gage was also included for comparison and checking. In rounded figures the total annual average delivery of Colorado River water to Mexico for the ten year period 1944-53 was 8,000,000 acre-feet.

During this period the flow across the border into Mexico varied from a maximum of 11,370,000 acre-feet in 1944 to a minimum of 3,460,000 acre-feet in 1951. The maximum discharge is 42% above the ten year average while the minimum is 43% of the average.

Records show that the Salton Sea in Imperial Valley, California, has been rising rather steadily in recent years.* Next to the Great Salt Lake, this Inland Sea is the largest salt water lake in the United States. At present the surface of the lake is a little less than 240 feet below mean sea level and it is in an area where the rate of evaporation from lakes and reservoirs is extremely high.

For ten years prior to the completion of the All American Canal it was several feet lower, the lowest in recent years being in 1936 when it stood at -248 feet elevation. It then began to rise and from 1940 through 1944 it rose at an average rate of about one foot a year during the priming of the All American Canal. Next came a period of five years when the average level of the lake was practically constant at 240.4 feet below sea level. During this time the annual average level did not vary either way from the mean by more than about one quarter of a foot. Since the year 1949, however, the lake has risen 5 feet more and stood at an average elevation of -235.4 feet during the water year 1954. In the flat basin of the Salton Sink such a rise in the level of the surface of this lake was accompanied by an increase in the area of 20 square miles with a corresponding increase in the loss of water by evaporation and an increase of 1,000,000 acre-feet in the volume of water in this sink.

The only source of water available to cause such an increase in the depth, area and volume of the Salton Sea is from the Colorado River. It must be the result of return flows and waste water from the canals and irrigated lands in Imperial Valley. Obviously the largest of the diversions to this area is through the All American Canal and, therefore, the records of the flow in the canal near Imperial Dam on the Colorado River and at Pilot Knob Wasteway were tabulated for study and analysis.

From the time that Colorado River Water was first diverted into this canal at Imperial Dam in 1940, the flow was rapidly increased until it reached 4,000,000 acre-feet for the year 1943. The area of land irrigated that season in the Imperial Irrigation District was reported as nearly 385,000 acres.** While the irrigated area was increased by about 5,000 acres each year for the next 5 years, the diversions were also increased but not in proportion to the irrigated area. The increase in diversion to the canal above Pilot Knob Wasteway in 1946 was 600,000 acre-feet. Since that time the average annual diversion at Imperial Dam through 1954 has exceeded $5\frac{1}{2}$ million acre-feet and above Pilot Knob Wasteway it was more than 4 million acre feet.

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*California's weird overflowing sea, Saturday Evening Post, August 30, 1952.

**Memorandum Supplement to Report on Water Supply of the Lower Colorado River Basin, Nov. 1935, U.S.B.R., Region 3, Page 47.

When the sudden increase in flow into the All American Canal took place in 1946, the average elevation of the Salton Sea was about 240 feet below mean sea level. It continued at nearly the same elevation until 1950 when the maximum diversion to the canal at Imperial Dam was recorded at more than 6,000,000 acre-feet. Since then the water level of the lake has risen steadily although the diversion in 1952 had been reduced to 5,200,000 acre feet and to 3,800,000 above Pilot Knob.

During the five year interval between the first large increase in the diversion to the All American Canal and the beginning of the rapid rise of the lake, there was an increase of only one foot in elevation, but for the next three years it rose at an average rate of a foot a year. The shore line of the lake is estimated at approximately 100 miles in length while the area is over 200,000 acres. With the large increase in available water supply, the irrigable acreage cultivated in Imperial Valley was increased by 45,000 acres. The rise in the level of the lake of about 4 inches in 1950 and about 15 inches in 1953 and also in 1954, increased the volume of water in the lake as well as its area. These two factors together required about 200,000 acre-feet of additional water per year which was increased to more than 300,000 acre-feet by 1954. These facts can be summed up by stating that the level of the Salton Sea has been raised nearly five feet in the last five years. In 1951 and 1952 diversions to the canal were reduced to a little over 5,200,000 acre-feet.

By far the largest loss of water in the Salton Sink is by evaporation from the more than 300 square miles of open water surface of the lake. At the elevation of 240 feet below sea level the water is approximately 33 feet in maximum depth which is relatively shallow for a lake or other body of water of its size. At this elevation and at the latitude of Southern California, the average annual depth of water evaporated per unit of area is not less than 8 feet and it may be as much as 11 or 12 feet in some years. For this report the average will be taken as 10 feet of depth per year. Neglecting the continued increase in area with every rise of a foot in elevation, this rate of evaporation would require 2,000,000 acre-feet of water per year to maintain the lake at a constant level. As a check on the annual loss of water discharged into the Salton Sea, neglect for the moment the increase in the return flow due to the increased use of water for irrigation and the increase in the area of the surface of the lake, a rise of 5 feet in 5 years over an area of 200,000 acres, is an average increase in the volume of dead storage in the Salton Sea of 200,000 acre-feet a year. Add 15% to allow for increase in bank storage and 10% for increase in area of the lake, and the resulting estimated annual loss is 2,250,000 acre-feet including evaporation.

Return flow from irrigation under the Alamo Canal in Mexico also finds its way ultimately to the Salton Sea and the average annual diversions of Colorado River water to this canal are about 1,250,000 acre-feet. A portion of the water diverted at Imperial Dam may be used for power development above Pilot Knob Wasteway where the corresponding average annual flow was 4,000,000 acre-feet. The sum of these two amounts is 5,250,000, and a loss of 2¼ million acre-feet out of 5¼ million is over 40% of those two major diversions to Mexico and the Imperial Valley of California. It may, therefore, be said that 2¼ million acre-feet of Colorado River water is annually lost by evaporation, increases to the volume of water in the lake and by bank storage due to the rise of the Salton Sea, and that this loss is equivalent to a third of the principal diversion of water for uses in the Imperial Valley of Southern California and Northern Mexico.

No further study has been made of the evaporation from reservoirs and it appears that the research on this subject which was planned as a cooperative project of the Bureau of Reclamation and the U. S. Geological Survey has been held in abeyance because of continued lack of funds for research in both of these federal agencies.

As stated in previous reports, the collection of stream flow records has continued in cooperation with the Water Resources Branch of the U. S. Geological Survey and State Offices, and all such records are readily available in the Commission's files. The Commission also receives, through the cooperation of the U. S. Weather Bureau, annual and monthly Climatological Data bulletins from Arizona, Colorado, New Mexico, Utah and Wyoming. Through the cooperation of the U. S. Soil Conservation Service, there are supplied reports on snow surveys made in cooperation with other agencies of federal and state governments. These reports cover the States of Utah and Arizona, the drainage basin of the Colorado River, the Rio Grande and the Platte and Arkansas Rivers.

The table of gaging stations and stream discharges, which appeared in previous Annual Reports, is again given in this Annual Report. U. S. Geological Survey and certain other reports of gaging stations and stream discharges for the water year 1954 have been added to the previous table in so far as the provisional records for these stations have been received. The provisional records for the year 1953 are also listed.

No forecasts of water supply were made by the Engineering Department of the Commission, nor have any "findings of facts" as to water deliveries or stream depletions been made by the Commission.

The following forecast of "April-July Inflow to Lake Mead" is quoted from the report from the Boulder City, Nevada office of the Bureau of Reclamation:

"Average precipitation in the Upper Colorado River Basin as reported from 13 index stations used for forecasting purposes was above normal during February 1955. Thus, the mean forecast as of March 1 is greater than the mean forecast as of February 1. During the last two weeks of February, heavy precipitation occurred, resulting in 158 percent of normal precipitation for the month. The accumulated October 1954 through February 1955 precipitation averaged 5.63 inches for the 13 index stations, or 105 percent of normal. Based on these data, the forecast of flow in the Colorado River near Grand Canyon, Arizona, for the period April through July 1955 is as follows:

Maximum*	11,700,000 acre-feet
Mean	8,600,000 acre-feet
Minimum*	5,500,000 acre-feet

*The forecast equation indicates that the probability is nine chances in ten that actual flow at Grand Canyon will fall between the above maximum and minimum amounts.

"The above forecast is based on the precipitation index furnished by the 13 stations which have been used for the past several years. Ordinarily the index furnished by these 13 stations can be expected to reflect anticipated runoff within the limits indicated. Because of the large area of watershed involved and the relatively few stations used, the opportunity for bias during years of unusual distribution of precipitation due to location of these stations, is great. Analysis of snow survey data for March 1 suggests the possibility that the above-normal precipitation condition during February indicated at the low elevations of the precipitation stations may not have been experienced at higher levels. For this reason and because the forecast method used does not account for the poorer yield which may result from the effect of two prior subnormal years, it seems unlikely that the actual runoff this year will approach the maximum of the forecast range.

"Actual runoff measured near Grand Canyon during April-July last year was 3,243,000 acre-feet. The maximum recorded April-July runoff occurred in 1952 (14,064,000 acre-feet), and the minimum recorded was 2,247,000 acre-feet in 1934."

The average annual discharge of the Colorado River at Lee Ferry is practically the same as that measured at the Grand Canyon gage.

The following excerpts are quoted from the section on the Colorado Basin of the bulletin issued by the Weather Bureau as of March 1st, entitled Water Supply Forecasts for the Western United States.

"Most of the Upper Colorado River Basin received precipitation amounts during February in excess of normal. Exceptions were the somewhat below normal amounts reported at some of the higher elevations along the Continental Divide, but despite this, precipitation during the month over the Colorado State portion of the area averaged near 120% of normal. Also, most of the drainage area in Utah and the southern portion of Wyoming received above-normal precipitation during the month. The major exception here was the Big Piney area in Wyoming where precipitation for the month was only 35% of normal. The San Juan Basin in southwestern Colorado, like most of the Upper Colorado Basin, averaged above normal for the month but experienced precipitation values which varied widely—percentages ranging from 46% to 177% of normal.

"Colorado River above Cisco: The above-normal precipitation which occurred over most of the area was in part offset by the lighter precipitation which was experienced along the Continental Divide. In general, the median forecasts of flow issued this month are not materially changed from those of a month ago. The outlook for the Uncompahgre River basin is the least promising of the area with only 67% of average runoff in prospect. For the Dolores Basin 75% to 80% of average runoff is indicated. Most favorable outlook is for the Collbran Creek where normal snow cover is reported and the forecast is for 98% of average runoff. For the remainder of the area the outlook is for runoff of 81% to 92% of average.

"**Green River Basin:** The current water supply outlook for the Green River basin varies from near average for the White and upper Yampa Rivers in Colorado to 50% of average for the tributaries of the Green River in the Big Piney country in Wyoming. Considerable variation may also be noticed in the forecasts for the Utah tributaries, which range from 52% of average runoff for the Strawberry River near Duchesne to 92% of average for the Ashley Creek near Vernal. The Green River contribution to the Colorado River is forecast to be 73% of the 1943-52 average runoff.

"**San Juan River Basin:** The above-normal precipitation during February has resulted in an improved outlook for the San Juan River basin as compared with that of a month ago. The current water supply outlook for the basin is for 82% to 90% of average runoff for the northern tributaries and 77% of average runoff for the main stem of the San Juan River."

At hearings on H.R. 4449 and S. 1555, bills to authorize the Colorado River Storage Project and Participating Projects in the second session of the 83rd Congress, opponents of the proposed legislation centered part of their arguments on assertions that before projects were to be authorized in the Upper Basin, studies of the quality of water of the Colorado River System should be made to determine whether future consumptive uses in the Upper Division States might seriously affect the quality of water available for use in the Lower Basin.

In response to a special request made by the Upper Colorado River Commission, Mr. John H. Bliss, State Engineer of New Mexico, conducted comprehensive studies and prepared an article entitled "Present and Future Quality of Colorado River Water at Lees Ferry." This paper was presented by Mr. Bliss at hearings before the House Sub-Committee on Irrigation and Reclamation on bills to authorize the Colorado River Storage Project and Participating Projects in the first session of the 84th Congress. It is appended hereto as Appendix C.

An article entitled "Utilizing Colorado River Water that Originates above Lee Ferry" was prepared by H. T. Person, Engineering Adviser to the Commission from Wyoming and Dean of the College of Engineering of the University of Wyoming, as a special service to the Upper Colorado River Commission. This paper was presented before the Sub-Committee on Irrigation and Reclamation of the Interior and Insular Affairs Committee of the House of Representatives, 84th Congress, first session, at hearings on bills to authorize the Colorado River Storage Project and Participating Projects. It is appended as Appendix D.

APPENDIX A

BUDGET

FISCAL YEAR ENDING JUNE 30, 1956

PERSONAL SERVICES		
Secretary and General Counsel	$13,750.00	
Chief Engineer	10,000.00	
Assistant Chief Engineer	10,000.00	
Administrative Assistant	3,772.95	
Secretary	2,640.00	$40,162.95
TRAVEL		15,000.00
CURRENT EXPENSE		
Reporting	$ 2,500.00	
Telephone and Telegraph	1,200.00	
Insurance and Bonds	850.00	
Accounting	500.00	
Miscellaneous	250.00	
Printing (Office forms)	350.00	
Printing (Annual report)	2,000.00	7,650.00
CAPITAL OUTLAY	$ 500.00	
Automobile	2,500.00	3,000.00
INFORMATION		5,312.25
OFFICE SUPPLIES AND EXPENSE		3,500.00
		$74,625.20

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APPENDIX B

REPORT OF EXAMINATION
UPPER COLORADO RIVER COMMISSION
GRAND JUNCTION, COLORADO

June 30, 1954

DALBY & McNULTY
Certified Public Accountants
First National Bank Building
Grand Junction, Colorado

Walter E. Dalby, C.P.A.
John E. McNulty, C.P.A.

September 10, 1954

Upper Colorado River Commission
Grand Junction, Colorado

We have examined the balance sheets of the General Fund and the Property and Equipment Fund of the Upper Colorado River Commission as of June 30, 1954, and the related statement of revenue and expense for the year then ended. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

In our opinion, the accompanying balance sheets and revenue and expense statement present fairly the financial position of the Upper Colorado River Commission at June 30, 1954, and the results of its operations for the year then ended.

/s/ DALBY & McNULTY
Certified Public Accountants

BALANCE SHEET—GENERAL FUND

UPPER COLORADO RIVER COMMISSION

June 30, 1954

ASSETS

CASH			
Office cash fund		$ 55.00	
Demand deposit		60,903.02	$60,958.02
RETURNABLE DEPOSIT—United Air Lines			425.00
DEFERRED CHARGE—Prepaid rent			296.17
			$61,679.19

LIABILITIES, RESERVES, AND FUND BALANCE

ACCOUNTS PAYABLE—For supplies and expenses			$ 2,439.28
RESERVES			
For fiscal year 1954-1955 assessments received prior to June 30, 1954		$27,370.83	
For encumbrances		3,000.00	
For contingencies		1,124.12	31,494.95
UNAPPROPRIATED FUND BALANCE			
Balance at July 1, 1953		$48,123.60	
Less: Appropriation for expenses		20,435.25	
		$27,688.35	
Add:			
Excess provision for encumbrances for fiscal year ended June 30, 1953	$17.50		
Excess of revenues over expenditures for fiscal year ended June 30, 1954	39.11	56.61	27,744.96
			$61,679.19

BALANCE SHEET—PROPERTY AND EQUIPMENT FUND

UPPER COLORADO RIVER COMMISSION

June 30, 1954

ASSETS

PROPERTY AND EQUIPMENT—at cost		
Furniture and fixtures		$ 6,592.22
Automobile		2,409.58
Engineering equipment		1,521.45
		$10,523.25

FUND BALANCE

FUND BALANCE		
Investment in property and equipment at July 1, 1953		$10,669.95
Transactions for fiscal year ended June 30, 1954:		
Retirements	$201.59	
Additions	54.89	146.70*
		$10,523.25

*Indicates a deduction.

REVENUE AND EXPENSE STATEMENT
UPPER COLORADO RIVER COMMISSION
For the fiscal year ended June 30, 1954

	BUDGET AMOUNT	ACTUAL AMOUNT	ACTUAL AMOUNT OVER-UNDER*
Revenues:			
Assessments	$63,261.96	$63,261.96	$ 0
Sale of reports	0	79.60	79.60
Sale of equipment	0	80.00	80.00
Appropriated from surplus	20,435.25	20,435.25	0
TOTAL REVENUES	$83,697.21	$83,856.81	$ 159.60
Expenses:			
Personal services:			
Administrative salary	$17,522.95	$17,522.91	$ .04*
Engineering salaries	20,250.00	20,249.96	.04*
Clerical salaries	3,193.19	3,097.57	95.62*
Social security tax	382.26	351.06	31.20*
	$41,348.40	$41,221.50	$ 126.90*
Capital outlay	$ 643.89	$ 54.89	$ 589.00*
Office supplies	$ 3,657.89	$ 3,328.62	$ 329.27*
Information:			
Exhibits	$ 200.00	$ 151.90	$ 48.10*
Publications	1,900.00	1,852.64	47.36*
Public relations	5,823.36	6,262.23	438.87
Radio	3,000.00	3,000.00	0
Office and equipment rental	2,000.00	2,073.19	73.19
	$12,923.36	$13,339.96	$ 416.60
Travel	$19,131.56	$18,456.97	$ 674.59*
Current expenses:			
Reporting	$ 1,400.00	$ 1,374.20	$ 25.80*
Telephone and telegraph	1,800.00	1,771.71	28.29*
Insurance and bonds	600.00	582.49	17.51*
Accounting	400.00	365.00	35.00*
Printing	1,500.00	1,485.45	14.55*
Secretarial services	242.11	556.49	314.38
Engineering services	0	1,260.42	1,260.42
Miscellaneous	50.00	20.00	30.00*
	$ 5,992.11	$ 7,415.76	$ 1,423.65
TOTAL EXPENSES	$83,697.21	$83,817.70	$ 120.49
EXCESS OF REVENUES OVER EXPENSES		$ 39.11	$ 39.11

CASH RECEIPTS AND DISBURSEMENTS

UPPER COLORADO RIVER COMMISSION

For the fiscal year ended June 30, 1954

Balance of cash and demand deposit at July 1, 1953		$ 60,198.23
Cash receipts:		
Assessments	$81,776.12	
Sale of reports	79.60	
Sale of equipment	80.00	81,935.72
		$142,133.95
Cash disbursements:		
Personal services	$41,651.99	
Travel	17,611.45	
Current expenses	5,447.25	
Capital outlay	43.89	
Information	10,636.13	
Office supplies	3,283.88	
Expenses of fiscal year ended June 30, 1953, not paid until after July 1, 1953	2,501.34	81,175.93
Balance of cash and demand deposit at June 30, 1954		$ 60,958.02

INSURANCE COVERAGE

UPPER COLORADO RIVER COMMISSION

June 30, 1954

	TYPE OF COVERAGE	AMOUNT OF COVERAGE
Furniture and fixtures	Fire and comprehensive	$7,500.00
Automobile	Comprehensive	Actual cash value
	Collision or upset	$100.00 deductible
	Bodily injury and property damage	$5/100,000.00
Treasurer	Fidelity bond	$40,000.00
Assistant treasurer	Fidelity bond	$40,000.00
Employees	Workmen's compensation	Various

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APPENDIX C

PRESENT AND FUTURE QUALITY OF COLORADO RIVER WATER AT LEES FERRY

By JOHN H. BLISS, New Mexico State Engineer and
New Mexico Member of Upper Colorado River Commission

Introduction

This report has been prepared at the direction of the Upper Colorado River Commission at its meeting in Denver, Colorado, October 30, 1954, to answer some of the questions which have been raised as to the quality of the water of Colorado River at Lees Ferry which can be expected to result from the consumptive use of water by projects constructed under the Colorado River Storage Project and Participating Projects. The authorization of the Initial Phase of this project is currently being sought in the Congress of the United States.

The writer is indebted to the Quality of Water Branch of the U. S. Geological Survey, the Bureau of Reclamation, the Department of the Navy, the Rubidoux Laboratory of the U. S. Department of Agriculture and the International Boundary and Water Commission for the basic data contained in this report and to a number of individuals of wide experience in the quality of water field for their advice and technical assistance in its preparation.

The Problem

The Colorado River Compact of 1922 apportioned the waters of the stream system between the Upper and Lower Basins, the division point being at Lees Ferry near the Utah-Arizona State Line. The Compact provided that 7,500,000 acre feet of water annually could be consumptively used by the States of the Upper Basin above Lees Ferry, provided that certain quantities were left in the stream for use in the Lower Basin. It provided for the beneficial consumptive use of 7,500,000 acre feet annually in the Lower Basin plus the right to increase this consumptive use by 1,000,000 acre feet per annum. It also provided under certain circumstances for the allocation of any unapportioned waters of the system which might be available for new uses on or after October 1, 1963.

As of the date of the original Colorado River Compact, approximately 2,050,000 acre feet of water on the average was being consumptively used annually in the Upper Basin and approximately 2,900,000 acre feet per year in the Lower Basin. Between 1922 and the date of the Upper Colorado River Compact, 1948, uses of water in the Upper Basin actually dropped slightly. However, including prospective uses by presently authorized projects, the present annual consumption will be about 2,400,000 acre feet. Uses in the Lower Basin have substantially increased during the period, being about 5,030,000 acre feet by 1938. Under Initial Stage development in the Upper Basin, including Glen Canyon and Echo Park Reservoirs and the 12 participating projects whose authorization was sought in the several bills before the Congress last year, consumptive uses above Lees Ferry would increase to about 3,200,000 acre feet annually. Ultimately it is assumed that the full consumptive uses contemplated by the compact will be attained in each basin (see Table I).

The compact states in Article VIII that "present perfected rights . . . are unimpaired by this compact." The word "impair" has been seized upon by certain Lower Basin interests as a basis for their contention that the Upper Basin is obligated to deliver a certain quality as well as a certain quantity of water at Lees Ferry. Whether the wording of the compact itself or the water law of the western states imposes any obligation on the part of the upstream user to deliver water of a given quality to a downstream user, or whether it does not, the question of quality has been raised by opponents of the legislation and should be answered as fairly and accurately as possible.

This report will attempt to show in some detail the effect of the Initial Phase of the Colorado River Storage Project and Participating Projects on the quality of Colorado River water at Lees Ferry. It will also show, in a general way, the quality of water which can be expected after full development of the Upper Basin as contemplated by the 1922 compact.

Factors Affecting Quality of Water

There are a number of factors which affect the quality of the water which falls in any stream basin. Precipitated as nearly pure water in the form of rain or snow it immediately starts to gather soluble materials from the soil over which or through which it passes. Man, in using water for his purposes, may change the quality of water in a river basin to a considerable extent. Some of these man-produced factors are irrigation; domestic, municipal and industrial uses; drainage, including the leaching of salts which may have accumulated in the soil; storage of water in major hold-over reservoirs; and the diversion of water outside of the natural drainage basin.

Up to the present time, at least, man's activities have had little or no effect upon the natural processes of precipitation, runoff or percolation to the natural streams. Whether, in the future, he may be able to produce an appreciable change in these factors seems questionable. It is assumed in this report that the natural accumulation of dissolved solids in the waters of the Colorado River Basin will not be changed by man's activities.

The consumptive use of water by irrigation is probably the major man-produced factor which affects the quality of the waters of western streams. In the irrigation process, water is diverted from a stream (or pumped from underground) and spread upon the land. A substantial portion of this water is taken up by the growing crops, the remainder either flowing back to natural channels as waste water, percolating into the ground and finding its way back to natural channels, or being evaporated into the air. Very little of the dissolved solids in the water is absorbed by the plants. The salts carried to the land, therefore, must either be carried back to the streams in the return waters or be deposited on the land. If permanent agriculture is to continue in any basin the salinity of the water in the soil cannot increase above the salt tolerance of the crops grown. Basically, therefore, irrigation uses of water within the Colorado River Basin or any river basin will consume the water required by the irrigation process but will return to the streams practically the same quantities of dissolved solids which were diverted from them.

To some extent the use of water for irrigation purposes will change the relative amounts of the several dissolved constituents. In passing over and through the soil there is a tendency for the water to drop some of its less soluble salts and to pick up some of the more soluble salts in the soil. The extent of such effect, which is called "base exchange" is limited for any single irrigation use. The total effect upon the quality of any given water supply will depend largely upon the extent of its use and re-use for irrigation purposes.

TABLE I

USES OF WATER IN COLORADO RIVER BASIN

Upper Colorado River Basin*	Irrigated Arceage	Depletion Ac. Ft.
Wyoming, Utah, Colorado, New Mexico and Arizona		
Year 1922	1,370,000	2,003,600
1920-24 Av.	1,366,000	2,049,200
Year 1948	1,385,000	1,926,000
1946-50 Av.	1,385,000	1,883,600
Present Depletion Including Presently Authorized Projects		
Based on 1929-51 Av.		2,421,000
Based on 1931-47 Av.		2,404,000
Initial Phase—Colo. River Storage Project		
Based on 1929-51 Av.		3,706,200
Based on 1931-47 Av.		3,671,200
Ultimate Project		7,500,000

* House Document 364—83rd Congress, 2nd Session

Lower Colorado River Basin*	Gila River		Colorado River	
	Acreage	Depletion Ac. Ft.	Acreage	Depletion Ac. Ft.
Year 1922				
Arizona	344,318		72,893	
New Mexico	8,933		4,217	
Utah			18,148	
Nevada			10,094	
California				
In-Basin			40,839	
Out-of-Basin			340,000	
Mexico	4,001		Not Known	

Totals				
In-Basin	357,252	1,029,100	146,191	501,500
Out-of-Basin-1922			340,000	2,186,600
Out-of-Basin 1920-24 Av:				2,404,000
Year 1948				
Arizona	716,111		113,416	
New Mexico	11,728		4,332	
Utah			22,100	
Nevada			11,321	
California				
In-Basin			63,676	
Out-of-Basin			427,850	
Mexico	3,962		Not Known	
Totals				
In-Basin	731,801	2,145,900		1,810,100
Out-of-Basin-1948				3,183,800**
Out-of-Basin-1946-50				3,215,500**

* Report on Water Supply of the Lower Colorado River Basin, Project Planning Report, U.S.B.R., November 1952.

** Includes the figure of 180,500 Ac. Ft. of water which was diverted to Metropolitan Water District in 1948. This diversion has increased substantially since 1948.

Domestic, municipal and industrial uses, although vital to development of the basin, will constitute a relatively small percentage of water consumption. Their relative effect on the quality of water will be much the same as that of irrigation. In the report it is assumed that use of water for these purposes will neither add nor subtract from the total quantities of dissolved solids carried by the streams.

Some basins where irrigation is now or may be practiced contain soils or ground waters or both which carry greater than usual quantities of soluble salts. In such areas, irrigation can be successfully practiced only by leaching away the excess salts. If the subsoil is porous, leaching may occur as a part of the irrigation process; if not, it may be necessary to install drainage conduits to carry away the excess salts and water. Even in basins where the salt content of the soil is normal, the process of irrigation will naturally leach some chemicals from the soil and leave some which were carried to the land by the irrigation waters. In each new irrigation project there will usually be some temporary increase in salt content of the return waters due to a flushing out of the irrigated lands.

An analysis of the arable lands of the Upper Basin which are being considered for irrigation development under the proposed Colorado River Project indicates that areas where the soil concentrations are greater than ordinary constitute but small fractions of the total. The important facts in any area where leaching of the soil may occur are: (1) that the resulting salt increase is usually limited in amount and (2) that it is a temporary condition. Because the individual Upper Basin projects all consume relatively small amounts of water compared to the total amount of water in the main rivers, the effect of such flushing by one or even several new projects constructed concurrently will have little net effect upon the quality of the water supply at Lees Ferry. Further, most of such leaching will have been completed long before the ultimate project is developed. In this report, therefore, no attempt has been made to evaluate the temporary effect of soil leaching on water quality in considering either the initial phases or the ultimate development of the project.

In 1948-49 a comprehensive study of Lake Mead* was conducted by the Department of the Navy in cooperation with the Department of Interior, Department of Commerce, University of California and others. The report, now in the process of publication, covers a detailed study and analysis of most of the physical phenomena and changes which occur in the operation of this large holdover reservoir.

One of the principal effects of storage is the mixing of the varying qualities of the seasonal runoffs of the stream. The relatively saline flows of the fall and winter months are sweetened by the better quality spring runoffs from snowmelt. Summer torrential flows may be either better or worse than the average qualities depending upon the areas drained by such storms. Further discussion of the smoothing effect of holdover storage on quality of released water will be found later in the report.

Since no salts are removed from solution by the evaporation process, the increase in salinity concentration resulting from reservoir evaporation will vary directly with the amount of such evaporation.

The Lake Mead studies indicate two other phenomena which have an effect upon the quality of water passing through the reservoir. Analysis of the qualities of inflow and outflow together with studies of the reservoir water itself show that some salts are actually precipitated out of solution in the storage basin. These salts, which in general comprise the less soluble constituents, seem in part to be precipitated because of temperature changes and in part to be carried down by the gradual settling of the finely divided sediments transported by the inflowing streams. In Lake Mead, the Virgin River branch or Overton Arm of the reservoir basin contains substantial deposits of sodium chloride and gypsum. The effect of these soluble beds on the quality of Lake Mead waters gave some concern to the geologists and others who studied the matter prior to Hoover Dam construction. Although studies indicate that some solution from these beds has occurred during the past 19 years of operation, the amount of such solution has not been as great as was originally feared and seems to be decreasing yearly as the beds become covered by silt deposits. C. S. Howard

* "Lake Mead Comprehensive Survey of 1948-49, by W. O. Smith, C. P. Vetter, G. B. Cummings and others, February 1954" in three volumes.

has estimated that in the 1935-48 period more than 9,000,000 tons of calcium carbonate and more than 1,000,000 tons of silica constituting about 7 percent of the dissolved solids in the waters entering Lake Mead were precipitated out during the 14-year period.* He found that a much larger quantity of salts, chiefly halite and gypsum have gone into solution within the reservoir basin in that period, the effect being a net increase in total dissolved solids discharging from the reservoir over those entering it of about 17 percent. These two phenomena counteract one another, making it impossible to fully evaluate the effects of either on the quality of water.

Transportation of water outside the natural basin of the Colorado River by means of transmountain diversions results in the physical removal of the dissolved solids carried by that water. Transmountain diversions as such have been attacked by some sources because they remove some of the "better waters" of the basin. The fact remains, however, that trans-basin diversions remove both salts and water while in-basin use remove only the water allowing the residual salts to be carried back to the streams to worsen the quality of the downstream supply.

In summation, consumptive use of water in the Upper Basin, as contemplated by and as provided for in the Colorado River Compact of 1922 necessarily affects the quality of the remaining waters. Essentially, it depletes the water supply but leaves the dissolved solids behind. Certain factors, including the deposition of less soluble salts from solution and the physical transportation of salts out of the basin by transmountain diversion, tend to mitigate this condition. Base exchange occurring as a result of the irrigation process will tend to change somewhat the percentages of the several dissolved constituents.

Dissolved Constituents and Their Significance

Natural waters vary greatly in the concentration and composition of dissolved constituents and correspondingly in their suitability for irrigation or other beneficial use. Further, the requirements for a good irrigation water may be inimical with those needed for other purposes. Domestic and industrial uses, for example, require a "soft" water whereas a desirable water for irrigation uses should be "hard." Waters of the Colorado River system will largely be used for irrigation purposes but there will also be a substantial demand for domestic and industrial supplies.

When used for irrigation, some of the constituents are beneficial to plants, some in moderate concentration appear to have little effect on plants or soils, while others impair plant growth or are harmful to soils.

In solution, a large proportion of the inorganic salts are ionized. The metallic elements called cations take a positive electrical charge while the nonmetallic elements or acid radicles called anions take a negative charge. The major cations—calcium, magnesium, sodium

* "Lake Mead Comprehensive Survey of 1948-49," Volume II

and potassium—and the major anions—carbonate, bicarbonate, sulfate, chloride and nitrate—constitute the bulk of the dissolved constituents in natural waters and very largely determine the quality. A number of minor constituents including boron, silica, fluoride, hydrogen measured as pH, and iron may also occur and be reported in chemical analyses of waters. These constituents usually occur in low concentrations and, with the exception of boron, are usually not of great importance in their relation to the soil or to plants.

In this report it is unnecessary to discuss the relative merits or demerits of the several dissolved constituents. There is considerable body of good literature on the subject which may be consulted if desired. Many of the effects of the dissolved constituents upon plants and soils are complicated and interrelated and often the effects of several constituents are additive. It is probably sufficient to say here that the three criteria by which the quality of an irrigation water is usually judged are (1) the total dissolved solids concentration, (2) the percentage ratio which the sodium ion bears to the total positive ions, both quantities being expressed in miliequivalents, and, (3) in areas where it occurs in sufficient concentration to be important, the boron concentration. In the last few years the sodium adsorption ratio has been advanced by workers as being more reliable than the sodium percentage as an indicator of the effect of relative cation concentration on sodium accumulation in the soil. For the purposes of this report, however, the earlier criteria will be used.

Permissible limits to define the quality of waters for irrigation use have been proposed by various workers and in general the values are in good agreement. A diagram or chart has been prepared by L. V. Wilcox and others of the Rubidoux Laboratory of the Department of Agriculture,* which sets forth graphically the suitability of irrigation waters based upon the first two criteria. (See Figure II)

The occurrence of boron in toxic concentrations in some irrigation waters makes it necessary to consider this element in grading water quality. C. S. Scofield** has proposed limits for boron that have proved satisfactory and are recommended. Investigation shows that boron concentrations in the waters of the Colorado River are too low to be significant and the details of its occurrence have not been included in the report in the quality of water tabulations. The available data, however, show that boron concentrations at Lees Ferry, even under full development of the Upper Basin, will lie within that range classified as "good" waters even for boron-sensitive crops.

Chemical Composition of Colorado River Waters

A continuous program of quality of water sampling of the Colorado River was initiated by the U. S. Geological Survey start-

* "The Quality of Water for Irrigation Use" by L. V. Wilcox, Tech. Bulletin No. 962 USDA.

** "The Quality of Water for Irrigation Use," p. 27.

ing in 1925. Since that time the program has been expanded to include many of the major points of water interest along the main stem and tributaries. Table II has been prepared to show the available records at those stations which are used in this report.

Since 1940, and including some years prior to 1930, the quality of water records have been published as Water Supply Papers of the Geological Survey. A large part of the data, particularly during the 1930-1940 period, is unpublished. These unpublished records have beeen generously supplied to the writer by the Washington Office of the Survey.

After examination of the records, it was decided that this report should cover the period from 1929 to 1951, the data since 1951 being generally unavailable for analysis. For this 23-year period, the data on both quantity and quality are either available at the several river stations used or can be supplied by correlation methods with reasonable accuracy, sufficient for the conclusions drawn by the report. Summary tables showing the total quantities of dissolved solids and the quantities of the several constituents are included herein.

TABLE II

AVAILABLE QUALITY OF WATER DATA AT SOME COLORADO RIVER STATIONS

Climatic Year	Values Reported*	Where Found**
	Colorado River at Cisco	
1929	Complete	U.S.G.S. Unpublished Data
1930	Complete	W. S. Paper
1931-1935	Complete	U.S.G.S. Unpublished Data
1936-1940	T.D.S.	U.S.G.S. Unpublished Data
1941-1943	T.D.S.	W. S. Papers
1944-1951	Complete	W. S. Papers
	Green River at Greenriver, Utah	
1929	Complete	U.S.G.S. Unpublished Data
1930	Complete	W. S. Paper
1931-1935	Complete	U.S.G.S. Unpublished Data
1936-1940	T.D.S.	U.S.G.S. Unpublished Data
1941-1943	T.D.S.	W. S. Papers
1944-1951	Complete	W. S. Papers
	San Juan River at Bluff	
1930	Complete	W. S. Paper
1931-1940	Complete	U.S.G.S. Unpublished Data
1941-1951	Complete	W. S. Papers

Colorado River at Lees Ferry

1929	Complete	U.S.G.S. Unpublished Data
1930	Complete	W. S. Paper
1943-1944	Complete	W. S. Papers
1945	T.D.S.	W. S. Papers
1948-1951	Complete	W. S. Papers

Colorado River at Grand Canyon

1926-1930	Complete	W. S. Papers
1931-1940	Complete	U.S.G.S. Unpublished Data
1941-1942	Complete	W. S. Papers
1944-1951	Complete	W. S. Papers

* As used herein, "Complete" includes total dissolved solids (T.D.S.) and most major ionic constituents; "T.D.S." means total concentrations only reported as conductance or as parts per million.

** Yearly summaries of most unpublished data have been published in W.S. Paper 970. The 1951 W. S. Papers on Quality of Water are in process of publication at present time.

COLORADO RIVER NEAR CISCO, UTAH

(Discharges and dissolved solids tonnages in thousands)

Water Year	Discharge	Calcium		Magnesium		Sodium & Potassium		Carbonate & Bicorbonate		Sulfate		Chloride		Total Dissolved Solids		Percent
	Ac. Ft.	T/AF	Tons	T/AF	Tons	T/AF	Tons	T/AF	Tons	T/AF	Tons	T/AF	Tons	T/AF	Tons	Sodium
1925																
6																
7																
8																
9	8511	.090	766	.034	289	.092	783	.19	1617	.29	2468	.053	451	.68	5788	33
1930	6097	.10	610	.038	232	.11	671	.21	1280	.35	2134	.075	457	.81	4939	36
1	2865	.14	401	.058	166	.21	602	.25	716	.58	1662	.15	430	1.29	3696	42
2	6687	.094	629	.034	227	.10	669	.21	1404	.31	2073	.065	435	.73	4882	36
3	4631	.10	463	.039	181	.12	556	.20	926	.37	1714	.080	371	.84	3890	38
4	2220	.14	311	.065	144	.22	488	.23	511	.64	1421	.15	333	1.37	3041	42
1935	4681	.10	468	.038	178	.12	562	.20	936	.35	1638	.082	384	.81	3792	36
6*	5766	.097	559	.036	208	.11	634	.20	1153	.33	1903	.073	421	.77	4440	37
7*	4664	.11	513	.044	205	.14	653	.22	1026	.42	1959	.097	452	.94	4384	39
8*	7422	.095	705	.034	252	.10	742	.20	1484	.31	2301	.069	512	.74	5492	35
9*	4252	.12	510	.047	200	.15	638	.22	935	.44	1871	.10	425	1.00	4252	38
1940*	3463	.13	450	.053	184	.18	623	.24	831	.51	1766	.12	416	1.14	3948	40
1*	6576	.10	658	.038	250	.12	789	.21	1381	.36	2367	.081	533	.83	5458	38
2*	7706	.096	740	.035	270	.11	848	.20	1541	.32	2466	.070	539	.75	5780	37
3*	5137	.11	565	.041	211	.13	668	.21	1079	.38	1952	.088	452	.88	4521	38
4	5903	.097	572	.033	194	.10	596	.23	1337	.29	1728	.076	446	.73	4298	36
5	5407	.10	551	.037	202	.12	642	.23	1232	.33	1759	.098	532	.82	4425	37
6	4062	.12	493	.044	181	.13	521	.24	994	.42	1700	.084	343	.88	3581	35
7	6051	.10	624	.033	199	.10	630	.22	1318	.30	1833	.085	515	.76	4577	36
8	6554	.11	740	.035	231	.10	671	.25	1616	.32	2088	.079	522	.79	5192	33
9	6287	.10	649	.034	212	.11	698	.23	1434	.30	1878	.097	608	.78	4908	36
1950	4236	.11	482	.045	189	.15	621	.24	1002	.38	1603	.14	584	.96	4076	39
1	3921	.12	471	.044	173	.13	510	.22	863	.40	1568	.12	471	.99	3882	37
Average	5352	.11	562	.039	208	.12	644	.22	1157	.36	1907	.086	462	.84	4489	37

* 1936-1943, total dissolved solids only reported; all other dissolved solids values derived by correlation curves based on 1929-1935 and 1944-1951 data.

Note: Dec. 1944, Oct. and Nov.,1949 and July 1950 values estimated from sequent months.

GREEN RIVER AT GREENRIVER, UTAH

(Discharges and dissolved solids tonnages in thousands)

based on 1929-1935 and 1944-1951 data.

Note: Dec. 1944, Oct. and Nov.,1949 and July 1950 values estimated from sequent months.

GREEN RIVER AT GREENRIVER, UTAH

(Discharges and dissolved solids tonnages in thousands)

Water Year	Discharge Ac. Ft.	Calcium T/AF	Calcium Tons	Magnesium T/AF	Magnesium Tons	Sodium & Potassium T/AF	Sodium & Potassium Tons	Carbonate & Bicarbonate T/AF	Carbonate & Bicarbonate Tons	Sulfate T/AF	Sulfate Tons	Chloride T/AF	Chloride Tons	Total Dissolved Solids T/AF	Total Dissolved Solids Tons	Percent Sodium
1925																
6																
7																
8	5759															
9	6464	.075	485	.029	188	.073	472	.23	1487	.21	1357	.030	194	.55	3555	32
1930	4554	.080	364	.031	141	.081	369	.24	1093	.24	1093	.035	159	.61	2778	33
1	2391	.084	201	.034	81	.099	237	.25	598	.27	646	.048	115	.68	1626	37
2	4822	.075	362	.026	125	.068	328	.24	1157	.18	868	.029	140	.51	2459	32
3	3525	.075	264	.029	102	.077	271	.23	811	.21	740	.034	120	.56	1974	34
4	1306	.086	112	.039	51	.124	162	.26	340	.32	418	.060	78	.77	1006	40
1935	2850	.073	208	.026	74	.066	188	.23	656	.18	513	.033	94	.50	1425	31
6*	4147	.077	319	.029	120	.077	319	.24	995	.21	871	.033	137	.57	2364	33
7*	4134	.086	356	.036	149	.10	413	.26	1075	.28	1158	.049	203	.70	2894	36
8*	4747	.082	389	.033	157	.092	437	.25	1187	.25	1187	.042	199	.64	3038	35
9*	3420	.086	294	.035	120	.10	342	.25	855	.28	958	.048	164	.69	2360	36
1940*	2376	.086	204	.035	83	.10	238	.25	594	.28	665	.048	114	.69	1639	36
1*	4242	.086	365	.035	149	.10	424	.25	1061	.28	1188	.048	204	.69	2927	36
2*	4990	.083	414	.033	165	.094	469	.25	1248	.26	1297	.043	215	.65	3244	35
3*	4270	.079	337	.031	132	.083	354	.24	1025	.23	982	.037	158	.60	2562	34
4	4476	.081	365	.029	132	.080	359	.27	1203	.22	1005	.032	141	.58	2612	33
1945	4159	.084	385	.031	128	.077	320	.29	1177	.22	898	.031	131	.60	2490	31
6	3469	.087	302	.032	110	.084	291	.29	1018	.23	800	.035	121	.63	2192	33
7	5484	.080	441	.027	150	.072	395	.27	1482	.20	1090	.030	162	.56	3062	32
8	4148	.080	333	.032	134	.078	325	.26	1087	.23	954	.034	140	.60	2495	32
9	4897	.087	426	.030	148	.080	394	.29	1428	.22	1098	.028	138	.62	3014	32
1950	5511	.088	487	.033	181	.077	423	.30	1666	.22	1231	.030	166	.61	3400	30
1	4722	.083	392	.031	146	.069	326	.27	1275	.21	992	.029	137	.60	2815	29
Average	4135	.082	339	.034	129	.083	342	.26	1066	.23	957	.036	149	.61	2519	34

* 1936-1943, total dissolved solids only reported; all other dissolved solids values derived by correlation curves based on 1929-1935 and 1944-1951 data.

Note: Oct. and Nov., 1949 values estimated from total dissolved solids.

SAN JUAN RIVER NEAR BLUFF, UTAH

(Discharges and dissolved solids tonnages in thousands)

Water Year	Discharge Ac. Ft.	Calcium T/AF	Calcium Tons	Magnesium T/AF	Magnesium Tons	Sodium & Potassium T/AF	Sodium & Potassium Tons	Carbonate & Bicarbonate T/AF	Carbonate & Bicarbonate Tons	Sulfate T/AF	Sulfate Tons	Chloride T/AF	Chloride Tons	Total Dissolved Solids T/AF	Total Dissolved Solids Tons	Percent Sodium
1925																
6																
7																
8																
9*	3111	.086	266	.018	56	.059	182	.20	615	.22	698	.013	39	.51	1580	29
1930	1724	.10	172	.023	40	.073	126	.22	379	.29	500	.015	26	.63	1086	29
1	888	.12	107	.027	24	.097	86	.22	195	.37	328	.020	18	.77	683	33
2	2948	.087	257	.018	53	.060	177	.20	590	.23	678	.012	35	.52	1533	29
3	1242	.10	124	.024	30	.084	104	.20	248	.33	410	.018	22	.68	845	32
4	662	.13	86	.030	20	.12	79	.23	152	.45	298	.024	16	.89	589	34
1935	2183	.082	179	.015	33	.056	122	.19	415	.20	437	.011	24	.48	1048	29
6	1631	.10	163	.022	36	.069	113	.22	359	.27	440	.014	23	.61	995	28
7	2336	.094	220	.020	47	.065	152	.22	514	.25	584	.013	30	.57	1332	29
8	2466	.088	217	.019	47	.064	158	.20	493	.23	567	.012	30	.53	1307	29
9	1239	.10	124	.022	27	.069	86	.22	273	.27	335	.016	20	.61	756	28
1940	996	.11	110	.024	24	.093	93	.22	219	.35	349	.020	20	.73	727	33
1	4242	.092	390	.019	81	.062	263	.22	933	.21	891	.012	51	.53	2248	28
2	3078	.090	277	.022	68	.058	179	.21	646	.23	708	.013	40	.54	1662	27
3	1445	.11	159	.027	39	.069	100	.23	332	.29	419	.020	29	.65	939	27
4	2289	.084	192	.018	41	.046	105	.21	481	.18	412	.013	30	.47	1076	23
1945	1620	.10	162	.023	37	.067	109	.23	373	.25	405	.018	29	.59	956	28
6	865	.12	104	.030	26	.090	78	.26	225	.37	320	.024	21	.78	674	29
7	1488	.10	149	.023	34	.078	116	.21	313	.31	461	.016	24	.65	967	30
8	2319	.080	171	.016	34	.049	105	.19	406	.19	406	.013	28	.46	984	26
9	2523	.083	209	.019	47	.049	124	.19	479	.20	505	.012	30	.48	1211	25
1950	902	.11	99	.030	27	.072	65	.21	190	.33	298	.022	20	.68	614	27
1	668	.12	80	.030	20	.088	59	.22	147	.37	247	.027	18	.79	528	30
Average	1864	.094	175	.021	39	.065	121	.21	390	.25	465	.015	27	.57	1058	29

COLORADO RIVER AT LEE'S FERRY, ARIZONA

(Discharges and dissolved solids tonnages in thousands)

1	668	.12	80	.030	20	.088	59	.22	147	.37	247	.027	18	.79	528	30
Average	1864	.094	175	.021	39	.065	121	.21	390	.25	465	.015	27	.57	1058	29

COLORADO RIVER AT LEE'S FERRY, ARIZONA

(Discharges and dissolved solids tonnages in thousands)

Water Year	Discharge Ac. Ft.	Calcium		Magnesium		Sodium & Potassium		Carbonate & Bicarbonate		Sulfate		Chloride		Total Dissolved Solids		Percent Sodium
		T/AF	Tons	T/AF	Tons	T/AF	Tons	T/AF	Tons	T/AF	Tons	T/AF	Tons	T/AF	Tons	
1925																
6																
7																
8																
9	19190	.098	1881	.031	595	.093	1785	.22	4222	.30	5757	.048	921	.70	13930	32
1930	13050	.10	1305	.034	444	.11	1436	.23	3002	.34	4437	.060	783	.78	10179	35
1*	6376	.12	778	.046	293	.16	997	.23	1479	.44	2830	.11	697	1.01	6468	39
2*	15250	.091	1382	.029	438	.095	1448	.20	3124	.27	4127	.053	806	.65	9969	36
3*	9729	.099	965	.034	331	.11	1072	.21	2040	.33	3257	.071	692	.77	7464	36
4*	4377	.13	573	.053	234	.19	844	.24	1063	.54	2362	.13	579	1.21	5288	41
1935*	9895	.090	890	.029	290	.10	1010	.20	1999	.28	2739	.067	664	.68	6734	37
6*	11930	.099	1185	.030	361	.10	1218	.21	2510	.31	3655	.059	707	.72	8545	36
7*	11870	.10	1194	.034	399	.10	1227	.22	2630	.32	3800	.063	746	.75	8930	35
8*	15410	.089	1368	.029	444	.092	1416	.21	3312	.26	4039	.050	777	.64	9892	35
9*	9360	.11	1010	.037	346	.12	1110	.23	2117	.34	3221	.071	665	.80	7505	36
1940*	7055	.12	846	.042	295	.14	981	.23	1636	.40	2846	.095	668	.93	6575	37
1*	16020	.10	1630	.030	481	.096	1535	.22	3589	.29	4702	.053	843	.70	11162	34
2*	17010	.083	1419	.030	506	.084	1422	.18	3095	.28	4790	.048	811	.62	10625	34
3	11240	.087	978	.034	382	.097	1090	.20	2248	.30	3372	.063	708	.70	7868	35
4	13200	.079	1043	.029	383	.086	1135	.19	2508	.25	3300	.050	660	.61	8052	36
1945*	11530	.11	1246	.037	427	.12	1369	.25	2902	.33	3862	.078	902	.82	9468	36
6*	8722	.12	1034	.038	335	.12	1048	.27	2370	.34	2957	.079	691	.85	7408	35
7*	13491	.098	1322	.033	442	.092	1245	.24	3248	.29	3945	.056	750	.70	9411	33
8	13670	.095	1299	.030	410	.087	1189	.23	3144	.26	3554	.054	738	.67	9159	33
9	14340	.097	1391	.031	445	.088	1262	.24	3442	.27	3872	.056	803	.68	9751	33
1950	11040	.10	1104	.038	420	.10	1104	.24	2650	.31	3422	.067	740	.76	8390	33
1	9817	.11	1080	.037	363	.10	982	.25	2454	.32	3141	.071	697	.79	7755	33
Average	11894	.099	1171	.033	394	.10	1214	.22	2643	.31	3652	.062	741	.73	8719	35

* 1931-1942 and 1945-1947 values derived by correlation with Grand Canyon and checked against sum of values for Green River at Green River, Colorado River near Cisco and San Juan River near Bluff.

COLORADO RIVER NEAR GRAND CANYON, ARIZONA

(Discharges and dissolved solids tonnages in thousands)

Water Year	Discharge Ac. Ft.	Calcium		Magnesium		Sodium & Potassium		Carbonate & Bicarbonate		Sulfate		Chloride		Total Dissolved Solids		Percent Sodium
		T/AF	Tons	T/AF	Tons	T/AF	Tons	T/AF	Tons	T/AF	Tons	T/AF	Tons	T/AF	Tons	
1926	14420	.090	1298	.029	418	.11	1586	.22	3172	.27	3893	.076	1096	.71	10238	39
7	17260	.10	1726	.030	518	.11	1899	.22	3797	.32	5523	.072	1243	.77	13290	37
8	15630	.090	1407	.030	469	.094	1469	.22	3439	.25	3908	.065	1016	.67	10472	35
9	19430	.10	1943	.031	602	.11	2137	.22	4275	.31	6023	.065	1263	.75	14573	36
1930	13420	.11	1476	.035	470	.12	1610	.25	3355	.34	4563	.084	1127	.85	11407	37
1	6721	.13	874	.046	309	.18	1210	.27	1815	.44	2957	.15	1008	1.11	7460	43
2	15970	.099	1581	.029	463	.11	1757	.24	3833	.27	4312	.073	1166	.72	11498	37
3	10010	.11	1101	.035	350	.13	1301	.25	2503	.34	3403	.10	1001	.86	8609	39
4	4656	.14	652	.053	247	.22	1024	.28	1304	.53	2468	.18	838	1.31	6099	45
1935	10220	.10	1022	.030	307	.12	1226	.24	2453	.28	2862	.094	961	.76	7767	39
6	12320	.11	1355	.031	382	.12	1478	.25	3080	.31	3819	.083	1023	.80	9856	36
7	12410	.11	1365	.034	422	.12	1489	.26	3227	.32	3971	.087	1080	.83	10300	37
8	15630	.10	1563	.030	469	.11	1719	.26	4064	.27	4220	.072	1125	.73	11410	36
9	9618	.12	1154	.038	366	.14	1347	.27	2597	.35	3366	.10	962	.90	8656	38
1940	7435	.13	967	.042	312	.16	1190	.27	2007	.40	2974	.13	967	1.02	7584	41
1	16940	.11	1863	.030	508	.11	1863	.26	4404	.29	4913	.072	1220	.76	12874	36
2	17260	.094	1622	.031	535	.10	1726	.22	3797	.29	5005	.068	1174	.71	12255	35
3*	11430	.098	1118	.035	404	.11	1323	.24	2758	.31	3524	.090	1025	.79	9075	37
4	13530	.10	1353	.033	447	.11	1488	.28	3788	.27	3653	.076	1028	.75	10148	35
1945	11870	.12	1424	.038	451	.14	1662	.30	3561	.34	4036	.11	1306	.92	10920	37
6	9089	.13	1182	.039	355	.14	1272	.32	2908	.34	3090	.11	1000	.94	8544	37
7	13740	.11	1511	.034	467	.11	1511	.29	3985	.30	4122	.079	1085	.79	10855	34
8	13870	.11	1526	.031	430	.10	1387	.29	4022	.27	3745	.080	1110	.76	10541	34
9	14370	.11	1581	.033	474	.11	1581	.30	4311	.27	3880	.078	1121	.78	11209	34
1950	11080	.12	1330	.038	421	.12	1330	.32	3546	.31	3435	.095	1053	.87	9640	34
1	9839	.12	1181	.039	384	.13	1279	.30	2952	.33	3247	.10	984	.92	9052	36
Avg.**	12211	.11	1337	.034	416	.12	1474	.27	3241	.31	3808	.088	1071	.82	10014	37

* All 1943 dissolved solids values computed by correlation with Lee's Ferry

** 1929-1951 used as basis for average

Effect of Initial Phase Depletions

With the data available, an operation study of Glen Canyon reservoir for the 1929-1951 period was made which included evaporation from Echo Park Reservoir and the effect of depletion due to the operation of the 12 participating projects whose authorization was sought in the bills before the Congress last year. This list may be changed somewhat in current legislation but unless substantially enlarged or reduced will have little effect upon the conclusions drawn therefrom.

The quality of river water at Lees Ferry was used in making the reservoir analysis. Since no quality of water data were taken at this station for the years 1931-1942 and 1945-1947, it was necessary to estimate them from records of adjacent stations. The records for Colorado at Grand Canyon are complete and the records for Colorado near Cisco, Green River at Greenriver, Utah, and San Juan near Bluff are substantially complete for the 1929-1951 period. The missing Lees Ferry record was, therefore, supplied by hydrologic comparison with the Grand Canyon record and checked against the sum of the data for the three upstream stations. The resulting figures are believed to represent with reasonable accuracy the long time quality of the water available to Glen Canyon reservoir. Where other necessary records were missing they were supplied from the same type of correlation curves.

In considering the effect of transmountain diversions upon the reservoir operation, it was necessary to estimate the qualities of the several waters which would be diverted. An average figure of 0.08 tons of salt per acre foot was used in the analysis. A subsequent check of the few available data indicates that a more probable figure would be perhaps twice that concentration. In either case, the total effect of transmountain diversions on the end result is quite small.

The Initial Phase operation, including the effect of currently authorized but uncompleted projects will reduce the historical water supply by about 14 percent. The reservoir operation study indicates that the widely divergent concentrations in the natural flow of the river will be largely smoothed out. Upstream depletions will increase the present average salt concentrations from 0.73 to about 0.85 tons per acre foot of water. Undoubtedly there will be some change in sodium percentage but because of the limited depletion of the over-all water supply, it should be slight. The general conclusion to be drawn from the study is that consumption of water by the Initial Phase projects will have little practical effect upon the quality of water discharged from Glen Canyon Reservoir.

OPERATION OF GLEN CANYON RESERVOIR—Initial Phase

Construction of Colorado River Storage Project (Glen Canyon and Echo Park Reservoirs plus 12 Participating Projects)

Water Year	In-Basin Uses ** Ac. Ft.	Transm'tn Diver.		Reservoir Inflow		Reser. Evap. Ac. Ft.	Quality of Mixed Water			Releases and Spills		End-of-Yr. Storage	
		Water Ac. Ft.	T.D.S. Tons	Water Ac. Ft.	T.D.S. Tons		Water Ac. Ft.	T.D.S. Tons	Tons per Ac. Ft.	Water Ac. Ft.	T.D.S. Tons	Water Ac. Ft.	T.D.S. Tons
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
7	1250*	316*	25	14974	11725*				(.78)				
1928	1208*	309*	25	13793	11155*				(.81)			26000	20800
9	1318*	330*	26	17542	13904	639	43542	30704	.798	16903	13320	26000	21384
1930	1132*	283*	23	12635	10156	639	38635	31540	.816	11996	9789	26000	21751
1	902	153	12	5321	6456	572	31321	28207	.901	10500	9460	20249	18747
2	1224	291	23	13735	9946	547	33984	28693	.844	10039	8473	23398	20220
3	1175	228	18	8326	7446	557	31724	27666	.872	9561	8337	21606	19329
4	774	103	8	3500	5280	452	25106	24609	.980	10164	9961	14490	14648
1935	1014	177	14	8704	6720	343	23194	21368	.921	10425	9601	12426	11767
6	1186	296	24	10448	8521	323	22874	20288	.887	9889	8772	12662	11516
7	1015	272	22	10583	8908	330	23245	20424	.879	9889	8692	13026	11732
8	1220	309	25	13881	9867	380	26907	21599	.803	9604	7712	16923	13887
9	954	218	17	8188	7488	407	25111	21375	.851	9359	7965	15345	13410
1940	818	173	14	6064	6561	339	21409	19971	.933	9924	9259	11146	10712
1	1100	205	16	14715	11146	344	25861	21858	.845	9382	7928	16135	13930
2	1210	296	24	15504	10601	483	31639	24531	.775	8576	6647	22580	17884
3	1015	295	24	9930	7844	566	32510	25728	.791	8831	6985	23113	18743
4	1029	282	23	11889	8029	587	35002	26772	.765	9937	7602	24478	19170
1945	1005	258	21	10267	9447	597	34745	28617	.824	10235	8434	23913	20183
6	899	252	20	7571	7388	548	31484	27571	.876	10543	9236	20393	18335
7	1187	329	26	11945	9385	522	32338	27720	.857	10192	8735	21624	18985
8	1134*	291*	23	12245	9136	556	33869	28121	.830	10000E	8300	23313	19821
9	1167*	297*	24	12876	9727	603	36189	29548	.816	10000E	8160	25586	21388
1950	1062*	253*	20	9725	8370	618	35311	29758	.843	10000E	8430	24693	21328
1	1017*	228*	18	8572	7737	585	33265	29065	.874	10000E	8740	22680	20325

* Estimated from relationship curves based on water supply.

** In-Basin depletions includes exaporation from Echo Park Reservoir (from U.S.B.R. study)

E Estimated

OPERATION OF GLEN CANYON RESERVOIR—Ultimate Phase

Construction of Colorado River Storage Project

* Estimated from relationship curves based on water supply.
** In-Basin depletions includes exaporation from Echo Park Reservoir (from U.S.B.R. study)
E. Estimated

OPERATION OF GLEN CANYON RESERVOIR—Ultimate Phase

Construction of Colorado River Storage Project

Climatic Year	Transm't Diversions Present Auth. + Future Ac. Ft.	Tons	Historical T.D.S. Tons	Reservoir Inflow Water Ac. Ft.	Reservoir Inflow T.D.S. Tons	Reser. Evap. Ac. Ft.	Quality of Mixed Water Water Ac. Ft.	Quality of Mixed Water T.D.S. Tons	Quality of Mixed Water Tons per Ac. Ft.	Releases and Spills Water Ac. Ft.	Releases and Spills T.D.S. Tons	End-of-Yr. Storage Water Ac. Ft.	End-of-Yr. Storage T.D.S. Tons
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
												19320	19320
1927	2046*	164	11523	9510	11359	620	28830	30679	1.06	8150	8639	20060	22040
8	1957*	157	9079	9820	8922	640	29880	30962	1.04	9280	9651	19960	21311
9	2180*	174	13930	12500	13856	630	32460	35167	1.08	11760	12701	20070	22466
1930	1766*	141	10179	8300	10038	640	28400	32504	1.14	7690	8767	20070	23737
1	1081	86	6468	4869	6382	600	24939	30119	1.21	7488	9060	16851	21059
2	1784	143	9969	8442	9826	566	25293	30885	1.22	7462	9104	17265	21781
3	1512	121	7464	5971	7343	542	23236	29124	1.25	7483	9354	15211	19770
4	757	61	5288	4644	5227	481	19855	24997	1.26	7481	9426	11893	15571
1935	1510	121	6734	6365	6613	404	18258	22184	1.22	7483	9129	10371	13055
6	1893	151	8545	7247	8394	382	17618	21449	1.22	7465	9107	9771	12342
7	1542	123	8930	7721	8807	375	17492	21149	1.21	7473	9042	9644	12107
8	2051	164	9892	9556	9728	396	19200	21835	1.14	7474	8520	11330	13315
9	1607	128	7505	6502	7377	401	17832	20692	1.16	7466	8661	9965	12031
1940	1008	80	6575	6178	6495	355	16143	18526	1.15	7474	8595	8314	9931
1	1774	142	11162	10589	11020	377	18903	20951	1.11	7472	8294	11054	12657
2	1988	159	10625	11121	10466	483	22175	23123	1.04	7480	7779	14212	15344
3	1762	141	7868	6971	7727	484	21183	23071	1.09	7481	8154	13218	14917
4	1579	126	8052	8345	7926	479	21563	22843	1.06	7481	7930	13603	14913
1945	1624	130	9468	7445	9338	476	21048	24251	1.15	7483	8605	13089	15646
6	1370	110	7408	6046	7298	442	19135	22944	1.20	7477	8972	11216	13972
7	1803	144	9411	8291	9267	418	19507	23239	1.19	7476	8896	11613	14343
8	1823*	142	9159	8700*	9017	440*	20313	23360	1.15	7480*	8602	12393	14758
9	1880*	150	9751	9260*	9601	450*	21653	24359	1.12	7480*	8379	13723	15980
1950	1578*	126	8390	7000*	8264	480*	20723	24244	1.17	7480*	8752	12763	15492
1	1458*	117	7755	6300*	7638	470*	19063	23130	1.21	7480*	9051	11113	14079

* Estimated from relationship curves based on water supply.

Effect of Ultimate Depletions

A reservoir operation study was also made for ultimate depletion of 7,500,000 acre feet of water in the Upper Basin. The analysis shows that the salt concentration in the releases from Glen Canyon will increase. Neglecting the modifying factors mentioned on page 5, the salt concentrations will vary between 1.04 and 1.26 and will average about 1.15 tons per acre foot.

Base Exchange and Sodium Percentage

Base exchange which occurs as a by-product of the irrigation process results generally in an increase in the sodium percentage. In most of the western streams of the country, the waters tend to be gradually changed by base exchange from "hard" to "soft" waters.

A determination of the magnitude of the increase which will take place as a result of irrigation uses in the Upper Basin is exceedingly difficult because of the many factors which affect such change. It may be possible to approach a reasonable answer, however, by comparison with the Rio Grande Basin where detailed records of such changes have been kept for many years. In making such comparison the dangers of applying the hydrology of one river basin to that of an adjacent basin cannot be overlooked. In this instance, however, because of the many similar characteristics of the two basins, it is believed that the figures derived by the comparison can be adopted with reasonable assurance.

Quality of water records of the Rio Grande below Elephant Butte Reservoir have been obtained by the Rubidoux Laboratory since 1931, the data being published in the annual reports of the International Boundary and Water Commission. For the 22-year period up to 1952, the following averages appear.

River Station	Discharge-A.F.	T.D.S.-T/AF	% Sodium
Below Caballo Reservoir	801,000	0.71	44%
At El Paso	596,000	1.10	53%
At Fort Quitman	209,000	2.37	62%

The station below Caballo Reservoir is at the head of the Elephant Butte Project, the El Paso station is at the head of the El Paso County division of the project and Fort Quitman is at the lower end of the El Paso Valley.

Considering 801,000 acre feet as the available project water supply, the net depletion at El Paso is 33% and at Fort Quitman is 74%. Plotting the sodium percentages at the stations against the depletions (Figure 1) gives an approximate measure of the change in sodium percentage as the water supply is depleted.

For the purpose of determining the worst possible effect of depletions in the Upper Basin on the quality of water delivered to the Lower Basin, it will be assumed that the virgin flow of the river at Lees Ferry does not exceed 15,000,000 acre feet per year. The average discharge with present depletions will then be

13,000,000 acre feet, which the Initial Phase projects will deplete by 14% and ultimate development will deplete by 42%. Entering the curve we find that these depletions would have increased the average sodium percentage of the Elephant Butte Project supply by 4 percentage points (44% to 48%) and 11 percentage points (44% to 55%) respectively. If we make the reasonable assumption that similar changes in sodium percentage will take place in the Upper Colorado River basin as a result of the contemplated depletions of that water supply, the Initial Phase sodium percentage will change but slightly and the maximum change under complete development will increase the present 35% to about 46%.

Losses from Solution in Large Reservoirs

It has been pointed out elsewhere in this report that substantial quantities of dissolved solids in Lake Mead storage have been precipitated from solution but that this process is masked by the taking into solution of other salts from extensive saline beds within the reservoir basin. In the Elephant Butte reservoir, however, there are no saline deposits such as occur in Lake Mead and it is possible to measure closely the losses of salts from solution which have occurred in that reservoir.

Complete records have been kept of the chemical quality of water entering and leaving Elephant Butte reservoir since 1933. They have been published annually in the reports of the International Boundary and Water Commission through the year 1946, after which year the inflow data are incomplete. The data include not only the total quantities of dissolved solids but the quantities of the several ionic constituents. A determination was made of the total quantities of several constituents in the reservoir at the start of the period January 1, 1933 and of the measured inflows to the reservoir for the 1933-1946 period; also of the outflows from the reservoir during the same period and the quantities remaining in the lake as of December 31, 1946. These data do not include the unmeasured salt inflows from side streams entering directly into the reservoir, the amounts of which are but a small percentage of the total. (See Table III)

An accounting of all dissolved solids into and out of the lake during this 14 year period presents some very interesting facts.

TABLE III

COMPUTATION OF SALT BALANCE IN ELEPHANT BUTTE RESERVOIR — Jan. 1, 1933 to Jan. 1, 1947

(Values in Thousands)

	TONS							End of Yr.
	Ca	Mg	Na/K	HCO_3	SO_4	Cl	T.D.S.	Storage A. F.
In Storage 1-1-31*	136	30	171	299	396	116	1046	1273
1931 Inflow—R.G. at San Marcial	68	15	92	143	219	62	549	
1932 Inflow—R.G. at San Marcial	139	31	170	312	396	116	821	
1931 Outflow	81	15	103	99	238	59	617	924
1932 Outflow	81	20	107	97	262	59	659	
In Storage 1-1-33	181	41	223	558	511	176	1140	1395
1933-46 Inflows —R.G. at San Marcial	1168	241	1319	1456	3094	794	9030	
Total Into Res., 1933-46	1349	282	1542	2014	3605	976	10170	
1945-46 Av.—R.G. at San Marcial	.080T/AF	.015T/AF	.080T/AF	.112T/AF	.178T/AF	.047T/AF	.562T/AF	
1946—R.G. below E.B. Res.	.084T/AF	.018T/AF	.099T/AF	.120T/AF	.205T/AF	.067T/AF	.644T/AF	
Salt Concentrations (Av. of above)	.082T/AF	.017T/AF	.090T/AF	.116T/AF	.192T/AF	.057T/AF	.603T/AF	
In Storage 1-1-47	65	13	71	92	151	45	476	789
1933-46 Outflows— R.G. below E.B. Res.	1077	228	1278	1357	2940	820	8388	
Total out of Res., 1933-46	1142	241	1349	1449	3091	865	8864	
Excess of Inflows over Outflows	207	41	193	565	514	105	1306	
% of Total Inflow**	15.3%	14.5%	12.5%	28.0%	14.3%	10.8%	12.8%	

Note: All values recorded excepting those for 1929-1932 which were estimated from correlation curves based on discharge.

* Average of concentrations of dissolved constituents for years 1929 and 1930.

** Equals percent loss of various constituents from solution in reservoir basin.

It shows that one-eight (12.8%) of the total quantity of salts entering the reservoir are precipitated from solution within the reservoir basin. The total loss is actually greater than the above figure by the amount of salt entering as unmeasured side inflow. The data shows that the less soluble constituents, Calcium (15.3%) and Carbonate and Bicarbonate (28.0%) comprise a greater than average part of these precipitated salts but, rather surprisingly, that the more readily soluble ions, Sodium and Potassium (12.5%) and Chloride (10.8%) are also lost from solution in substantial quantities. Calcium carbonate alone comprises only about 43% of the precipitated salts. As stated elsewhere in this report, this phenomenon has not been adequately explained, but is thought by some to result partly from temperature changes in the water and partly by the settlement of finely divided sediments which seem to carry the dissolved solids down with them.

If, as Dr. Howard has determined, over 6.3% of the dissolved solids entering Lake Mead have been precipitated as calcium carbonate, it is evident that precipitation of a substantial portion of the other dissolved constituents also occurred. It appears logical by comparison with the Elephant Butte data that at least twice that percentage of all dissolved constituents in the lake influent have been precipitated. There is good evidence that at least one-eight (and probably more) of the total dissolved solids which will enter Glen Canyon reservoir will remain permanently within the reservoir basin itself. Further, there seems to be no good reason why a substantial deposition of salts from solution should not occur in each of a series of hold-over reservoirs on the stream although the amounts of such depositions will undoubtedly vary somewhat with local conditions.

Effect on Ultimate Quality of Lees Ferry Water: It can be concluded, therefore, from the Elephant Butte data, substantially verified by the record at Lake Mead, that about one-eight of the salts entering Glen Canyon reservoir will be permanently deposited from solution within the reservoir basin. Further, there is reason to believe that similar deposition will also occur in holdover reservoirs both above and below Glen Canyon. A loss of 12.5% of the Glen Canyon reservoir salts would result in an effluent under ultimate development of the Upper Basin of only about 1.00 tons per acre foot of dissolved solids.

Such a water supply with a sodium content of less than 50% constitutes a good water supply as defined by salinity experts, being equal to or better than the average water supply used successfully for many years by the Elephant Butte Project, one of the most successful reclamation projects of the West.

The Upper Colorado River Project and the Compact of 1922

The States of the Upper Basin, by the terms of the Colorado River Compact of 1922, have the obligation of not depleting the flow of the Colorado at Lees Ferry below an aggregate of 75,000,000 acre feet for any period of 10 consecutive years. In Article VIII of the Compact there is also an obligation on the part of all seven

States not to impair any rights to the beneficial use of water which were perfected as of the date of the compact. This Article then goes on to explain that any claims of such present perfected rights in the Lower Basin which might be made against water users in the Upper Basin "shall attach to and be satisfied from water that may be stored" in a reservoir with a "storage capacity of 5,000,000 acre feet" constructed "on the Main Colorado River within or for the benefit of the Lower Basin."

Certain Lower Basin interests are attempting to bend the meaning of Article VIII, particularly the use of the word "impair" to support their contention that the Upper Basin is obligated not to affect in any way the quality of the water available to the Lower Basin. If this contention is correct, then Articles III and VIII of the compact directly contradict one another. Article III gives the Upper Basin States the right to physically consume 7,500,000 acre feet of water each year. However, with the consumptive use of the first acre foot of that amount, the chemical quality of the water at Lees Ferry will be altered to some minute extent and this effect will increase as each additional new acre foot of water is consumed. Under the above interpretation, therefore, it would be impossible to consume any water in the basin above that appropriated prior to 1922 without violating the Compact. It should be obvious, therefore, that, when agreement was reached by the contracting states and the compact was signed in Santa Fe, New Mexico, November 24, 1922, the compact recognized the right of the Upper Basin to use its full compact allotment with all of the attendant affects which such use might reasonably impose upon both the quantity and quality of the water to the Lower Basin.

It should be further pointed out that Article VIII imposes an obligation on all seven contracting States, not on the Upper Basin alone, to see that the then perfected rights are unimpaired. If the contention of these Lower Basin interests is correct, then not only the Upper Basin but each and every water user in both basins whose water rights postdate the year 1922 and who by consumptive use affect the quantity or quality of the water to any user whose right antedates 1922, is a violator of the compact.

In connection with the contention of the Lower Basin interests that impair means quality as well as quantity, it should be pointed out that these interests now make no distinction between 1922 perfected rights and those obtained and developed since that date. In their current contention, they would require that not only 1922 and earlier rights on the stream but all Lower Basin rights which may eventually be perfected under the terms of the compact must also be "unimpaired" as to quality. Obviously neither the Upper Basin nor any upstream user properly can be saddled with such a responsibility.

Transmountain diversions are under attack by some interests as impairing the general quality of the water supply of the Colorado River since such diversions usually take waters from high in the mountains and thus are accused of removing some of the best waters of the basin. As pointed out previously in this report, such diversions actually remove both the water and the dissolved salts from the basin and thus the remaining supply is of better quality than would have resulted had the water been consumed within the basin. As a matter of fact, the only way in which the Upper Basin could even attempt to consume 7,500,000 acre feet of water annually, or any substantial part thereof, without impairing the quality of the remaining supply would be by transporting that entire amount bodily out of the Colorado River drainage basin together with the salts dissolved therein and consuming it in other stream basins.

Effects of Holdover Storage on Quality of Water

The natural flow of the Colorado River is quite variable, both from month to month and from year to year. Over 65% of the annual discharge at Lees Ferry usually occurs during the four months of spring runoff, April through July. These discharges, largely derived from melting snows are generally of excellent quality. The flows of the river during the other eight months are usually well below the monthly average excepting for occasional floods from torrential summer storms. The concentration of the dissolved solids during these months increases substantially. The river operation study shows that under present day conditions of relatively unregulated flow above the Lees Ferry gaging station, the salt concentration in the waters of the Colorado at that point from 1929 through 1951 varied from about 0.28 to 2.44 tons per acre foot. Under regulated flow from Echo Park and Glen Canyon reservoirs, these seasonal and annual variations would largely be ironed out. Under Initial Phase construction the concentrations would vary within the narrow range from about .76 to 1.00 tons per acre foot. Under ultimate upstream development the concentrations would be higher but the fluctuation would still remain within a narrow range.

TABLE IV

MONTHLY CONCENTRATIONS OF WATER OF COLORADO RIVER AT GRAND CANYON

(Total Dissolved Solids in Tons per Ac. Ft.)

Month	1927	1928	1929	1930	1931	1932	1933	1934
October	1.64	.91	1.84	.96	1.45	1.48	1.80	1.63
November	1.59	1.18	1.45	1.21	1.38	1.53	1.62	1.76
December	1.47	1.41	1.53	1.35	1.51	1.72	1.66	1.68
January	1.59	1.29	1.61	1.53	1.70	1.51	1.52	1.64
February	1.33	1.22	1.43	1.33	1.48	1.19	1.39	1.51
March	1.24	1.10	1.19	1.26	1.42	1.10	1.37	1.47
April	.78	.77	.74	.66	1.12	.69	1.20	1.15
May	.38	.44	.42	.50	.72	.44	.75	.63
June	.41	.37	.33	.44	.51	.38	.36	.85
July	.61	.52	.57	.89	.89	.55	.81	1.65
August	1.08	1.07	1.15	1.27	1.11	1.20	1.43	2.49
September	1.25	1.55	1.09	1.34	1.99	1.50	1.74	2.27
Annual	.77	.69	.75	.85	1.07	.72	.86	1.30

A record of the diversions to the Imperial Irrigation District in California through the Alamo Canal in earlier years and more recently through the All-American Canal, taken from official sources, shows that the monthly diversions of water for irrigation purposes expressed as percent of the annual total, average about as follows:

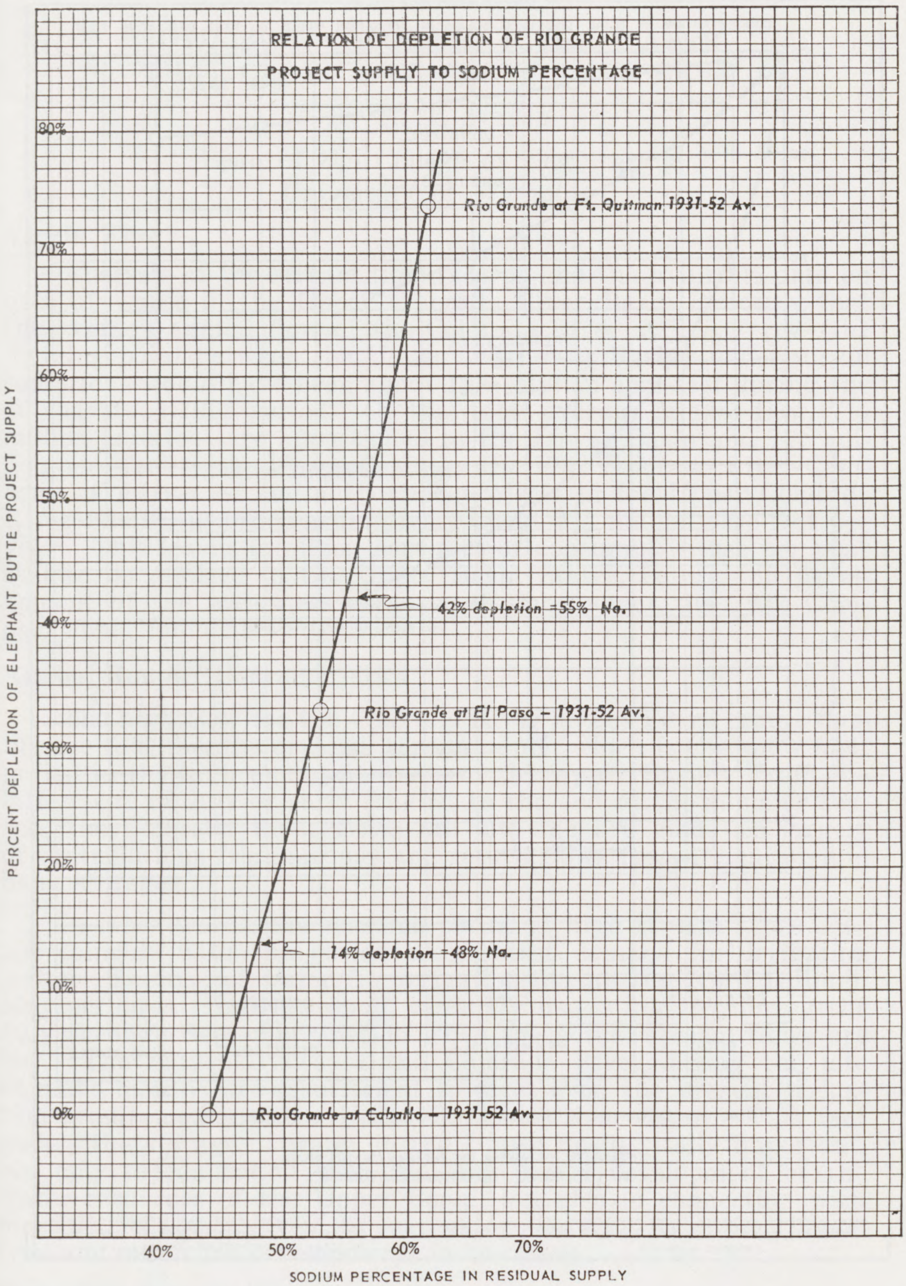
January	5.7%	July	10.3%
February	6.4%	August	9.4%
March	8.6%	September	8.6%
April	9.5%	October	9.2%
May	10.1%	November	7.0%
June	9.7%	December	5.5%
		Annual	100%

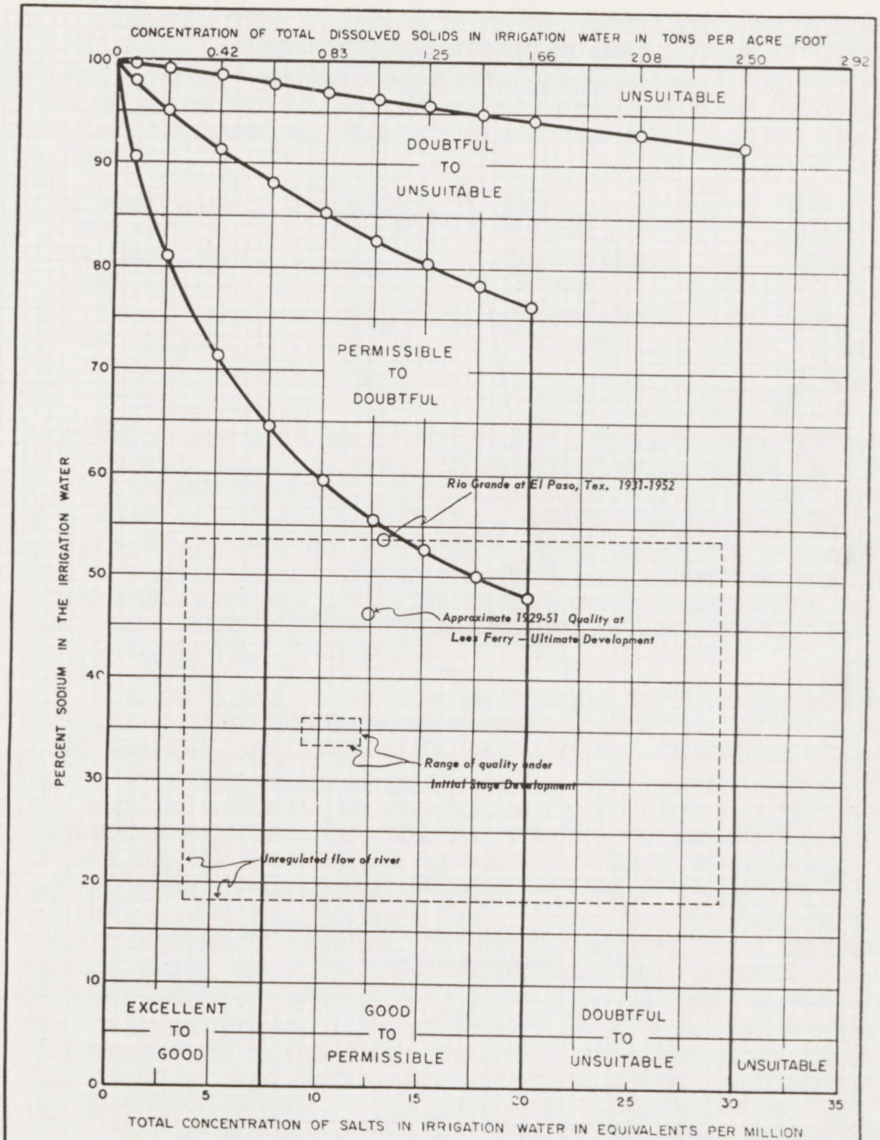
A record is also available of the monthly average concentrations of salts in the waters of the Colorado River at the Grand Canyon Station for the years 1927 through 1934 prior to the initial filling of Lake Mead. Under ultimate development with a concentration at Lees Ferry averaging 1.00 tons per acre foot, these data show that over sixty percent of the time (63.0%) the water supply for Lower Basin uses will still be lower in mineral content than it was during the many years of operation prior to the construction of Hoover Dam. (See Table IV)

In commenting upon the present and future quality of the water of the Colorado River, Mr. Julian Hinds, one of the most prominent water engineers of the west said*: "The quantity and quality of solids dissolved in the water were carefully checked. The dissolved solids in the unregulated river varied with the flow and ranged from less than 300 parts per million during floods to about 1,000 parts per million at low flow. Lake Mead equalizes this variation to an average mineral content of about 600 parts per million (0.81 tons per acre foot). Boron and fluorine are not present in harmful amounts. Exhaustive studies show that the mineral content under the most unfavorable future conditions will be lower than the average for waters diverted and successfully used in the Yuma and Imperial Valleys prior to the construction of Hoover Dam. It is fully established that the water of the Colorado River is of high quality, except for a fairly high percentage of hardness which can be removed at a reasonably low cost." The writer of this report can add little to Mr. Hinds' statement excepting to say that his findings are in complete agreement with those made by Mr. Hinds.

* "Colorado River Aqueduct, The Metropolitan Water District of Southern California, by Julian Hinds, General Manager and Chief Engineer, Los Angeles, California, October 1950," Page 13.

Figure I


RELATION OF DEPLETION OF RIO GRANDE
PROJECT SUPPLY TO SODIUM PERCENTAGE
80%
70%
60%
50%
40%
30%
20%
10%
0%
Rio Grande at Ft. Quitman 1931-52 Av.
42% depletion = 55% Na.
Rio Grande at El Paso – 1931-52 Av.
14% depletion = 48% Na.
Rio Grande at Caballo – 1931-52 Av.
PERCENT DEPLETION OF ELEPHANT BUTTE PROJECT SUPPLY
40%
50%
60%
70%
SODIUM PERCENTAGE IN RESIDUAL SUPPLY



SUITABILITY OF WATER OF THE COLORADO RIVER
AT LEES FERRY, FOR IRRIGATION PURPOSES

GRAPH PREPARED BY UNITED STATES DEPARTMENT OF AGRICULTURE, RUBIDOUX LABORATORY, RIVERSIDE, CALIF. (MODIFIED SLIGHTLY)

NOTE. IN COLORADO RIVER MAIN STREAMS 10 E.P.M. CONCENTRATION EQUALS 0.083 TONS PER ACRE FOOT OF TOTAL DISSOLVED SOLIDS (APPROX.)

APPENDIX D

UTILIZING COLORADO RIVER WATER THAT ORIGINATES ABOVE LEE FERRY

By H. T. Person

Dean of the College of Engineering
University of Wyoming

Virgin Flow*

Analysis of the stream flow records and the available data on uses of water in the Upper Colorado River Basin indicates that the average annual flow of the Colorado River at Lee Ferry (the dividing point between the Upper and Lower Basin) under virgin conditions would have been about 15½ million acre-feet during the 40-year 1914-1953 period. Of this total average annual flow, 7½ million acre-feet are apportioned to the Lower Basin and 7½ million acre-feet to the Upper Basin by the 1922 Colorado River Compact. Constructed and authorized projects in the Upper Colorado River Basin will use consumptively about 2½ million acre-feet per year. This leaves 5 million acre-feet of consumptive use per year still to be realized in the Upper Basin States, before full development of the water resources is attained under the 1922 Compact apportionment.

Annual Run-off Characteristics

The high flow for the Colorado River at Lee Ferry occurs during the four months of April through July, which is the snow melt period in the high mountain areas of the Upper Basin. From the latter part of July or early August to the end of the summer season, the Colorado River flows are low and are made up largely of contributions from springs and return flows from irrigation and bank storage.

In other words, the seasonal period of high stream flows does not coincide with the period of greatest demand for irrigation water. The use of water for irrigation during the April through May period is relatively small, while the use is highest during the July through September period when the actual stream flows are low. The natural flows of the Colorado River during the late summer months are insufficient to meet even the present irrigation requirements of the Upper Colorado River Basin. This fact makes the storage of water in the Upper Basin vitally important, not only in connection with the long period development of the water resources of the Upper Basin, but also in connection with meeting the seasonal year to year water needs for irrigation, industrial and municipal developments in the Basin.

Periodical Run-off Characteristics

The annual flows of the Colorado River are highly variable. During the period 1914 through 1954 there were 12 years during

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* The term "Virgin flow" means the flow of the river undepleted by the activities of man.

which the measured flows at Lee Ferry have exceeded 16 million acre-feet. During this same period there were nine years in which the annual discharge has been less than 10 million acre-feet. The virgin flows of the Colorado River at Lee Ferry have varied from a maximum of 24 million acre-feet in 1917, to a minimum of 5½ million acre-feet in 1934. The annual virgin flows are shown on the the accompanying Charts A and B.

Reasons for Carry-Over Storage

Chart A has been prepared to show the annual water supplies available from the Upper Colorado River Basin, the present uses of Upper Basin water by the Lower and Upper Basins, and the uses by the projects or units of the Upper Colorado River Project proposed for authorization under the bills now being considered. The present estimated use of Upper Basin water in the Lower Basin is 5.35 million acre-feet per year, and is shown in red on the Chart. The average present consumptive use in the Upper Basin under constructed and authorized projects is 2½ million acre-feet per year, and is shown in solid blue. The estimated average consumptive use by the storage and participating units proposed for authorization in the bills under consideration is about 1¾ million acre-feet per year and is shown in the cross-hatched blue. The unused water in the Upper Basin is shown in orange. It is noted that the Chart shows that the water supplies for the years 1931, 1934 and 1940 would have been sufficient for little if any additional utilization in the Upper Basin.

Chart B shows the 1914-1953 water supply situation in the Upper Colorado River Basin with the Upper Basin meeting the Lee Ferry delivery obligation of 75,000,000 acre-feet in any 10 year consecutive period. The red on the Chart represents the water delivery by the Upper Basin to the Lower Basin. The blue on the Chart again represents the present use in the Upper Basin, and the cross-hatched blue represents the use by the storage and participating units now being considered for authorization. On this Chart the black line has been drawn to show a total consumptive use of 7½ million acre-feet in the Upper Basin in accordance with the 1922 Colorado River Compact apportionment.

From this Chart it is evident that the Upper Basin needs carry-over storage, not only to make possible the use of the 7½ million acre-feet apportioned to it by the 1922 Compact, but also to take care of present uses, and the uses contemplated by the projects included in the bills which are now under consideration.

Carry-Over Storage Required

Every engineer who has studied the Upper Colorado River situation has arrived at the conclusion that carry-over storage is essential in connection with the further development and utilization of the water resources of the Upper Basin. This is the conclusion of the Bureau of Reclamation. This is the conclusion of the engineering firm of Leeds, Hill and Jewett in their report "Depletion of Surface Water Supplies of Colorado West of Continental Divide," prepared for the Colorado River Water Conservation Board in which they say, "Increased diversions of water for use by agriculture and industry on the Western Slope and for trans-mountain diversions will depend upon the provisions of sufficient storage capacity in reservoirs for conservation of flood flows and some cyclic regulation; in order that Colorado may make full use of the water allocated to it by the Compacts, cyclic regulation of Colorado River over periods longer than twenty years will also be necessary."

An examination of Chart B shows that the period from 1914 through 1930 was one of generally high flows. During this period the Colorado River water supplies were adequate for the Upper Basin to meet the Lee Ferry delivery obligations, to provide the 7½ million acre-feet of consumptive use allocated to the Upper Basin and to furnish water to store in carry-over storage reservoirs. During the period 1931 through 1953 carry-over storage water would have to be used 9 years to meet the Lee Ferry delivery obligation, the present uses in the Upper Basin and the contemplated uses under the projects included in the bills now being considered. Also, during this 1931 through 1953 period, carry-over storage water would have to be used 14 years to meet the Lee Ferry delivery obligation and to provide 7½ million acre-feet consumptive use for the Upper Basin.

A study of the 1914-1953 stream flows indicates that something over 30 million acre-feet of active carry-over storage capacity will be required in order to permit the Upper Basin to meet its Lee Ferry delivery obligation and consumptively use the 7½ million acre-feet per year apportioned it by the 1922 Colorado River Compact. Possibly as additional stream flow records become available, it may be found that the required carry-over storage capacity may be even greater.

Sufficient Water Available

A study of the flows of the Colorado River at Lee Ferry for the 1914-53 period, indicates that there would have been sufficient water available during this period to meet the Lee Ferry delivery obligation, and to permit a total annual consumptive use in the Upper Basin of 7½ million acre-feet, provided adequate carry-over storage capacity is provided in the Upper Basin. Referring again to the Chart B, this means that the excess flow indicated by the orange color above the black line representing the 7½ million acre-feet delivery obligation at Lee Ferry and the 7½ million acre-feet consumptive use in the Upper Basin, would have been sufficient to fill the deficiencies represented by the white spaces below the black line.

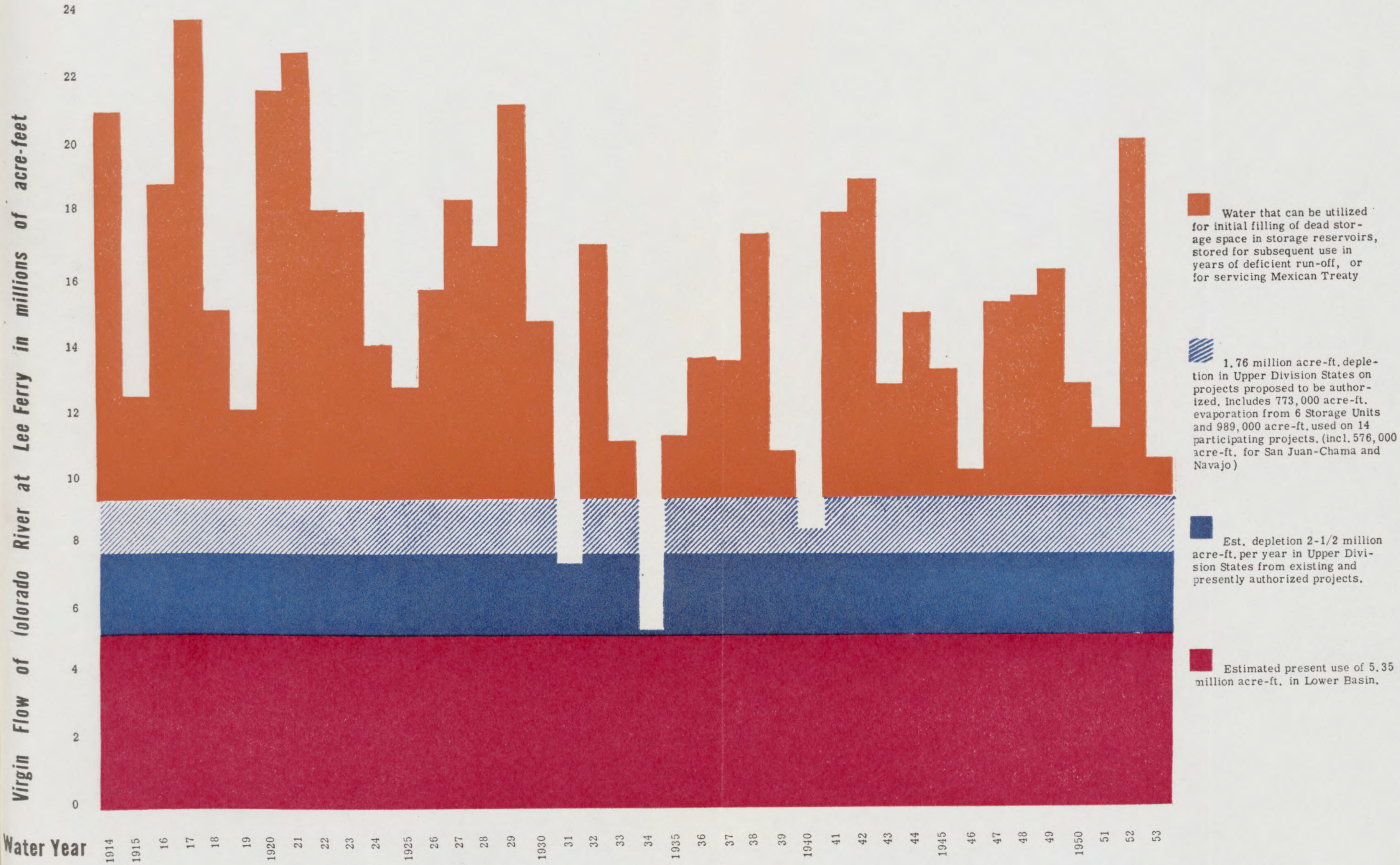
Carry-Over Storage Should be Provided Now

It has been suggested that some consumptive use development could be made in the Upper Basin without large quantities of carry-over storage capacity. That limited development can be made, if local project storage is provided to equalize the seasonal and annual variations of the particular tributary stream involved, is certainly true. However, if the carry-over storage is going to be provided with the minimum interference with established water needs, a large part of this carry-over storage capacity must be provided before too much additional consumptive use development is made. Providing carry-over storage capacity as early as possible is essential to permit filling of the inactive storage capacity without interfering with existing consumptive use rights. Also providing the storage capacity ahead of additional consumptive use development will permit initial filling with minimum interference with the operation of existing facilities. The present developments in the Colorado River Basin indicate now is the time to provide a large part of the required carry-over storage capacity.

It has been suggested that additional stream flow records may possibly show that the Upper Colorado River water supplies are inadequate to permit an annual consumptive use in the Upper Basin of 7½ million acre-feet, and that this fact might not warrant as much carry-over storage capacity as is now contemplated. It is granted that the records may be of insufficient duration to assure a complete water supply picture, and that additional years of records may possibly show that the Upper Basin use will be limited to something less than 7½ million acre-feet per year. However, the records are of sufficient duration to fully justify providing the carry-over storage capacity contemplated in the bills now under consideration.

Utilizing Colorado River Waters That Originate Above Lee Ferry

Chart A.

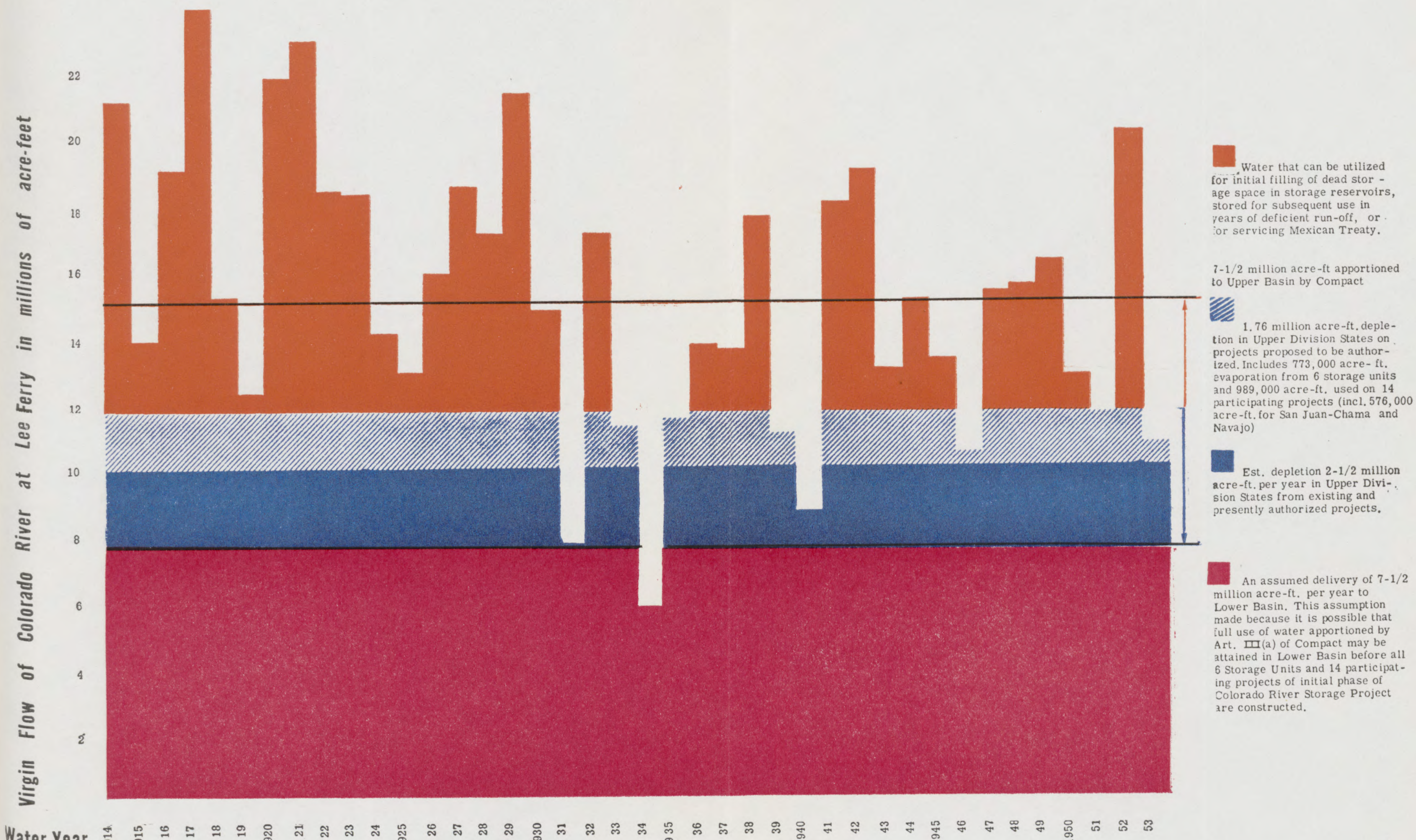


Now is the time to construct major hold-over storage reservoirs while uses of Colorado River Water in both Upper and Lower basins are below the ultimate apportionments of the Compact in order to insure filling of these reservoirs from large supplies of unused (orange) waters with a minimum of interference to downstream non-consumptive uses.

Note that existing and presently authorized depletions of water in the Upper Basin plus depletions from projects proposed to be authorized are less than present uses in the Lower Basin, and constitute slightly more than half the use apportioned to the Upper Basin by the Colorado River Compact.

Utilizing Colorado River Waters That Originate Above Lee Ferry

Chart B.



Note that even with the assumption that the Lower Basin might be using 7.5 million acre-feet annually there is more than sufficient water for the initial projects proposed to be authorized.

APPENDIX E

ATTENDANCE AT MEETINGS OF THE COMMISSION

January 15-17, 1954

John R. Erickson, Commissioner for the State of New Mexico and Vice Chairman, Santa Fe, New Mexico.

Jean S. Breitenstein, Commissioner for the State of Colorado, Attorney, Colorado Water Conservation Board, Denver, Colorado.

George D. Clyde, Commissioner for the State of Utah, Director, Utah Water and Power Board, State Capitol, Salt Lake City, Utah.

L. C. Bishop, Commissioner for the State of Wyoming, State Engineer, State Capitol, Cheyenne, Wyoming.

John Geoffrey Will, Secretary and General Counsel, Upper Colorado River Commission.

R. D. Goodrich, Chief Engineer, Upper Colorado River Commission.

Ival V. Goslin, Assistant Chief Engineer, Upper Colorado River Commission.

Byron G. Rogers, United States Representative, Denver, Colorado.

Wayne N. Aspinall, United States Representative, Palisade, Colorado.

Ivan C. Crawford, Director, Colorado Water Conservation Board, Denver, Colorado.

R. J. Tipton, Consulting Engineer, Colorado Water Conservation Board, Denver, Colorado.

Omer Griffin, Assistant Attorney General, Denver, Colorado.

Glenn G. Saunders, Denver Water Department, Denver, Colorado.

Charles R. Neill, Executive Vice President, North Fork Water Conservancy District, Hotchkiss, Colorado.

L. R. Patterson, Assistant Vice President, Public Service Company of Colorado, Denver, Colorado.

E. A. Stansfield, Counsel, Public Service Company of Colorado, Denver, Colorado.

Antonio M. Fernandez, United States Representative, Santa Fe, New Mexico.

John H. Bliss, New Mexico Interstate Stream Commission, Santa Fe, New Mexico.

R. H. Robinson, Attorney General, Santa Fe, New Mexico.

Fred E. Wilson, Legal Adviser to the Commissioner of New Mexico, Albuquerque, New Mexico.

I. J. Coury, New Mexico Interstate Stream Commission, Farmington, New Mexico.

Ed H. Foster, Chairman, San Juan Reclamation Association, Farmington, New Mexico.

Jack Cline, San Juan Water Users Association, Fruitland, New Mexico.

Tom Bolack, Mayor, Farmington, New Mexico.

Henry F. Hannis, President, Middle Rio Grande Flood Control Association, Albuquerque, New Mexico.

John P. Murphy, Secretary, Middle Rio Grande Flood Control Association, Albuquerque, New Mexico.

Arthur V. Watkins, United States Senator, Orem, Utah.

Wallace F. Bennett, United States Senator, Salt Lake City, Utah.

William A. Dawson, United States Representative, Salt Lake City, Utah.

Douglas Stringfellow, United States Representative, Ogden, Utah.

E. R. Callister, Attorney General, Salt Lake City, Utah.

J. A. Howell, Chairman, Utah Water & Power Board, Ogden, Utah

Hugh W. Colton, Utah Water and Power Board, Vernal, Utah

Jay R. Bingham, Utah Water and Power Board, Springville, Utah

B. H. Stringham, Chairman, Colorado Development Committee of 21 Counties, Vernal, Utah

Henry Millecam, Mayor, Vernal, Utah

L. Y. Siddoway, Executive Manager, Chamber of Commerce, Vernal, Utah

Willey Baucam, Chamber of Commerce, Vernal, Utah

C. R. Henderson, Chamber of Commerce, Vernal, Utah

O. L. Johnson, Chamber of Commerce, Vernal, Utah

Chris McKinley, Chamber of Commerce, Vernal, Utah

Grady Russell, Chamber of Commerce, Vernal, Utah

Ernest Untermann, Director, Utah Field House of Natural History, Vernal, Utah

J. H. Ratliff, Humphreys Phosphate Company, Vernal, Utah

Wayne Malin, Roosevelt Commercial Club, Roosevelt, Utah

Bennie Schmiett, Chamber of Commerce, Roosevelt, Utah

Thomas W. Jensen, Utah Water Users Association, Salt Lake City, Utah

H. T. Godfrey, President, Salt Lake City Water Users Association, Salt Lake City, Utah

Dr. J. E. Broaddus, Salt Lake City, Utah

David Moffat, Engineer, Utah Power & Light Company, Salt Lake City, Utah

L. Blaine Liljenquist, Inland & Uintah Freight Lines, Vernal and Salt Lake City, Utah

Walker Wallace, Planning Organization, Salt Lake City, Utah

T. Clark Callister, Millard County Water Users Association, Fillmore, Utah

Verl G. Dixon, Provo, Utah

John S. McAllister, Sanpete County Water Users Association, Mt. Pleasant, Utah

Henry Roberts, Utah County Commissioner, Provo, Utah

Leo P. Harvey, Chairman, Utah County Water Users Association, Pleasant Grove, Utah

Don V. Tibbs, Sanpete County Attorney, Manti, Utah

Wm. Henry Harrison, United States Representative, Sheridan, Wyoming

Howard B. Black, Attorney General, Cheyenne, Wyoming

Joe L. Budd, Assistant to Commissioner, Big Piney, Wyoming

Norman W. Barlow, Assistant to Commissioner, Cora, Wyoming

N. B. Bennett, Jr., Chief, Branch of Project Planning, Bureau of Reclamation, Washington, D. C.

J. R. Riter, Chief Development Engineer, Bureau of Reclamation, Denver, Colorado

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C. B. Jacobson, Hydrology Division, Region 4, Bureau of Reclamation, Salt Lake City, Utah

John L. Mutz, Area Engineer, Bureau of Reclamation, Albuquerque, New Mexico

W. L. Miller, Chief Engineer, Office of Indian Affairs, Washington, D. C.

G. B. Keesee, Area Irrigation Engineer, Office of Indian Affairs, Gallup, New Mexico

Norman M. Littell, Counsel, Navaho Tribal Council, Washington, D. C.

Charles M. Tansey, Jr., Assistant Counsel, Navaho Tribal Council, Farmington, New Mexico

March 15, 1954

Meeting adjourned due to absence of a quorum.

June 30, 1954

Robert J. Newell, Commissioner for the United States of America and Chairman, 3 Hulbe Road, Boise, Idaho

John R. Erickson, Commissioner for the State of New Mexico and Vice Chairman, State Engineer, Santa Fe, New Mexico.

E. L. Dutcher, Commissioner for the State of Colorado, Member, Colorado Water Conservation Board, Gunnison, Colorado

George D. Clyde, Commissioner for the State of Utah, Director, Utah Water and Power Board, State Capitol, Salt Lake City, Utah

L. C. Bishop, Commissioner for the State of Wyoming, State Engineer, State Capitol, Cheyenne, Wyoming.

John Geoffrey Will, Secretary and General Counsel, Upper Colorado River Commission

Ival V. Goslin, Assistant Chief Engineer, Upper Colorado River Commission

Jean S. Breitenstein, United States District Judge, Denver, Colorado

Ivan C. Crawford, Director, Colorado Water Conservation Board, Denver, Colorado

Hatfield Chilson, Attorney, Colorado Water Conservation Board, Denver, Colorado

Omer Griffin, Assistant Attorney General, Denver, Colorado

Fred E. Wilson, Legal Adviser to the Commissioner from New Mexico, Albuquerque, New Mexico

I. J. Coury, New Mexico Interstate Stream Commission, Farmington, New Mexico

Ed H. Foster, Chairman, San Juan Reclamation Association, Farmington, New Mexico

Jack Cline, San Juan Water Users Association, Fruitland, New Mexico

W. Carlos Powell, Santa Fe, New Mexico

E. R. Callister, Attorney General, Salt Lake City, Utah

J. A. Howell, Chairman, Utah Water & Power Board, Salt Lake City, Utah

Wayne D. Criddle, Assistant to the Director, Utah Water and Power Board, Salt Lake City, Utah

Hugh W. Colton, Utah Water and Power Board, Vernal, Utah

L. Y. Siddoway, Colorado River Development Committee of 21 Counties, Vernal, Utah

O. L. Johnson, Vernal Lions Club, Vernal, Utah

C. R. Henderson, Uintah County Commissioner, Vernal, Utah

G. Ernest Untermann, Director, Utah Field House of Natural History, Vernal, Utah

Thomas W. Jensen, Utah Water Users Association, Salt Lake City, Utah

Leo P. Harvey, Utah County Water Users Association, Pleasant Grove, Utah

S. E. Price, Greater Utah Valley, Inc., Springville, Utah

B. H. Adams, Utah County Commission, Provo, Utah

Herbert F. Smart, Salt Lake Chamber of Commerce and Utah Wildlife Federation, Salt Lake City, Utah

H. T. Person, Dean of the School of Engineering, University of Wyoming, Laramie, Wyoming

Earl T. Bower, Director, National Reclamation Association, Worland, Wyoming

E. O. Larson, Regional Director, Region 4, Bureau of Reclamation, Salt Lake City, Utah

G. B. Keesee, Area Irrigation Engineer, Office of Indian Affairs, Gallup, New Mexico

William E. Welsh, Secretary-Manager, National Reclamation Association, Washington, D. C.

September 20, 1954

Robert J. Newell, Commissioner for the United States of America and Chairman, 3 Hulbe Road, Boise, Idaho

John R .Erickson, Commissioner for the State of New Mexico and Vice Chairman, State Engineer, Santa Fe, New Mexico

E. L. Dutcher, Commissioner for the State of Colorado, Member, Colorado Water Conservation Board, Gunnison, Colorado

George D. Clyde, Commissioner for the State of Utah, Director, Utah Water and Power Board, State Capitol, Salt Lake City, Utah

L. C. Bishop, Commissioner for the State of Wyoming, State Engineer, State Capitol, Cheyenne, Wyoming

John Geoffrey Will, Secretary and General Counsel, Upper Colorado River Commission

R. D. Goodrich, Chief Engineer, Upper Colorado River Commission

Ival V. Goslin, Assistant Chief Engineer, Upper Colorado River Commission

Ivan C. Crawford, Director, Colorado Water Conservation Board, Denver, Colorado

R. J. Tipton, Consulting Engineer, Colorado Water Conservation Board, Denver, Colorado

Hatfield Chilson, Attorney, Colorado Water Conservation Board, Loveland, Colorado

F. C. Merriell, Colorado River Water Conservation District, Grand Junction, Colorado

Harold Christy, Water Development Association of Southeastern Colorado, Pueblo, Colorado

George Cory, Chamber of Commerce, Montrose, Colorado

Willard S. Snyder, Assistant Attorney, Denver Water Board, Denver, Colorado

Clifford H. Jex, Engineer, Western Colorado Water Association, Grand Junction, Colorado

Silmon Smith, Member, Colorado Water Conservation Board, Grand Junction, Colorado

Charles R. Neill, Executive Vice President, North Fork Water Conservancy District, Hotchkiss, Colorado

Duane L. Barnard, Attorney, Granby, Colorado

Don Dugan, Manager, Chamber of Commerce, Grand Junction, Colorado

Joe Starbuck, Chairman, Montrose Water Committee, Montrose, Colorado

Miles Kara, Administrative Assistant to Wayne N. Aspinall, U. S. Representative, Palisade, Colorado

William Nelson, Daily Sentinel, Grand Junction, Colorado

Bob Lucas, Editor, Editorial Department, Denver Post, Denver, Colorado

Fred E. Wilson, Legal Adviser to the Commissioner from New Mexico, Albuquerque, New Mexico

John H. Bliss, New Mexico Interstate Stream Commission, Santa Fe, New Mexico

I. J. Coury, New Mexico Interstate Stream Commission, Farmington, New Mexico

Alan F. Pugh, Daily Times, Farmington, New Mexico

E. R. Callister, Attorney General, Salt Lake City, Utah

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Sterling E. Price, Greater Utah Valley, Inc., Springville, Utah

L. Y. Siddoway, Executive Manager, Chamber of Commerce, Vernal, Utah

Jack C. Turner, Chamber of Commerce, Vernal, Utah

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William E. Welsh, Secretary-Manager, National Reclamation Association, Washington, D. C.

October 14, 1954

Robert J. Newell, Commissioner for the United States of America and Chairman, 3 Hulbe Road, Boise, Idaho

John R. Erickson, Commissioner for the State of New Mexico and Vice Chairman, State Engineer, Santa Fe, New Mexico

E. L. Dutcher, Commissioner for the State of Colorado, Member, Colorado Water Conservation Board, Gunnison, Colorado

George D. Clyde, Commissioner for the State of Utah, Director, Utah Water and Power Board, State Capitol, Salt Lake City, Utah

L. C. Bishop, Commissioner for the State of Wyoming, State Engineer, State Capitol, Cheyenne, Wyoming

John Geoffrey Will, Secretary and General Counsel, Upper Colorado River Commission

R. D. Goodrich, Chief Engineer, Upper Colorado River Commission

Ival V. Goslin, Assistant Chief Engineer, Upper Colorado River Commission

Ivan C. Crawford, Director, Colorado Water Conservation Board, Denver Colorado

George J. Bailey, Member, Colorado Water Conservation Board, Walden, Colorado

Dan B. Hunter, Member, Colorado Water Conservation Board, Dove Creek, Colorado

George A. Pughe, Member, Colorado Water Conservation Board, Craig, Colorado

J. M. Dille, Member, Colorado Water Conservation Board, Greeley, Colorado

R. M. Gildersleeve, Engineer, Colorado Water Conservation Board, Denver, Colorado

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Harry L. Potts, Denver Water Board, Denver, Colorado

Omer Griffin, Assistant Attorney General, Denver, Colorado

Frank Delaney, Colorado River Water Conservation District, Glenwood Springs, Colorado

N. M. Williams, State Planning Commission, Denver, Colorado

William Nelson, Daily Sentinel and Chamber of Commerce, Grand Junction, Colorado

Mrs. O. J. Muril, Izaak Walton League, Denver, Colorado

Frank Gregg, Colorado Conservation Magazine, Denver, Colorado

Neil Robertson, United Press, Denver, Colorado

Gordon G. Gauss, Associated Press, Denver, Colorado.

Fred E. Wilson, Legal Adviser to the Commissioner from New Mexico, Albuquerque, New Mexico

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I. J. Coury, New Mexico Interstate Stream Commission, Farmington, New Mexico

Hugh W. Colton, Member, Utah Water and Power Board, Vernal, Utah

William R. Wallace, President, Utah Water Users Association, Salt Lake City, Utah

Thomas W. Jensen, Secretary, Utah Water Users Association, Salt Lake City, Utah

B. H. Stringham, Chairman, Colorado Development Committee of 21 Counties, Vernal, Utah

L. Y. Siddoway, Executive Manager, Chamber of Commerce, Vernal, Utah

Howard B. Black, Attorney General, Cheyenne, Wyoming

Paul A. Rechard, Engineer, Wyoming Natural Resource Board, Cheyenne, Wyoming

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October 30, 1954

Robert J. Newell, Commissioner for the United States of America and Chairman, 3 Hulbe Road, Boise, Idaho

John R. Erickson, Commissioner for the State of New Mexico and Vice Chairman, State Engineer, Santa Fe, New Mexico

E. L. Dutcher, Commissioner for the State of Colorado, Member, Colorado Water Conservation Board, Gunnison, Colorado

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L. C. Bishop, Commissioner for the State of Wyoming, State Engineer, State Capitol, Cheyenne, Wyoming

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Harold D. Doll, Vice President, Forney Films, Inc., Fort Collins, Colorado

Gerald Tunnell, Forney Films, Inc., Fort Collins, Colorado

Phil Robertson, United Press, Denver, Colorado

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Lincoln O'Brien, President, New Mexico Newspapers, Inc., Santa Fe, New Mexico

Alan F. Pugh, Farmington Daily Times, Farmington, New Mexico

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B. H. Stringham, Chairman, Colorado Development Committee of 21 Counties, Vernal, Utah

L. Y. Siddoway, Executive Manager, Chamber of Commerce, Vernal, Utah

Jack C. Turner, Chamber of Commerce, Vernal, Utah

C. R. Henderson, Uintah County Commissioner, Vernal, Utah

Howard B. Black, Attorney General, Cheyenne, Wyoming

H. T. Person, Dean of School of Engineering, University of Wyoming, Laramie, Wyoming

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Norman W. Barlow, Assistant to Commissioner, Cora, Wyoming

J. R. Riter, Chief Development Engineer, Bureau of Reclamation, Denver, Colorado

November 7, 1954

Robert J. Newell, Commissioner for the United States of America and Chairman, 3 Hulbe Road, Boise, Idaho

John R. Erickson, Commissioner for the State of New Mexico and Vice Chairman, State Engineer, Santa Fe, New Mexico

Hatfield Chilson, Proxy for E. L. Dutcher Commissioner for the State of Colorado, Attorney, Colorado Water Conservation Board, Loveland, Colorado

George D. Clyde, Commissioner for the State of Utah, Director, Utah Water and Power Board, State Capitol, Salt Lake City, Utah

L. C. Bishop, Commissioner for the State of Wyoming, State Engineer, State Capitol, Cheyenne, Wyoming

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Joseph D. Mansfield, Special Counsel, Arizona Interstate Stream Commission, Yuma, Arizona

Burr Sutter, Assistant Counsel, Arizona Interstate Stream Commission, Phoenix, Arizona

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I. J. Coury, New Mexico Interstate Stream Commission, Farmington, New Mexico

Alan F. Pugh, Farmington Daily Times, Farmington, New Mexico

Ed H. Foster, San Juan County Reclamation Association, Farmington, New Mexico

B. H. Stringham, Chairman, Colorado Development Committee of 21 Counties, Vernal, Utah

L. Y. Siddoway, Executive Manager, Chamber of Commerce, Vernal, Utah

William R. Wallace, President, Utah Water Users Association, Salt Lake City, Utah

Thomas W. Jensen, Secretary, Utah Water Users Association, Salt Lake City, Utah

H. T. Godfrey, President, Salt Lake County Water Users Association, Salt Lake City, Utah

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Elmer Carver, Ogden, Utah

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James D. Geissinger, Regional Solicitor, Department of the Interior, Denver, Colorado

W. J. Macfarland, Associated Press, Washington, D. C.

December 10-11, 1954

Robert J. Newell, Commissioner for the United States of America and Chairman, 3 Hulbe Road, Boise, Idaho

John R. Erickson, Commissioner for the State of New Mexico and Vice Chairman, State Engineer, Santa Fe, New Mexico

E. L. Dutcher, Commissioner for the State of Colorado, Member, Colorado Water Conservation Board, Gunnison, Colorado

George D. Clyde, Commissioner for the State of Utah, Director, Utah Water and Power Board, State Capitol, Salt Lake City, Utah

L. C. Bishop, Commissioner for the State of Wyoming, State Engineer, State Capitol, Cheyenne, Wyoming

John Geoffrey Will, Secretary and General Counsel, Upper Colorado River Commission

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Omer Griffin, Assistant Attorney General, Denver, Colorado

Frank Meeker, Chamber of Commerce, Montrose, Colorado

Fred E. Wilson, Legal Adviser to Commissioner from New Mexico, Albuquerque, New Mexico

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I. J. Coury, New Mexico Interstate Stream Commission, Farmington, New Mexico

Hubert Ball, Chief Engineer, Middle Rio Grande Conservancy District, Albuquerque, New Mexico

Bernard Shiffman, San Juan Basin, Farmington, New Mexico

Alan F. Pugh, Farmington Daily Times, Farmington, New Mexico

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Robert B. Porter, Assistant Attorney General, Salt Lake City, Utah

Thomas W. Jensen, Utah Water Users Association, Salt Lake City, Utah

Sterling E. Price, Greater Utah Valley, Inc., Springville, Utah

Glendon E. Johnson, Representing Senator Wallace F. Bennett, Salt Lake City, Utah

J. W. Robinson, Former Congressman from Utah, Salt Lake City, Utah

Norman W. Barlow, Assistant to Commissioner, Cora, Wyoming

Joe L. Budd, Assistant to Commissioner, Big Piney, Wyoming

E. O. Larson, Regional Director, Region 4, Bureau of Reclamation, Salt Lake City, Utah

J. Stuart McMaster, Solicitor, Region 4, Bureau of Reclamation, Salt Lake City, Utah

Cecil B. Jacobson, Hydrology Division, Bureau of Reclamation, Salt Lake City, Utah

Reid Jerman, Regional Planning Engineer, Bureau of Reclamation, Salt Lake City, Utah

H. P. Dugan, River Regulation Section, Bureau of Reclamation, Denver, Colorado

John L. Mutz, Area Engineer, Bureau of Reclamation, Albuquerque, New Mexico

W. L. Miller, Chief Engineer, Bureau of Indian Affairs, Washington, D. C.

G. B. Keesee, Area Irrigation Engineer, Bureau of Indian Affairs, Gallup, New Mexico

APPENDIX F

UPPER COLORADO RIVER COMMISSION

Key Gaging Stations

Derived from reports of U. S. Geological Survey and others. Not to be construed as findings.

Unit of flow—1000 acre-feet

Ref. (1)	Stream (2)	Drainage Area Sq. Miles (3)	Flows in Water Years 1952 (4)	1953 (5)	(Provisional) 1954 (6)
1.	Animas River near Cedar Hill, N. M.	1,092	985.4	442.3	426.8
2.	Animas River at Durango, Colorado	692	813.0	391.9	
3.	Animas River at Farmington, N. M.	1,360	935.2	373.6	376.5
4.	Arapaho Creek at Monarch Lake Outlet, Colorado	47.1	80.9	53.2	37.4
5.	Ashley Creek near Jensen, Utah	386	93.2	27.9	
6.	Ashley Creek at Sign of the Main, near Vernal, Utah	241	132.2	65.1	
7.	Ashley Creek near Vernal, Utah	101	102.5	58.1	
8.	Big Sandy Creek at Leckie Ranch, Wyo.	94	73.6	48.0	54.7
9.	Blacks Fork near Millburne, Wyo.	156	131.9	114.8	71.5
10.	Blacks Fork near Green River, Wyo.	3,670	460.1	177.4	67.5
11.	Blue River at Dillon, Colorado	129	88.3	78.6	36.0
12.	Boulder Creek below Boulder Lake, Wyo.	130	162.8	117.9	147.9
13.	Bloomfield Canal (See Citizens Ditch)				
14.	Brush Creek near Jensen, Utah	255	27.7	7.6	
15.	Brush Creek near Vernal, Utah	82	35.4	19.7	
16.	Burnt Fork near Burnt Fork, Wyo.	53	30.1	19.8	12.4
17.	Carter Creek near Manila, Utah		11.1	5.2	3.0

Ref. (1)	Stream (2)	Drainage Area Sq. Miles (3)	Flows in Water Years 1952 (4)	(Provisional) 1953 (5)	1954 (6)
18.	Carter Creek at mouth near Manila, Utah	110	68.2	33.6	22.3
19.	Citizens Ditch (Bloomfield Canal) near Turley, N. M. Diverting water around Blanco gage		70.4	72.2	79.1
20.*	Colorado River near Cameo, Colorado	8,055	4,130.4	2,572.8	1,552.0
21.	Colorado River near Cisco, Utah	24,100	7,707.0	4,037.0	2,329.0
22.	Colo. River near Colo.-Utah State line	20,680	6,847.0	3,773.0	2,086.0
23.*	Colo. River at Glenwood Springs, Colo.	4,560	2,441.0	1,589.0	885.9
24.	Colorado River near Grand Lake, Colo.	103	80.8	44.0	
25.	Colorado River at Hite, Utah	76,600	14,780.0	7,767.0	5,015.0
26.	Colo. River at Hot Sulphur Springs, Colo.	782	345.6	164.2	80.4
27.	(A) Colo. River at Lee Ferry, Ariz.	@109,889	7,980.5	8,822.4	6,119.2
28.	Colorado River at Lees Ferry, Ariz.	@108,335	17,961.6	8,804.6	6,101.1
29.	Cottonwood Creek near Orangeville, Utah	200	152.7	62.1	41.2
30.	Crystal River near Redstone, Colorado	225	356.2	211.4	142.5
31.	#Dirty Devil River near Hite, Utah				
32.	Dolores River near Cisco, Utah		1,086.0	290.8	208.5
33.	(D) Dolores River at Dolores, Colorado	556	492.8	195.1	
34.	Dolores River at Gateway, Colorado	4,350	1,092.0	293.4	203.2
35.	Duchesne River at Myton, Utah	2,705	797.2	272.0	148.3
36.	Duchesne River near Randlett, Utah	3,820	1,041.0	354.9	191.4
37.	Duchesne River near Tabiona, Utah	352	252.5	140.3	77.7
38.	Eagle River below Gypsum, Colorado	957	580.7	402.9	221.1

Ref. (1)	Stream (2)	Drainage Area Sq. Miles (3)	Flows in Water Years 1952 (4)	(Provisional) 1953 (5)	1954 (6)
39.	Eagle River at Redcliff, Colorado	72	42.5	28.8	14.8
40.	East River at Almont, Colorado	295	353.8	200.8	126.3
41.	(D) East Fork of Smith Fork near Robertson, Wyoming	53	51.0	30.2	18.4
42.	(D) #East Fork of Beaver Creek near Lonetree, Wyoming		5.8	6.7	4.2
43.	Elk River at Clark, Colorado	206	276.4	178.1	135.1
44.	Escalante River near Escalante, Utah	315	8.9	4.4	2.2
45.	Ecsalante River near mouth, Utah		73.0	60.8	49.6
46.	(D) Florida River near Durango, Colorado	96	98.9	37.3	
47.	(D) Fontenelle Creek near Fontenelle, Wyo.	224	62.9	33.5	
48.	(D) Fontenelle Creek near Herschler Ranch	152	69.6	40.3	39.8
49.	Fraser River near Winter Park, Colo.	27.6	14.9	6.36	4.3
50.	Green River near Greendale, Utah		2,226.0	1,288.0	1,251.0
51.	Green River at Green River, Utah	40,920	6,838.0	3,395.0	2,618.0
52.	(D) Green River near Green River, Wyo.	7,670	1,574.0	1,086.8	1,189.0
53.	Green River near Jensen, Utah	**	4,522.0	2,492.0	2,056.0
54.	Green River near Linwood, Utah	14,300	2,016.0	1,205.0	1,227.0
55.	Green River near Ouray, Utah	**	6,425.0	3,399.0	2,665.0
56.	(D) Green River at Warren Bridge, Wyo.	468	396.4	358.7	394.1
57.	Gunnison River and Redlands Power Canal near Grand Junction, Colorado	8,020	2,625.0	1,331.0	663.5
58.	Gunnison River near Gunnison, Colorado	1,010	740.3	480.8	283.8

Ref. (1)	Stream (2)	Drainage Area Sq. Miles (3)	Flows in Water Years 1952 (4)	(Provisional) 1953 (5)	1954 (6)
59.	Gunnison River below Gunnison Tunnel, Colorado	3,980	1,407.0	668.8	
60.	(D) Hams Fork near Frontier, Wyo.		147.2	74.0	61.6
61.	Henrys Fork at Linwood, Utah	530	109.2	58.1	15.6
62.	(D) Henrys Fork near Lonetree, Wyo.	55	42.9	28.4	14.7
63.	(D) LaPlata River at Colorado-New Mexico State line	331	45.3	11.4	
64.	(D) LaPlata River at Hesperus, Colorado	37	53.4	22.3	
65.	Little Snake River near Dixon, Wyo.	988	577.6	258.8	157.2
66.	Little Snake River near Lily, Colorado	3,730	728.5	268.7	178.3
67.	Little Snake River near Slater, Colo.	285	226.6	113.0	76.2
68.	(D) Los Pinos River near Bayfield, Colo.	284	322.5	175.9	
69.	(C) Los Pinos River at LaBoca, Colorado		282.2	64.1	
70.	Los Pinos River at Ignacio, Colorado	448	259.2	43.9	
71.	Mancos River near Towoac, Colorado	550	60.7	11.8	10.0
72.	McElmo Creek near Colorado-Utah state line		24.9	20.0	20.8
73.	McElmo Creek near Cortez, Colorado	233	28.4	21.3	22.1
74.	Middle Fork Beaver Creek near Lonetree, Wyoming		23.9	14.2	8.6
75.	Minnie Maud Creek near Myton, Utah		11.2	0.9	
76.	Navajo River at Edith, Colorado	165	156.4	65.2	62.5
77.	North Fork Gunnison River near Somerset, Colorado	521	474.7	248.0	142.3
78.	(D) North Piney Creek near Mason, Wyoming	58	49.8	38.8	40.4

Ref. (1)	Stream (2)	Drainage Area Sq. Miles (3)	Flows in Water Years 1952 (4)	(Provisional) 1953 (5)	1954 (6)
79.	(A) Paria River at Lees Ferry, Arizona	1,550	18.9	17.8	18.1
80.	(D) #Pine Creek near Fremont Lake, Wyo.				
81.	(D) Pine Creek at Pinedale, Wyoming	118	81.3	87.2	90.1
82.	Plateau Creek near Cameo, Colorado	604	183.4	103.0	72.3
83.	Price River near Heiner, Utah	455	225.3	79.9	63.4
84.	Price River at Woodside, Utah	1,500	247.8	60.1	52.4
85.	Ranch Creek near Fraser, Colorado	19.9	20.2	8.61	
86.	Rio Blanco River near Pagosa Springs, Colorado	58	89.1	44.4	40.0
87.	Roaring Fork at Aspen, Colorado	109	81.3	59.4	32.6
88.	Roaring Fork at Glenwood Springs, Colo.	1,460	1,239.0	800.1	477.9
89.	San Juan River near Blanco, N. M.	3,558	1,490.1	509.9	514.2
90.	San Juan River near Bluff, Utah	23,010	2,542.0	934.7	984.9
91.	San Juan River at Farmington, N. M.	7,240	2,401.0	841.7	896.9
92.	San Juan River at Pagosa Springs, Colo.	298	415.1	183.7	150.7
93.	San Juan River at Rosa, N. M.	1,990	1,234.9	459.7	433.4
94.	San Juan River at Shiprock, N. M.	12,900	2,481.8	873.4	943.4
95.	San Miguel River near Placerville, Colorado	308	217.3	138.8	103.0
96.	San Rafael River near Green River, Utah	1,690	314.8	80.9	39.1
97.	Savery Creek near Savery, Wyoming	330	150.2	59.0	39.4
98.	Sheep Creek near Manila, Utah	46	20.4	7.0	1.5
99.	Sheep Creek at mouth near Manila, Utah	111	30.7	14.8	8.3

Ref. (1)	Stream (2)	Drainage Area Sq. Miles (3)	Flows in Water Years 1952 (4)	(Provisional) 1953 (5)	1954 (6)
100.	(B) Sheep Creek Upper Canal, near Manila, Utah		4.2	3.1	2.8
101.	(B) Sheep Creek Lower Canal, near Manila, Utah		11.3	8.8	8.8
102.	Slater Fork near Slater, Colorado	161	79.6	42.0	29.9
103.	(D) Snake River near Montezuma, Colorado	59	57.1	44.9	25.4
104.	South Fork White River at Buford, Colo.	170	259.2	188.6	130.4
105.	(C) Spring Creek at LaBoca, Colorado near Colo.-N. Mex. state line	58	22.1	21.5	24.3
106.	Strawberry River at Duchesne, Utah	1,040	292.8	89.9	
107.	Taylor River at Almont, Colorado	440	304.4	245.3	166.6
108.	(D) Tenmile Creek at Dillon, Colorado	113	104.8	90.5	44.0
109.	Tomichi Creek at Gunnison, Colorado	1,020	197.1	124.6	50.3
110.	Troublesome Creek near Troublesome, Colo.	178	68.0	28.7	13.5
111.	Uinta River near Neola, Utah	181	183.1	105.7	95.1
112.	Uncompahgre River at Colona, Colorado	437	219.5	144.1	87.6
113.	Vasquez Creek near Winter Park, Colo.	27.8	17.6	4.8	2.5
114.	(D) West Fork Beaver Creek near Lonetree, Wyoming		17.4	12.6	6.8
115.	(D) West Fork Smith Fork near Robertson, Wyo.	37	19.2	14.2	6.4
116.	White River at Buford, Colorado	240	274.8	208.6	
117.	White River near Meeker, Colorado	762	606.0	455.4	301.1
118.	White River near Watson, Utah	4,020	694.4	475.9	340.6
119.	Whiterocks River near Whiterocks, Utah	115	120.4	63.4	57.9
120.	Williams River near Leal, Colorado	89.5	94.9	65.3	32.9

Ref. (1)	Stream (2)	Drainage Area Sq. Miles (3)	Flows in Water Years 1952 (4)	1953 (5)	(Provisional) 1954 (6)
121.	Willow Creek near Ouray, Utah	967	35.3	13.6	
122.	Yampa River near Maybell, Colorado	3,410	1,447.0	829.2	522.2
123.	Yampa River at Steamboat Springs, Colo.	604	447.1	285.3	156.2

* This is a U. S. G. S. station but is not required at the present time for administration by the Upper Colorado River Commission.

** Drainage area not shown in latest U. S. G. S. water supply paper available.

\# This station is to be installed or reestablished and operated by the U.S.G.S.

(A) Lee Ferry one mile down stream from the mouth of the Paria River is the 1922 "Compact Point," and the discharge at this point is taken as the sum of Nos. 27 and 79.

(B) Discharge measurements reported in U. S. G. S. Water Supply Paper 1059 (1946) p. 384.

(C) Add Spring Creek to Los Pinos River at LaBoca to give flow at Colorado-Utah state line.

(D) Discontinued.

@ Area from Final Report of Engineering Advisory Committee to Upper Colorado River Compact Commission, November, 1948.

TRANSMOUNTAIN DIVERSIONS IN UTAH

Not to be construed as findings.

Ditch or Tunnel	Lcation	Acre-feet Year 1953	1954
Ephraim Tunnel	Near Ephraim	3,720	2,480
Reeder Ditch	Near Spring City	45	75
Twin Creek Tunnel	Near Mt. Pleasant	103	144
Horseshoe Tunnel	Near Ephraim	540	362
Cedar Creek Tunnel	Near Spring City	224	191
Spring City Tunnel	Near Spring City	1,960	1,430
Fairview Ditch	Near Fairview	1,700	
Candland Ditch	Near Mt. Pleasant	134	
Black Canyon Ditch	Near Spring City	180	218
Larsen Tunnel	Near Ephraim	923	705
Madsen Ditch	Near Ephraim	20	4
John August Ditch	Near Ephraim	235	224
Coal Fork Ditch	Near Mt. Pleasant	205	167
Lower Hobble Creek Ditch	Near Heber	1,260	995
Strawberry River and Willow Creek Ditches	Strawberry River, Willow Creek	1,990	1,290
Strawberry Tunnel	Strawberry River	80,970	78,910
Tropic and East Fork Canal	Near Tropic		2,180
Duchesne Tunnel near Kamas, Utah	North Fork Duchesne River		26,350

TRANSMOUNTAIN DIVERSIONS IN COLORADO

Not to be construed as findings.

Ditch or Tunnel	Lcation	Acre-feet Year 1953	1954
Alva B. Adams Tunnel (East Portal)	Shadow Mountain Reservoir	180,000	302,070
Berthoud Pass Ditch	Fraser River Tributaries	594	212
Eureka Ditch	Tonahutu Creek	26	27
Grand River Ditch	Colorado River Tribs.	19,750	12,740
Moffat Tunnel (East Portal)		35,070	19,540
Independence Pass Tunnel (Twin Lakes Tunnel)	Roaring Fork Tribs.	40,300	27,470
Williams Fork Tunnel (Jones Pass)	Williams River	7,420	5,420
Boreas Pass Ditch	Blue River	273	136
Hoosier Pass Tunnel	Blue River	4,836	3,550
Columbine Ditch	Tenmile Creek Tribs.	1,040	844
Fremont Pass Ditch	Tenmile Creek	none	none
Ewing Ditch	Eagle River	1,140	498
Wurtz Ditch	Eagle River	2,010	905
Busk-Ivanhoe Tunnel	Fryingpan River	5,080	3,200
Larkspur Ditch	Tomichi Creek	217	none
Tabor Ditch	Gunnison River	182	174
Fuchs Ditch	N. Fork Los Pinos River	381	1,186
Raber-Lohr Ditch	Los Pinos River	1,340	3,650
Treasure Pass Ditch	San Juan River	96	60
Squaw Pass Ditch	San Juan River	192	211
Piedra Ditch	San Juan River	42	none

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APPENDIX G

UPPER COLORADO RIVER COMMISSION

520 Rood Avenue

Grand Junction, Colorado

September 24, 1954

My dear Mrs. Howell:

At the September 20th meeting of the Upper Colorado River Commission I was unanimously directed by the Commission to advise you formally of our deep sense of loss through Judge Howell's death.

Throughout the negotiations which resulted in the Upper Colorado River Basin Compact, and from the beginning of the organization of the Upper Colorado River Commission, the late Judge Howell was one upon whom we leaned most heavily for guidance. His judgment was sound, his enthusiasm was contagious, and his love for his fellow man was reflected in a spirit of courtesy and gentleness that pervaded our meetings through his presence. He can not be replaced, but his example is an inspiration to all of us.

With best personal regards, I am

Sincerely yours,

/s/ JOHN GEOFFREY WILL
John Geoffrey Will
Secretary and General Counsel

Mrs. J. A. Howell
Adams Avenue, between 23rd and 24th Streets
Ogden, Utah

lsb

APPENDIX H

RESOLUTION OF THANKS TO JEAN S. BREITENSTEIN

COM. ERICKSON: Mr. Chairman, I would like to offer a resolution to the Commission for the Commission to express its appreciation for the outstanding service that Judge Breitenstein has given over the years, and to express its regrets for his leaving this work and the work of the Commission. He has served I know in one capacity or another, first as Legal Adviser to the Colorado Commissioner and later as the Colorado Commissioner, since the inception of the present program, and prior to that during the negotiations leading up to the signing of the Upper Colorado River Basin Compact.

I move that a resolution be adopted expressing the Commission's appreciation and regret at his having to leave the Commission.

COM. BISHOP: I second that.

THE CHAIRMAN: You have heard the motion and it has been seconded.

COM. CLYDE: Mr. Chairman, I would like to also second that motion and to add these comments: I have known Judge Breitenstein only for a short time but I have learned to admire and respect his judgment and his ability and the great assistance he has given this Commission in the work on the program relating to the Colorado River Storage Project. We regret to see him go but we wish him success in his new venture.

THE CHAIRMAN: Is there other comment?

COM. BISHOP: Question.

(Thereupon a vote was taken and Com. Erickson's motion carried unanimously.)

APPENDIX I

RESOLUTION OF THANKS TO ED. L. DUTCHER

WHEREAS, Ed. L. Dutcher, has long been noted as a leader in his State, who worked hard and constructively for the conservation, utilization, and development of the resources of the Upper Colorado River Basin States; and

WHEREAS, Ed. L. Dutcher, at great personal sacrifice, devoted unselfishly of his time and energy to the interests of the State of Colorado and the Upper Colorado River Basin States in the solving of complex and controversial problems confronting the Upper Colorado River Commission; and

WHEREAS, Ed. L. Dutcher served faithfully and efficiently as a member of the Upper Colorado River Commission representing the State of Colorado during one of its most trying periods, and

WHEREAS, Ed. L. Dutcher, in the interests of his business and family found with much regret that it would be impossible for him to continue as a member of the Commission;

NOW, THEREFORE, BE IT RESOLVED, by the Upper Colorado River Commission, that said Commission desires by means of this resolution to express its heartfelt thanks and gratitude to Mr. Dutcher for his faithful service and cooperation during the period he served as a member of the Commission. Much credit is due Mr. Dutcher for his tireless efforts in cultivating enthusiasm and fostering progressive development of the water resources of the States of the Upper Colorado River Basin. The Commission and its staff wish continued prosperity and happiness for Mr. Ed L. Dutcher and family in their many worthwhile endeavors.

BE IT FURTHER RESOLVED, that the Secretary of the Upper Colorado River Commission is hereby directed to forward a copy of this resolution to Ed. L. Dutcher.

APPENDIX J

RESOLUTION OF THANKS TO JOHN R. ERICKSON

WHEREAS, John R. Erickson, was a leader of ability and note among those individuals concerned with the development, conservation, and utilization of the water resources of the West; and

WHEREAS, John R. Erickson served for a long period and through trying times and situations as State Engineer of New Mexico and Commissioner on the Upper Colorado River Commission representing New Mexico; and

WHEREAS, John R. Erickson, devoted his exceptional abilities and energy to the development and conservation of the water and other natural resources of the Upper Colorado River Basin States, and

WHEREAS, John R. Erickson by his steadying influence, his understanding of human nature, his unselfish devotion to duty, and his unfailing sense of humor earned the deep respect and affection of all the members of the Upper Colorado River Commission and of its staff; and

WHEREAS, John R. Erickson, in the interests of his family and his desire to contribute his talents to the benefit of his fellow men, has accepted a position in Egypt with considerable advancement to his career; thus, making his resignation as Commissioner from the State of New Mexico necessary;

NOW, THEREFORE, BE IT RESOLVED, by the Upper Colorado River Commission, that said Commission desires to express its thanks to Mr. Erickson for his faithful service, his fine cooperation, and his aid in solving many of the complicated technical and administrative problems confronting the Commission during his tenure as Commissioner, and that the Commission sincerely wishes him the best of luck and continued success in his new position as well as health and happiness in a long future for himself and family.

BE IT FURTHER RESOLVED, that the Secretary of the Upper Colorado River Commission is hereby directed to forward a copy of this resolution to Mr. John R. Erickson.