RESEARCH REPORT

OWRT TITLE II CONTRACT C-4202

HYDROLOGY SUPPORT STUDY

FOR

A CASE STUDY OF FEDERAL EXPENDITURES ON A WATER AND RELATED LAND RESOURCE PROJECT

BOISE PROJECT, IDAHO AND OREGON

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for and in cooperation with the
Idaho Water Resource Board

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TABLE OF CONTENTS

PAGE

LIST OF TABLES

PAGE

PAGE

PAGE

PAGE

FOREWORD

The Water Resources Research Institute has provided the administrative coordination for this study and helped organize with staff of the Idaho Water Resource Board the study team that conducted the investigation. It is the Institute's policy to make available the results of significant water-related research conducted in Idaho's universities and colleges. The Institute neither endorses or rejects the findings of the authors. However, it does recommend careful consideration of the accumulated data contained within this report by those who are assuredly going to continue to study water problems of the Boise River Basin and its hydrologic interplay with both the Payette and Snake Rivers.

ABSTRACT

This study of the water use and water control of the Boise River Project as a part of a case study of Federal expenditures on a water and related land resources project has reviewed the basic hydrologic system, the reservoir system, the irrigation system, the water rights, the ground water conditions, the floods and flood control, and general reservoir operations over time. Emphasis in the study has been the accumulation, classification, and arrangement of water information for later use in the overall research effort of studying whether the objectives of water development are being met. This has been done recognizing that the planning for and development of the Boise River Project has been evolutionary over a period of over 100 years. Where possible an audit has been presented of whether the water use and water control functions are meeting good standards. Brief conclusions are presented with recommendations for mroe detailed studies that might be accomplished in future phases of this continuing project.

INTRODUCTION

The Boise River system in western Idaho represents a water resource development typical of reclamation developments in the Western United States. Development has taken place over a 110 year period during which time the predominant agricultural interests of the populous have been diluted to some extent by industrial and commercial endeavor but particularly by the activities of State and Federal government centered around the Capital City of Boise. The Boise Project has been the subject of a continuous planning and development effort by both the U.S. Bureau of Reclamation and the U.S. Army Corps of Engineers. For these reasons it was chosen as the case study for this research.

This report was prepared to present basic hydrologic information on river flows, reservoir operations, irrigation water use, and floods. These data will contribute to later phases of research concerned with the post-audit analysis of federal expenditures on this major water and related land resource development project in Idaho. The study addresses both surface and ground water aspects of the Boise Project.

Basin Description

The Boise River, a major tributary of the Snake River, is part of the Columbia River drainage system. The Boise River basin (Figure 1) can be divided into two general areas on the basis of its topography. The lower watershed includes the portion of the basin below Lucky Peak Dam and is characterized by river bottom

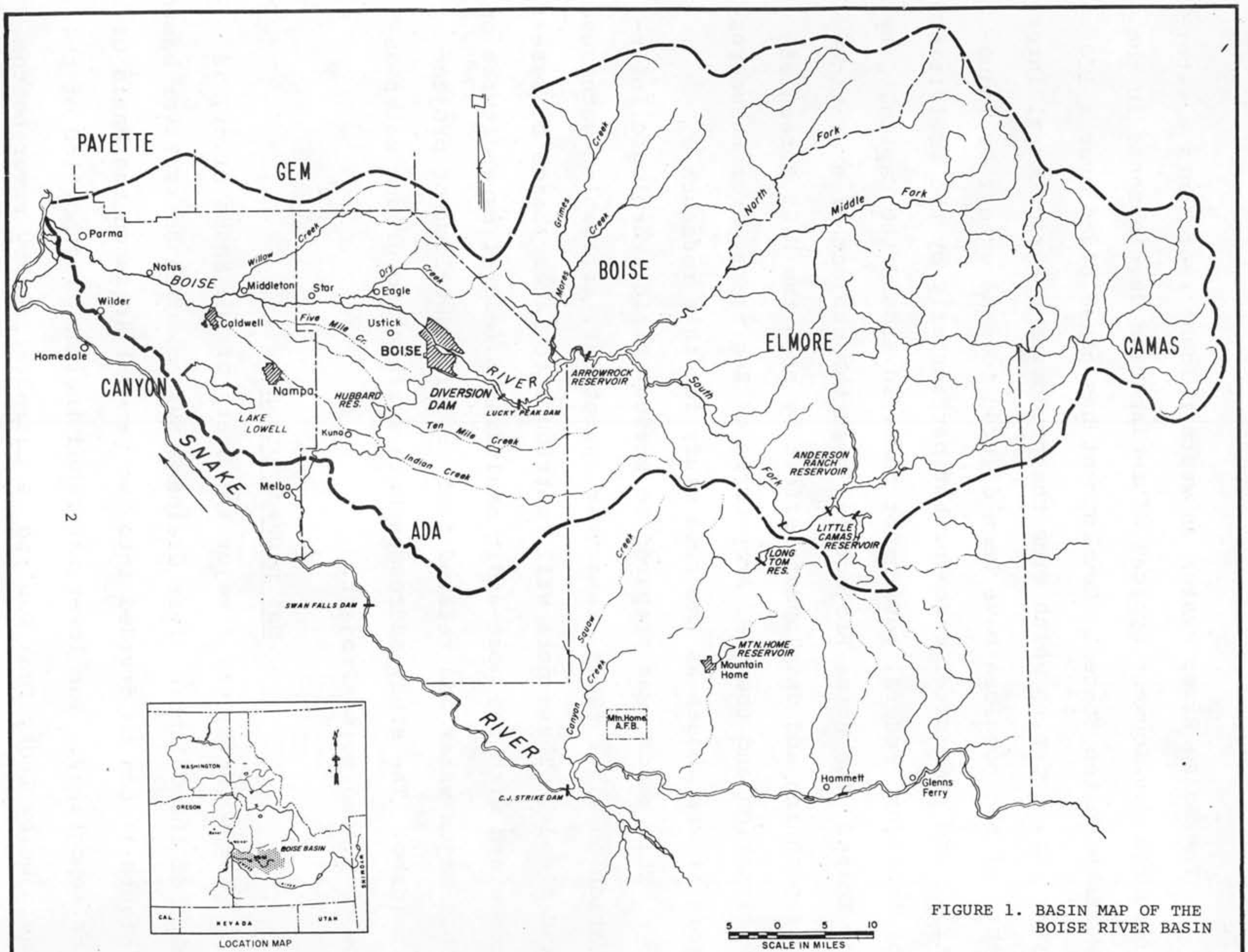


FIGURE 1. BASIN MAP OF THE BOISE RIVER BASIN

land, terraces, and low rolling hills with a few distinct mountains. The upper watershed is composed of steep mountains with a highly dissected pattern of V-shaped valleys.

Total drainage area of the Boise River Basin is 4234 square miles with the upper basin above Lucky Peak Dam having a basin area of 2650 square miles. The principal water courses flow in a westerly direction from headwaters in the Sawtooth Mountains about 200 miles to join the Snake River at River mile 391.3. The elevation ranges from about 2200 feet at the mouth of the Boise River to 10,600 feet along the eastern boundary of the basin in the Sawtooth Mountains.

Major tributaries of the Boise River are:

North Fork	382 square miles
Middle Fork	380 square miles
South Fork	1314 square miles
Mores Creek	426 square miles

These four tributaries comprise about 97 percent of the drainage area above Lucky Peak Dam and about 63 percent of the total drainage area of the basin. Streams in the lower watershed flow only during the spring and early summer.

The climate of the Boise River watershed is characterized by hot, dry summers and moderately cold winters. The area is dominated by Pacific maritime air, considerably modified by the topographic barriers that confront the easterly flow of air from the ocean to the Rocky Mountains. Polar continental air occasionally enters the area during the winter months causing short periods of extremely low temperatures. The maximum recorded temperature for the Boise Valley is 112°F and the minimum recorded temperature is -38^{o}F.

An isohyetal map of normal annual precipitation, adopted from studies made by the U.S. Army Corps of Engineers, is presented as Figure 2. Mean annual precipitation over the upper portion of the watershed is about 28 inches; it ranges from about 14 inches near Lucky Peak Dam to approximately 50 inches at higher elevations. In the Sawtooth Mountains where the annual precipitation depths are greater, over one-half of the annual amount occurs during the winter months, mostly as snow. At the higher elevations snow starts accumulating in September or October. The snow pack ripens to a maximum water equivalent in April or May. Most floods are of the spring snowmelt type, with occasional spring rain floods superimposed on snowmelt conditions.

The Boise basin hydrometeorological network is comprised of stream gages, precipitation temperature, and evaporation stations and a good network of high elevation snow courses. Figure 3 gives a map identifying the type and location of the present stations. Numerous older stations have been discontinued, some due to the effect of backwater at storage projects.

Federal expenditures for water development date back to authorization of the Boise Project in 1905. Development has continued since then with the last major construction being Lucky Peak Dam in 1955. The water resource development has been multipurpose in nature with consideration for the agricultural use of water in irrigating semi-arid lands the primary purpose. Flood control has become more important as urban growth has increased. Production

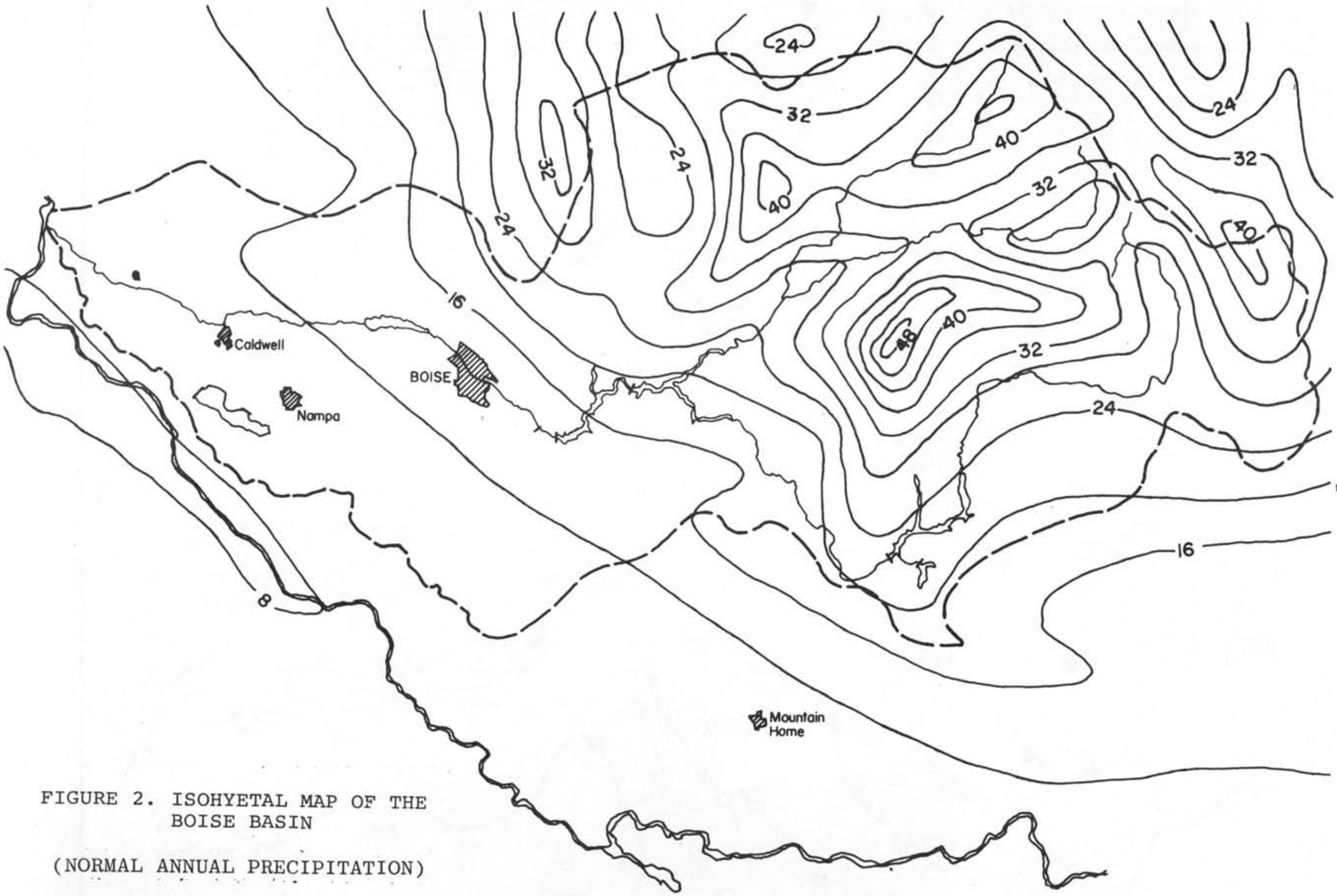


FIGURE 2. ISOHYETAL MAP OF THE BOISE BASIN

(NORMAL ANNUAL PRECIPITATION)

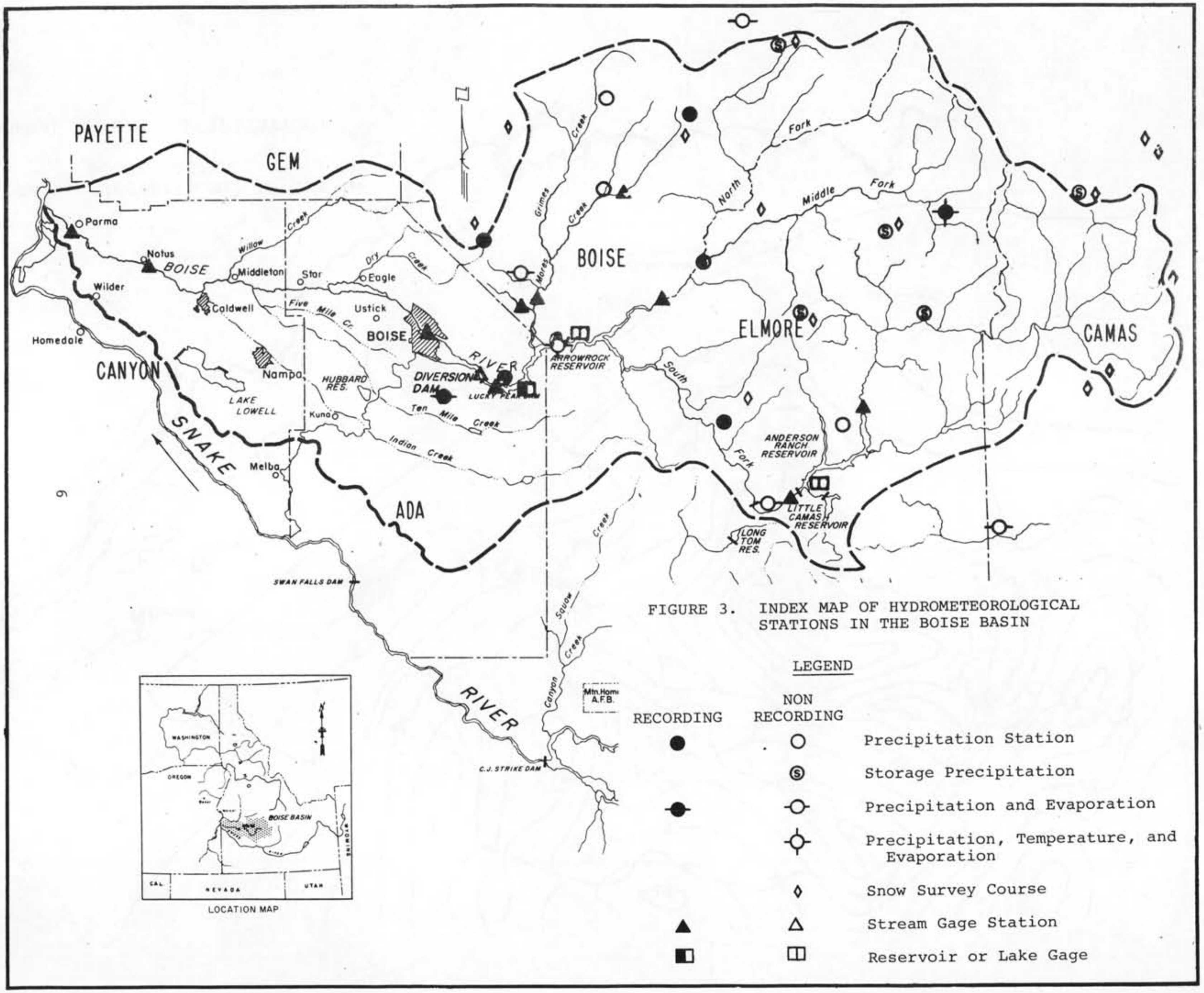


FIGURE 3. INDEX MAP OF HYDROMETEOROLOGICAL STATIONS IN THE BOISE BASIN

of hydropower, an integral part of the project, has been primarily for pumping water to lands outside the project.

Later parts of the report will give more specific information on both water use and water control elements of the Boise Project. The area discussed in this study is limited to project lands within the Boise River Basin served by water development facilities built with Federal monies.

RUNOFF

A brief indication of the flow characteristics of important segments of the Boise River are presented to clarify various features of the project. Three representative locations have been selected. The Boise River near Twin Springs represents characteristics of the northern portion of the basin including both the North Fork and the Middle Fork of the Boise River (drainage area of 830 square miles). The second site for which information is presented is the South Fork of the Boise River at Anderson Ranch Dam. It represents the southeastern part of the basin and encompasses an area of 982 square miles. The third site for which characteristic flow data is presented is at Diversion Dam (Boise River near Boise) which has a drainage area of 2680 square miles. Diversion Dam is between Lucky Peak Dam and the City of Boise. This site represents the area influenced by the accumulated effects of three major reservoirs and is the major diversion point for water used in the basin. The Boise River is also gaged at Notus, Idaho near the confluence of the Boise River and the Snake River. Measured discharges at this station reflect the effects of irrigation diversions and return flows for the entire reach of the river below Diversion Dam.

Records of measured flow for these four stations are available in U.S. Geological Survey Water Supply Papers for surface water flow in Idaho, and a convenient record of regulated monthly flows has been compiled by the Idaho Water Resource Board for the three representative locations mentioned above.

Flow records for the representative sites are presented for a dry year, a wet year and a near average year in the following set of figures. To be consistent with other parts of this report, the representative years chosen are: dry year (1960-61), near average year (1969-70), and wet year (1970-71). These periods were chosen because good records were available and all major features of the Boise project were operational during these years.

Recorded flows reflect the effect of upstream storage and diversions. If there are upstream reservoirs, the measured mean daily flow at a gaging site is adjusted to mean daily "natural" flow by the relationship:

$$Q_n = Q_m + \frac{\Delta S_1}{C_1} + \frac{\Delta S_2}{C_1} + \ldots \frac{\Delta S_n}{C_1}$$

where

Q_n = natural flow in c.f.s.

Q_m = recorded discharge in c.f.s.

ΔS_1 = daily change in storage in first upstream reservoir in acre feet.

ΔS_2 = daily change in storage in second upstream reservoir in acre feet.

ΔS_n = daily change in storage in nth upstream reservoir in acre feet.

C_1 = conversion factor for converting daily change in storage in acre feet to equivalent acreage discharge in c.f.s. The Boise River Watermaster uses C_1 = 2.0, 2.0 acre feet of storage is equivalent to 1.0 c.f.s. of discharge within 1% of accuracy.

The Twin Springs station is unaffected by upstream diversions and has continuous records from 1911 to present. Figures 4a, 4b, and 4c show hydrographs of the mean daily natural flow for three representative years. A useful summary of monthly flows in acre feet for Boise River near Twin Springs is available from the Idaho Water Resource Board. In addition, a graph of natural flows is contained in the Idaho Water Resource Inventory (1968) along with hydrographs of maximum discharge, 20% probability, mean, 80% probability and minimum monthly discharges for the period 1912-1965.

Figures 5a-c and 6a-c are hydrographs of the natural and regulated flow of the South Fork at Anderson Ranch Dam and of the Boise River at Diversion Dam for the three representative years. Tabulations of natural flows at Diversion Dam contained in the annual reports of the Boise River Watermaster, supplement the hydrographs which have been presented as Figures 6a-c.

No measurements have been made which permit a description of natural runoff from arid lands in the part of the drainage below Diversion Dam. It is obvious that the natural runoff is very low because streams in the areas where irrigation is not practiced flow only when there are major storms. In irrigated areas return flow is the dominant flow in natural and artificial channels. This is discussed in more detail in the Irrigation Return Flow section.

A study of water yield maps for Idaho by Rosa (1968) indicates that runoff from the portion of the Boise River basin below Diversion Dam averages less than 1 inch per year. Rosa's water yield map for this area is contained in the Idaho Water Resource Inventory (1968).

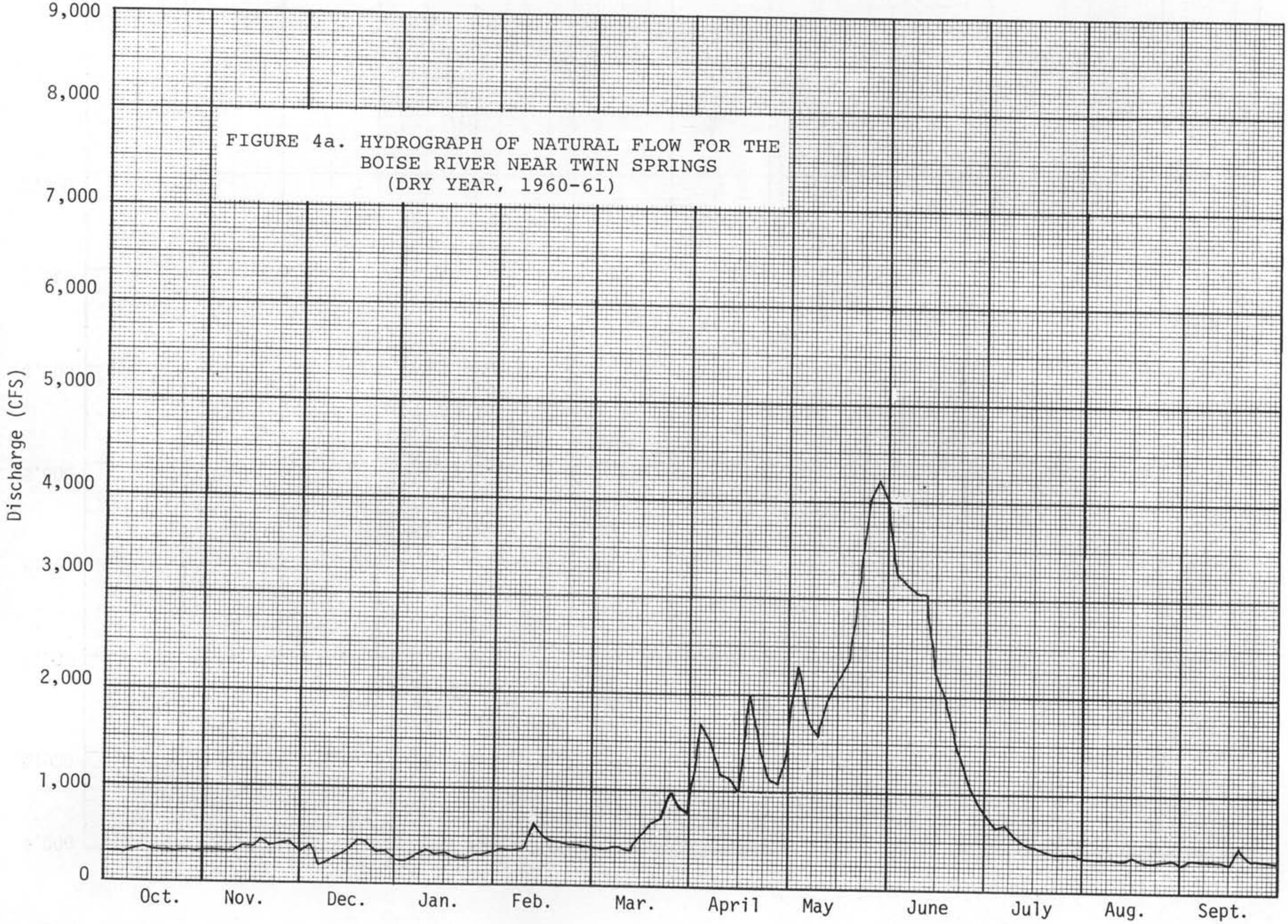


FIGURE 4a. HYDROGRAPH OF NATURAL FLOW FOR THE BOISE RIVER NEAR TWIN SPRINGS (DRY YEAR, 1960-61)

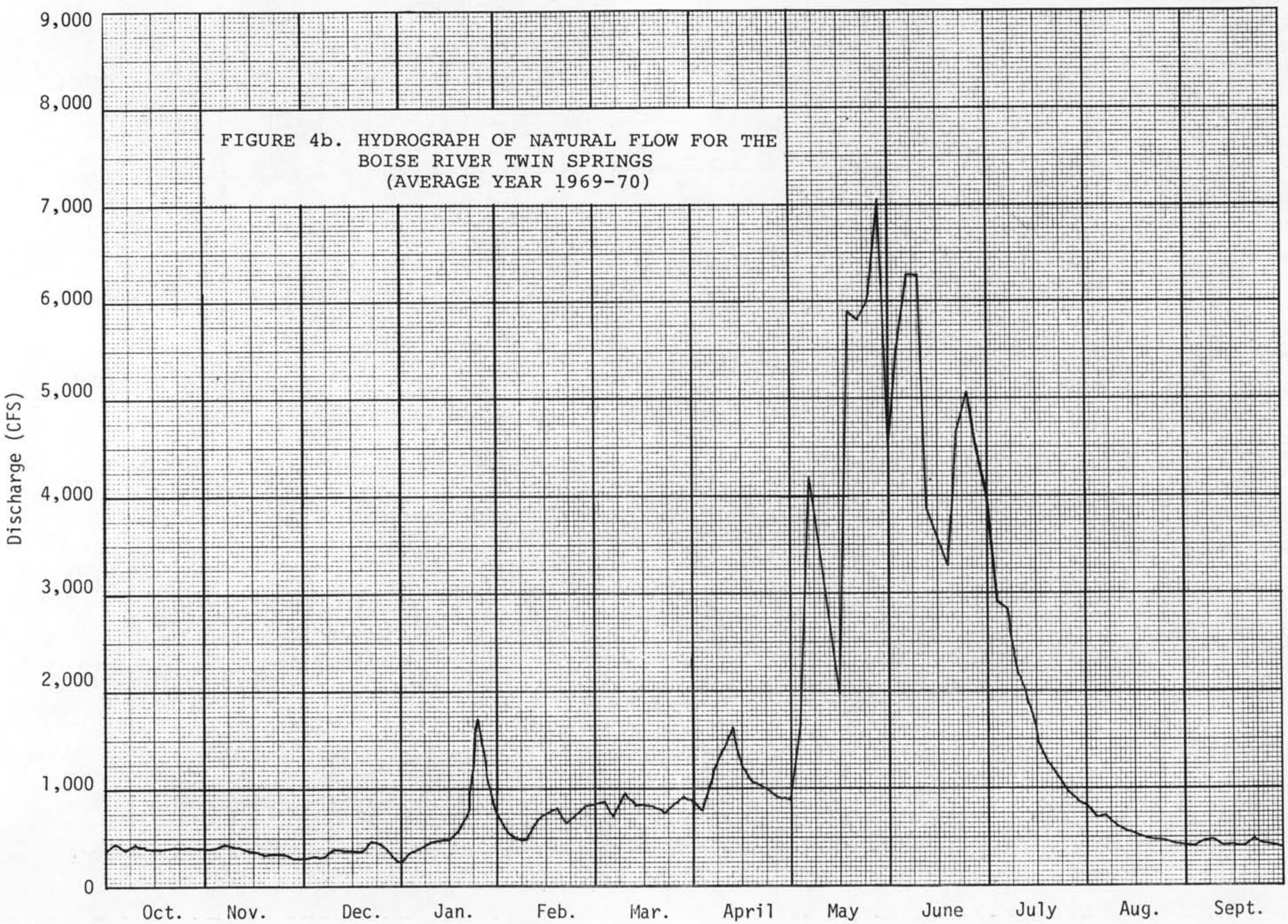


FIGURE 4b. HYDROGRAPH OF NATURAL FLOW FOR THE BOISE RIVER TWIN SPRINGS (AVERAGE YEAR 1969-70)

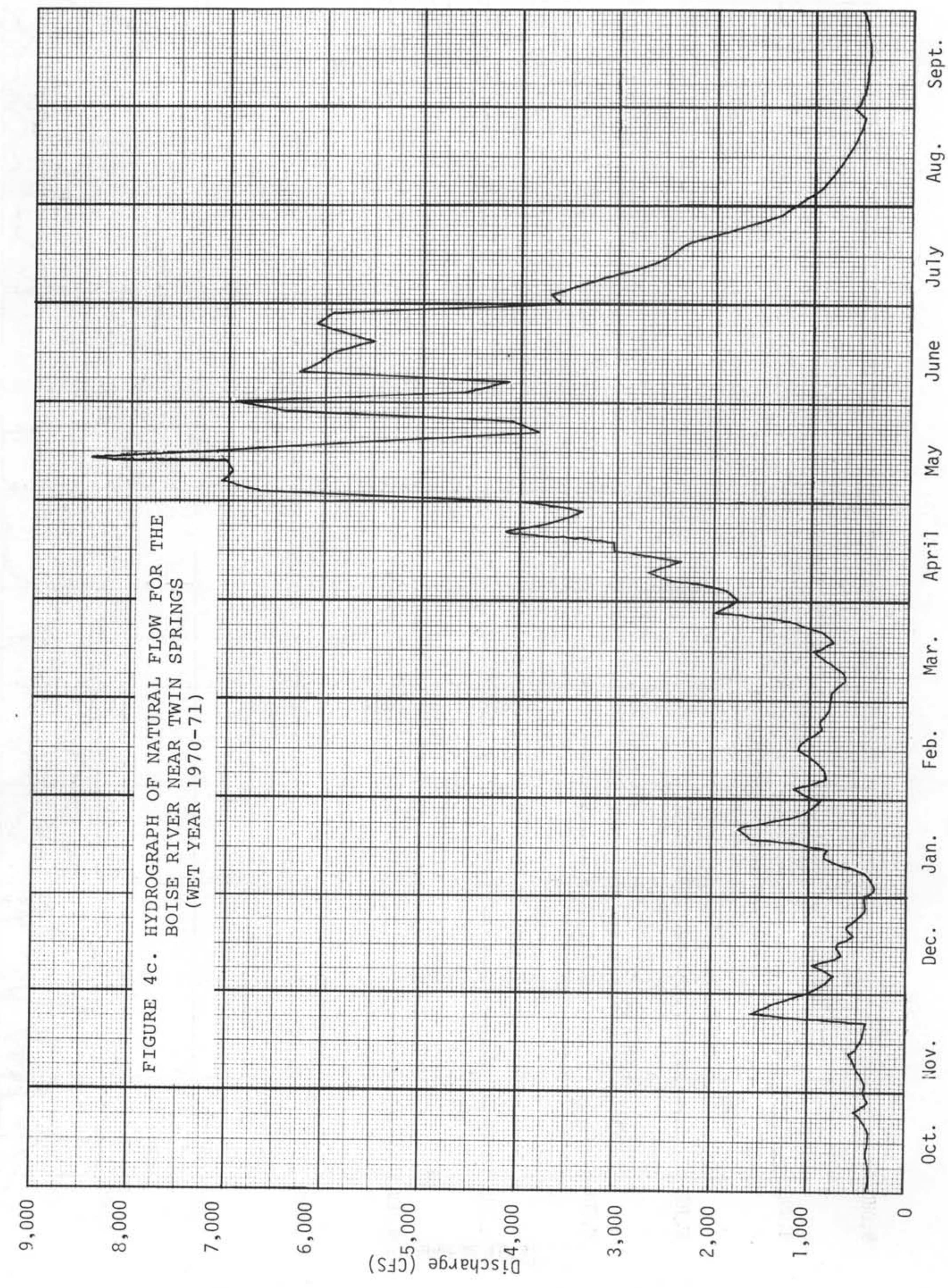


FIGURE 4c. HYDROGRAPH OF NATURAL FLOW FOR THE BOISE RIVER NEAR TWIN SPRINGS (WET YEAR 1970-71)

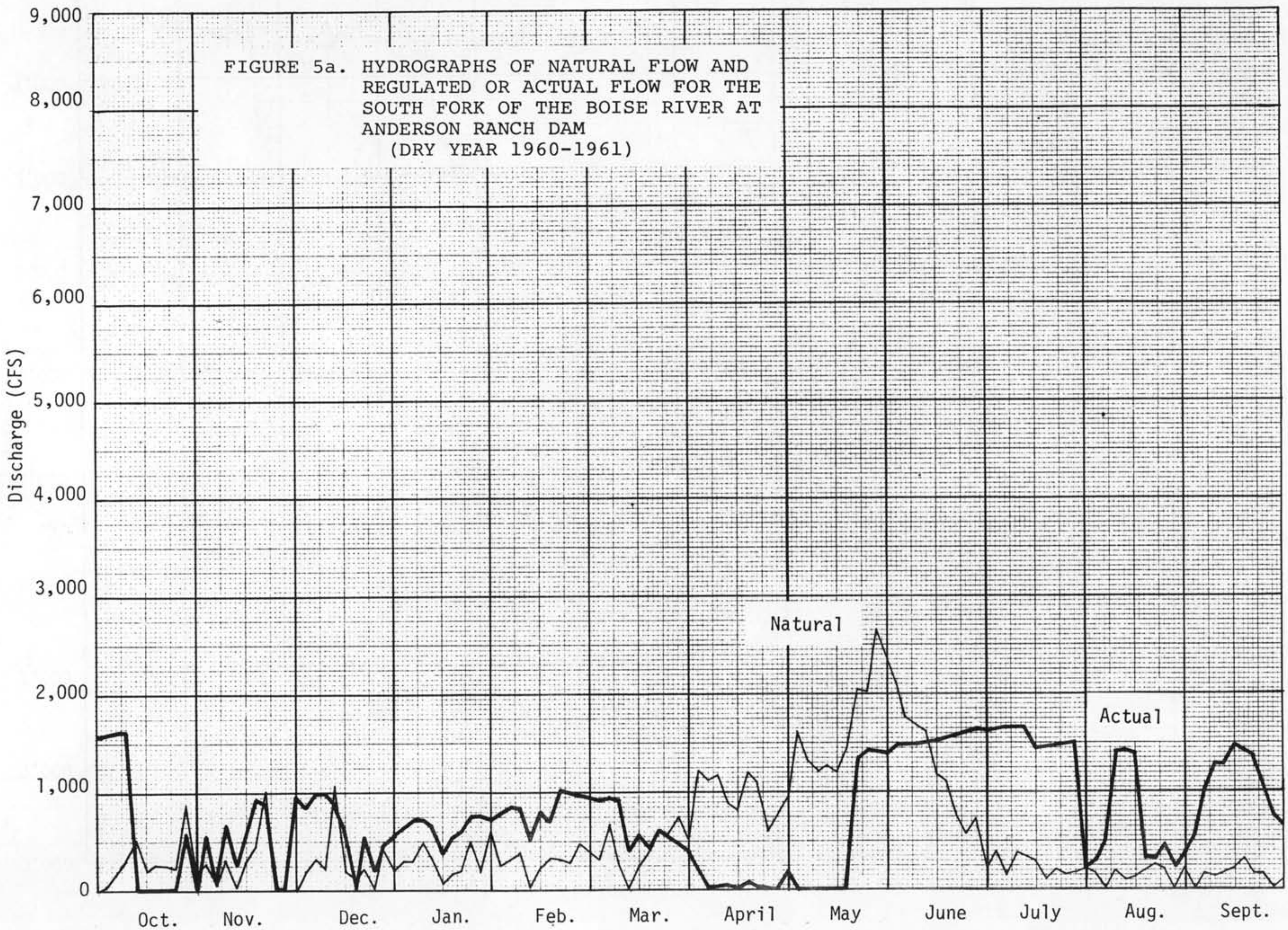


FIGURE 5a. HYDROGRAPHS OF NATURAL FLOW AND REGULATED OR ACTUAL FLOW FOR THE SOUTH FORK OF THE BOISE RIVER AT ANDERSON RANCH DAM (DRY YEAR 1960-1961)

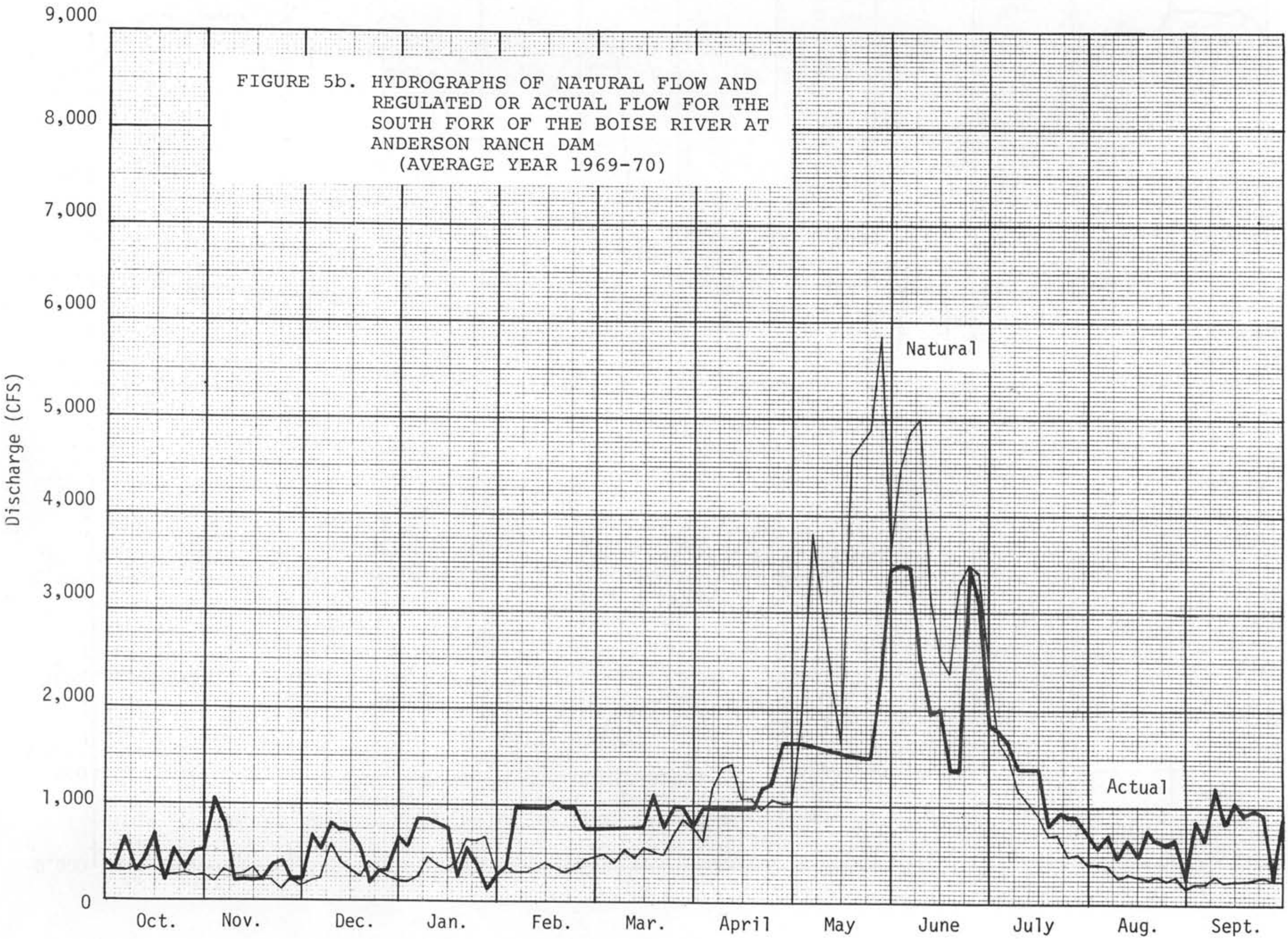


FIGURE 5b. HYDROGRAPHS OF NATURAL FLOW AND REGULATED OR ACTUAL FLOW FOR THE SOUTH FORK OF THE BOISE RIVER AT ANDERSON RANCH DAM (AVERAGE YEAR 1969-70)

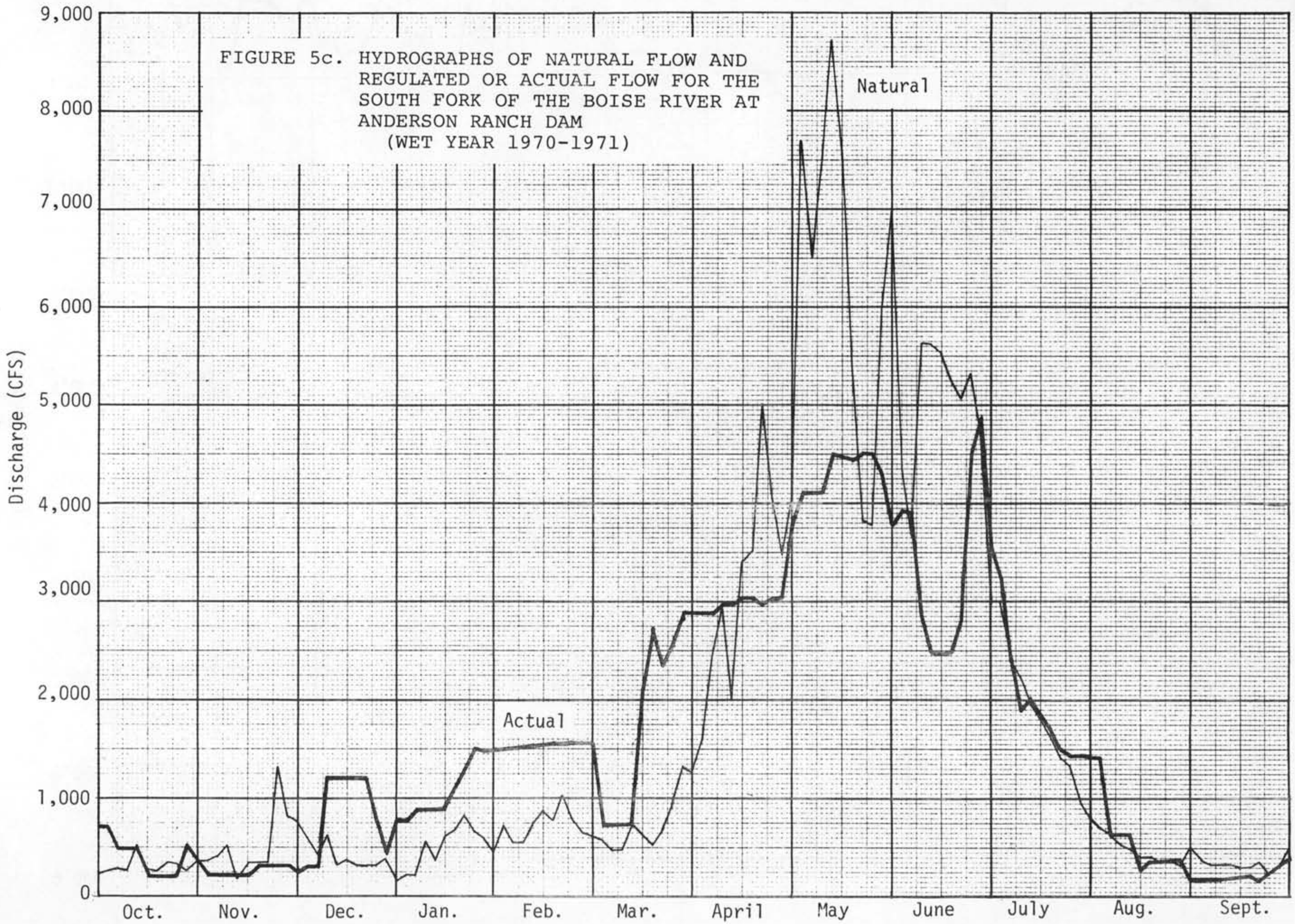


FIGURE 5c. HYDROGRAPHS OF NATURAL FLOW AND REGULATED OR ACTUAL FLOW FOR THE SOUTH FORK OF THE BOISE RIVER AT ANDERSON RANCH DAM (WET YEAR 1970-1971)

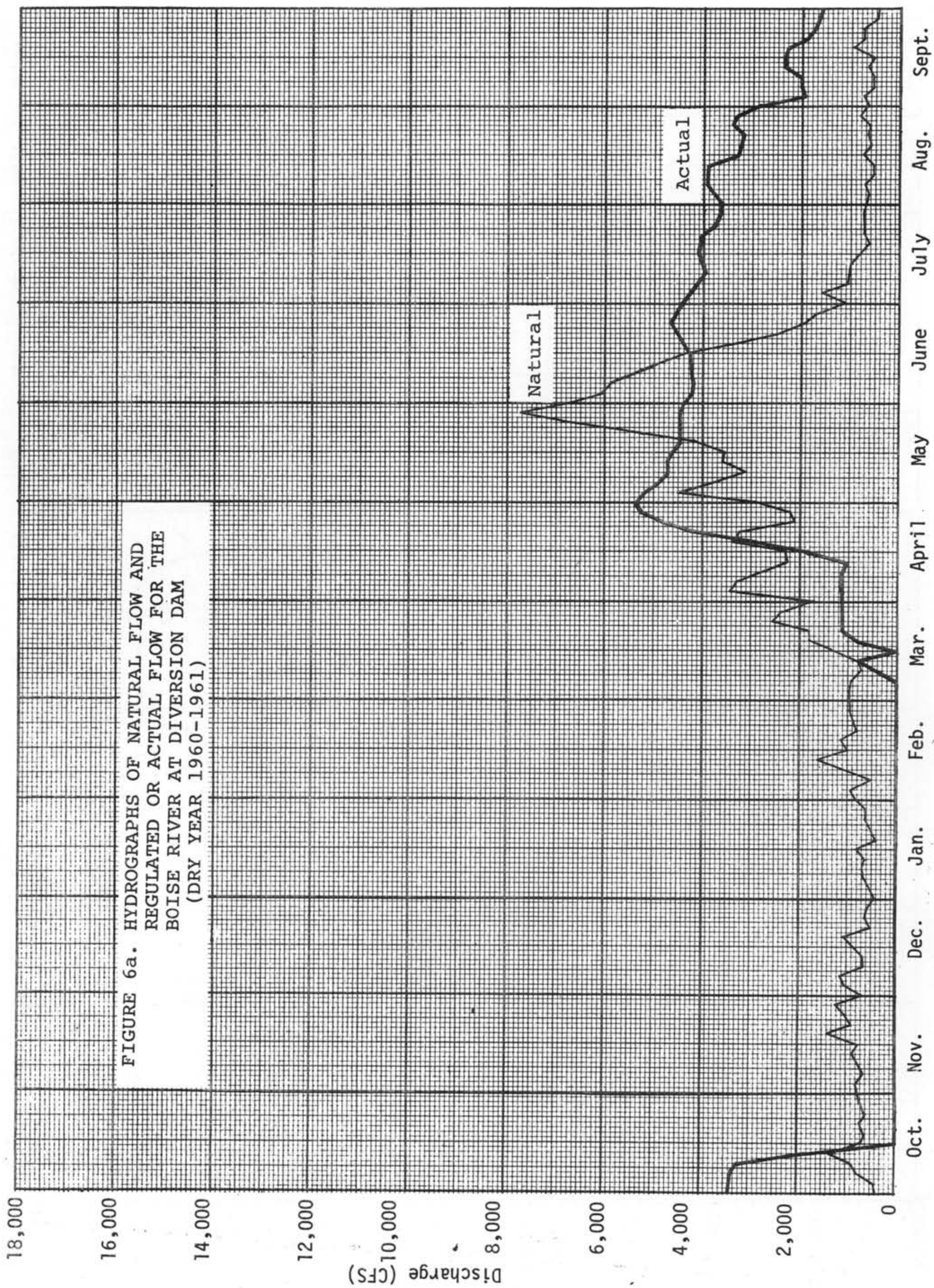


FIGURE 6a. HYDROGRAPHS OF NATURAL FLOW AND REGULATED OR ACTUAL FLOW FOR THE BOISE RIVER AT DIVERSION DAM (DRY YEAR 1960-1961)

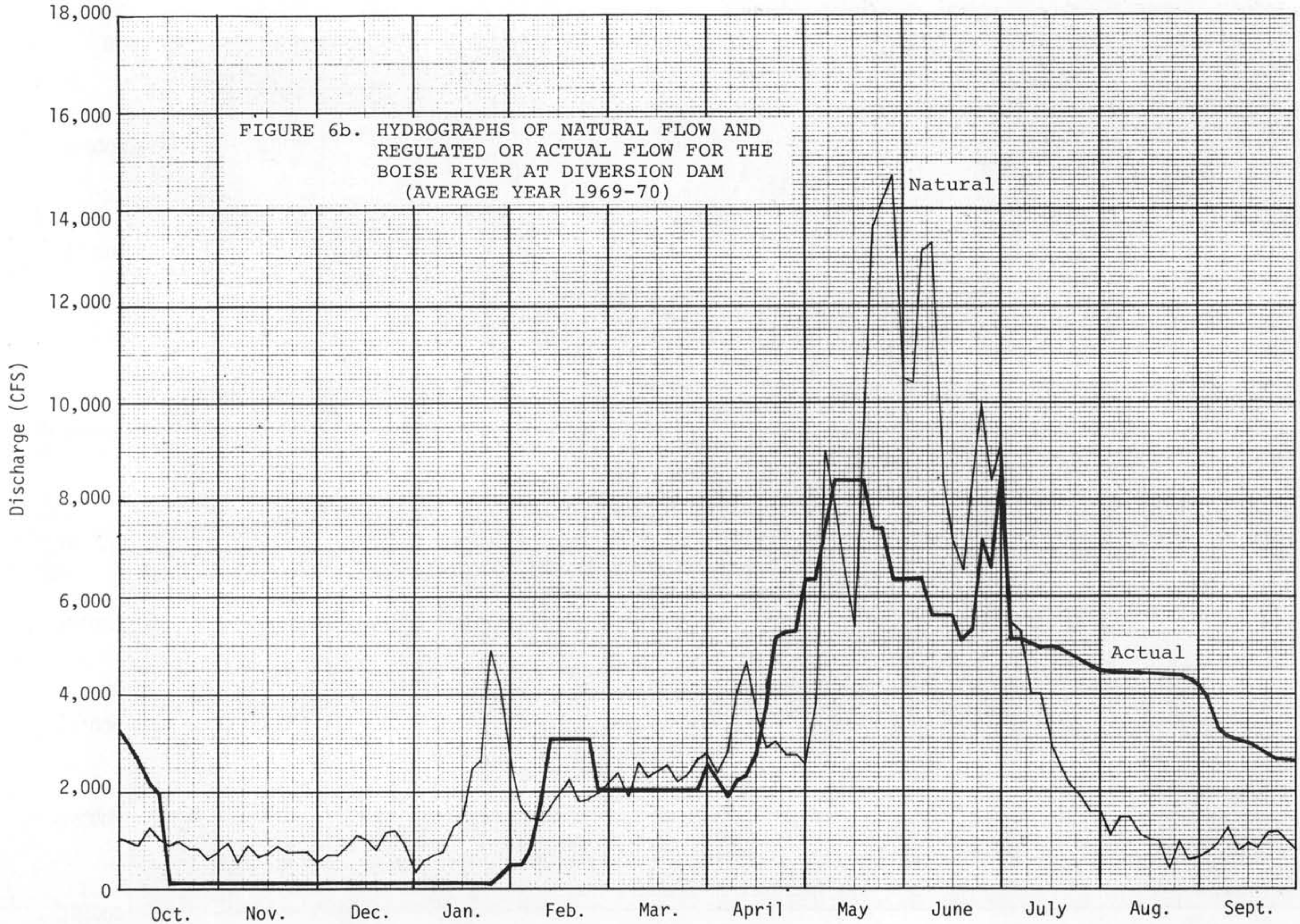


FIGURE 6b. HYDROGRAPHS OF NATURAL FLOW AND REGULATED OR ACTUAL FLOW FOR THE BOISE RIVER AT DIVERSION DAM (AVERAGE YEAR 1969-70)

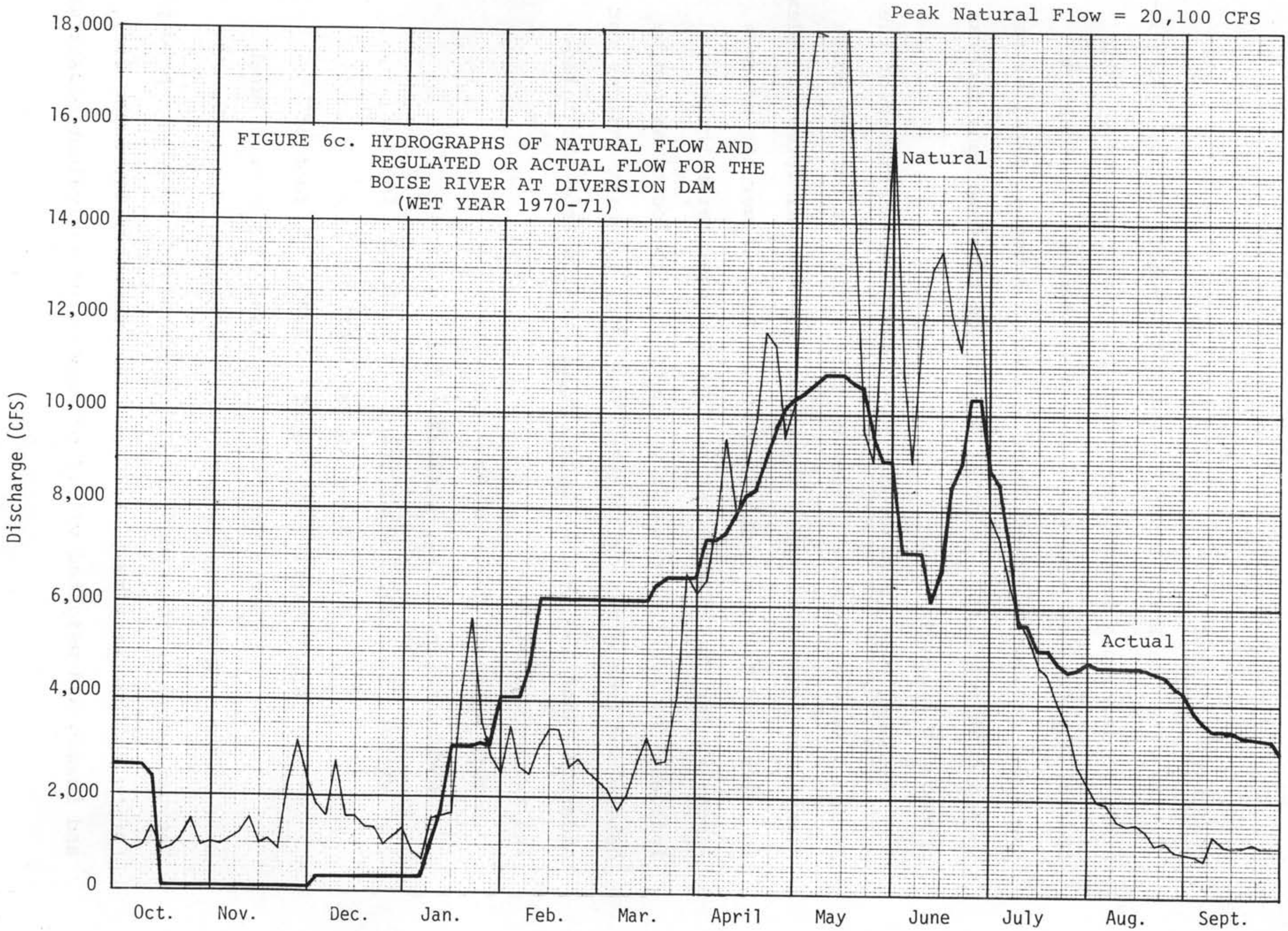


FIGURE 6c. HYDROGRAPHS OF NATURAL FLOW AND REGULATED OR ACTUAL FLOW FOR THE BOISE RIVER AT DIVERSION DAM (WET YEAR 1970-71)

Forecasts of Runoff

Because the Boise River is fed by snowmelt, it has been possible to develop a rather successful forecast procedure. Four federal agencies make seasonal runoff forecasts. In addition, the Boise Project Board of Control makes a somewhat parallel but independent appraisal. A brief discussion of these four federal procedures follows.

National Weather Service. The River Forecast Center of the National Weather Service issues monthly forecasts for the Boise River near Boise from April through July. A total forecast index is calculated for the South Fork of the Boise River at Anderson Ranch and for the Boise River at Twin Springs. With these two indices, the April through July runoff at both locations can be determined from graphical plots. The total forecast indices for Anderson Ranch and Twin Springs are calculated from the following two equations.

Twin Springs: $R_t = 30.9X - 178.6$

Anderson Ranch: $R_{ar} = 43.3X + 353.0$

where: R_t - April-July runoff in 1000 acre feet of Boise River at Twin Springs

R_{ar} = April-July runoff in 1000 acre feet of South Fork of Boise River at Anderson Ranch

X = Index value taken from graphs

The variables in the index are weighted values of monthly precipitation at four stations, Arrowrock Dam, Centerville, Idaho City, and Lowman and weighted values of snow water equivalent measurements at Atlanta Summit, Galena, Moores Creek Summit and Trinity Mountain.

The sum of R_t and R_{ar} are then used in a third plot to determine the forecast for the Boise River near Boise (Diversion Dam) gage. The National Weather Service calls this Boise + ΔS, but in this report the forecast value is designated R_D

The new equation is presented below:

$$R_D = 1.283\ X_1 - 90.0$$

where: R_D = April-July runoff in 1000 acre feet for the Boise River near Boise (Diversion Dam) gage.

$X_1 = R_t + R_{ar}$

Soil Conservation Service. The SCS makes runoff forecasts each month between February and April of April through September runoff. A May through September runoff forecast is made on May 1. Only one equation is used:

$$R_S = 25.47\ X_1 + 40.85\ X_2 - 267.01$$

where:

R_S = April-September runoff of the Boise River at the near Boise River gage in thousands of acre feet.

X_1 = Total August through March precipitation at Idaho City in inches.

X_2 = Average of maximum snow water equivalent observed to date at Atlanta Summit, Bogus Basin, Moore's Creek Summit, and Trinity Mountain.

A new equation is to be prepared in the near future.

U.S. Bureau of Reclamation. The Bureau of Reclamation prepares forecasts for seasonal values of natural or unregulated runoff volume of the Boise River near Boise (Diversion Dam) on a monthly basis beginning in January. The seasonal runoff R_B refers to the period October to July; the entire filling period of the reservoirs. A succession of forecast equations have been used and the latest equation is as follows:

$$RB = 0.686\ X_1 + 24.69\ X_2 + 3.076\ X_3 + 26.13\ X_4 - 1170$$

where:

R_B = October through July natural flow runoff of the Boise River at Diversion Dam (1,000 A.F.).

X_1 = July-September antecedent natural flow runoff of Boise River at Diversion Dam (1,000 A.F.).

X_2 = Summation of October-March precipitation. Anderson Ranch Dam + Arrowrock Dam times 2 + Centerville Arbaugh Ranch + Idaho City (inches).

X_3 = Summation of April 1 snow water equivalent Atlanta Summit + Jackson Peak + Moores Creek + Trinity Mountain + Vienna Mines times 2 (inches).

X_4 = Summation of April + 0.250 May + 0.166 June precipitation for four stations as weighted as in X_2 (inches).

For cases when forecast is made in advance of availability of that current month's data an estimate is made on the basis of the long time mean for that month at that location.

Early forms of the forecast equation used by the U.S. Bureau of Reclamation used mean December and March temperatures at Idaho City as well as antecedent runoff data for first, second and third antecedent years.

To illustrate more specifically how the forecast is prepared, a sample worksheet (Table 1) is presented for the average year condition of 1970. Forecasts were also computed for 1961 and 1971. It was assumed that data were available up to the beginning of the month on all forecast parameters. The month of January 1961 was not presented because some basic data of snow water equivalent were not available. Table 2 gives the comparative results of these example years using the newest U.S. Bureau of Reclamation runoff forecast equation.

U.S. Army Corps of Engineers. The Corps of Engineers prepares forecasts for seasonal volume of natural runoff for the Boise River near Boise (Diversion Dam). Forecasts of April-July runoff are made each month beginning in January. The natural runoff for April through July (R_C) is a function of the computed generated runoff value R_C'. R_C is obtained from a graph included in the Reservoir Regulation Manual (1956) by using the computed value of R_C' as an index. The units are in inches of runoff and to obtain the forecast value in acre feet, one is required to multiply by 141,333. The equation for the computed generated runoff value (R_C' is as follows:

$$R_C' = 0.398\ X_1 + 0.301\ X_2 + X_3 - 4.65$$

where:

R_C' = April to July computed runoff depth of natural flow of Boise River at Diversion Dam.

X_1 = April 1 basin snow water equivalent in inches. This is obtained from a graphical method of weighting the measured snow water equivalent according to elevation zone

Table 1. Sample Worksheet Illustrating Use of U.S. Bureau of Reclamation Forecast Equation for Predicting Natural Runoff of Boise River at Diversion Dam for April 1, 1970

X_1 = July - Sept antecedent runoff (1000 acre feet)
= July + Aug + Sept natural runoff from Watermaster Report
= 128.9 + 51.3 + 48.7 $X_1 = 228.9$

X_2 = October-March Precipitation (Inches)

Station	Oct.	Nov.	Dec.	Jan.	Feb.	March	Season
Anderson Ranch	0.89	0.38	4.98	11.14	5.56	1.70	19.73
Arrowrock X 2	0.86	1.36	6.44	18.18	2.14	1.82	30.80
Centerville	0.34	0.65	3.44	11.41	1.42	2.62	19.88
Idaho City	0.79	0.95	3.95	10.74	1.36	1.93	19.72
	2.88	3.34	18.81	51.47	5.56	8.07	90.13

$X_2 = 90.13$

X_3 = April 1 Snow Water Equivalent (Inches)
= Atlanta Summit + Jackson Peak + Moores Cr Summit + Trinity Mountain + Vienna Mine X2 (Inches)
= 35.4 + 34.2 + 35.6 + 44.4 + 73.8 $X_3 = 223.4$

X_4 = Spring Precipitation (Inches)

Station	Average Monthly Precipitation April	May	June
Anderson Ranch	1.30	1.28	1.40
Arrowrock X 2	2.82	2.82	2.60
Centerville	1.96	1.95	1.95
Idaho City	1.84	1.76	1.80
	7.92	7.81	7.75
Weighting Factor	1.00	0.25	0.166
Weighted Total	7.92	1.95	1.29

$X_4 = 11.16$

$R_B = 0.686X_1 + 24.69X_2 + 3.076X_3 + 26.13X_4 - 1170$ = 2191.1 (Oct-July in 1000 ac ft)
Less natural runoff Oct-Mar -528.5

April - July runoff forecast (1000 ac ft) = 1662.6

Table 2. Sample Results of Boise River Forecast Procedure Applied to Example Years 1961, 1970 and 1971 (1000 Acre Feet)

Dry Year - 1961

	Jan.	Feb.	March	April
Actual Runoff from Beginning of Month to July 31	949.6	907.1	848.3	757.1
Forecasted Runoff from Beginning of Month to July 31	-	1040.6	1008.1	1020.1
% Error	-	15%	+19%	+35%

Average Year - 1970

	Jan.	Feb.	March	April
Actual Runoff from Beginning of Month to July 31	1921.5	1794.5	1692.8	1543.7
Forecasted Runoff from Beginning of Month to July 31	1392.7	2265.6	1882.8	1662.6
% Error	-28%	26%	11%	8%

Wet Year - 1971

	Jan.	Feb.	March	April
Actual Runoff from Beginning of Month to July 31	3011.9	2855.8	2688.5	2477.0
Forecast Runoff from Beginning of Month to July 31	2443.7	2602.7	2369.7	2418.0
% Error	-19%	-9%	-12%	-2%

and snow area covered.

X_2 = Sum Station Precipitation

$\frac{\text{(Basin Normal average precipitation)}}{\text{(Sum of Normal average precipitation)}}$ where the basin normal average precipitation (NAP) is 28.2 and the summation of the NAP for the stations used in the forecast procedure are Atlanta, Arrowrock Centerville, Idaho City, Lowman, and Pine.

X_3 = Effective basin spring precipitation, April-July in inches. This is taken from a graph in which snow cover 1st of April in percent is plotted against effective basin spring precipitation in inches.

The forecast generated runoff is adjusted to reflect total runoff by adding the March 31 recession volume and deducting an estimate of the July 31 recession volume.

$$\text{Forecast runoff} = R_C' + \frac{9\text{(March 31 flow in cfs)}}{141{,}333} - 0.08$$

where the March 31 flow is the natural flow of Boise River near Boise in inches. The recession runoff after July 31 is assumed to be 0.08 inches.

Comparisons of Forecasts

Table 3 contains comparisons of agency forecasts for a common period April 1 through July 31 for 1970 and 1971. The Bureau of Reclamation forecasts were derived using the new procedure, because actual forecasts made in 1970 and 1971 used a different equation. Plate A-4 of the Boise River Reservoir Regulation Manual was used to adjust the various forecasts to a common initial runoff forecast date of April 1. Average natural flow in August and September was deducted to adjust April to September forecasts to the April to July period.

Table 3. Comparison of Agency Forecasts for Boise River near Boise, 1970 and 1971, Forecasts in 1000 Acre Feet

	January 1	February 1	March 1	April 1
1970				
NWS		2155	1785	1680
SCS		1905	1705	1750
USBR	1150	1900	1690	1662
USCE		1921	1722	1637
Actual April-July runoff	1569	1569	1569	1569
1971				
NWS		2695	2425	2394
SCS		2305	2205	2405
USBR	2040	2170	2120	2418
USCE	1920	2305	2163	2495
Actual April-July runoff	2467	2467	2467	2467

A comparison of forecasts by the four agencies shows considerable differences in runoff volumes. All forecasts improve with proximity to the forecast date, however in 1970 all forecasts were high beginning in February and remained considerably above the actual runoff through April 1. It should be pointed out that only the USBR and Corps of Engineers forecasts are used in reservoir regulation decisions.

Consequences of errors in the April-July runoff forecast are evident in examination of the rule curves for reservoir space required for flood control. These curves, contained in the Corps of Engineers Reservoir Regulation Manual, indicate that a 300,000 acre foot error in the April 1 - July 31 forecast, as occurred on March 1, 1971, would require a difference in required storage on April 1 of 165,000 acre feet. This is 17 percent of the 988,000 acre feet of space available for flood control. Forecast comparisons as outlined in Table 3 and comparisons for other years indicate that a further evaluation of forecast procedures should be performed and new procedures such as one recently developed by the Agricultural Research Service might be considered.

FLOODS AND FLOOD FREQUENCY

Perhaps as a result of man's increased activities in the flood plain, water development projects on the Boise River have progressively considered flood control as a more important part of the project. Most of the emphasis has centered on protection of the Boise urban area and the agricultural lands downstream from Boise. In addition, the value of storage on the Boise River as a means of controlling flood damages on the Lower Columbia River has been recognized.

Floods on the Boise River normally occur from snowmelt runoff in the period from April to June. The severity is increased when the runoff from high intensity rainstorms is superimposed on that from snowmelt flows. Occasionally there have been high runoff events caused by rain on frozen ground. Little is known about the frequency and general behavior of such floods. Thunderstorm floods have been a critical problem on the Boise Front tributary drainages such as Cottonwood Creek, Crane Gulch, and Stuart Gulch. Floods on these normally dry stream channels have caused problems in Boise City proper. Since this report is devoted to the projects of the main river, floods of the tributary drainages have not been discussed. Reports that have pertinent information on the tributary drainage problem are:

1. The 1967 report "Flood Plain Information, Boise, Idaho and Vicinity, Boise River and Northside Tributaries" by the U.S. Corps of Engineers (1967).

2. Postflood Report, December, 1964, January 1965, Spring 1965, Walla Walla District, U.S. Corps of Engineers, 1966.
3. A U.S. Geological Survey report, "Cloudburst Flood at Boise, Idaho, August 20, September 22, 26, 1959," C.A. Thomas (1959).
4. An Intermountain Forest and Range Experiment Station report, "Appendix Survey Report, Boise River Watershed" Idaho and Oregon, U.S. Department of Agriculture (1949).
5. A Field Flood Control Coordinating Committee Report, "Run-off and Waterflow Retardation and Soil Erosion Prevention for Flood Control Purposes-The Boise River, 1940", U.S. Dept. of Agriculture (1940).

Historic Occurrences

Several contacts made in this study indicate that earliest reference to a major flood in historical times is a flood in 1862 just at the beginning of settlement of the valley. E.G. Steward (1930) stated:

> "A Mr. Costen, who owned a ranch south and east of Barber, came to the valley in 1862, and he stated that on the Fourth of July of that year that all of the valley in the river bottom between there and Caldwell was covered with water."

According to Dr. M. Wells of the Idaho State Historical Society, a Mr. William E. Welch, former Boise River Watermaster, made a special study and verified the occurrence of this flood.

The largest measured flood magnitude of record was that of June 14, 1896 when a flow of 35,500 cfs was observed. Larger floods may have occurred in 1871 and 1872 (51).

Another important historic flood was caused by a very intense rainstorm, sometimes referred to as the "Rattlesnake Creek Thunderstorm", of November 18-23, 1909. Most of these high intensity rainstorm floods appear to occur during periods other than the snowmelt flood season. This particular storm centered in the Middle Fork Drainage of the Boise River at Rattlesnake Creek. The storm was comprised of a series of low pressure systems and consisted of three bursts of thunderstorm precipitation. The maximum recorded precipitation for different time intervals is shown in Table 4.

Table 4. Maximum Precipitation Intensities During the Rattlesnake Creek Storm of November 18-23, 1909, Boise River Drainage, Idaho

DEPTH (Inches)	DURATION (Hours)
4.4	6
6.6	12
7.4	24
8.8	36
10.8	48
13.0	90

Indications were that the accumulated snow pack up to November 18 was below normal for that season of the year. Nevertheless, the storm resulted in a peak discharge at the Highland gage (Boise

River near Boise) of 15,200 cfs on November 23, 1909. This compares with the normal natural flow for that season of the year of about 1000 cfs. An excellent analysis of this storm has been made by the U.S. Corps of Engineers and is available for review in the open file report, U.S. Corps of Engineers, (1940). The Rattlesnake Creek storm and resulting flood typify high peak-low volume rainstorm floods which can effectively be controlled by the storage which is now provided.

In December, 1964, an intense rainstorm caused the greatest natural flow on record. This storm was centered lower in the basin, thus the existing structures provided complete control. With the outflow at Lucky Peak Dam regulated at 52 cfs, the instantaneous flood peak was rated at 44,000 cfs and the mean daily annual peak was 20,500 cfs.

Another flood occurred in 1971 which is the largest springtime snowmelt flood since Lucky Peak Reservoir was completed and the 1955 formalized flood control operation plan for all 3 reservoirs was instituted. The floods maximum natural flow of 20,500 cfs was reduced to 6880 cfs at Boise.

<u>Flood Frequencies</u>

Frequency curves display the probability that an event of a given magnitude will be exceeded. Flood frequency curves are usually prepared using annual maximum flow data, and show the probability that exists for various flood magnitudes to be exceeded for any year. The accuracy of such probability prediction is dependent upon the length of available record and the accuracy of the recorded flood measurements.

As the Boise Project was developed, various flood frequency curves were prepared to display probability of flooding under both natural (no project) conditions and regulated conditions (with project). The purpose of constructing both natural and regulated frequency curves was to predict the flood reduction effect of the project.

This section will contain a discussion of available flood data and make a comparison of the predicted regulation of the Boise Project with the apparent regulation achieved after twenty years of flood control operation.

Areas of potential flood damage occur along virtually the entire reach of Boise River from Diversion Dam to the confluence with the Snake River. The City of Boise represents the location of greatest potential damage. Good flow records are available for Boise River at Boise as well as just above the city (Boise River near Boise). Flows below the Diversion Dam (Boise River near Boise minus diversions in the New York Canal) and at Boise reflect the flood regulation achieved by the storage system and the federal project diversion. For these reasons frequency studies have generally been concerned with the locations above and at Boise.

Flooding of agricultural lands below Boise is a frequent problem. The Boise River flood control operating plan was heavily influenced by channel capacities in the lower river which are limited to about 6500 cfs. The numerous irrigation diversions and return flows make frequency analysis very difficult below Boise. No attempt has been made in this study to evaluate flow frequencies for locations downstream from Boise.

Natural annual peak flows for the period of record, 1895-1973, are listed in Table 5. These data were used to construct a frequency curve shown on Figure 7. The curve indicates that, under conditions of no regulation, there would be a ten percent chance each year of flows exceeding 22,000 cfs and a fifty percent chance of flows being greater than 13,000 cfs.

Also shown on Figure 7 is a frequency curve derived from estimates of flood peaks for the period 1865-1894. These estimates were contained in a report of the U.S. Department of Agriculture (1940) and were apparently derived from hydrograph reconstruction studies. They are shown here for comparison because they were also used, with later recorded data, in project studies. The estimated peak flows 1865-1894 are shown in Table 6. It is apparent that the early flood estimates, made from very sketchy information, were too high.

Regulated maximum discharges for the Boise River at Boise gage are shown in Table 7. The reader should be aware that storage began in 1915 at Arrowrock Reservoir. Adequate data on irrigation diversions were not available prior to 1917. In the period before 1940 the values of historical maximum annual flow were computed as the sum of Boise River at Dowling Ranch plus recorded flow of Mores Creek at Arrowrock minus diversions above the Boise River at Boise gage.

Figure 8 is a graphical comparison of the natural peak discharges with regulated flow peaks. It should be pointed out that

Table 5. Flood Discharge Data of Annual Maximum Mean Daily Natural Flow of the Boise River for Period 1895-1974

Year	Date	Peak Natural Flow-cfs	Year	Date	Peak Natural Flow-cfs
1895	May 6	7,900	1935	May 25	9,500
1896	Jun 14	35,500	1936	Apr 24	19,790
1897	Apr 19	29,500	1937	May 6	7,700
1898	Apr 27	7,960	1938	May 2	19,290
1899	May 10	19,000	1939	May 1	8,410
1900	May 11	12,000	1940	May 13	9,870
1901	May 16	13,900	1941	May 27	8,860
1902	May 29	8,190	1942	May 27	10,690
1903	Jun 2	16,800	1943	Apr 18	25,040
1904	Apr 15	19,700	1944	May 16	7,630
1905	Jun 2	6,260	1945	May 5	11,640
1906	May 12	8,710	1946	Apr 19	18,840
1907	Apr 15	17,000	1947	May 9	13,840
1908	Apr 22	10,600	1948	May 29	15,260
1909	Jun 6	16,000	1949	May 16	12,830
1910	Mar 22	16,600	1950	May 17	13,670
1911	Jun 13	15,100	1951	May 29	14,030
1912	Jun 9	15,600	1952	Apr 28	23,430
1913	May 28	13,300	1953	Apr 29	12,780
1914	Apr 16	11,300	1954	May 21	14,460
1915	Apr 20	6,230	1955	May 10	10,480
1916	Jun 19	16,500	1956	May 25	22,950
1917	May 15	17,850	1957	May 21	16,930
1918	Jun 14	12,600	1958	May 22	21,750
1919	May 30	11,580	1959	May 16	9,040
1920	May 18	9,620	1960	May 13	11,840
1921	May 17	18,740	1961	May 27	7,830
1922	May 26	18,170	1962	Apr 21	11,340
1923	May 26	11,950	1963	May 24	11,480
1924	May 18	5,190	1964	Dec 25	27,290
1925	May 20	14,350	1965	May 1	20,500
1926	May 6	7,090	1966	May 10	8,220
1927	May 18	20,060	1967	May 25	15,600
1928	May 10	20,710	1968	Jun 4	7,050
1929	May 25	9,370	1969	Apr 24	15,930
1930	May 30	7,560	1970	May 28	14,850
1931	May 15	5,270	1971	May 14	20,250
1932	May 14	13,580	1972	Jun 2	19,600
1933	Jun 4	12,510	1973	May 20	9,550
1934	Mar 30	6,110	1974	May 9	18,470

1895-1916 Flows are recorded maximums, Boise River near Boise
1917-1954 Boise River at Dowling Ranch + Mores Creek near Arrowrock + Storage changes
1955-1974 Boise River near Boise + storage changes

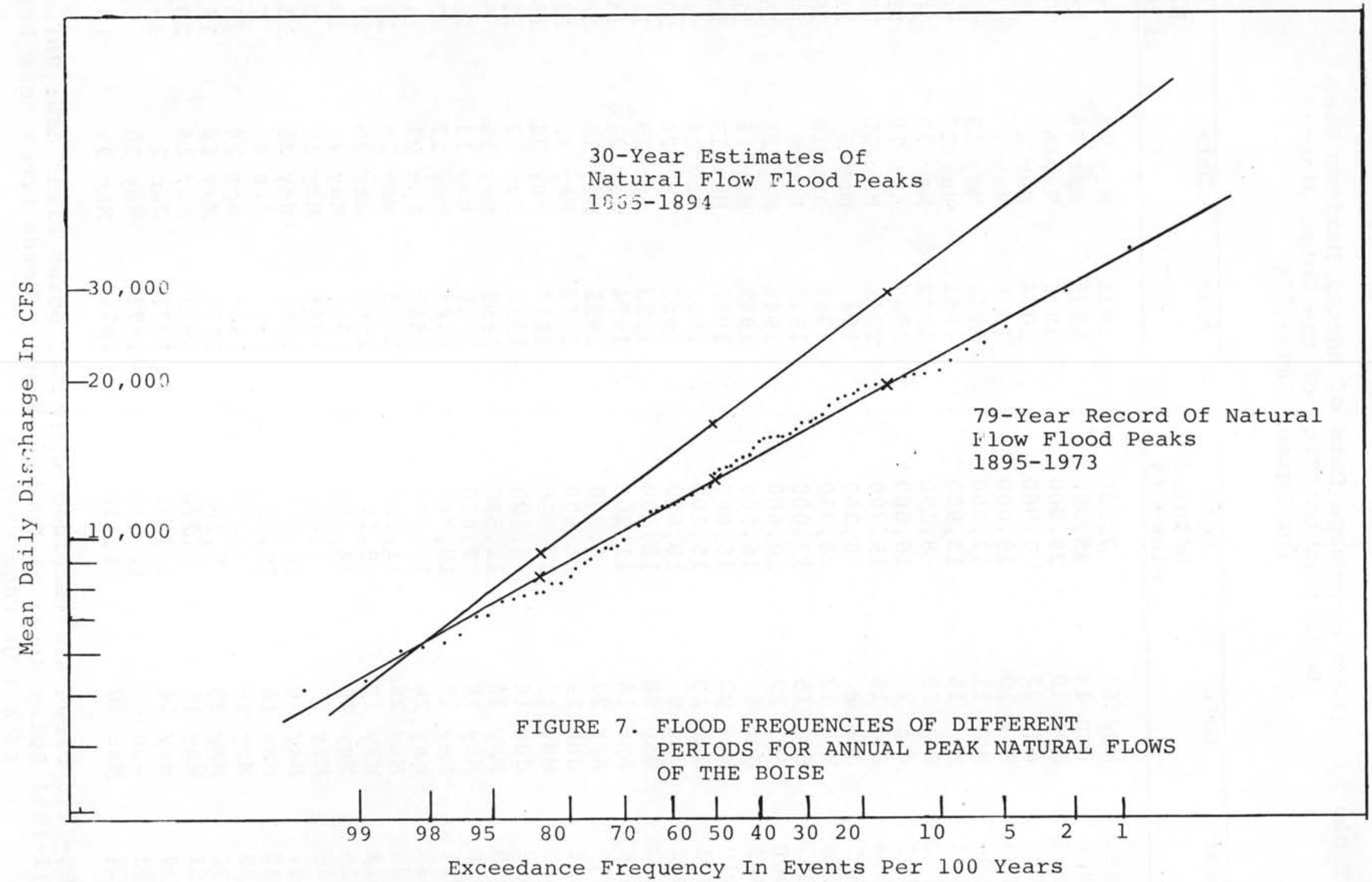


FIGURE 7. FLOOD FREQUENCIES OF DIFFERENT PERIODS FOR ANNUAL PEAK NATURAL FLOWS OF THE BOISE

Table 6. Estimates of Maximum Annual Daily Flow 1865-1894

Year	Date	Estimated Peak Natural Flow-	Year	Date	Estimated Peak Natural Flow-cfs
1865	May 4	21,500	1880	May 22	16,300
1866	Apr 25	16,000	1881	Apr 20	29,600
1867	Apr 30	20,200	1882	Jun 6	16,800
1868	May 12	3,800	1883	May 31	13,000
1869	May 6	16,200	1884	May 13	14,200
1870	May 12	15,600	1885	Jun 3	15,000
1871	May 28	43,000	1886	May 22	19,300
1872	May 20	50,000	1887	May 31	16,100
1873	Jun 7	11,800	1888	May 17	6,900
1874	May 25	36,000	1889	Apr 28	5,400
1875	Apr 18	36,000	1890	May 3	20,800
1876	May 28	15,200	1891	May 16	11,400
1877	May 15	13,700	1892	May 26	18,000
1878	Apr 3	11,000	1893	May 16	17,800
1879	May 27	13,000	1894	Apr 24	35,000

the regulation represents four different conditions: (1) no regulation other than irrigation diversions in the early period up to 1915; (2) regulation with Arrowrock Reservoir plus irrigation diversions in the reach above Boise; (3) regulation with Arrowrock Reservoir, Anderson Ranch Reservoir plus irrigation diversions in the reach down to the Boise River at Boise gage and (4) regulation with Arrowrock, Anderson Ranch, and Lucky Peak reservoirs, plus irrigation diversions in the reach to Boise. The respective periods have been marked on Figure 8.

Table 7. Flood Discharge Data of Annual Maximum Mean Daily Historically Regulated Flow of the Boise River at Boise for Period 1917-1974

Year	Date	Peak Flow cfs	Year	Date	Peak Flow cfs
1917	Jun 22	9,455	1946	Apr 29	10,800
1918	Jun 14	9,280	1947	May 9	8,390
1919	May 30	10,157	1948	May 29	9,500
1920	Jun 9	4,050	1949	May 30	5,710
1921	May 17	15,387	1950	Jun 1	6,720
1922	May 26	13,207	1951	May 14	7,510
1923	May 26	7,092	1952	Apr 27	7,790
1924	May 23	1,298	1953	Jun 19	8,110
1925	May 20	11,787	1954	May 22	6,030
1926	May 3	1,799	1955	Jun 12	1,740
1927	Jun 14	12,548	1956	Mar 11	6,840
1928	May 11	16,133	1957	Jun 8	6,870
1929	Jun 17	3,974	1958	May 29	6,320
1930	May 30	3,944	1959	Apr 16	1,800
1931	May 12	1,686	1960	May 15	5,710
1932	May 15	10,460	1961	Apr 11	1,560
1933	Jun 16	8,628	1962	Jul 1	1,540
1934	Apr 23	1,823	1963	May 25	5,870
1935	May 25	5,812	1964	Jun 20	4,630
1936	Apr 24	15,272	1965	May 22	7,170
1937	May 29	2,467	1966	Apr 4	1,760
1938	May 28	12,390	1967	Jul 5	1,640
1939	May 5	4,494	1968	May 4	1,600
1940	May 13	6,220	1969	Apr 22	6,280
1941	May 27	5,330	1970	Jun 30	5,030
1942	May 27	6,900	1971	May 16	6,850
1943	Apr 19	20,500	1972	May 7	6,710
1944	May 16	3,870	1973	May 12	1,460
1945	May 6	7,080	1974	May 8	7,350

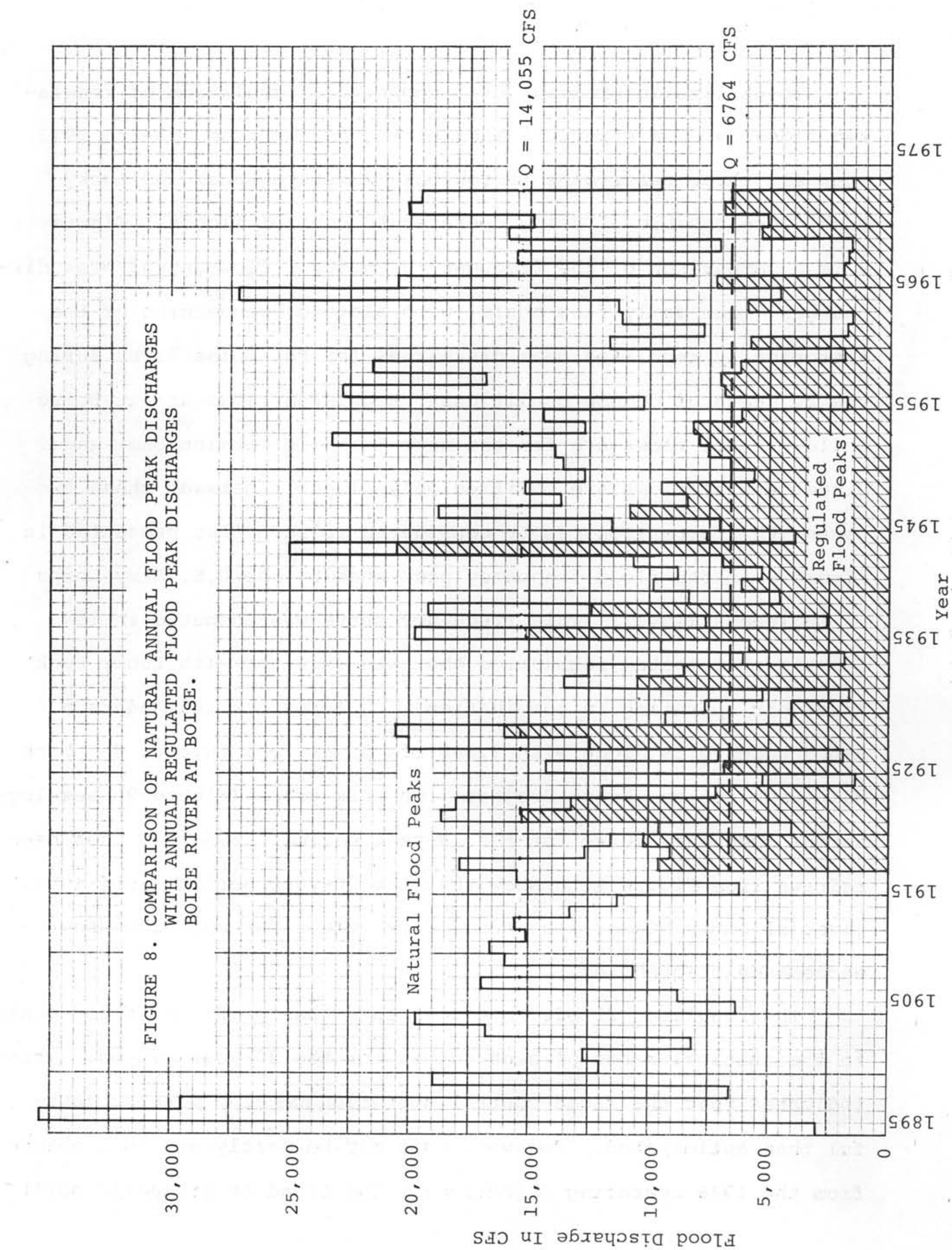


FIGURE 8. COMPARISON OF NATURAL ANNUAL FLOOD PEAK DISCHARGES WITH ANNUAL REGULATED FLOOD PEAK DISCHARGES BOISE RIVER AT BOISE.

To utilize information of a compatible population of regulated flood data, a study was made of the period from 1954 to 1973 when all three reservoirs (Arrowrock, Anderson Ranch and Lucky Peak) were capable of being operated to control floods. Figure 9 is a comparison of the frequency of natural flow annual peak discharges (mean daily flow basis) with plotted frequencies of the historically regulated peak discharges for the Boise River during the 20 years of common conditions. Regulated flows are at Boise while natural flows are for the near Boise (Diversion Dam) gage. Since natural flows are modified only slightly between these two gages; the comparison can be considered valid. Also presented in Figure 9 is the flood frequency predicted by the U.S. Army Corps of Engineers (1946). This frequency curve was computed in 1945 for the anticipated regulation that was expected with Lucky Peak Reservoir operating in combination with Arrowrock and Anderson Ranch Reservoirs along with 2,800 cfs diversions through New York Main Canal of the Boise Project. On this graph (Figure 9) the log-normal frequency curve for the 79-year period, 1895-1973, has been redrawn from Figure 7 to show that the 20-year period, 1954-1973, gives slightly higher peak flood flow values for corresponding exceedance frequencies.

The regulated floods have been less than predicted flood peaks in the critical range of high values for the 20-year period. This indicates that the flood control operation has been more successful than anticipated. However, this may be partly due to a change from the 1946 operating objectives. The trend to gradually shift

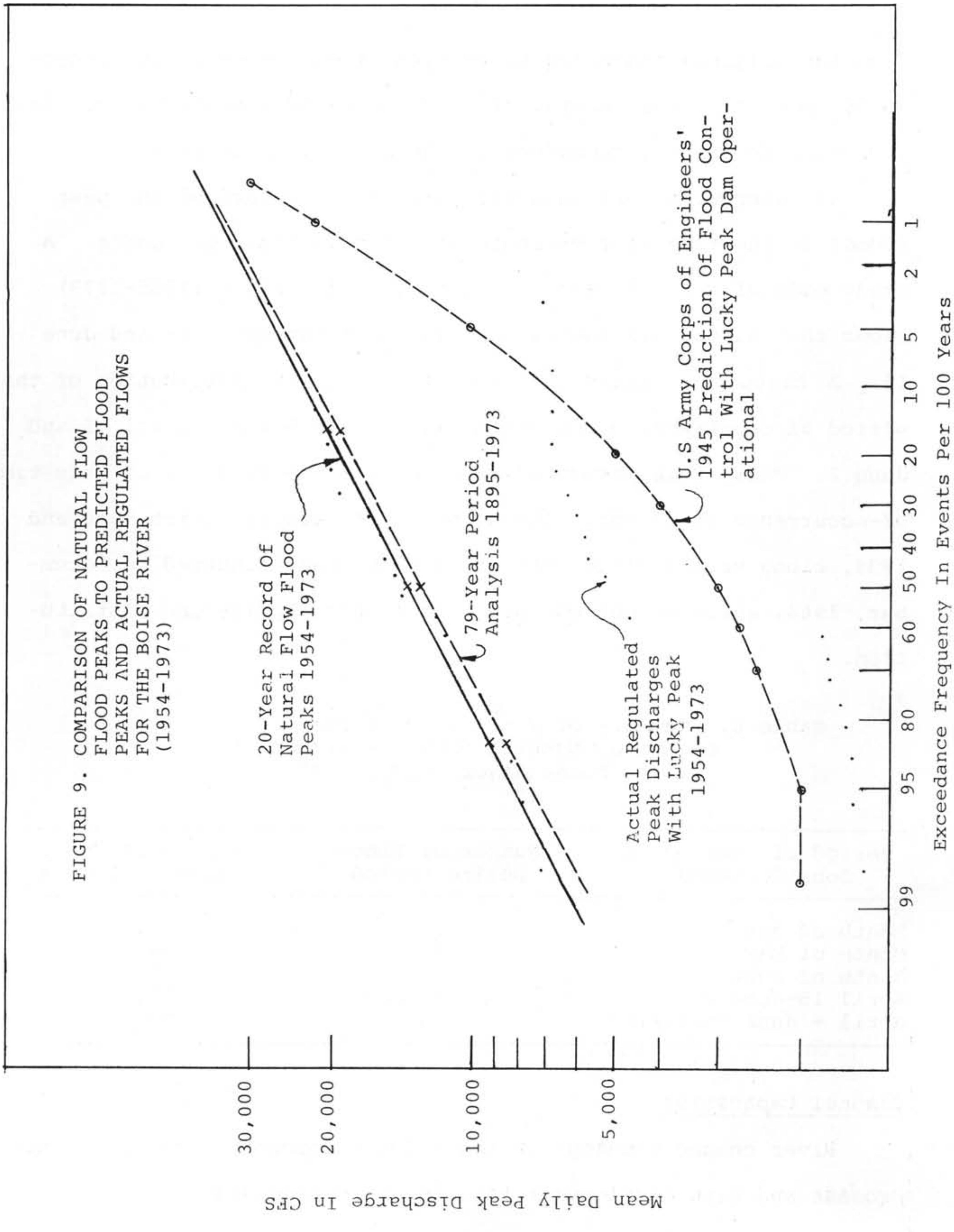


FIGURE 9. COMPARISON OF NATURAL FLOW FLOOD PEAKS TO PREDICTED FLOOD PEAKS AND ACTUAL REGULATED FLOWS FOR THE BOISE RIVER (1954-1973)

from the original operating objectives is discussed in the RESERVOIRS section. Daily characteristics of flood reductions are also presented in figures contained in the RESERVOIRS section.

An interesting and valuable part of the record of the past floods is the time of occurrence of the peak flood discharge. A study made of the 109 year period mentioned earlier (1865-1973) shows that almost all the floods occur between April 15 and June 15. A histogram analysis shows a very uniform distribution of the period of occurrence of snowmelt flood peaks between April 15 and June 2. Table 8 is presented to summarize the findings of this time-of-occurrence of floods. There were three events, March 1910 and 1934, along with a winter rainstorm flood that occurred in December, 1964, which do not conform to the usual April-June distribution.

Table 8. Summary of Time-of-Occurrence of Annual Natural Peak Discharges of the Boise River - 1865-1973

Period of Year Under Consideration	Number of Floods During Period	Percent of Total Number of Floods
Month of April	20	18.3
Month of May	68	62.4
Month of June	18	16.5
April 15-June 2	90	82.5
April - June inclusive	106	97.3

Channel Capacities

River channels change in their lower reaches by an aggradation process and with development this is often accelerated.

The capacity of a downstream river channel to carry flood flows is a major consideration in development of any plan for operation of a reservoir system. The Boise River Flood control plan is greatly influenced by channel capacities which are limited to about 6500 cfs in the lower reaches. Bench-mark channel capacity data was found in the report of the U.S. Department of Agriculture (1940) and is presented in Table 9. Apparently there are no data on present channel capacities, and considerable aggradation may have taken place. Thus a resurvey of the river cross sections should be considered as part of any future control program.

Flood Damages

Because a later phase of research on this overall project will be involved with economic analyses, a search was made for pertinent information on flood damages. This section merely reports where this information can be found and what period or project was concerned.

Excellent information on flood damages is contained in the report of U.S. Department of Agriculture (1940). A copy of this report contains an excellent map showing areas of flooding for various flood discharges. It would be useful to compare with later flood plain maps reported in Flood Plain Information Report of the U.S. Army Corps of Engineers (1967). The U.S. Geological Survey (1968) has also published maps showing potential flooding in the Boise Valley. Flood damage data are presented in Project Investigations Report 35A of the U.S. Bureau of Reclamation (1940) a report on the Anderson Ranch Reservoir project. A detailed

Table 9. "Bench-Mark" type Data on Channel Capacity at Various Locations along the Boise River

Location	Maximum channel capacity at bridges[1]			
	Initial survey		Resurvey	
	Date	Capacity	Date	Capacity
Capitol Boulevard	Oct 1930	18,680	Sept 1939	11,810
Fairview	Mar 1931	14,085	Sept 1939	15,140
Strawberry Glen	Jan 1938	18,228	Sept 1939	18,496
Eagle Is. (N. Channel)	Jan 1938	16,177	Sept 1939	18,400
Star (New)	Mar 1938	20,820	Sept 1939	15,447
Caldwell	Jan 1926	65,900	Sept 1939	35,125
Parma	Jan 1939	12,296	Sept 1939	12,342

Approximate location	Maximum channel capacity at clear sections[2]	
	Date	Capacity
Below Fairview Bridge	Oct. 1939	6,098
Head of Eagle Island	Oct. 1939	6,055
Below Eagle Island	Oct. 1939	8,956
Below Star Bridge	Oct. 1939	8,478
Above Caldwell	Oct. 1939	9,143
At Notus Gaging Station	Oct. 1939	8,170
Below Parma Bridge	Oct. 1939	11,642
West of Parma	Oct. 1939	12,342

[1]Compiled from field data obtained from the State of Idaho, Department of Public Works, Bureau of Highways; Works Progress Administration; and by the engineering section of the Boise River Watershed Survey.

[2]Compiled from data obtained from the Water Department, U.S. Engineer Office, Bonneville, Oregon.

Taken from Table II-C-32 of the Survey Report, Field Flood Control Coordinating No. 17B, U.S. Department of Agriculture (1940).

analysis is presented in the U.S. Army Corps of Engineers (1946) report entitled "Review of Survey Report, Boise River, Idaho, with View to Control of Floods". The U.S. Army Corps of Engineers (1956) Reservoir Regulation Manual for Boise River Reservoirs contains a discharge damage curve for floods in Boise River. Data for this curve were updated for the U.S. Army Corps of Engineers study (1968) Interim Report No. 6, "Lucky Peak Power Plant - Twin Springs Dam and Reservoir, Boise, Idaho".

The U.S. Army Corps of Engineers publishes special postflood reports. An example of this is U.S. Corps of Engineers (1966), "Postflood Report December 1964, January 1965, Spring 1965, Walla Walla District." It is apparent that damage surveys are needed to update estimates of damages prevented under current operating procedures. Much development has occurred within the flood plain, particularly in urban areas.

WATER RIGHTS STATUS AND EVOLUTION

Early Rights

Earliest water rights on the Boise River precede the establishment of the State. Case notes in an important water rights case, Farmers Cooperative Ditch Co. v Riverside Irrigation, et al., 16 Idaho 526 (1909) show rights dating back to 1863. This was a diversion in 1863 by Tom Davis about 1.5 miles from the Boise town limits. The water right was later transferred to a Cyrus Jacobs in 1872 and was operated as the Jacobs Canal Company.

A claim was made by M.B. Palmer for the earliest right on the river for a diversion in 1864 of 1200 inches of water near Middleton. This Palmer Ditch by 1900 was 20 miles long and irrigated nearly 3000 acres. It apparently became the Middleton Mill Ditch Co. in 1889.

There was a steady acquisition of water rights during the period before 1900 and as competition for use of the low flow during the summer period intensified, there naturally developed conflict. Thus it was inevitable that judicial action was required to develop a workable water rights program of allocating water to the competing uses.

Early records indicate that the water was appropriated for milling, manufacturing, floating logs, irrigation and for sewage purposes. It is evident that the irrigation use dominated over time and it was the court cases regarding irrigation that finally fashioned workable water decrees.

Development of Irrigation Districts

To meet the needs of water users, larger canals and better maintained diversions were needed. This need was met by the formation of irrigation districts and cooperative canal companies. Late in 1900 the Idaho legislature provided for the formation of irrigation districts, which became quasimunicipal organizations. The organization of the Pioneer Irrigation District in the vicinity of Caldwell was quite typical of this trend. The Canyon County commissioners scheduled an election to ratify the organization and the referendum was favorable. This district then included five precincts and purchased two older canal systems.

This action strengthened irrigation management and provided for more workable systems in the early part of 1900 but there still remained conflicts between existing companies, the new districts, and adjacent districts.

Early Decrees for Adjudication

The early water right decrees on the Boise River were preceded by many court cases involving claims of different individuals and companies that contended they had been harmed by the over allocation of the Boise River waters. The major case came about through an adjudication case started in August 1902 by the Farmer's Cooperative Ditch Company against the Riverside Irrigation District, Ltd., et al. Every other ditch and canal company using water from the river, about 150 in all, joined as defendants. The plaintiff in the case claimed violation of rights to water that were his by priority and that were being denied by later appropriators.

The case began in the district court of the Seventh Judicial District, Canyon County and encountered an expected legal entanglement which spans several years and produced over 1500 pages of printed testimony. The case was temporarily settled and signed by District Judge George H. Stewart on January 18, 1906. The decision is now called the Stewart Decree. This court decision in effect determined the priorities for all appropriators on Boise River from June 1, 1864 to April 1, 1904. In addition, the Stewart Decree provided a mechanism for the distribution of water through a "sliding scale" concept. A portion of the decree defining the sliding scale concept is quoted below:

> "The various rights shall receive 100% until the natural flow of the waters of the Boise River shall decrease, until all the rights in said decree cannot receive 100%, at which time the various rights shall first be cut to 75% of the amount of water decreed as the natural flow of the Boise River decreases, beginning the latest right and proceeding to the earliest rights, should the natural flow of the waters in Boise River decrease below the amount necessary to supply said 75% of the water rights, the various rights beginning with the latest and proceeding to the earliest, as aforesaid, shall be reduced to 60% of the amount decreed."

The case was appealed to the Idaho Supreme Court in 1908, where it was affirmed as to priority and acreage, but was remanded to the district court "for the sole and only purpose of determining the duty of water on bench and bottom lands." In 1914 testimony was taken before the court as to the duty of water on bench and bottom lands and transcribed as a record of more than 2600 pages. The final decree of the court concerning the duty of water was never issued.

Another court case which began in 1909 is known as the "Flood Water Suit" or "Bryan Decree". This case in the Seventh Judicial District involved the Pioneer Irrigation District v. American Ditch Association, et al., Judge E.L. Bryan signed a decree February 14, 1929, which primarily covered water right priorities from July 2, 1894 up to April 1, 1914. All the rights which it decreed were made subsequent to the Stewart Decree in legality. Like the Stewart case, this case was also appealed to the Supreme Court. Some of the rights involved were upheld but the case was remanded to the District Court for retrial on the question of duty of water and for the purpose of determining those rights not upheld.

On January 30, 1932, Judge A.O. Sutton signed an order temporarily establishing the various rights in this suit and providing for a duty of water similar to the "Sliding Scale" in the Stewart Decree. On June 23, 1933, Judge Chas. E. Winstead of the Third Judicial District, sitting as a Judge in the Seventh Judicial District, signed a continuing order making the 1932 order of Judge Sutton effective for 1933 and continuing. This order still remains in effect today.

<u>Federal Water Right Filings</u>

The earliest Federal right grew out of a filing by C.W. Moore, et al. as Application No. 553, License No. 430 with a priority date of December 14, 1903. This was transferred to the Secretary of Interior on February 24, 1904. The original application was for 5200 cfs but was modified to 1355 cfs for irrigation of 240,000 acres in Boise Valley. No mention is made of reservoirs but this application was preparatory to the development of Boise Project storage in Lake Lowell.

The second Federal filing was Application 6887, and License No. 4800, applied for by W.E. Weymouth Supervising Engineer for the U.S. Reclamation Service. The original request was for 3553 cfs for a power installation of 100,000 hp. and 634 cfs for irrigation. This right was approved for 1500 cfs for power and 926.5 cfs for irrigation. The priority date is June 15, 1909 and involved the storage of water in Lake Lowell. The power water use right was for the small power plant at Diversion Dam.

Another filing was made in the name of the U.S. Reclamation Service by W.E. Weymouth as Application No. 10166 and License No. 7180 for 8000 cfs with a priority date of January 13, 1911. This involved the storage regulation provided by Arrowrock Reservoir.

An application by B.E. Stoutmeyer, District Council for the U.S. Bureau of Reclamation was made as Application No. 22831, License No. 16098 for 300 cfs. This has a priority date of August 18, 1924 listed 164,572 acres of Boise Project land to be served by the water and involved an enlargement of the Main (New York) Canal.

The Bryan Decree recognizes these federal rights and identifies the rights as follows:

> "That subject to the awards made in said Decree it is entitled to 1500 second feet from June 16, 1909 for power purposes only at the Government power plant at its diversion dam at the head of New York Canal; and to 8000 second feet from January 11, 1911 for storage in Arrowrock Reservoir during flood water season only and thereafter

to be drawn out and used in irrigation of lands of the Boise Project and other lands entitled to same." (dated February 14, 1929).

By an enlargement at Arrowrock Reservoir, R.J. Newell for the U.S. Bureau of Reclamation filed Application No. R-25986, Permit No. R-652 for 15,000 acre feet of water with a priority date of June 25, 1938. This was to serve Federal project lands in Ada and Canyon counties, and was the first right identified in terms of annual storage amounts in a reservoir.

To cover the operations and development of Anderson Ranch Dam and Reservoir a filing was made for the U.S. Bureau of Reclamation as Application No. 26522, License No. R-698 for 493,161 acre feet for power and irrigation use. The priority date is December 9, 1940 and mentions a land acreage to be served of 275,766 acres, and a power plant of 324 ft. head and 20,000 KW capacity.

The last Federal filing was the U.S. Bureau of Reclamation filing for 307,000 acre feet of storage (278,200 usable capacity) in Lucky Peak Reservoir constructed by the U.S. Army Corps of Engineers. This was Application No. R-35086, Permit No. R-1183 with a priority date of April 12, 1963. This filing includes a provision for 50,000 acre feet of storage for the Idaho Fish and Game Department for maintaining minimum flows in the Boise River below Boise Diversion Dam for the benefit of the fishery.

Decreed Rights and Storage Allocations

To present a basis for analysis of patterns of water use and reservoir regulation a brief summary of decreed water rights and storage space allocations is presented. Table 10 lists all rights that apply to the Boise Project, including the rights which permit storage in the four reservoirs. Rights with a priority date after 1911 are not a part of the Stewart or Bryan decrees. The total of all rights for diversion to the Boise Project at Diversion Dam is 2904.58 cfs.

A complete summary of all decreed rights by canal from the Stewart and Bryan Decrees is presented in Table 11 identifying each canal and the total right.

The storage rights shown in Table 10 were obtained by the U.S. Bureau of Reclamation mainly for irrigation water supply. Contracts were then made between the USBR and various irrigation districts and canal companies for the stored water. These contracts are not water rights but do define the space allocations of water stored under the federal right. Space allocations in Anderson Ranch, Arrowrock, and Lucky Peak reservoir are shown in Tables 12, 13, and 14, respectively. Allocations are given in total acre-feet and percent of the total space. The accounting of these allocations during reservoir operations is discussed in the section, RESERVOIRS.

Administration

Surface water rights on the Boise River are administered by the Watermaster who acts under the authority of the Idaho Department of Water Administration (as of July 1, 1974, the Idaho Department of Water Resources). The Watermaster is responsible for the

Table 10. Water Rights of the Boise Project

Date of Priority	Point of Diversion	Amount
May 1, 1866	Diversion Dam	15.10 cfs
June 1, 1864 June 1, 1869	Diversion Dam	20.34 cfs
October 1, 1887	Diversion Dam	1.20 cfs
August 20, 1888	Diversion Dam	8.90 cfs
March 23, 1900	Diversion Dam	219.10 cfs
March 23, 1900	Diversion Dam	58.86 cfs
December 14, 1903	Diversion Dam	1,354.58 cfs
June 15, 1909	Diversion Dam	926.50 cfs
January 13, 1911	Arrowrock Reservoir	8,000.00 cfs
August 18, 1924	Diversion Dam 2/	300.00 cfs
June 25, 1938	Arrowrock Reservoir 2/	15,000 acre-feet
December 9, 1940	Anderson Ranch Reservoir 2/	493,161 acre-feet
April 12, 1963	Lucky Peak Reservoir 1/	307,000 acre-feet

1/ License pending upon proof of beneficial use on or before March 20, 1975.

2/ Licensed Rights, not included in the Stewart or Bryan Decrees.

Table 11. Summary of Stewart and Bryan Decree Filings by Canal

Name of Canal		Total Filing cfs
Andrew Ditch		23.50
Ballentyne		15.3526
Baxter		4.00
Boise City		36.3745
Boise Valley		55.78
Boone Ditch		12.70
Bowman & Swisher		9.38
Bubb (South Boise Mutual)		21.14
Caldwell Highline		79.20
Campbell (Canyon Ditch Company)		28.14
Canyon County		80.37
Davis (Little Davis)		13.94
Eagle Islands Canals		54.02
Aiken	5.20	
Conway & Hamming	5.70	
Graham & Gilbert	4.40	
Hart & Davis	9.96	
Lemp Ditch	6.00	
Mace & Catlin	10.92	
Mace & Mace	1.76	
Seven Suckers	1.28	
Warm Springs Slough	8.80	
Eureka No. 1		33.32
Eureka No. 2		50.00
Farmers Union		191.4995
Haas Ditch		17.34
Island High Line		20.00
Little Pioneer		26.82
Lower Center Point		19.60
Mammon		9.36
Meeves		1.80
Middleton Mill		64.562
Middleton Water		112.794
Miscellaneous		11.40
R.B. Betty	0.10	
Crawforth Pump	1.60	
Boise River	1.60	
Drainage District #4	1.04	
Manville-Leonard	3.50	
McCurry Pump	0.56	
Surprise Valley Farms	3.00	
New Dry Creek		62.0842
New Union		13.76
New York Main		2904.58 1/
Parma Ditch		12.76
Penitentiary		2.24
Phyllis		692.215
Pioneer Dixie		58.50
Ridenbaugh		535.14
Riverside		290.374
Roedel Ditch		3.20
Rossi Mill		10.00
Sebree (Farmers Co-op)		318.59
Settlers		186.443
Siebenberg		12.28
Thurman Mill		35.652
Upper Center Point		14.82
	Total	6145.0038

This data is taken from 1973, "Watermaster Report", Water Distribution of Boise River, District No. 63. Details on individual rights are identified in detail in that report.

1/ 300 cfs of New York Main Canal not decreed.

Table 12. Storage Allocations in Anderson Ranch Reservoir (1972 status)

Irrigation District or Company	Storage (Acre Feet)	Percent of Space
Boise-Kuna Irrigation District	112,149	26.83
New York Irrigation District	41,006	9.81
Wilder Irrigation District	125,108	29.93
Big Bend Irrigation District	3,887	9.93
Nampa-Meridian	77,784	18.61
Total of Boise Board of Control	359,934	
Ridenbaugh	15,137	3.62
Pioneer Irrigation District	25,582	6.12
Farmers Union Ditch Company	5,727	1.37
New Dry Creek Ditch Company	1,296	0.31
Settlers Irrigation District	5,810	1.39
Boise Valley Irrigation Ditch Company	961	0.23
South Boise Mutual Irrigation Company	543	0.13
Ballentyne Ditch Company	376	0.09
Capitol View Irrigation Company	460	0.11
Pioneer Ditch Company	2,174	0.52
Subtotal	418,000	100.00
Power	5,200	
	423,200	

Data from Musselman, D.L., 1972. Water Distribution of Boise River, District No. 63.

Table 13. Storage Allocations in Arrowrock Reservoir (1972 status)

Irrigation District or Company	Storage (Acre Feet)	Percent of Space
Boise Project Board of Control	177,816	62.01
Nampa & Meridian	55,055	19.25
Pioneer Irrigation District	21,019	7.33
Farmers Union Ditch Company	2,874	1.00
Settlers Irrigation District	1,778	0.62
Farmers Co-op Canal Company	1,227	0.428
Ridenbaugh Canal Company	3,832	2.337
Hillcrest	23,000	8.02
	286,600	99.998

Data from Musselman, D.L., 1972. Water Distribution of Boise River, District No. 63.

Table 14. Storage Allocations in Lucky Peak Reservoir (1972).

District or Company	Storage (Acre Feet)	Percent of Space
Ballentyne	1300	0.467
Boise City	1000	0.360
Boise Valley	2500	0.899
Bubb (South Boise Mutual)	500	0.180
Canyon County	6000	2.157
Capitol View Irrigation District	300	0.108
Davis Ditch (Garden City)	1500	0.539
Eagle Island Water Co.	7650	2.750
Eureka Water Co. #1	2800	1.006
Farmers Union	10000	3.595
Little Pioneer	500	0.180
Middleton Irrigation Association	6380	2.293
Middleton Mill	4620	1.661
New Dry Creek	3000	1.078
New Union	1400	0.503
Phyllis (Pioneer Irr. District)	16000	5.751
Ridenbaugh	35000	12.580
Rossi Mill	700	0.252
Settlers	10000	3.595
Thurman Mill	800	0.288
Idaho Fish & Game	50000	17.972
Uncontracted Space	116250	41.786
Total	278200	100.000

Data from Musselman, D.L., 1972. Water Distribution of Boise River, District No. 63.

measurement and distribution of water according to all decreed and licensed rights.

Diversion rights to canals are valid only during the April 1 to October 15 irrigation season, while rights for on or off stream storage are valid the entire year. The Watermaster makes a daily calculation of the natural flow below Lucky Peak Dam using the equation described in RUNOFF. As soon after April 1 as the natural flow becomes less than the demand, strict regulation of decreed rights begins. Until such time as both conditions are met, canals are allowed to divert in excess of their right.

The regulation begins by stopping all diversions that do not have a decreed water right, and by notifying all canals that they must not divert natural flow in excess of their decreed right (see Table 11). If the natural flow is then not great enough to satisfy all rights, the sliding scale method previously mentioned in conjunction with the Stewart Decree is used to apportion the flow. The rights of the Bryan Decree are reduced to 75 percent in order or priority date, the latest being reduced first. Subsequently, these rights are reduced to 60 percent and then to zero. After all diversions having rights under the Bryan Decree have been shut off, the same 75-60-0 percent reduction is applied to rights under the Stewart Decree. Each day during the irrigation season this procedure is used to equate natural flow diversions to the natural flow.

When it is determined that a canal must reduce its diversion of natural flow, the actual diversion is usually not reduced. The canal can charge the amount of the reduction to a storage water allocation, or if the canal does not have storage, water can usually be purchased from the unallocated space in Lucky Peak Reservoir. However, in years of very short water supply, diversions would be reduced.

Return flow is used to meet the rights of most of the canals below Caldwell. For this reason it is usually not necessary to reduce these diversions in sequence with the diversions above Caldwell, nor to supply them from natural flow originating above Lucky Peak Dam. As compared to the total of all rights, 6145 cfs, the amount required from above Lucky Peak Dam (Figure 1) to satisfy all rights below the dam is about 5600 cfs.

Ground Water Rights and Recent Filings

In the past decade there has been active interest on the part of private water users in the development of additional lands for irrigation both within the project area and in adjacent arid land areas. This has been accomplished in a large part by ground water pumping. There are also sizeable irrigation developments in the Dry Lake area to the south of Lake Lowell that are being served by high-lift pumping from the Snake River. Further information will be presented on this aspect of recent development in the section entitled BOISE VALLEY GROUND WATER.

A complete record of recent ground water filings is difficult to summarize due to the mix of domestic water filings and the fact that many filings are still pending. However, to give some indi-

Table 15. Extract of Information on Ground Water Rights Applications and Reported Wells Drilled in Boise River Basin

Year	Applications	Total cfs Applied for	Wells Reported Drilled
1968	101	232	363
1969	80	103	305
1970	78	88	409
1971	133	257	641

IRRIGATION

The location and names of major canals are indicated on Figure 10 - foldout. A more detailed map of this group of canals is available from the Boise River Watermaster. The total capacity of canals diverting water from the Boise River is approximately 6700 cfs. More detail of canals, diversion locations and major surface drains is shown on the schematic diagram, Figure 11.

The irrigation system in the Boise Valley can be divided into three general subsystems. The largest area is the Federal Project lands served mainly by diversion from the Main (New York) Canal. This canal diverts water from the Boise River at Diversion Dam to irrigate lands south of the river. More specifically, the area served by the Main (New York) Canal extends south from the Boise River to the Snake River and west past Lake Lowell to lands in the Big Bend area on the Oregon border. The distribution of water to these lands is complex and involves the superposition of reservoir storage on numerous older decreed rights. This portion of Boise Project lands is administered by the Boise Board of Control.

The second general category of the irrigation system comprises those lands north of the Boise River and south from Diversion Dam to the Snake River. These irrigated areas are included in older irrigation districts which divert from the river and which have not participated in the federally supported projects.

The northwest portion of the valley is irrigated with water diverted from the Payette River. This transbasin diversion is part of the Payette Division of the Boise Project and is administered by the Black Canyon Irrigation District.

A small amount of water from the South Fork of the Boise River is also diverted into the Little Camas Canal and transported out of the Boise basin to the Mountain Home Irrigation District in Elmore County. The capacity of this canal is listed as 90 cfs.

Boise Project Board of Control System

The Boise Board of Control lands and irrigation system are administered under the five separate districts indicated below:

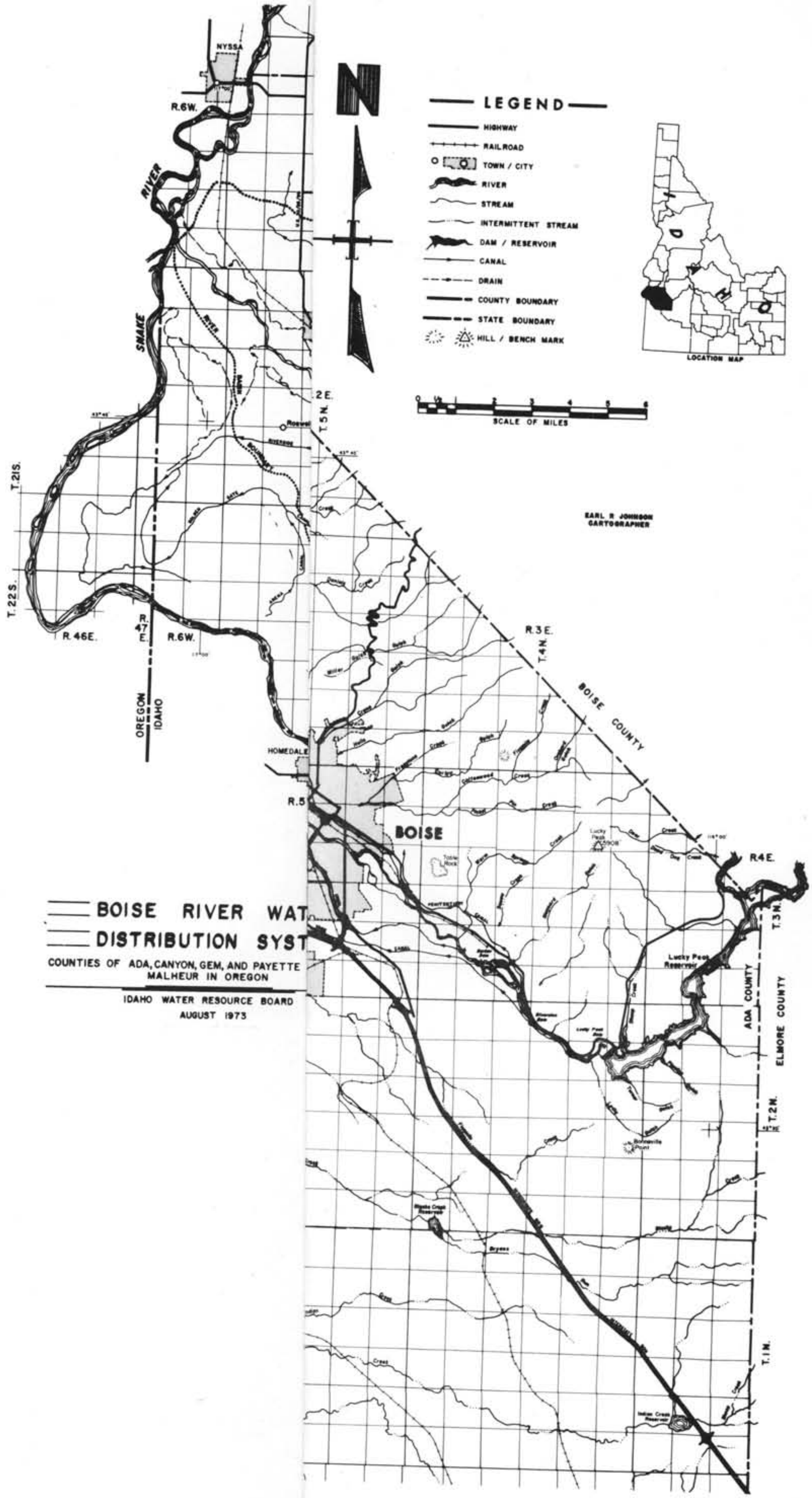
1. New York Irrigation District
   17,611 acres
   Operates north of the New York Canal extending northwesterly through T2 and 3N; R1W and R1, 2 and 3E covering lands formerly affected by the Old New York Canal Company. Headquarters at Boise, Idaho.

2. Boise - Kuna Irrigation District
   48,628 acres
   Operates between Diversion Dam and Richards Point wasteway in Sec. 12, T2N, R2W and Deer-Flat-Nampa Canal, headquarters at Kuna, Idaho.

3. Nampa & Meridian Irrigation District
   27,000 acres of decreed water rights lands and
   40,343 acres of government water rights lands
   Operates lands below the Ridenbaugh Canal, headquarters at Nampa, Idaho.

4. Wilder Irrigation District
   56,538 acres
   Operates to the west of the Kuna District and to the east of the Oregon state line, headquarters at Caldwell, Idaho.

5. Big Bend Irrigation District
   1,724 acres
   Operates in the State of Oregon inside the bend of the Snake River, Headquarters at Parma, Idaho.


NYSSA
R.6W.
SNAKE
RIVER
2E.
T.5N.
T.21S.
T.22S.
R.46E.
R.47E.
R.6W.
OREGON
IDAHO
HOMEDALE
R.5
BOISE
R.3E.
T.4N.
BOISE COUNTY
R4E.
T.3N.
Lucky Peak Reservoir
ADA COUNTY
ELMORE COUNTY
T.2N.
T.1N.
LEGEND
HIGHWAY
RAILROAD
TOWN / CITY
RIVER
STREAM
INTERMITTENT STREAM
DAM / RESERVOIR
CANAL
DRAIN
COUNTY BOUNDARY
STATE BOUNDARY
HILL / BENCH MARK
LOCATION MAP
SCALE OF MILES
EARL R JOHNSON
CARTOGRAPHER
BOISE RIVER WAT
DISTRIBUTION SYST
COUNTIES OF ADA, CANYON, GEM, AND PAYETTE
MALHEUR IN OREGON
IDAHO WATER RESOURCE BOARD
AUGUST 1973

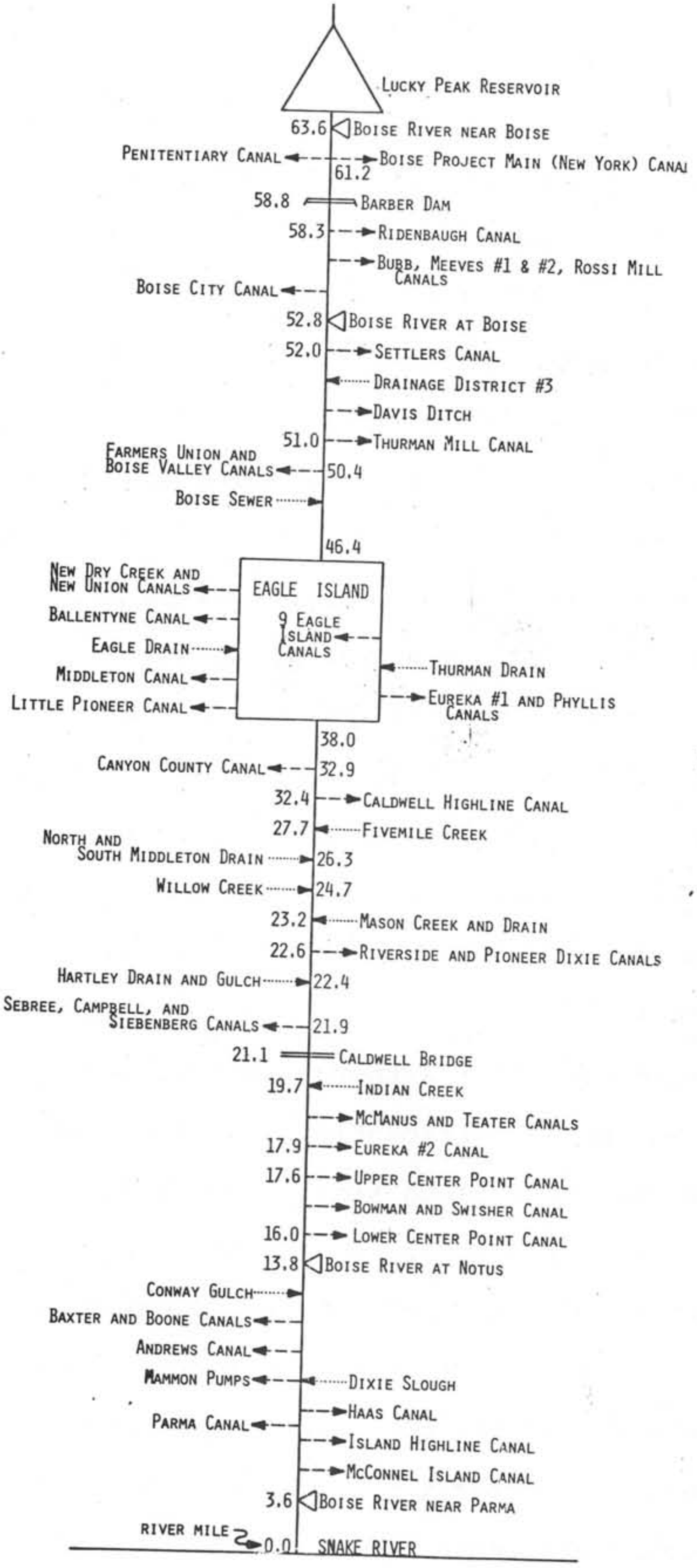


FIGURE 11. BOISE RIVER DIVERSIONS AND DRAINS

A more detailed description of the Boise Project Board of Control system is presented in Table 16 which lists acreages according to upper and lower system by watermaster division. The upper system, 116,263 acres, includes the area served directly from Boise River, mostly by the Main (New York) and Ridenbaugh canals. The lower systems, 50,623 acres, includes the area that receives water after it has first been stored in Lake Lowell. Water is distributed to Boise Project land by four Board of Control watermaster divisions plus the Nampa-Meridian and Settlers irrigation districts. A finer breakdown of acreages in the major districts is being prepared for use in a ground water model.

The diversions to the Boise Board of Control lands are made through the Main (New York), the Ridenbaugh, Penitentiary, and the Settlers canals. Table 17 gives the month by month irrigation diversions for a dry year, near average year and wet year for the Boise Project Board of Control lands from the Boise River. The reader should note that although 1960-61 was a dry year, the total diversion was not significantly lower than average.

The Boise Board of Control computes delivery in acre-foot per acre each year for both the upper and lower systems. An average of these irrigation deliveries has been plotted in Figure 12. Water delivery has varied over time with a definite trend toward increased per acre use during the earlier years. Apparently there were shortages in many of the early years. An indication of when additional storage became available has been marked on the grpah. This appears to have some influence for each time period. In the case of the

Table 16. Classification of Boise Project Board of Control Land by Irrigation District and Watermaster Division in Acres (1971 Status)

District	System	Division 2	Division 3	Division 4	Division 5	Nampa and Meridian	Settlers	Total
New York	Upper	16,131	923			557		17,611
Boise-Kuna	Upper	11,932	36,139	74		348	136	48,629
Nampa-Meridian	Upper	5,692	3,564	2,175		24,292		35,723
	Lower			2,175		2,446		4,621
Wilder	Upper		79	13,132				13,211
	Lower			14,144	29,184			43,328
Big Bend	Lower				1,724			1,724
Settlers	Upper					98	420	518
Pioneer	Lower			42				42
Ridenbaugh	Upper	193	4	32				229
	Lower			104		680		784
Other	Upper	106	22	10		204		342
	Lower			107	17			124
Sub-totals	Upper	34,054	40,731	15,423		25,499	556	116,263
	Lower			16,572	30,925	3,126		50,623
Total		34,054	40,731	31,995	30,925	28,625	556	166,886

Table 17. Summary of Irrigation Diversion to Boise Project Board of Control System for Dry, Average and Wet Years. (Acre-Feet)

	March	April	May	June	July	Aug.	Sept.	Oct.	Total
1960-61 Dry Year									
New York Main Canal	35,500	100,446	168,214	151,130	146,920	133,442	73,064	-	808,716
Penitentiary Canal		160	572	528	612	366	242	-	2,480
Ridenbaugh Canal		0	0	1,120	12,590	17,816	194	-	31,720
Settlers Canal		278	320						598
Totals	35,500	100,884	169,106	152,778	160,122	151,624	73,500	-	843,504
1969-70 Average Year									
New York Main Canal	4,272	87,444	158,680	155,654	163,652	159,018	111,662	49,492	889,311
Penitentiary Canal		46	463	434	492	517	357	60	2,369
Ridenbaugh Canal							1,909		1,909
Settlers Canal		85	481	447	489	508	299	93	2,402
Totals	4,272	87,575	159,624	156,535	164,633	160,043	114,227	49,645	895,991
1970-71 Wet Year									
New York Main Canal	-	85,980	176,686	164,784	171,516	171,026	127,722	52,618	950,332
Penitentiary Canal		0	528	495	526	594	423	210	2,776
Ridenbaugh Canal		-	-	-	192	3,988	4,026	-	8,206
Settlers Canal		41	525	476	488	491	344	79	2,444
Totals		86,021	177,739	165,755	172,722	176,099	132,515	52,907	963,758

1960-61 dry year it is observed that water use was below the average rate but subsequent to that use rates have been maintained very close to the long-time average. The same total acreage figures have been used for many years to determine acre-foot per acre water use even though some lands have been taken out of irrigation. However, it is also evident that new lands within the project have been irrigated. A detailed survey of actual irrigated land would be of great value in assessing water use and water control.

Total yearly diversions to the Main (New York) canal is presented in the bar graph on Figure 13. These are actual river diversions as distinguished from irrigation deliveries. This record of river diversions shows a stabilization in the amount of water diverted in the later years.

Non-Federal Irrigation Districts and Canal Companies

The non-federal irrigation districts and canal companies involve many diversions from the river at various points beginning just below Diversion Dam. Water use on the non-federal system is much less well documented than for the Boise Project Board of Control system. Table 18 presents a summary of the reported diversions to each canal as computed by the Boise River Watermaster for the year 1972. A marked variation in the amount of water diverted per acre of irrigated land is evident. It also indicates a much higher diversion rate to non-federal lands than to those supervised by the Boise Project Board of Control.

To illustrate how these diversions have varied, a study was

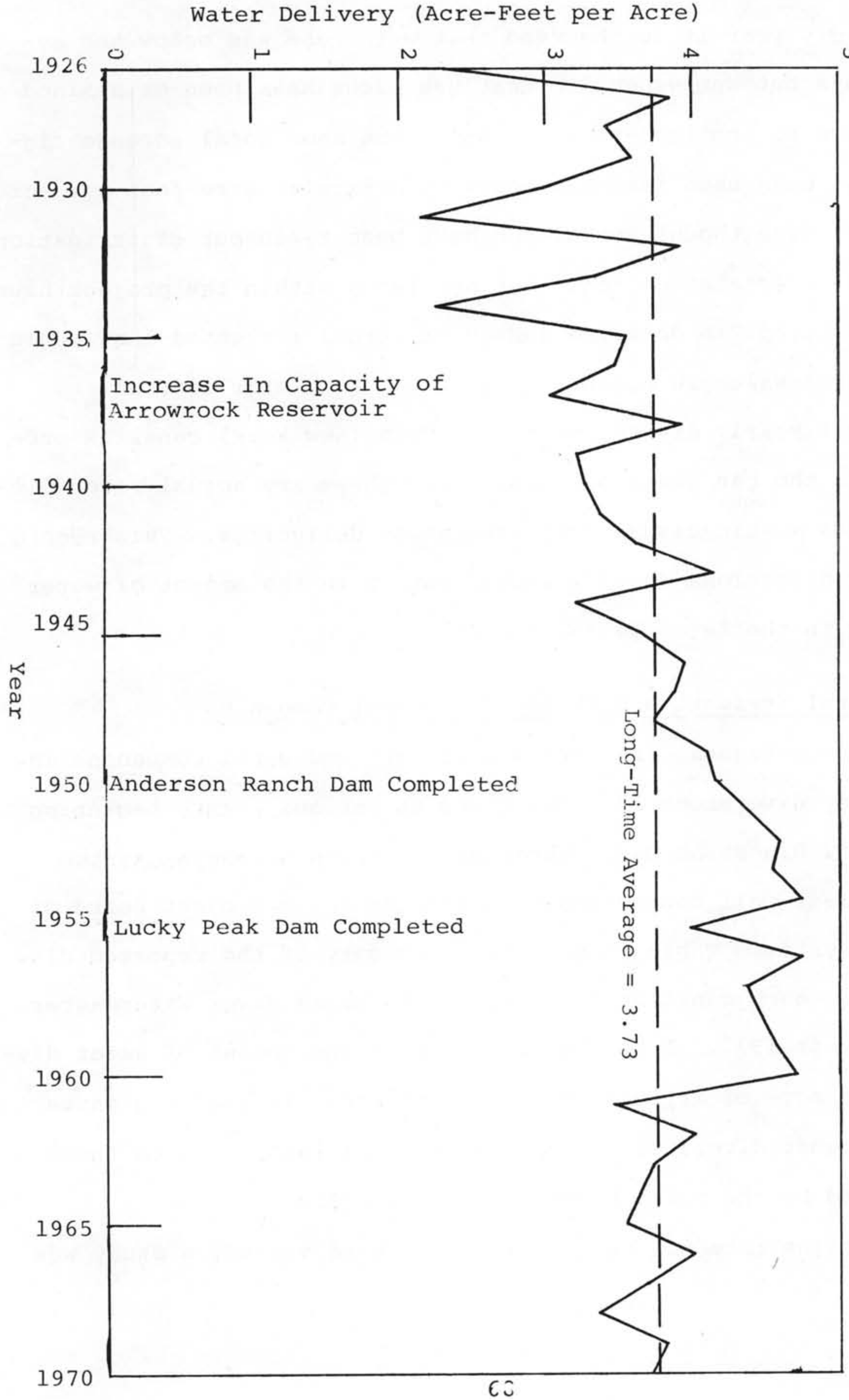


FIGURE 12. LONG-TIME RECORD OF AVERAGE IRRIGATION DELIVERY OF WATER TO BOISE PROJECT BOARD OF CONTROL LANDS

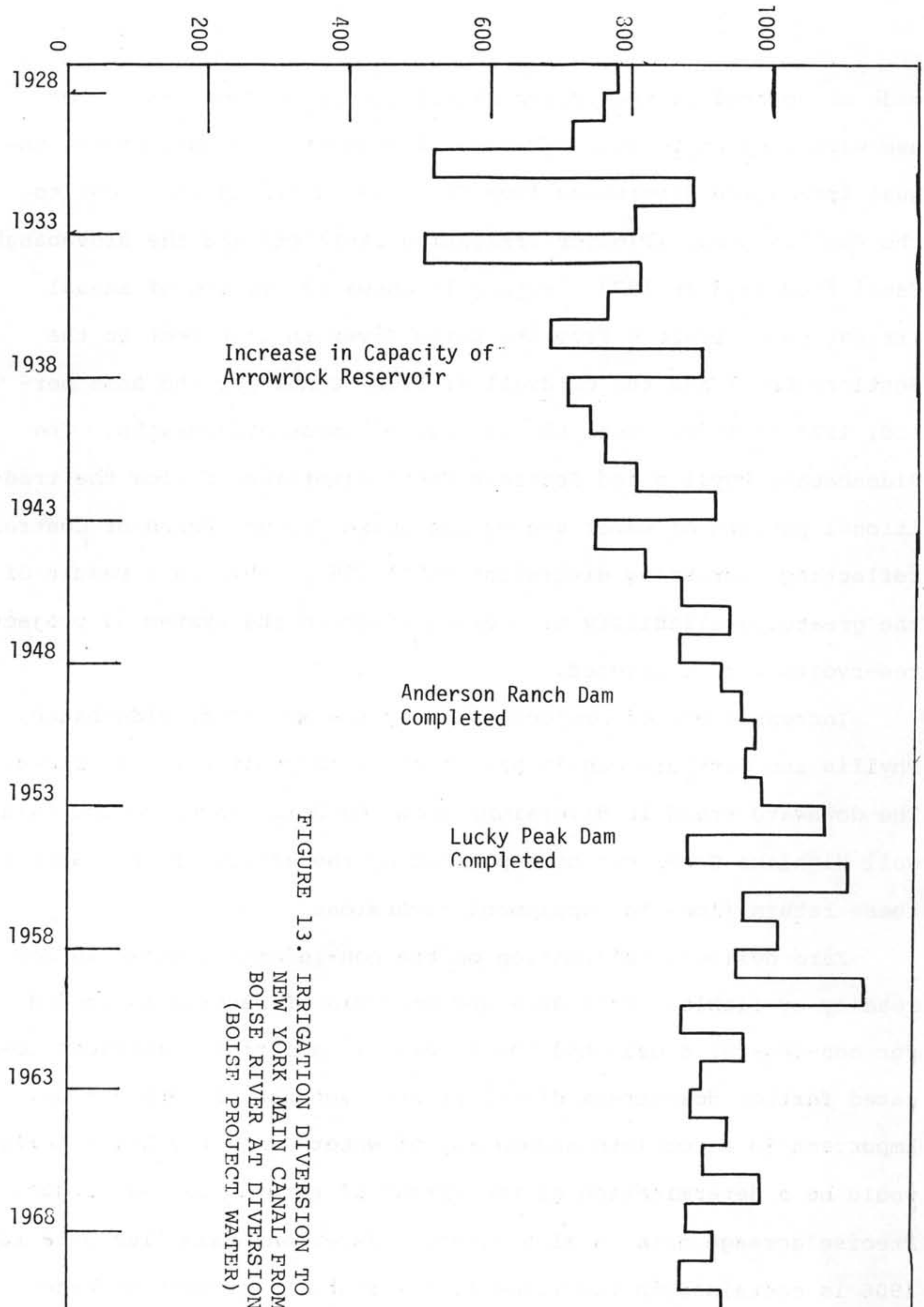


FIGURE 13. IRRIGATION DIVERSION TO THE NEW YORK MAIN CANAL FROM THE BOISE RIVER AT DIVERSION DAM (BOISE PROJECT WATER)

made of several of the larger canals to define some pattern of use with respect to time. Figure 14 presents a record of the annual irrigation diversions from the Boise River in acre feet to the Phyllis Canal (Pioneer Irrigation District) and the Ridenbaugh Canal from 1928 to 1972. Figure 15 shows the record of annual irrigation diversions from the Boise River in acre feet to the Settlers Canal and the Caldwell Highline Canal for the same period, 1928 to 1972. Note the pattern of these hydrographs. The Ridenbaugh, Phyllis and Settlers Canal diversions follow the traditional pattern of water use by the Boise Project Board of Control; reflecting increasing diversions until 1955. This is a result of the greater availability of storage water in the system as projected reservoirs were completed.

Increased use of project water by the New York, Ridenbaugh, Phyllis and Settlers canals has resulted in greater return flows. The downward trend in diversions from the Boise River to the Caldwell Highline Canal can be explained by the effect of the reuse of these return flows to supplement diversions.

Farm delivery information on the non-federal systems is not readily available. More data and analysis of records is needed for non-federal canals and the lands. In addition, districts located farther downstream divert greater amounts of return flow. Important in a complete accounting of water use in the Boise Valley would be a determination of the extent of return flow water use. Precise acreage data is also needed. Excellent base line data for 1906 is contained in the files of the Idaho Department of Water Resources.

Table 18. Diversion Rates from Boise River of Non-Federal Canals in Downstream Order[1/]

Reach of River	Canal Name	Acreage	1972 Diversion Rate Ac-Ft/Ac
Lucky Peak Dam to Boise	Ridenbaugh	26,877	6.77
	Bubb	1,057	3.50
	Meeves #1 & #2	99	10.02
	Rossi Mill	500	6.68
	Boise City	1,828	6.80
Boise to Star	Settlers	12,282	4.38
	Davis Ditch	634	6.27
	Thurman Mill	1,799	5.90
	Farmers Union & Boise Valley	11,629	6.55
	New Dry Creek & New Union	3,747	5.77
	Ballentyne	763	8.01
	9 Eagle Island Canals	2,628	4.35
	Middleton	9,580	5.68
	Phyllis & Eureka #1	26,162	5.41
	Little Pioneer	1,286	10.43
	Canyon County	4,007	6.69
	Caldwell Highline	13,960	4.13
Star to Notus	Riverside & Pioneer Dixie	13,645	6.85
	Sebree	15,500	6.22
	Campbell	802	16.01
	Siebenberg	646	6.10
	McManus & Teater	168	8.48
	Eureka #2	2,625	15.04
	Upper Center Point	641	9.57
	Bowman & Swisher	424	6.97
	Lower Center Point	880	12.09
Notus to Parma	Baxter	200	22.30
	Boone	517	0
	Andrews	1,068	7.38
	Mammon	468	3.85
	Haas	867	4.79
	Parma	602	14.00
	Island Highline	945	14.20
	McConnel Island	1,600	8.08
	Miscellaneous	763	29.10
Total		161,199	5.96

1/ From Musselman (1972), Water Distribution of Boise River. Acres are an estimate only, not a detailed survey.

FIGURE 14. IRRIGATION DIVERSION TO PHYLLIS CANAL (PIONEER IRRIGATION DISTRICT) AND RIDENBAUGH CANAL FROM BOISE RIVER

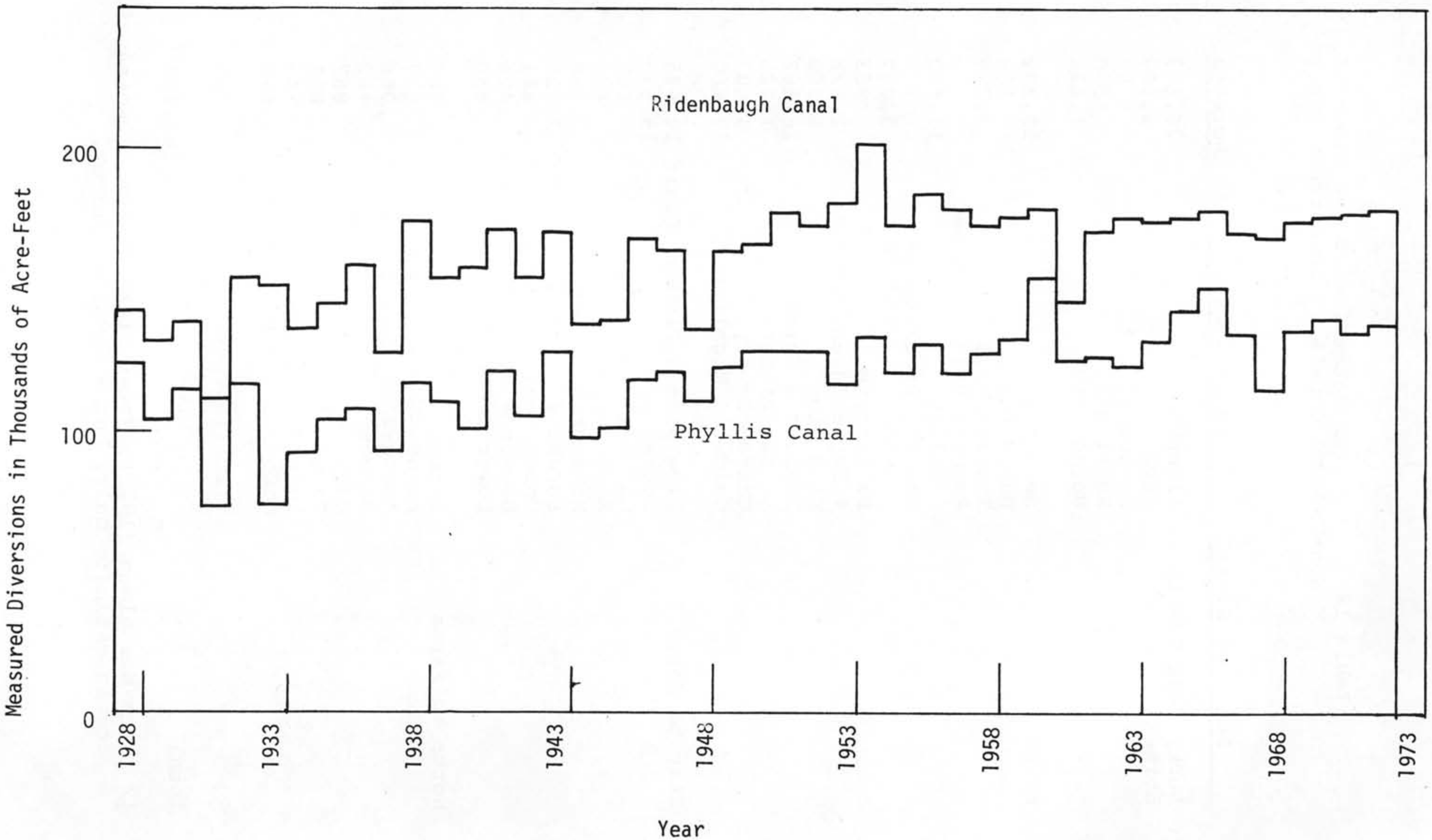
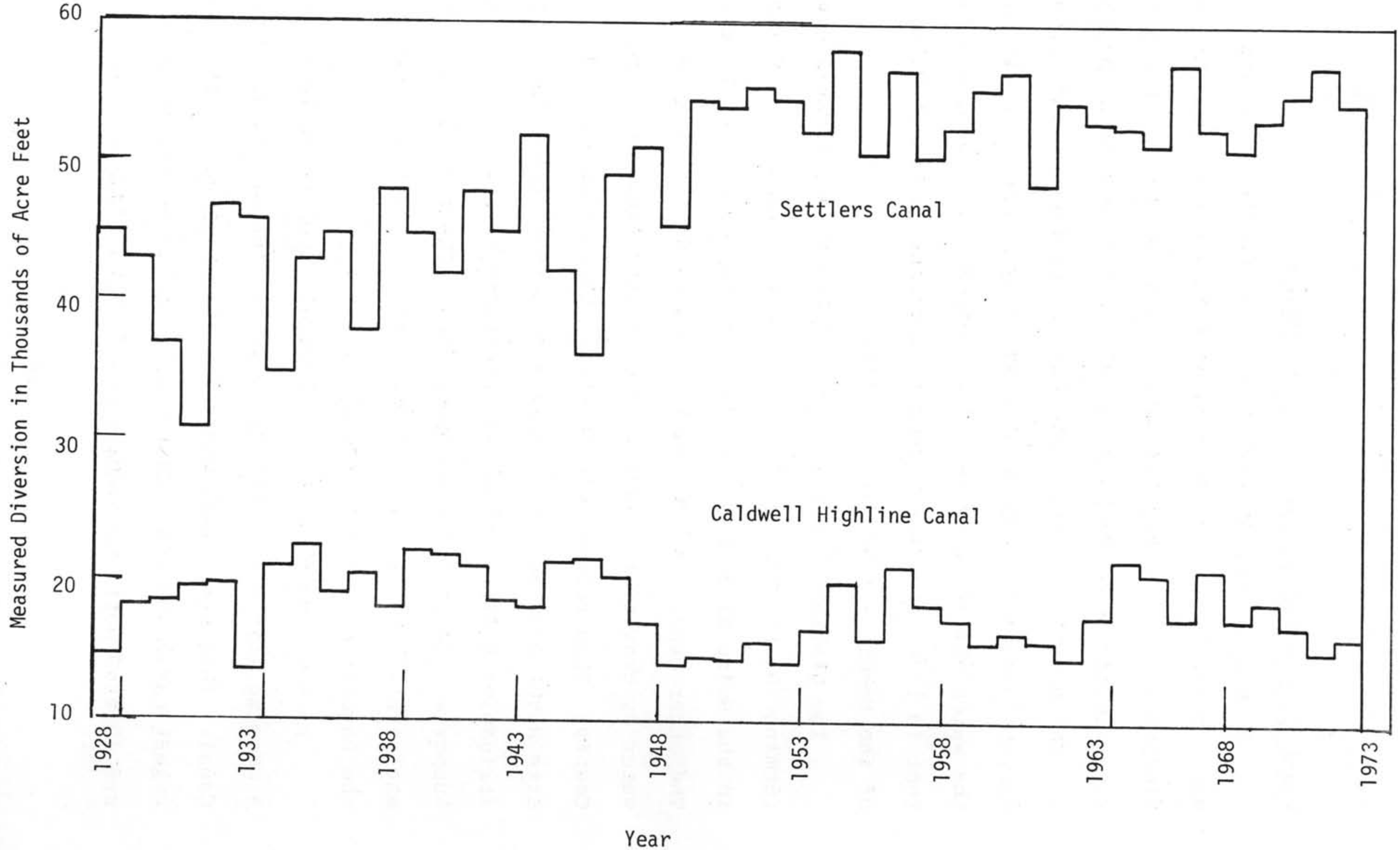


FIGURE 15. IRRIGATION DIVERSIONS TO THE SETTLERS CANAL AND CALDWELL HIGHLINE CANAL FROM BOISE RIVER



Black Canyon Irrigation District System

This district, located in the northwestern portion of the Boise River basin, includes canal system served by a transbasin diversion from the Payette River. This portion of the Boise River water development was planned and built as a federal project under the Reclamation Act. The main water supply comes from the Black Canyon Canal which begins at Black Canyon Dam. A small portion of the water delivered by the Black Canyon Canal (about 15,790 acre feet in 1971) is water pumped from drains in Emmett Valley, part of the Emmett Irrigation District.

The gravity supply line of the Black Canyon Canal divides, one forming the D-Line and the H-Line canals, which supply lands within the Boise River basin north of Notus and east of Parma, Idaho. The other branch of the Black Canyon Canal, the A-Line, supplies water by gravity to lands in the Payette River drainage in Payette County. This report does not treat this system located in the Payette River drainage, but it is administered under the Black Canyon Irrigation District which was organized as a part of the federally supported irrigation development under the Reclamation Act. The entire Black Canyon Irrigation District is often referred to as the Payette Division of the Boise Project.

Part of the Black Canyon Irrigation District is supplied by a pumping lift with a 500 cfs capacity out of the Black Canyon Canal. This pump canal divides at the pumping outlet into the C-East Canal and the C-West Canal. Lands served by these canals are located north of Middleton and Notus, Idaho. These canals are indicated to a limited extent on Figure 10. Detailed maps are available in the Central Snake Project Office of the U.S. Bureau of Reclamation at 214 Broadway Avenue, Boise, Idaho.

Another element of the Black Canyon Irrigation District system is the Notus Canal which serves the area paralleling the Boise River above the Sebree (Farmers Cooperative) Canal. The Notus Canal receives water by way of a siphon under the Boise River from the Wilson and Elijah drains. At times, the Boise Board of Control supplies the Notus Canal with small amounts of storage water from Lake Lowell Reservoir. The area served by the Notus Canal is known as the Notus First Unit of the Payette Division of the Boise Project. The Notus Canal has four separate wasteways or overflow spillways. These are Conway Gulch Wasteway, Emergency Spillway, Sand Hollow Wasteway and End Wasteway.

Acreages served by the principal canals of the Black Canyon Irrigation District in the Boise River basin are presented in Table 19. Descriptions of the principal drains and wasteways of the Black Canyon Irrigation District is presented in the IRRIGATION RETURN FLOW section.

Monthly diversion data are presented in Table 20 for 1961 (Dry Year), 1970 (Average Year) and 1971 (Wet Year) for the three Boise Valley canal systems within the Black Canyon Irrigation District that receive Payette River water. Also given in Table 20 is the acre feet per acre diversion by the respective canals.

Table 21 gives similar data for on-farm deliveries. Note there is only a small difference in the rate of use among the 3

Table 19. Acreages Served by Black Canyon Irrigation District Canals within the Boise River Basin

Canal	Acres Served
H-Line Canal	250
D-Line Canal	13,086
C-West Canal	3,221
C-East Canal	21,235
Black Canyon Canal Total	37,792*
Notus Canal	6,910

* This does not include 13,363 acres of land served in the Payette Drainage by the A-Line Canal, 837 acres of lands of the Black Canyon Irrigation District diverting directly out of the Black Canyon Canal in the Payette Drainage known as BC ID Takeouts, and portions of 5,200 acres of the Emmett Irrigation District lands north of the Payette River.

example years. However, during the dry year the difference between the average per acre diversion and average per acre farm delivery indicates than an increase in efficiency was attained in the conveyance system. Table 22 lists farm deliveries from the Notus Canal for the same representative years. Water used on the Notus Unit is mainly drain water from lower Boise Project Board of Control land. However, it is sometimes supplemented by a small amount of storage from Lake Lowell.

Comparison of the above data with Figure 12 indicates that farm deliveries per acre on the Black Canyon Irrigation District lands are about 1.0 acre foot per acre more than the farm deliveries on the Boise Project Board of Control land. The difference in water use rates may be the result of the sandy soils and rough topography of the Black Canyon Irrigation District. A detailed analysis was not made to identify any particular reason for the difference in water use rates.

Excellent records of diversions, farm deliveries, wasteway runoff, and canal losses are available in the office of the Black Canyon Irrigation District at Notus. This data is also made available in the office of the Idaho Water Resource Board. These records, which have been kept since the beginning of the project would be very useful in a detailed analysis of water use efficiency.

<u>Little Camas Canal System</u>

The diversion through the Little Camas Canal from the Boise

Table 20. Irrigation Diversions to Principal Canals of the Black Canyon Irrigation District of the Boise River Drainage. Diversions are in Acre-Feet.

Name of Canal	April	May	June	July	Aug	Sept	Oct	Totals	Ac Ft/Acre Diversion per acre
1961 (Dry Year)									
D- & H-Line Canals	6,274	17,347	16,552	17,190	17,192	11,484	2,900	89,410	6.68
C-West Canal	1,770	4,452	4,756	5,020	5,008	2,640	706	24,352	7.55
C-East Canal	10,032	27,146	25,840	27,632	27,098	16,116	4,162	138,026	6.51
Totals	18,076	48,945	47,148	49,842	49,298	30,240	7,858	251,788	6.66
1970 (Average Year)									
D- & H-Line Canals	5,662	15,608	16,020	18,160	18,215	9,985	2,755	86,405	6.44
C-West Canal	1,492	4,925	4,392	4,426	4,293	2,439	558	22,525	6.97
C-East Canal	9,096	28,340	25,666	29,806	30,078	16,145	3,659	142,790	6.72
Totals	16,250	48,873	46,078	52,392	52,586	28,569	6,972	251,720	6.65
1971 (Wet Year)									
D- & H-Line Canals	4,290	17,164	16,024	17,761	16,953	12,045	2,408	86,645	6.50
C-West Canal	1,402	4,746	4,340	4,721	4,549	3,723	646	24,127	7.49
C-East Canal	6,585	29,132	27,472	29,396	29,806	19,558	3,506	145,455	6.85
Totals	12,277	51,042	47,836	51,878	51,308	35,326	6,560	256,227	6.80

Data taken from office tabulations of measurements made by the Black Canyon Irrigation District, Notus, Idaho.

Table 21. Irrigation Farm Deliveries from Principal Canals of the Black Canyon Irrigation District in the Boise River Drainage. Diversions are in Acre-Feet.

Name of Canal	April	May	June	July	Aug	Sept	Oct	Totals	Ac Ft/Acre Delivery per acre
1961 (Dry Year)									
D- & H-Line Canal	3,573	13,508	12,839	13,699	13,813	7,876	2,307	67,615	5.07
C-West Canal	1,064	3,471	3,097	3,514	3,660	2,515	595	17,916	5.56
C-East Canal	5,854	21,852	20,479	23,152	22,626	11,725	2,307	107,995	5.07
Totals	10,491	38,831	36,415	40,365	40,099	22,116	5,209	193,526	5.13
1970 (Average Year)									
D- & H-Line Canal	2,784	11,261	11,299	13,363	13,934	6,419	891	59,951	4.48
C-West Canal	592	3,893	3,347	3,642	3,664	1,516	151	16,805	5.25
C-East Canal	3,656	19,983	18,323	22,464	23,873	11,165	1,833	101,297	4.78
Totals	7,032	35,137	32,969	39,469	41,471	19,100	2,875	178,053	4,73
1971 (Wet Year)									
A- & H-Line Canal	2,030	12,376	11,892	14,056	13,300	8,576	768	62,998	4.72
C-West Canal	566	3,767	3,226	3,668	3,635	2,677	260	17,799	5.54
C-East Canal	2,256	21,886	20,117	22,735	23,399	13,555	1,411	105,359	4.94
Totals	4,852	38,209	35,235	40,459	40,334	24,808	2,439	186,336	4.94

Table 22. Irrigation Farm Delivery from Notus Canal
(1000 Acre-Feet)

Year	April	May	June	July	Aug	Sept	Oct	Total	Acre-Feet per Acre
1961 (Dry Year)	2,013	7,296	8,014	8,929	8,534	5,859	746	41,391	5.99
1970 (Average Year)	1,520	4,911	6,447	7,159	7,121	3,429	374	30,961	4.48
1971 (Wet Year)	1,272	5,064	5,857	7,536	7,945	4,330	336	32,340	4.68

River drainage is not a part of the federally funded irrigation development of the Boise Project. The water is used by the Mountain Home Irrigation District which is not within the Boise River drainage. The pattern of use is reasonably uniform and averages 10,500 acre feet per year. Figure 16 is a hydrograph of average monthly diversion to the Mountain Home Irrigation District through the Little Camas Canal. Records of these diversions are published in the U.S. Geological Survey Water Supply papers for Idaho. Computed natural flows of the Boise River usually do not reflect this small diversion.

Summary of Total System Diversions

Figure 17 gives a comparison of the total annual diversions from the Boise River above Notus with the natural flow runoff from 1915 to 1972. For several years total diversions actually exceeded runoff because of carry over storage and use of return flows.

Other Systems

In recent years, private irrigation developments are playing an increasing role both within and adjacent to the Boise River drainage. Recent (1972) soil survey data indicate that approximately 17,500 acres of land within the Boise River Drainage located along the benches and slopes tributary to the Snake River are now irrigated with water pumped from the Snake River. Most of these developments have occurred since 1960. Also, recent ground water developments for irrigation on lands within the Boise River drainage comprises over 34,000 acres. Little data exists on the water use of these projects. Any future studies should consider the problems associated with the impact of this new land development on that area previously developed under Federal Reclamation Law.

FIGURE 16. HYDROGRAPH OF AVERAGE MONTHLY INTERBASIN DIVERSION FROM SOUTH FORK OF BOISE RIVER TO LITTLE CAMAS CANAL IN ACRE FEET (PERIOD 1917, 1924-1970)

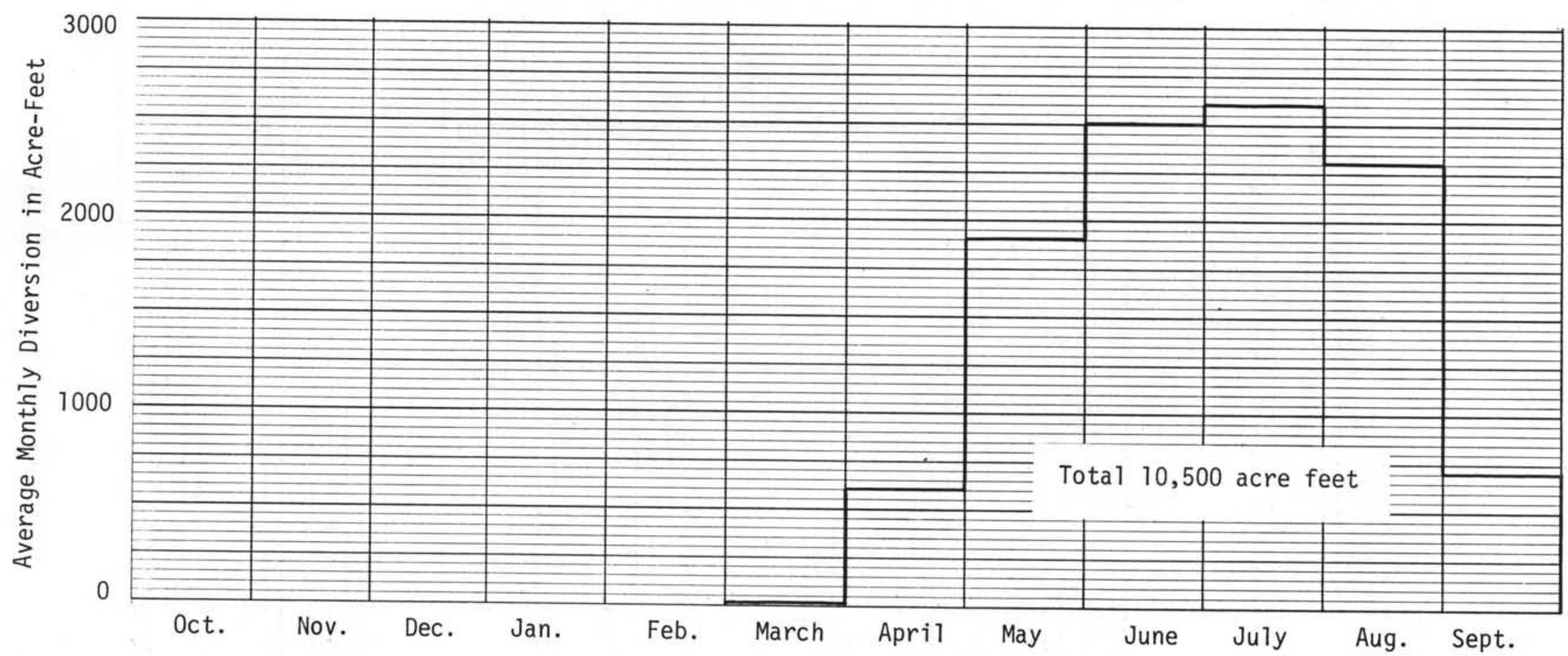
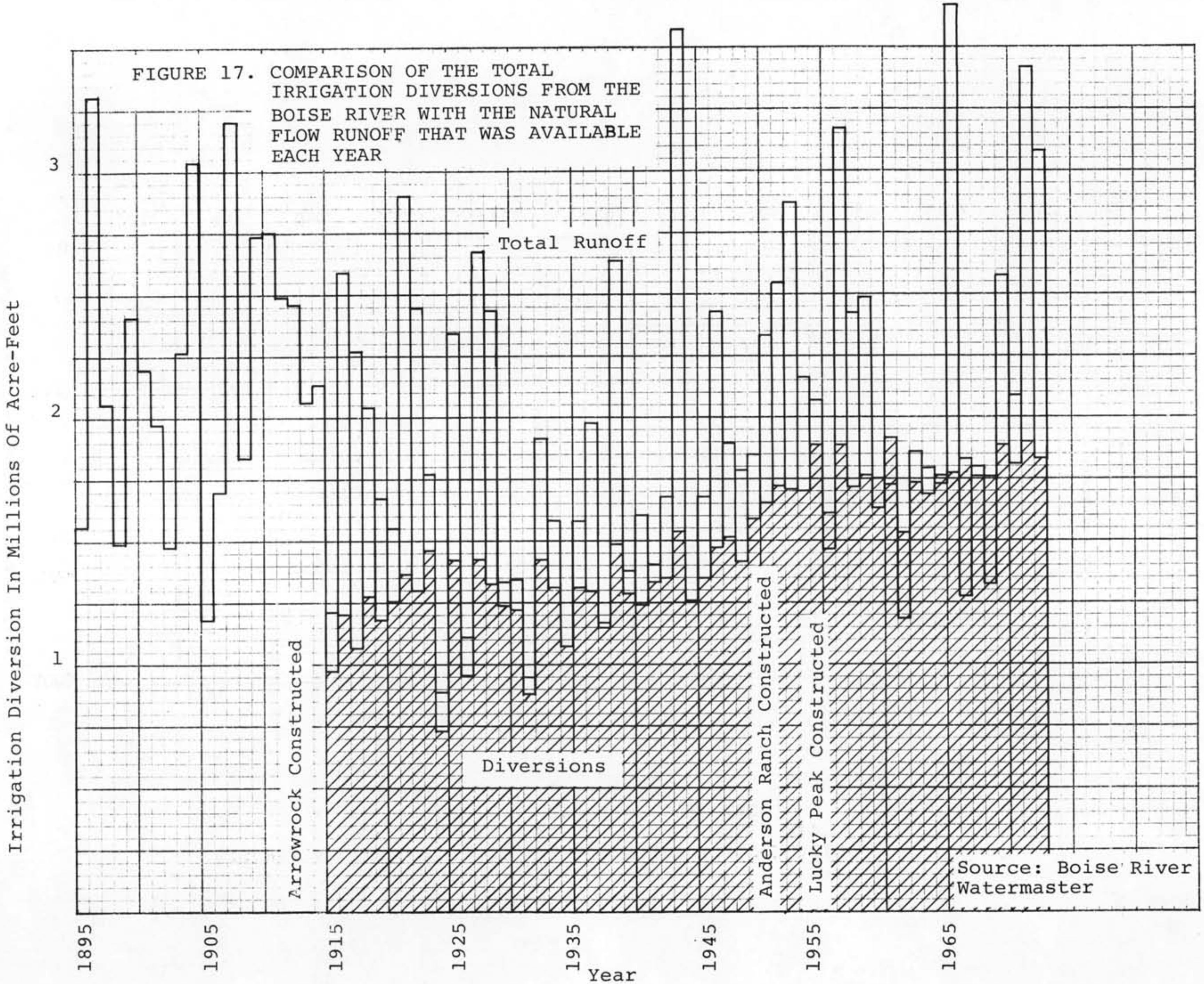


FIGURE 17. COMPARISON OF THE TOTAL IRRIGATION DIVERSIONS FROM THE BOISE RIVER WITH THE NATURAL FLOW RUNOFF THAT WAS AVAILABLE EACH YEAR



IRRIGATION RETURN FLOWS

Return flows from irrigation diversions are a significant factor in the operation and character of the Boise River. During the irrigation season, ground water levels rise and the flows through surface drains increase. This flow along with direct surface return and canal spills is then either rediverted by other canals or directly discharged into the Boise River. The Boise River itself acts as a drain when intercepting ground water and surface return flows. The combined surface and ground water return flow is a significant amount throughout the entire year.

Surface Drains

About eleven principal drain systems discharge into the Boise River between Lucky Peak Reservoir and the mouth of Boise River. In downstream order these systems are: Drainage District #3, Thurman Drain, Eagle Drain, Five Mile Creek, North and South Middleton Drain, Willow Creek, Mason Creek and Drain, Hartley Drain and Gulch, Indian Creek, Conway Gulch, and Dixie Slough. In the past, most of those drains were intermittent tributary streams to the Boise River.

The Boise Valley below Boise is crossed by many surface drains which do not discharge directly to the Boise River. These drains are either tributary to other drains or are intercepted by canals which pick up flow for rediversion. In the lower end of the Boise Valley, some drains discharge directly to the Snake River. One of the largest of these is Sand Run Gulch which discharges as much as 75 cfs during the non-irrigation season.

After irrigation diversions begin in April, the flow in surface drains increases until a somewhat steady rate is reached, and this flow is maintained throughout the irrigation season. When diversions for irrigation are completed in October, the drain system return flows gradually decrease throughout the winter as ground water levels decline. In late March the drains are found to have the lowest discharge of the year. Local storms often cause the drains to discharge at unusually high rates for short periods of time.

All of the principal drains enter the Boise River below the streamgage at Boise; only two of the drains enter below Notus. The largest drains are concentrated in the reach of the river between the cities of Middleton and Caldwell. When the natural flow of the river becomes too small to satisfy all diversions and many canals begin to use storage water, canals below Middleton usually obtain all of their water from surface and seepage return flows to the river. Only in very dry years when drains are discharging much less than normal do these canals need additional water from storage. Even during years of extremely low runoff, canals on the lower end of the river below Notus do not require storage water.

Following is a short description of some of the major surface drain systems in the Boise Valley. In many cases these systems are made up of a complex network of tributary drains which is constantly changing because of new construction or relocation.

Drainage District #3. Return flows from three small drains are included in this system. These are the Booth, Myers, and Ridenbaugh drains. They enter the Boise River from the south within the city of Boise, and collect return flows from land irrigated in the immediate vicinity. Discharge of these drains varies from 15 cfs in the summer to almost no flow in the winter.

Thurman Drain. This drain is located below the Settlers Canal on the south side of the river and discharges into the South Channel of the Boise River near Eagle Island. It collects return flows from the Settlers Canal and includes return flows from the end of the Thurman Mill Canal. Discharge ranges from 25 cfs in the summer to less than 15 cfs in the winter.

Eagle Drain. Eagle Drain enters the Boise River on the North Channel of Eagle Island at the town of Eagle. It drains the area below the Farmers Union and Dry Creek Canals from Boise to Eagle. Discharge ranges from 60 cfs in the summer to 15 cfs in the winter.

Five Mile Creek. Sometimes called Fifteen Mile Creek, Five Mile Creek enters the Boise River from the south near Middleton serving as a drain for the area below the Boise Project Main Canal and between the City of Boise and Mason Creek Drain. It receives return flows and spills from the Main, Ridenbaugh, and Phyllis Canals. Five Mile Creek is a major source of irrigation water for the Caldwell Highline Canal, the last of a series of major canals which cross this drain. Just prior to entering the river, a diversion of about 17 cfs is made by a small canal. Discharge to the river varies from 140 cfs in the summer to less than 40 cfs in the winter. However, because of the great reuse of water from the drain, flows are quite variable.

Mason Creek. Mason Creek drains land served by the same canals as Five Mile Creek and also provides irrigation water to the Caldwell Highline Canal. Maxon Creek serves as a lateral between the Boise Project Main (New York) Canal and the Ridenbaugh Canal, however it functions as a drain below the Ridenbaugh Canal. Near the river, Mason Creek branches into two channels which reach the river at approximately the same location near Caldwell. These channels are called Mason Creek and Mason Drain. The combined discharge of the two channels varies from 200 cfs in the summer to 60 cfs in the winter.

Indian Creek. Indian Creek and two tributary drains, the Wildon and the Elijah, drain the area below the Ridenbaugh Canal between Mason Creek and Lake Lowell. Similar to Mason Creek, Indian Creek begins to act as a drain below the Ridenbaugh Canal. Above that point Indian Creek functions as a portion of the Boise Project Main Canal and all return flows or surface runoff is diverted to Lake Lowell via the Main (New York) Canal.

There are many artesian wells and springs which discharge to Indian Creek in the vicinity of Nampa. Indian Creek discharges into the Boise River below Caldwell, but during the irrigation season much of the flow is diverted before it reaches the river.

The largest diversions from the system are the Notus Canal which diverts flow from the Wilson and Elijah Drains to the northside of the Boise River, and the Riverside Canal which diverts flow from Indian Creek below Caldwell. Discharge into the Boise River is highly variable, ranging from 250 cfs at the end of the irrigation season to less than 100 cfs when canals are diverting water from Indian Creek.

North and South Middleton. The two forks of the Middleton Drain service the area below the Middleton Canal between Eagle and Middleton. The drain discharges into the Boise River at Middleton. Discharge varies from 200 cfs in the summer to 50 cfs in the winter.

Willow Creek. Willow Creek also discharges into the Boise River at Middleton. However, it collects return flows from the area irrigated by the lower end of the Middleton Canal and by the last few miles of the "C" Line East Canal of the Payette Division of the Boise Project. Flows in Willow Creek vary from 50 cfs in the spring to almost no flow in the winter.

Hartley Drain and Gulch. The two forks of this drain enter the Boise River above Caldwell. It drains the area receiving water from the lower end of the Middleton and Canyon County canals. It also drains a large portion of the Black Canyon Irrigation District that obtains water from the "C" Line East Canal between Willow Creek and Conway Gulch. Discharge ranges from 100 cfs in the summer to less than 25 cfs in the winter.

Conway Gulch. Conway Gulch drains the area irrigated by the "C" Line East, "C" Line West and Notus Canals between Hartley Gulch and Sand Run Gulch. These canals irrigate land in the Payette Division of the Boise Project. Conway Gulch discharges to Boise River at Notus. Discharge varies from 60 cfs in the summer to 200 cfs in the winter.

Sand Run Gulch. The last major drain north of the Boise River is Sand Run Gulch which parallels the river for more than ten miles before the drain discharges to Snake River. Return flows from the area irrigated by the Boise Project "D" Line Canal and the Sebree Canal contribute flow to this drain. A November flow of 75 cfs has been observed near the end of the drain.

Dixie Slough. The Dixie Slough is the last major drain on the south side of Boise River and discharges directly into the Boise River. This drain collects return flows from the irrigated area below the Riverside Canal south of Caldwell to a point about five miles below Notus. Flows range from 275 cfs in the summer to less than 100 cfs in the winter. The discharge of this drain is highly variable during the irrigation season because of variations in the reuse of the drain water.

Ross East End Drain. Return flows from land irrigated south of the river by the lower end of the Riverside Canal are collected by the Ross East End Drain. This drain eventually discharges to the Snake River. A November discharge of 12 cfs has been observed near the end of the drain.

Discharge Measurements

Measurements of the discharges from all the major drains which discharge into Boise River are reported by the Boise River Watermaster for the irrigation season only, April 15 to October 15. Daily values are estimated by interpolating between weekly measurements. The length of historic record varies with each drain, and locations of measurements have changed throughout the period of record. The Boise River Watermaster has measured all drains three times during the non-irrigation season, in November 1971, February 1972, and March 1973.

Distribution and Composition of Total Gain

Very little return flow enters the Boise River above Boise. In this reach there are no major surface drains and the total gain to the river between Lucky Peak Dam and Boise is negative throughout most of the year. From Boise to Notus, the total gain in flow to the river can be calculated by adding the recorded diversions to the measured flow of the Boise River at Notus less measured flow of Boise River at Boise gage. The total gain includes all surface return flows and ground water gains or losses. Because natural runoff during most of the year is very small in this reach, the total gain in flow is a good representation of total return flow to the river. Table 23 lists the Boise-Notus total gain by month in thousands of acre-feet for the years 1959-72.

The total gain to the Boise River follows the same pattern as individual surface drains. The lowest gain is in March just prior to the irrigation season when the total gain from the Boise River at Boise to the Boise River at Notus gaging stations is approximately 500 cfs. By May the gain usually increases to 1000 to 1500 cfs. The gain remains at this level through September and gradually decreases throughout the non-irrigation season.

In a given year, the magnitude of the total gain to the river varies with the available water supply. In the low runoff year of 1961, the Boise to Notus total gain averaged less than 1000 cfs during the irrigation season; in the same period of the high runoff year of 1965, this gain averaged over 1500 cfs. This relationship can partially be explained by the fact that less efficient use is made of the available water when the supply is abundant. When the supply is low, gross diversions are less and more of the surface return is reused. The drain discharges become highly variable during periods of greater water reuse.

An estimate of the distribution of the gain by reach from Boise to Notus was found by calculating the net gain above Eagle Island, near Star below the Caldwell Highline Canal, and at Caldwell Bridge, based on miscellaneous measurements at these locations. It was found that the ratio of the gain in these reaches to the total gain does not vary greatly throughout the year. The following ratios were calculated for the four reaches: Boise to above Eagle Island - 0.06; above Eagle Island to near Star - 0.13; near Star to Caldwell Bridge - 0.39; Caldwell Bridge to Notus - 0.42.

It is significant to note that over 80 percent of the return is below Star.

Of the total gain from Boise to Notus, the major source is from surface drains. Based on 1959-72 measurements taken by the Boise River Watermaster, 60 to 65 percent of the gain is contributed by the eleven major surface drains during their peak discharge, from April through October. From miscellaneous measurements taken in the non-irrigation season on days that did not follow excessive precipitation, it was found that these drains accounted for about 75 percent of the total Boise to Notus gain. This increase is logical since diversions from surface drains are generally not made after October 15. The remainder of the gain, or the unidentified gain, originates from very small surface drains which flow during the irrigation season and from ground water seepage directly to the river channel.

The total gain from Notus to Parma varies in much the same manner as the upper portion of the river. Limited data indicates that the total gain approaches 500 cfs during the irrigation season and decreases to zero by the end of March. Two major surface drains, Dixie Drain and Conway Gulch, discharge into the river in this reach. These two drains comprise about 65% of the total gain from May through September when the gain is at its peak. No data exists on return to the river below Parma; however, there are no major surface drains that discharge into the river below that location.

Table 23. Total Gain to Boise River Between Boise and Notus 1959-1972 (1000 AC-FT)
Includes Effects of all Reservoirs

W-YR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
59	65.2	42.3	37.3	32.0	27.1	25.6	41.2	94.6	72.0	73.4	94.5	82.6	687.8
60	61.1	38.2	34.1	34.3	36.0	33.9	31.4	109.0	84.3	82.1	90.8	81.3	716.5
61	63.0	43.2	38.3	32.6	28.5	28.1	26.1	66.9	63.3	56.7	52.8	63.1	562.6
62	49.7	36.6	33.3	30.4	32.8	29.8	31.1	79.8	55.5	72.5	75.3	79.8	606.6
63	70.6	41.2	36.8	31.3	40.9	28.8	29.8	58.4	88.0	70.0	75.1	83.4	654.3
64	63.4	45.8	39.9	42.5	38.3	42.0	40.5	64.6	88.9	75.9	88.3	88.5	718.6
65	62.3	42.1	46.4	42.1	30.6	36.0	69.7	92.4	101.6	91.1	96.2	82.4	792.9
66	68.7	44.0	37.5	32.8	26.7	24.7	64.5	83.9	87.9	69.8	68.9	68.7	678.1
67	56.1	41.1	38.6	34.5	29.9	25.8	40.6	63.5	78.6	76.9	76.0	81.5	643.1
68	66.3	40.9	37.2	34.8	30.5	26.3	22.1	65.1	67.3	66.9	81.3	61.1	599.8
69	61.5	42.3	39.3	49.5	33.0	42.3	52.1	89.3	89.4	74.2	76.1	75.0	724.0
70	66.7	43.4	40.4	52.7	36.9	37.4	51.3	93.4	89.8	93.0	85.3	97.1	787.4
71	65.7	46.2	42.7	56.9	41.3	56.8	71.5	123.6	124.9	95.6	84.1	87.0	896.3
72	70.8	45.6	44.2	48.6	77.2	71.8	63.7	91.6	93.1	85.1	96.6	94.7	883.0
AVG	63.6	42.3	39.0	39.6	36.4	36.4	45.4	84.0	84.6	77.4	81.5	80.4	710.8

Diversion - Return Flow Relationships

Because of extensive reuse of water for irrigation, it is very difficult to estimate the effect of any single diversion on the return flow to Boise River. The absence of any continuous record of flow in the river between Boise and Notus prohibits analysis of diversion-return flow relationships even by general areas. An estimate of the return from Boise to Parma can be made by comparing the total annual gain to the river to gross diversions. Diversions from the Boise River from Diversion Dam to Parma average about 1,850,000 acre-feet. By adding to this the average diversion into the Boise Valley from the Payette River, 250,000 acre-feet, the total annual surface diversion is about 2,100,000 acre-feet. The average annual (1959-72) total gain to the Boise River from Boise to Parma is approximately 870,000 acre-feet. Therefore, the average return flow to the Boise River above Parma appears to be in the range of 40 percent of the total surface water diversion. This does not include the entire return flow, some of which flows directly or indirectly to Snake River.

Effect of Boise Project on Return Flows

A good indication of changes in the quantity of return flows to the Boise River resulting from the Boise Project would be the comparison of total gain to the river before and after the Project. However, the streamgage at Notus, which represents outflow from the basin, was not operated prior to the construction of Arrowrock Reservoir and Lake Lowell. Yet, the gage was in existence several years before the construction of Anderson Ranch and Lucky Peak reservoirs.

Table 24 shows the monthly total gain to Boise River from Boise to Notus for a 20-year period before the effects of regulation by Anderson Ranch or Lucky Peak were present. The average annual gain for this period, 1928-47, was 416,400 acre feet. This gain was calculated the same as the 1959-72 gain shown in Table 23, by adding total Boise to Notus diversions to the gaged difference. The 1959-72 gain, representing the effects of both Anderson Ranch (completed 1946) and Lucky Peak (completed 1955) reservoirs, was 710,800 acre feet, approximately 300,000 feet per year greater than prior to the existence of these two reservoirs. Total gains for the periods 1928-1972 are shown in Figure 18.

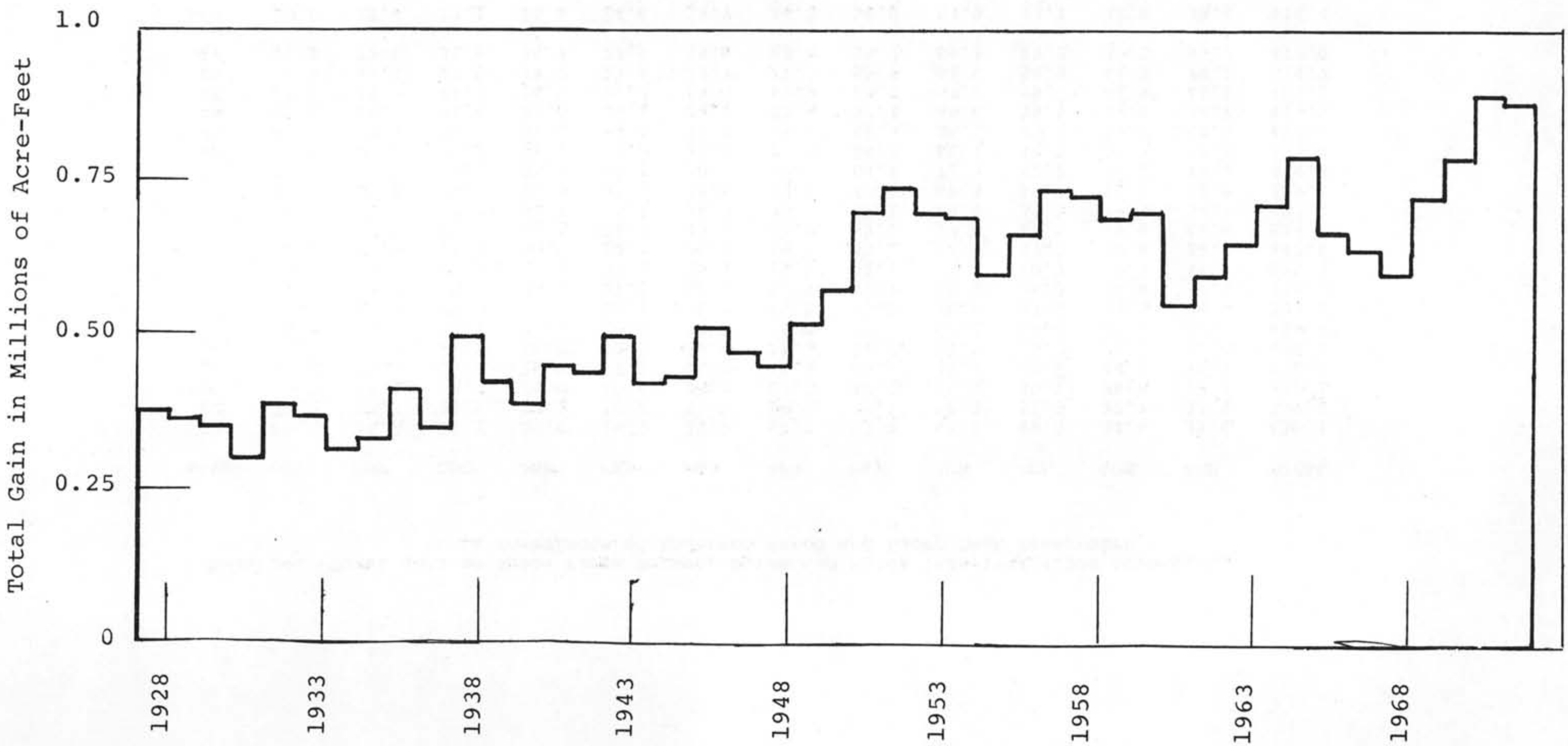
A comparison of the total diversions from above Diversion Dam to Notus indicate that diversions increased from an annual average of 1,475,000 acre feet from 1928-47 to 1,800,000 acre feet from 1959-72. The increased gain to the river is partially a result of this increase in diversion of 325 thousand acre feet from the river. As discussed in the BOISE VALLEY GROUND WATER section, average water table elevations have increased since the 1928-47 period. In some areas this has probably caused a much greater portion of present diversions to return to the river via surface drains rather than be stored in the aquifer, thus also tending to increase the total gain to the river.

The increase in total gain to the Boise River is also partially the result of the transbasin diversion from the Payette

Table 24. Total Gain to Boise River Between Boise and Notus 1928-1947 (1000 Acre-Feet)
Prior to effects of Anderson Ranch and Lucky Peak Reservoirs

W-YR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
28	45.1	28.2	26.5	35.0	19.2	27.2	52.7	57.2	61.7	43.3	34.6	39.6	470.3
29	22.5	22.3	23.6	20.8	18.2	43.5	28.4	39.1	58.3	31.3	27.7	33.5	369.2
30	6.1	18.0	23.0	20.6	29.6	23.1	27.0	44.5	55.4	39.1	36.8	38.7	382.7
31	31.6	25.2	23.0	25.0	17.5	21.0	18.3	43.5	39.3	21.5	18.9	21.8	306.5
32	-4.2	5.2	27.5	25.8	20.5	36.8	25.3	84.9	55.1	56.7	35.1	37.8	406.5
33	20.5	31.6	23.9	22.5	22.2	37.9	15.4	57.6	62.6	42.6	40.5	37.6	414.9
34	3.4	33.1	27.1	27.2	25.7	20.4	25.9	43.2	40.8	27.6	23.3	25.8	323.5
35	4.2	21.6	25.6	21.6	17.1	18.4	11.7	47.7	68.6	36.0	30.8	30.3	333.6
36	7.6	28.4	23.5	31.2	33.6	33.1	14.6	62.1	63.7	40.7	34.9	41.9	415.3
37	18.2	27.7	21.8	19.6	20.1	25.7	19.8	47.2	52.9	33.0	29.8	26.7	342.5
38	4.4	25.9	26.3	26.0	21.7	43.1	29.9	87.1	77.6	69.5	45.0	49.6	506.1
39	46.0	31.8	29.7	24.3	19.3	28.3	32.9	67.1	48.0	33.7	29.5	36.7	427.3
40	14.8	28.2	23.2	26.0	26.3	28.6	30.9	48.6	48.3	39.3	31.9	42.9	389.0
41	30.6	29.0	25.0	25.4	25.3	20.1	28.9	64.4	71.3	42.2	44.2	48.4	454.8
42	37.4	27.9	26.8	26.6	33.2	28.0	28.4	66.5	65.1	40.7	37.8	42.6	481.0
43	45.1	30.5	36.7	36.2	34.0	32.7	44.0	46.3	36.4	43.7	54.9	54.9	495.4
44	45.4	28.5	31.5	27.6	25.4	24.2	22.5	38.4	68.6	39.0	35.0	39.7	425.8
45	26.9	27.9	27.3	26.7	29.3	29.0	19.2	54.7	57.2	49.9	41.9	41.1	431.1
46	38.4	44.4	42.9	34.7	27.9	33.7	27.0	59.8	61.6	54.0	44.2	48.1	516.7
47	51.5	32.6	31.6	26.7	23.5	19.9	23.4	59.7	66.1	49.3	39.5	51.2	475.0
AVG	24.8	27.4	27.3	26.5	24.5	28.7	26.3	56.0	57.9	41.7	35.8	39.4	416.4

FIGURE 18. TOTAL GAIN TO BOISE RIVER FROM BOISE TO NOTUS



River into the Boise Valley by the Payette Division of the Boise Project, i.e. Black Canyon Irrigation District. These canals began diverting water from the Payette River Basin to the Boise Valley in 1939, but much larger diversions were begun after 1950. The present average annual diversion to the Boise Valley is about 250,000 acre feet. Therefore the total average annual increase in diversions to the Boise Valley from the 1928-47 to the 1959-72 period is approximately 575,000 acre feet.

Although it is difficult to quantify return flows resulting directly from the Boise Project, it can be stated that return flow to the Boise River has increased significantly as a result of the Project.

RESERVOIRS

Reservoir Characteristics

Water use and control on the Boise River includes four major reservoirs that are federally supported, and also some minor privately developed reservoirs. Information on the major reservoirs are shown in Table 25.

Table 25. Boise River Reservoirs

Reservoir	Stream	Capacity Gross (ac. ft.)	Capacity Active (ac. ft.)	Construction Agency	Construction Year
Anderson Ranch	S. Fork	493,200	423,200	USBR	1945
Arrowrock	Boise R.	286,600	286,600	USBR	1915
Lucky Peak	Boise R.	307,040	278,200	USCE	1954
Lake Lowell	Off-Stream	190,100	169,000	USBR	1908

Area-capacity curves for Anderson Ranch, Arrowrock, Lucky Peak, and Lake Lowell (Deer Flat) Reservoirs are presented in Figures 19, 20, 21, and 22 respectively.

Hubbard Reservoir is a small (4,000 acre feet) off-stream reservoir constructed at the turn of the century. It was used until 1930 for irrigation water supply storage and now serves for emergency regulation of the Main (New York) Canal. An area-capacity curve is presented in Figure 23.

Little Camas Reservoir is a small irrigation water supply

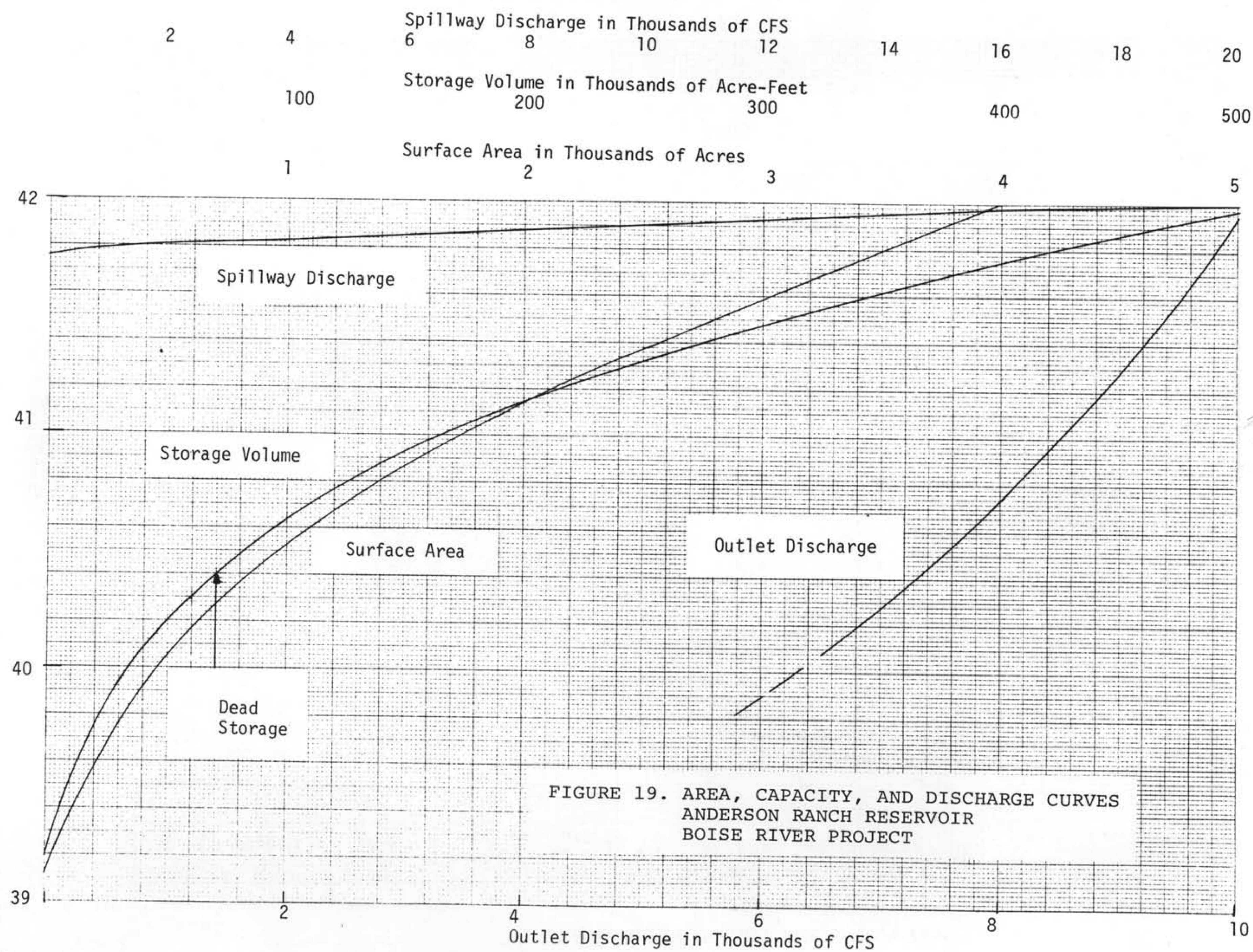


FIGURE 19. AREA, CAPACITY, AND DISCHARGE CURVES
ANDERSON RANCH RESERVOIR
BOISE RIVER PROJECT

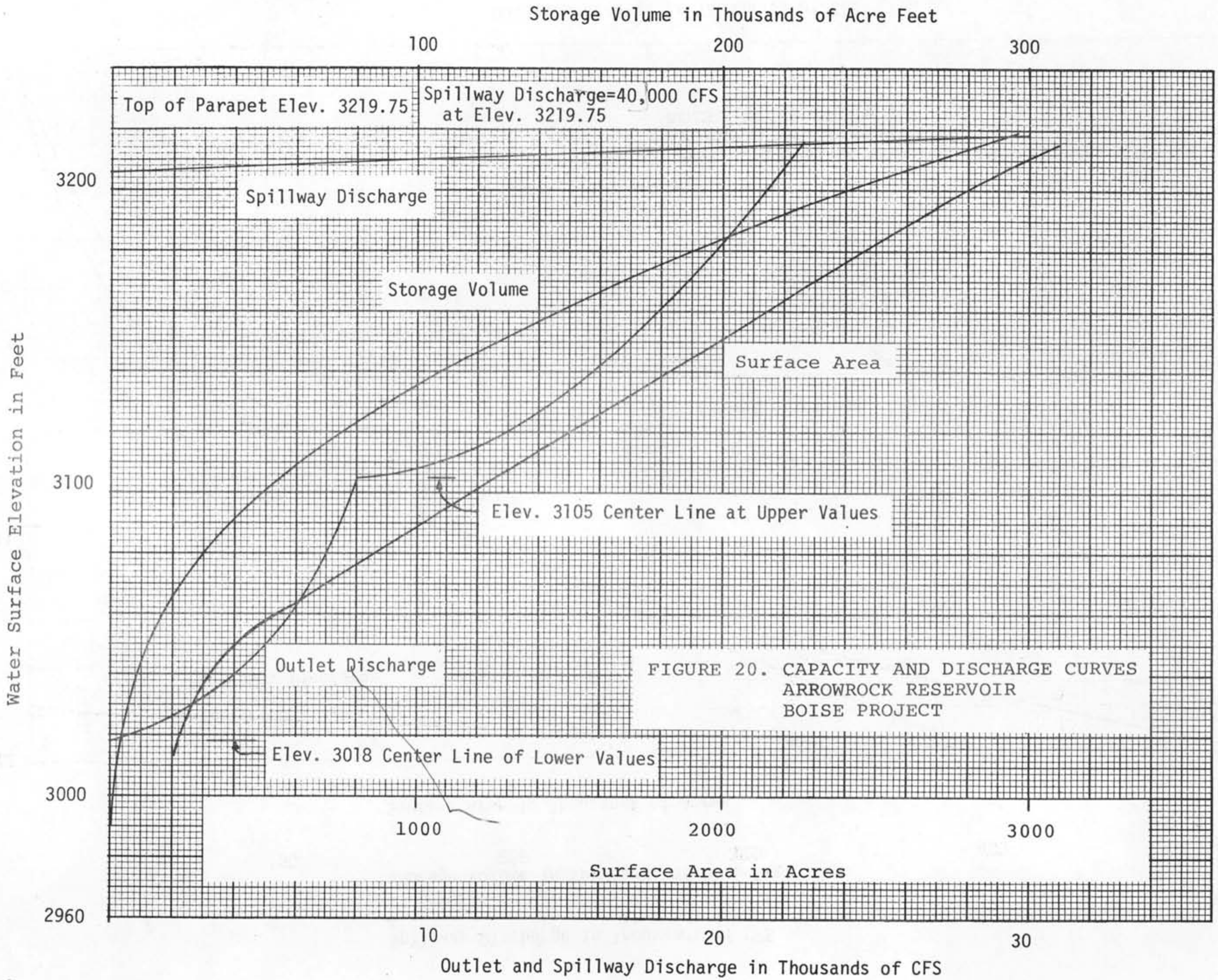


FIGURE 20. CAPACITY AND DISCHARGE CURVES
ARROWROCK RESERVOIR
BOISE PROJECT

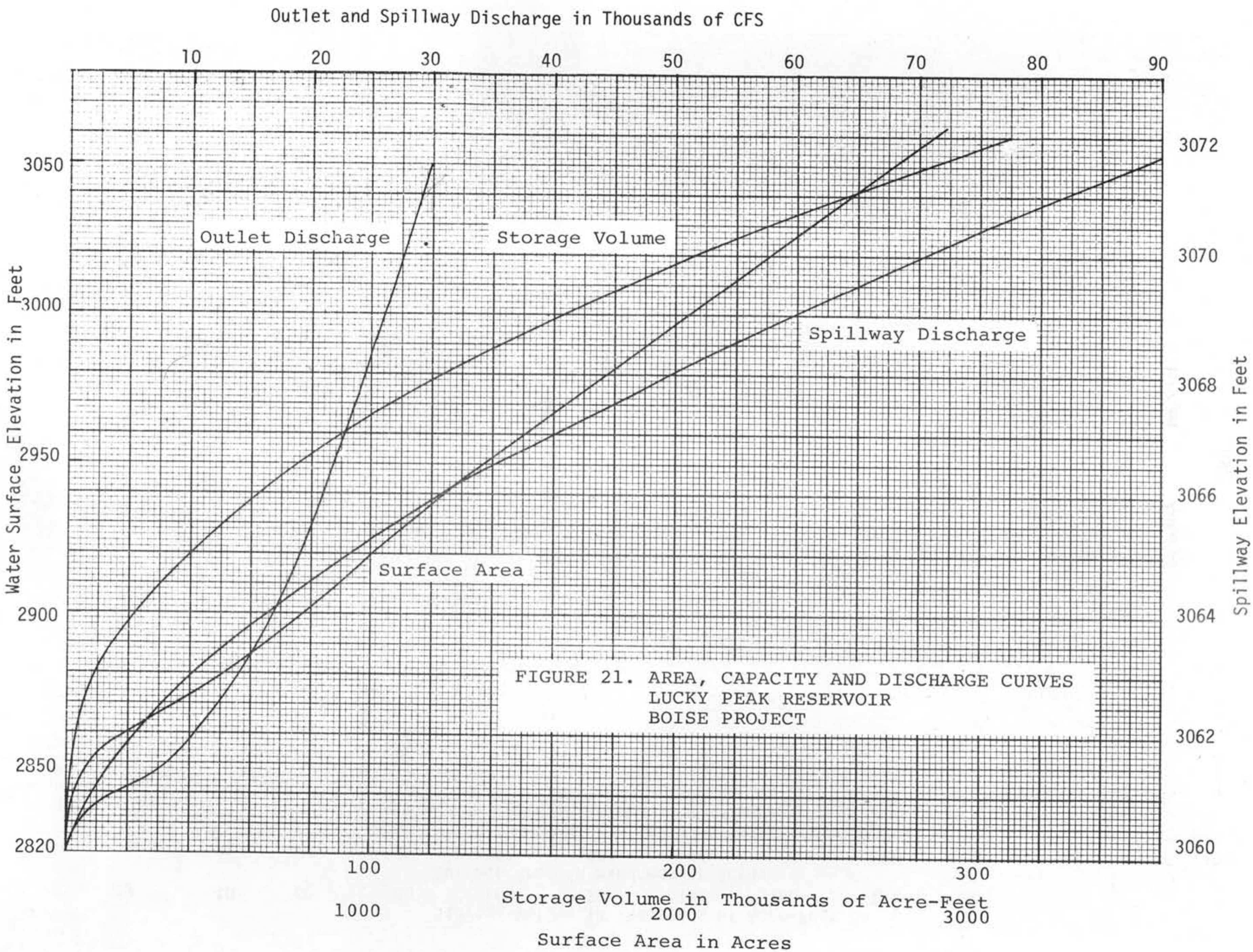


FIGURE 21. AREA, CAPACITY AND DISCHARGE CURVES
LUCKY PEAK RESERVOIR
BOISE PROJECT

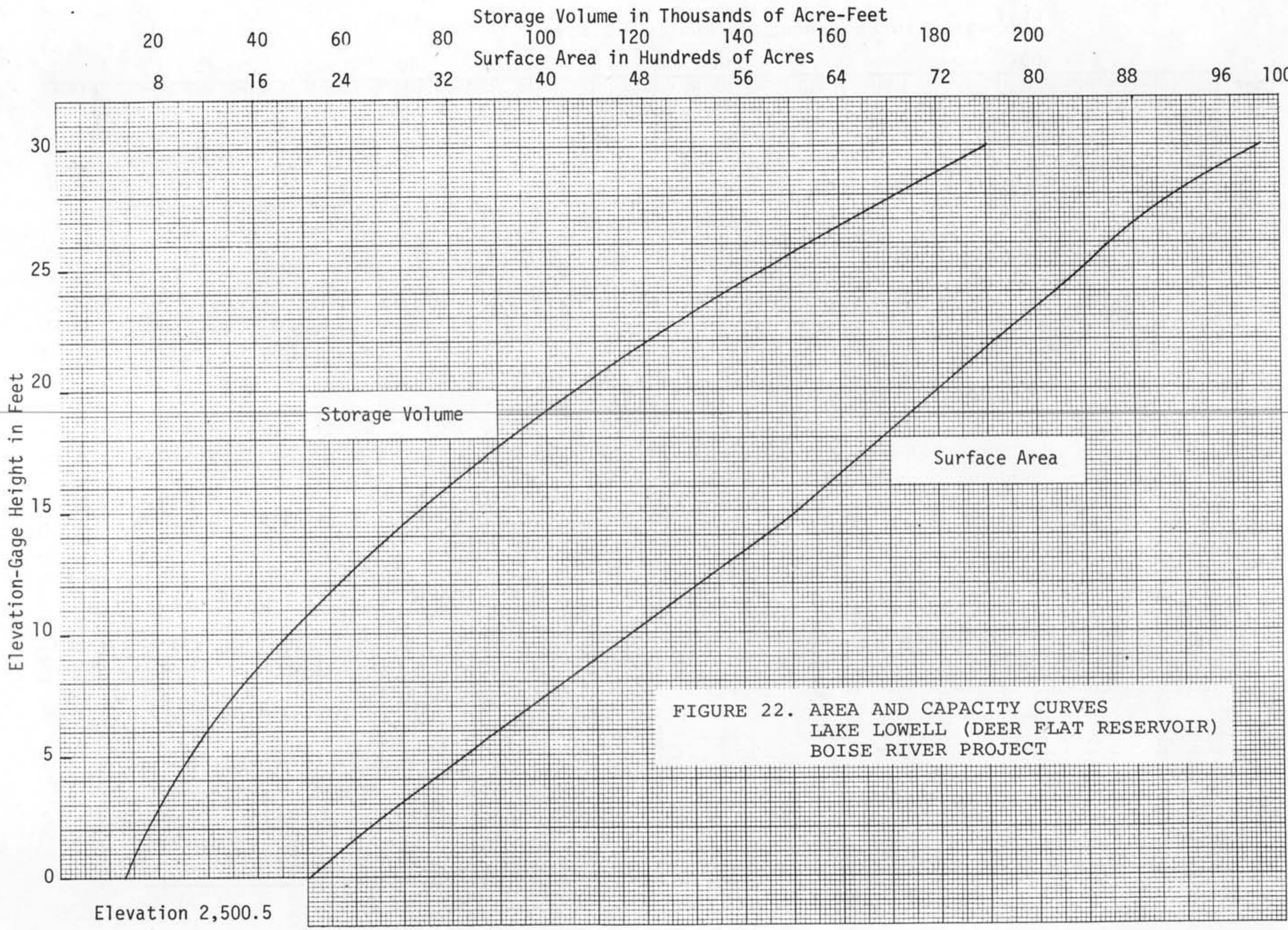


FIGURE 22. AREA AND CAPACITY CURVES
LAKE LOWELL (DEER FLAT RESERVOIR)
BOISE RIVER PROJECT

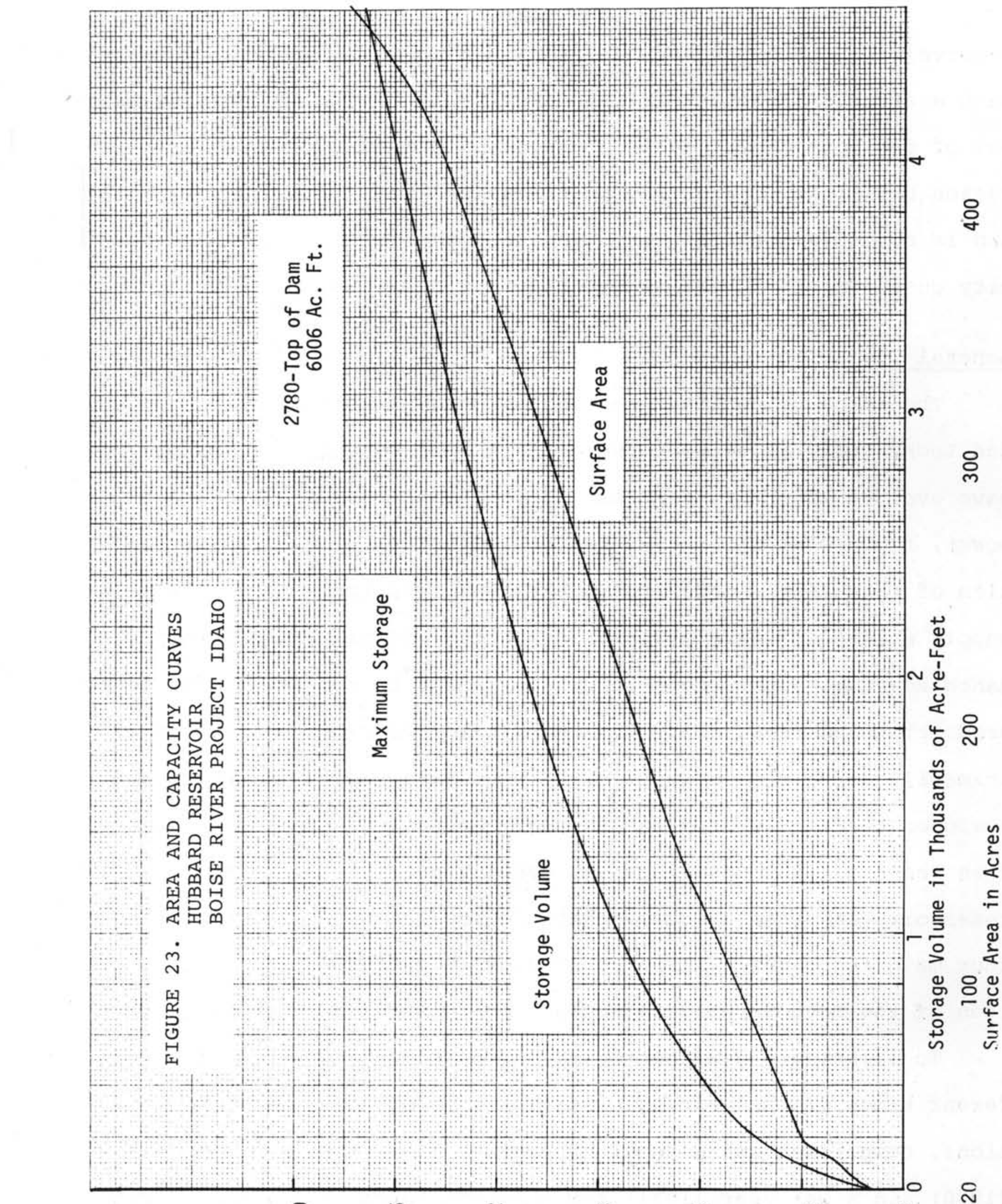


FIGURE 23. AREA AND CAPACITY CURVES
HUBBARD RESERVOIR
BOISE RIVER PROJECT IDAHO

reservoir in the headwaters of the South Fork of the Boise River with a storage capacity of 7,500 acre feet. The water is diverted out of the Boise River Basin and used by the Mountain Home Irrigation District. The effect on the Boise River flows is very slight and is normally not considered in water accounting. An area-capacity curve for Little Camas Reservoir is presented in Figure 24.

General Operation

The three Boise River reservoirs, Anderson Ranch, Arrowrock, and Lucky Peak, along with the off-stream reservoir Lake Lowell, have evolved into a system that has the functions of irrigation, power, flood control, and recreation. Initially, with construction of Lake Lowell and Arrowrock reservoirs, irrigation water supply was the primary purpose. With the addition of Anderson Ranch Reservoir, the operation was extended to regulation for power production and flood control. Lucky Peak Reservoir was justified primarily for flood control. The three main river reservoirs are now operated as a system for the four purposes mentioned above. This section first describes the general operating patterns of the reservoirs and then discusses detailed operation in terms of the four main functions. Also included in this section is a description of the methods used to account for contracted reservoir space.

To illustrate how the reservoirs have been operated at different times of the year under different kinds of runoff conditions, comparison was made of a dry year (1961), an average year (1970) and a wet year (1971) for Anderson Ranch, Arrowrock, Lucky Peak and Lake Lowell reservoirs. The results are presented in

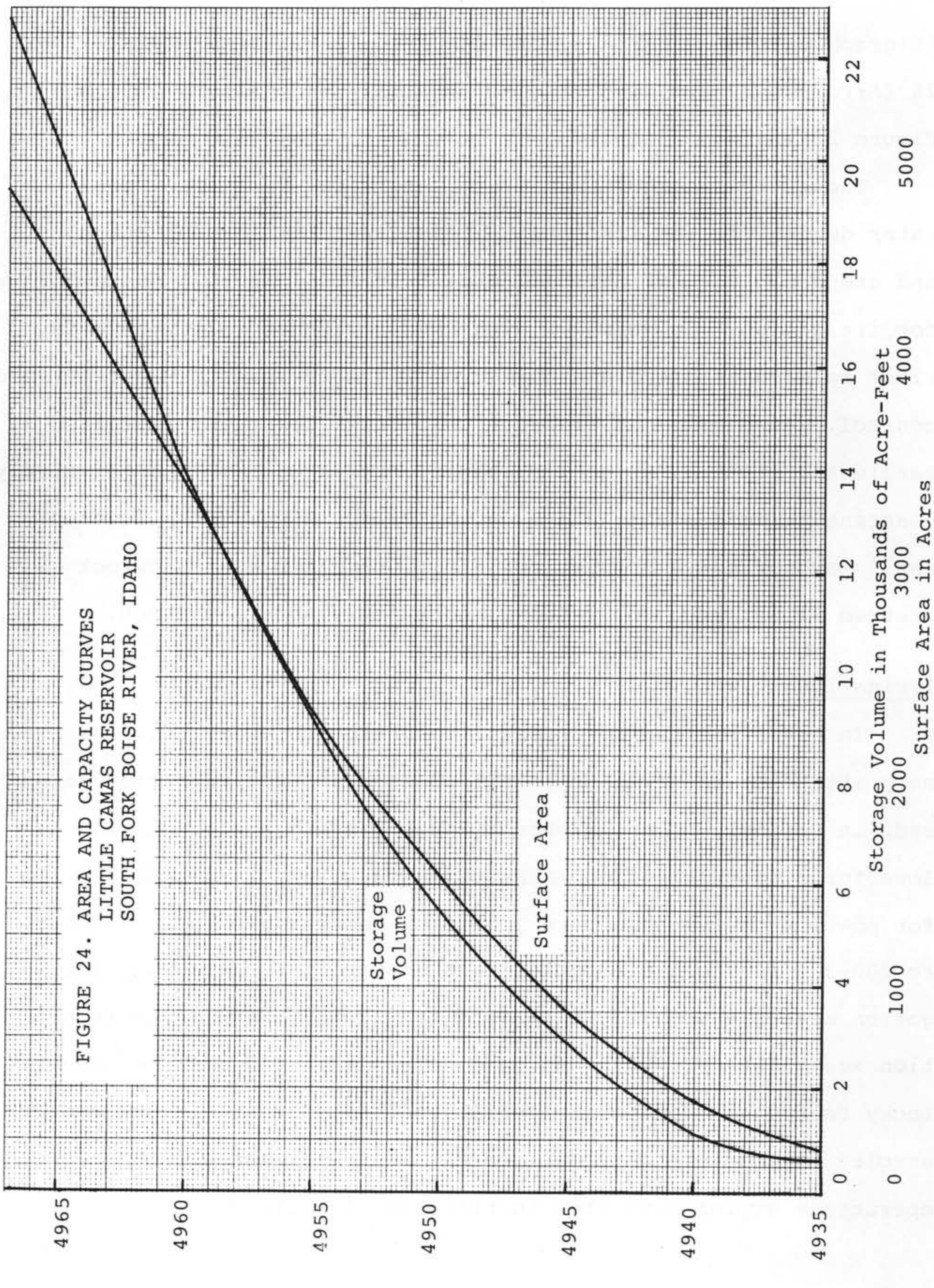


FIGURE 24. AREA AND CAPACITY CURVES
LITTLE CAMAS RESERVOIR
SOUTH FORK BOISE RIVER, IDAHO

in graphical form in Figure 25 (Anderson Ranch Reservoir), Figure 26 (Arrowrock Reservoir), Figure 27 (Lucky Peak Reservoir), and Figure 28 (Lake Lowell).

These figures show that, in general, the reservoirs store water during the non-irrigation season, October through March, and are drawn down at various rates from April through September for irrigation. In years of high runoff such as 1971, the main river reservoirs are drawn down from February through May for flood control. In average or dry years Arrowrock Reservoir is filled earliest after the irrigation season, Lucky Peak is kept relatively constant through April, and Anderson Ranch is gradually lowered until May for power production. For irrigation use Arrowrock is drafted first, then Lucky Peak, and finally Anderson Ranch.

Irrigation

In operating the reservoirs for irrigation water supply, primary attention is given to refill as soon as the irrigation season ends in October. The November through January period usually allows for a discharge from Anderson Ranch Reservoir of 400-500 cfs for power production, but in low water years this may be reduced to 200-300 cfs to assure sufficient storage for the coming irrigation season. Negligible release is made during the non-irrigation season at Arrowrock Dam, and only small releases are made at Lucky Peak Dam. During the refill period, discharge past the reservoirs may occasionally be increased to facilitate flood control operations or for diversion to fill Lake Lowell.

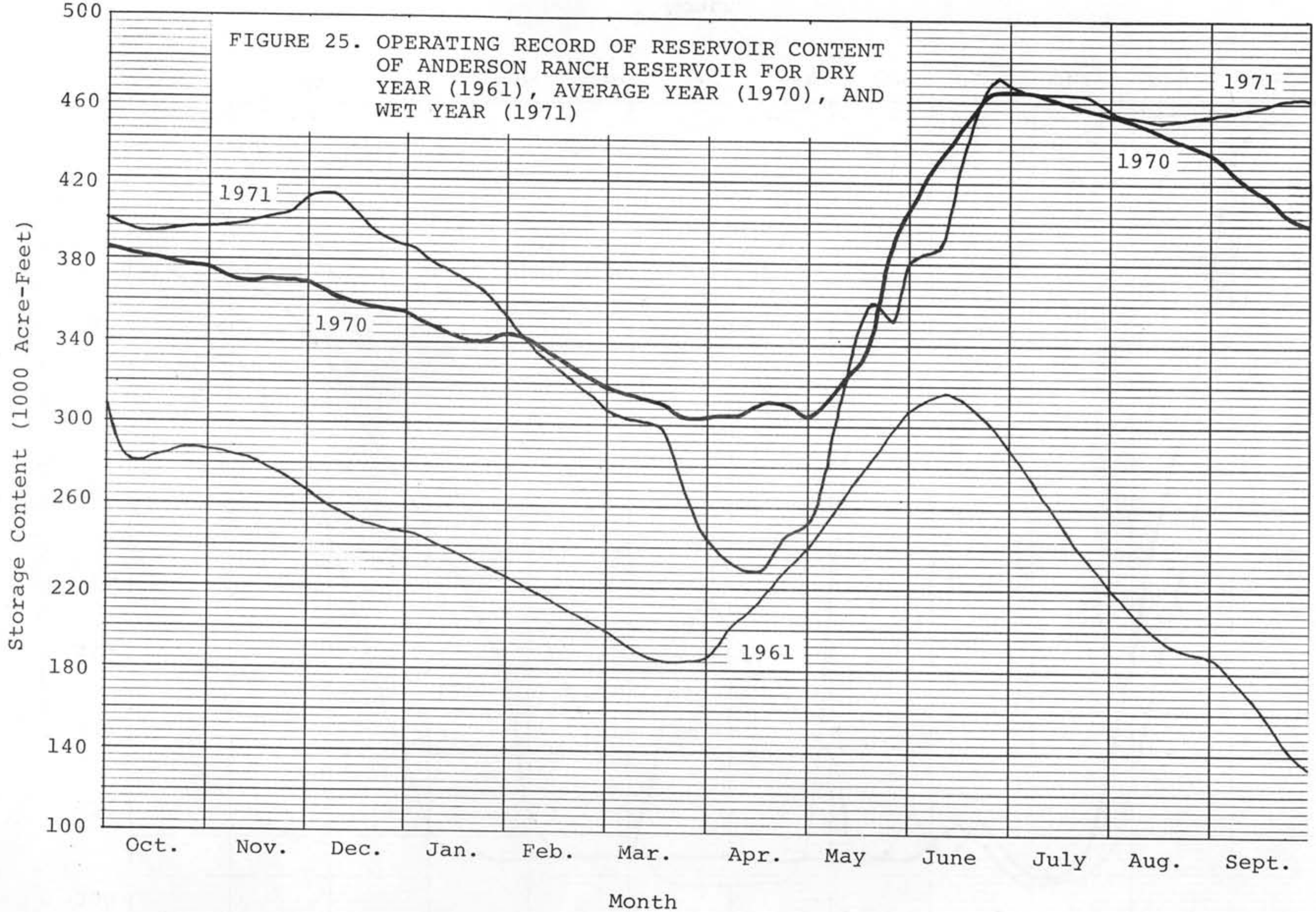


FIGURE 25. OPERATING RECORD OF RESERVOIR CONTENT OF ANDERSON RANCH RESERVOIR FOR DRY YEAR (1961), AVERAGE YEAR (1970), AND WET YEAR (1971)

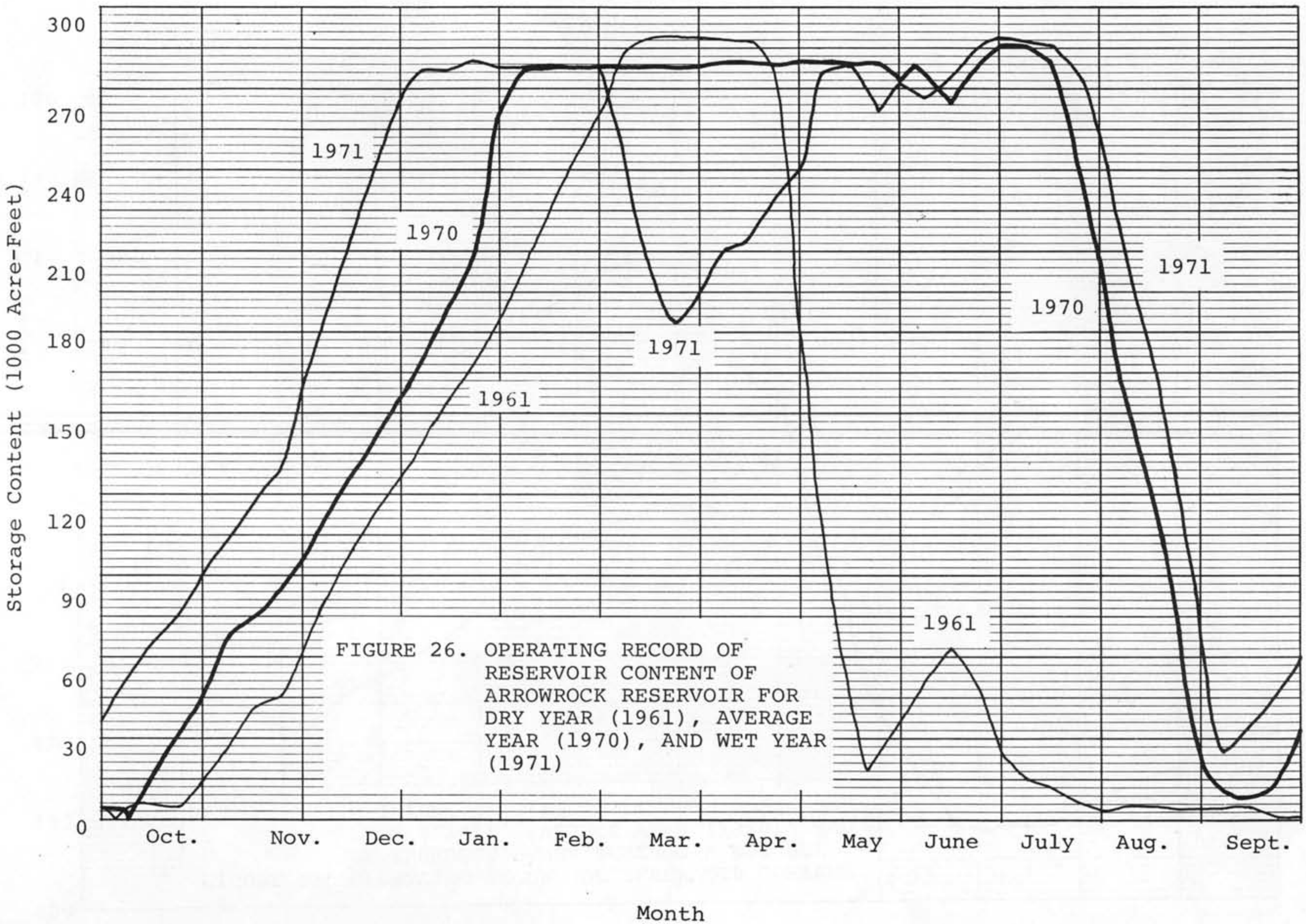


FIGURE 26. OPERATING RECORD OF RESERVOIR CONTENT OF ARROWROCK RESERVOIR FOR DRY YEAR (1961), AVERAGE YEAR (1970), AND WET YEAR (1971)

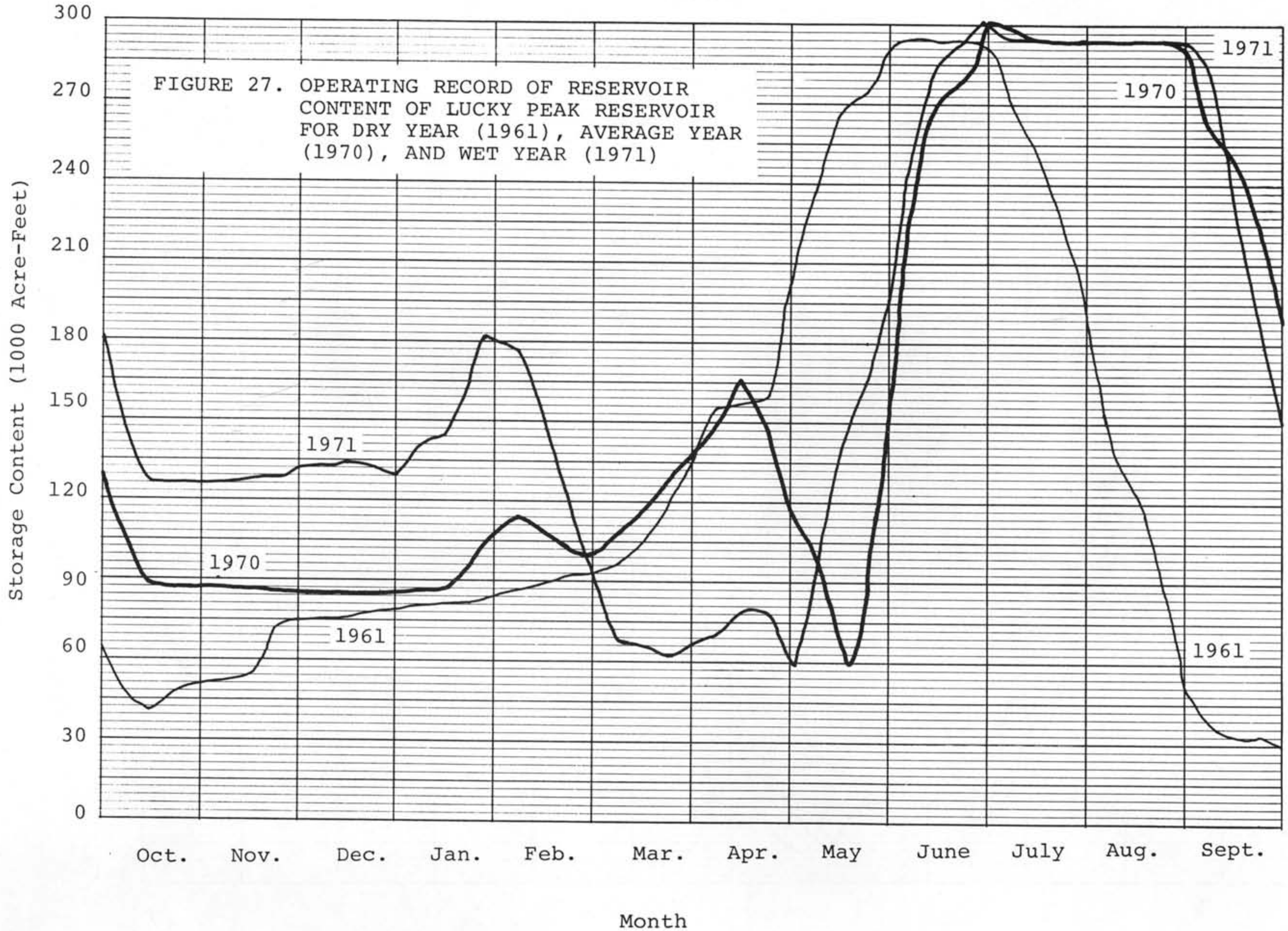


FIGURE 27. OPERATING RECORD OF RESERVOIR CONTENT OF LUCKY PEAK RESERVOIR FOR DRY YEAR (1961), AVERAGE YEAR (1970), AND WET YEAR (1971)

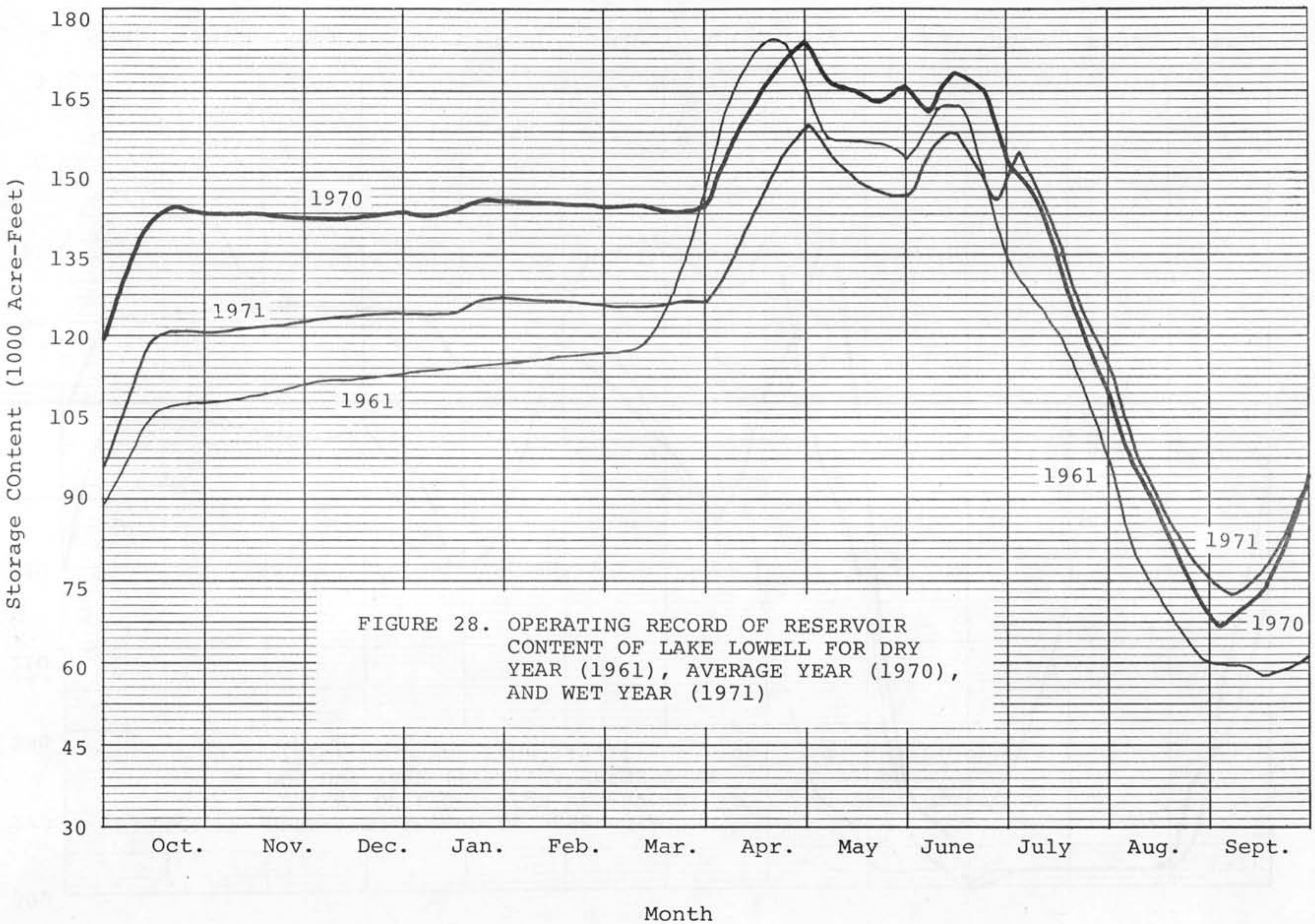


FIGURE 28. OPERATING RECORD OF RESERVOIR CONTENT OF LAKE LOWELL FOR DRY YEAR (1961), AVERAGE YEAR (1970), AND WET YEAR (1971)

The off-stream reservoir, Lake Lowell, obtains water by diversion from Boise River at Diversion Dam through the Boise Project Main (New York) Canal. The normal end-of-October content of Lake Lowell is 120,000-140,000 acre feet. If the reservoir is below this content, diversion from Boise River is usually begun in February or March. Operation of the canal during the November to January period rarely occurs. Lake Lowell is filled as soon after April 1 as possible, and in most years is full by May 1. When natural flow is insufficient to meet the decreed rights to divert to Lake Lowell, water previously stored in the upstream reservoirs may be moved down to Lake Lowell to assure its filling.

Canals on the Boise River below Diversion Dam begin diverting soon after April 1. When natural flow becomes insufficient to meet diversion demands, canals that have contracted for storage space in the on-stream reservoirs begin to use stored water and the reservoirs are drawn down. The maximum contents attained by the reservoirs is used to calculate the stored water available to each canal (see later discussion in this chapter on Storage Accounting). This storage is then used to supply the difference between diversion demands and natural flow. The magnitude of the natural flow thus determines the rate of reservoir drawdown.

Arrowrock Reservoir is drafted first in order to maintain the power head at Anderson Ranch Reservoir and a desirable recreation level at Lucky Peak Reservoir. This usually results in June through August flows of about 100-1200 cfs at Anderson Ranch Dam and 4500 cfs at Lucky Peak Dam. These flows are exceeded if a flood operation extends into the irrigation season or are less if the reservoirs do not fill to capacity. If the entire space in Arrowrock has been used before the end of August, both Anderson Ranch and Lucky Peak Reservoirs are drafted without exceeding power plant capacity at Anderson Ranch. After the end of August irrigation demands are met largely from storage in Lucky Peak Reservoir.

The operation of Lake Lowell during the irrigation season depends on the magnitude of diversions from the reservoir and the availability of storage space in the other reservoirs. Inflow to the lake is limited by the capacity of the Main (New York) Canal at Diversion Dam. The average April through June inflow to Lake Lowell from the Main (New York) Canal is about 600 cfs. By July, diversions have increased, allowing only about 400 cfs to reach the reservoir. Since this inflow is less than the outflow to the five canals originating at the reservoir, the lake is drawn down. The average July and August demand from Lake Lowell is 100 cfs. In years of low runoff the inflow after July is reduced to almost zero, and the lower canals operate entirely on Lake Lowell storage. The inflow to the reservoir is also reduced in years when a smaller content is desired at the end of the irrigation season to permit maintenance work on the outlet structure.

Flood Control

Flood control operations are governed by a Reservoir Regulation Manual for the Boise River Reservoirs and a 1953 Memorandum of Agreement between the Departments of Army and Interior. The

Manual, prepared in 1956, contains the detailed plan of flood control operation including forecast procedures, parameter curves for space evacuation, allocations of space, evacuation between the three reservoirs, operating procedure for floods which are too large to fully regulate, and organizational responsibilities.

The Memorandum of Agreement, which is contained in the Manual as Appendix A, committed the existing irrigation reservoirs (Arrowrock and Anderson Ranch) to a system of flood control operation with Lucky Peak Reservoir. Important features of the Agreement include:

(1) Commitment of 983,000 acre feet of space in the three reservoirs to use for flood control, when needed. This is essentially all of the active space in the reservoirs.

(2) Specification of flood space parameter curves to be used with agreed upon forecasts of runoff to determine evacuation requirements.

(3) Protection of space ownerships in Arrowrock, Anderson Ranch, and Lake Lowell against water loss as a result of flood control operations.

(4) Provision for coordination and agreement on runoff forecasts.

(5) Specification of a maximum regulated flow objective of 6500 cfs below Diversion Dam.

(6) Provision of evacuation and refill orders between the reservoirs.

(7) Provision for releases greater than 6500 cfs below

Diversion Dam when necessary in very large floods. These increased releases would be specified by the Chief of Engineers (U.S. Army Corps of Engineers) after consultation with the Commissioner of Reclamation.

(8) Provision for maintaining Lucky Peak Reservoir full for as long as possible after the flood control season for recreation purposes. This would be done by releasing Arrowrock water first for downstream irrigation uses.

(9) Provision for modification of the operating plan with respect to allowable releases and space requirements for flood control upon agreement of the Chief of Engineers and Commissioner of Reclamation or their authorized representatives.

Forecasts are prepared by both the Corps of Engineers and the Bureau of Reclamation. The forecast procedures used were described in the section on runoff. Table 26 contains examples of the use of these forecasts to determine the required release at Lucky Peak Reservoir for 1970 and 1971. The examples are for the period April 1-15, but any other period would be treated in a similar manner using appropriate forecasts. Note that in addition to the required average release rate (item 8), the table also shows the average releases that were made during the period (item 9). Because the Bureau of Reclamation forecast procedure has changed since the 1970 and 1971 example years, the estimated operating forecast, Item 1 in Table 26, is taken to be the average of the Corps of Engineers forecast and a forecast computed by the current

Table 26. Examples of Application of Boise River Forecast to Determine Flood Control Operation for Period April 1 - 15
(1000 Acre-Feet)

Item		1970	1971	Notes
1	Forecast, Apr 1-July 31 runoff	1,650	2,457	Avg of CE, BR (see Table 3)
2	Estimated Apr 1-15 runoff	170	255	Plate A-3, Reservoir Reg. Manual
3	Tentative Apr 15-July 31 forecast	1,480	2,202	Item 1 minus item 2
4	Required space April 15	270	730	Plate A-2. Reservoir Reg. Manual
5	Actual space, April 1	337	551	USGS records
6	Required evacuation, April 1-15	-67	179	Item 4 minus item 5
7	Total required release	103	434	Item 6 plus item 2
8	Required average release rate (cfs)	3,700	15,630	Item 7 expressed in cfs
9	Actual average release rate (cfs)	2,280	7,610	USGS records

Bureau of Reclamation procedure. Individual agency forecasts were presented earlier in Table 3.

No changes have been made in either the Manual or the Agreement since they were originally prepared. As discussed in FLOODS AND FLOOD FREQUENCY the system has achieved control of flood flows to about 7200 cfs or less at Boise since the plan was put into effect in 1954. Experience has apparently tended to permit flows above 6500 cfs below Diversion Dam when downstream diversions are capable of reducing the flow to 6500 cfs in the reaches of least channel capacity.

When the Manual and the Agreement were prepared, it was anticipated that diversions by the Boise Project Main (New York) Canal would be made in March and April. In years when flood control operations are required, the early spring diversions by the Main Canal have been much less than expected. This has reduced the capability to evacuate space and thus has changed the flood control operation.

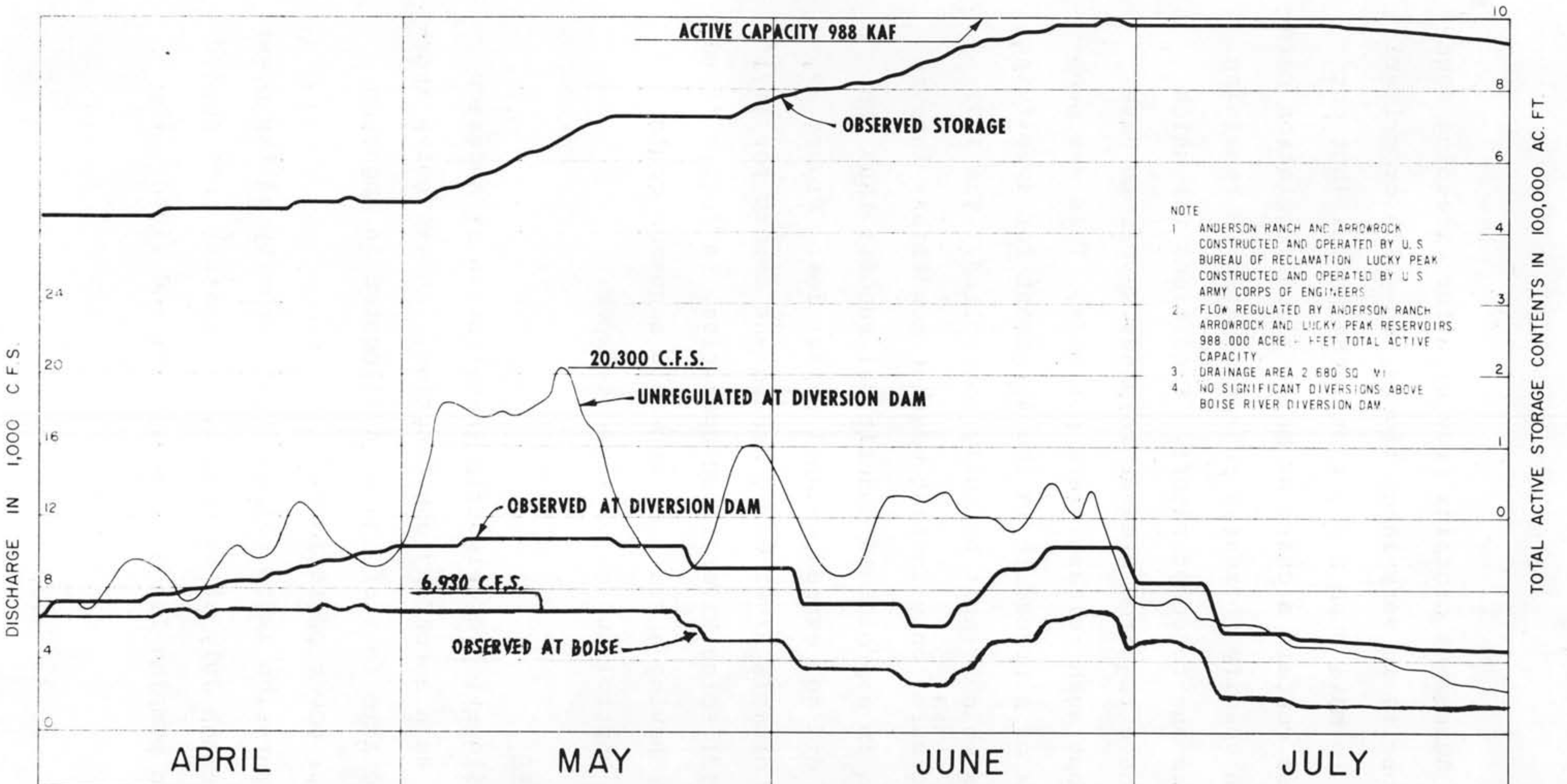
The curves which specify space requirements based on forecasts (Plate A-2, Boise River Regulation Manual) were constructed on the assumption that the Main (New York) Canal diversions could be relied upon in flood years. At least partly offsetting this in variable and undetermined amounts is the fact that the maximum flow below Diversion Dam can exceed 6500 cfs when the lower canals are diverting. There is an obvious need to review the assumptions used in preparation of both the Manual and the Agreement in light of current conditions.

Although the Agreement contains provision for exceeding downstream channel capacity in very large floods, no guide or criteria has been provided to make such a decision. The Manual (but not the Agreement) does contain a chart of major flood regulation parameter curves which specify increased releases based on remaining flood control space and forecast runoff. Conditions for which the Manual would have required greater releases appear to have occurred in 1971 but such releases were not made. This was probably due to a lack of a procedure in the Agreement for specifying releases in floods which cannot be fully controlled. The 1971 operation was successful only in that weather conditions late in the flood resulted in a prolonged noncritical runoff; thus the regulated outflow did not exceed channel capacities. Figure 29, reproduced from "Columbia River Water Management Report for 1971" illustrates the 1971 Boise River flood operation. A future flood, somewhat larger or having a critical snowmelt sequence could result in loss of control and major flood damages.

Hydroelectric Power

The 35,000 kilowatt hydroelectric installation at Anderson Ranch is operated as a secondary use function. An exclusive storage right of 5,200 acre feet of space is allocated in Anderson Ranch Reservoir for power operations.

The normal operation is to release full capacity of the power plant from May through July at essentially a constant rate needed to meet irrigation pumping loads. During fall and winter, the



COLUMBIA RIVER WATER MANAGEMENT GROUP

FIGURE 29. 1971 FLOOD REGULATION

BOISE RIVER AT AND NEAR BOISE, IDAHO

CHART 38

reservoir is operated to maintain the power head as high as possible and a lesser flow is released through the power plant. This usually amounts to an average of 400-500 cfs with daily fluctuations to meet load variations that are characteristic of the area power load.

Data for actual power production on load served are available on a very detailed basis in the Snake River Projects Office of the U.S. Bureau of Reclamation.

It should be mentioned that original project studies proposed power production for Lucky Peak Dam, but it was not included in the constructed project. More recent studies of the U.S. Corps of Engineers have projected storage development of the Twin Springs Reservoir site and provisions for adding power capability to Lucky Peak Dam. This is described in the two volume report of the U.S. Corps of Engineers Interim Report No. 6 (1968).

Recreation and Aquatic Life

Lucky Peak Reservoir is very popular with recreationists and to accomodate water based activities the reservoir level is maintained as high as possible with limited fluctuations until the beginning of September. To accomplish this, Arrowrock Reservoir is severely drafted and, to a lesser extent, Anderson Ranch, to meet irrigation demands. Anderson Ranch Reservoir releases are made gradually, when possible, so that disturbance to fishing activity below the dam is minimized.

The Idaho Fish and Game Department has contracted for 50,000 acre feet of space in Lucky Peak Reservoir for fishery maintenance below Lucky Peak Dam. In the fall after irrigation releases are stopped, about 100 cfs is released at Lucky Peak from this space. This discharge is maintained until the next irrigation season unless: (1) flood control operations require a greater release; or (2) the amount of water that is available from the space has been entirely used. In the latter event, a special agreement between the Idaho Fish and Game Department and the USBR may be made to release an amount less than 100 cfs from unallocated space in Lucky Peak. When the amount of water remaining in the unallocated space is less than average, this release would not be made.

In some years, releases cannot be made at Lucky Peak Dam for periods of up to six weeks when maintenance work is required on the outlet works at the dam.

Reservoir Storage Accounting

Allocations of storage space to individual canals and other uses are described in WATER RIGHTS and listed in Tables 12, 13, and 14. The entire space of Arrowrock and Anderson Ranch Reservoirs has been allocated to irrigation districts or canal companies with two exceptions. In Anderson Ranch, 5,200 acre feet have been allocated to power production; and in Arrowrock 23,000 acre feet have been reserved for future irrigation in the Hillcrest area of the Boise Valley. Of the total 278,200 acre feet of usable storage in Lucky Peak Reservoir, 116,250 acre feet of space have not been contracted for, and therefore is not committed to any use. Of the remaining storage, 111,950 acre feet are allocated to irrigation districts or canal companies and 50,000 acre feet to the Idaho Fish and Game Department. The amount of power, unallocated, and Fish and Game water available each year is calculated the same as that for irrigation allocations. The unallocated water in Lucky Peak is available for purchase at $0.50 per acre foot by canals and districts with existing water rights. The reserved water in Arrowrock is leased each year to the Boise Project Board of Control.

Early in the irrigation season when the four reservoirs (Anderson Ranch, Arrowrock, Lucky Peak and Lake Lowell) have reached their maximum content, the water available to all spaceholders for the coming season is calculated. The Boise Project Board of Control determines the amount available to spaceholders in Anderson Ranch, Arrowrock and Lake Lowell reservoirs, while the Bureau of Reclamation determines the amount available to Lucky Peak spaceholders. When all four reservoirs fill to capacity, spaceholders receive credit for 100 percent of their storage allocation. If all four reservoirs do not fill the storage received by each spaceholder is calculated using the percent of fill.

Even though a reservoir does not physically fill, it may be considered full if water storable under the rights of that reservoir is physically present in another reservoir. Arrowrock Reservoir and Lake Lowell have the earliest storage rights on the river, and therefore are considered filled when an amount equal to their capacities (286,000 and 169,000 acre feet) has been stored within the system. The next earliest storage right is for storage at Anderson Ranch Reservoir which has a usable capacity of 423,200 acre feet. Runoff at Anderson Ranch which is not committed to diversion rights on the lower Boise River can be stored at Anderson Ranch and attributed to storage there, if Arrowrock and Lake Lowell reservoirs have previously filled. Lucky Peak Reservoir has the latest storage right and can store all water not storable at Anderson Ranch, Arrowrock or Lake Lowell and which is not committed to other diversion rights. The maximum usable space in Lucky Peak is 278,200 acre feet, but not more than 265,000 is filled under normal conditions because of the danger of waves washing over the emergency spillway.

At the end of the irrigation season, the amount of storage water not used is calculated for each spaceholder. Unused water in Anderson Ranch and Lucky Peak reservoirs can be carried over to the next irrigation season and added to new water if the space fails to completely fill. However, spaceholders cannot accumulate more than 100 percent of their storage allocation. Stored water in Arrowrock and Lake Lowell is not credited as carryover for individual spaceholders. This procedure is a result of the nature of the original agreements with spaceholders in the reservoirs.

Table 27 shows the carryover credited to each reservoir for a dry year (1961), an average year (1970), and a wet year (1971). Because Arrowrock and Lake Lowell reservoirs do not credit individual spaceholders with carryover, the values shown for these reservoirs apply only to the next year's refill of those reservoirs.

The amounts for Anderson Ranch and Lucky Peak reservoirs are reserved for individual spaceholders. These amounts are not necessarily the same as the actual storage content of each reservoir at the end of the season, however the total carryover is equal to the actual content of the system.

Table 27. Representative Carryover of Usable Storage for Boise River Reservoirs.
(Units in 1000 Acre - Feet)

Year	Carry-Over Storage				
	Anderson Ranch	Arrowrock	Lucky Peak	Lake Lowell	Total
1961 (dry year)	92.9	0.7	1.3	61.1	156.0
1970 (avg. year)	246.3	1.3	265.6	116.8	630.0
1971 (wet year)	293.4	1.4	262.7	123.2	680.7

The Boise River Watermaster administers and accounts for the distribution of the stored water. When canals begin to use stored water, the Watermaster keeps a current account of each canal's remaining storage. Spaceholders in Anderson Ranch and Arrowrock reservoirs can use their storage as desired, but because the construction cost of Lucky Peak Dam was not allocated to irrigation, irrigation storage in this reservoir is operated differently than that in the other two on-river reservoirs. Unlike Arrowrock and Anderson Ranch, spaceholders in Lucky Peak are not charged for contracted space unless it is actually used and this charge is based solely on the cost of operation and maintenance. In addition, a spaceholder must have withdrawn any and all stored water that is available in the other two reservoirs before Lucky Peak water is used.

Estimated Long Term Operation

An operational model of the Boise River has been developed by the Idaho Water Resource Board. This model is a part of a series of surface water models used to evaluate hydrologic effects of alternative methods of management in the entire Snake River Basin. Using this model, monthly estimates of Boise River Reservoir contents and flows were made assuming present level of development in the years 1928 and 1968.

End of month storage resulting from this study is presented for Anderson Ranch, Arrowrock and Lucky Peak reservoirs in Figures 30 through 32, respectively. In addition to the simulated contents of these reservoirs, the historic reservoir contents are also shown. Differences between the simulated and observed values are the result of applying two assumptions uniformly each year throughout the entire period. These assumptions were:

a) All structural controls existing in the year 1973 exist during the entire period of operation;

b) All structures are operated throughout the period to reflect 1973 methods of operation.

The simulated values do not reflect the effects of special operations that frequently occur in the actual system. These operations occur at random and are impossible to predict in simulation studies.

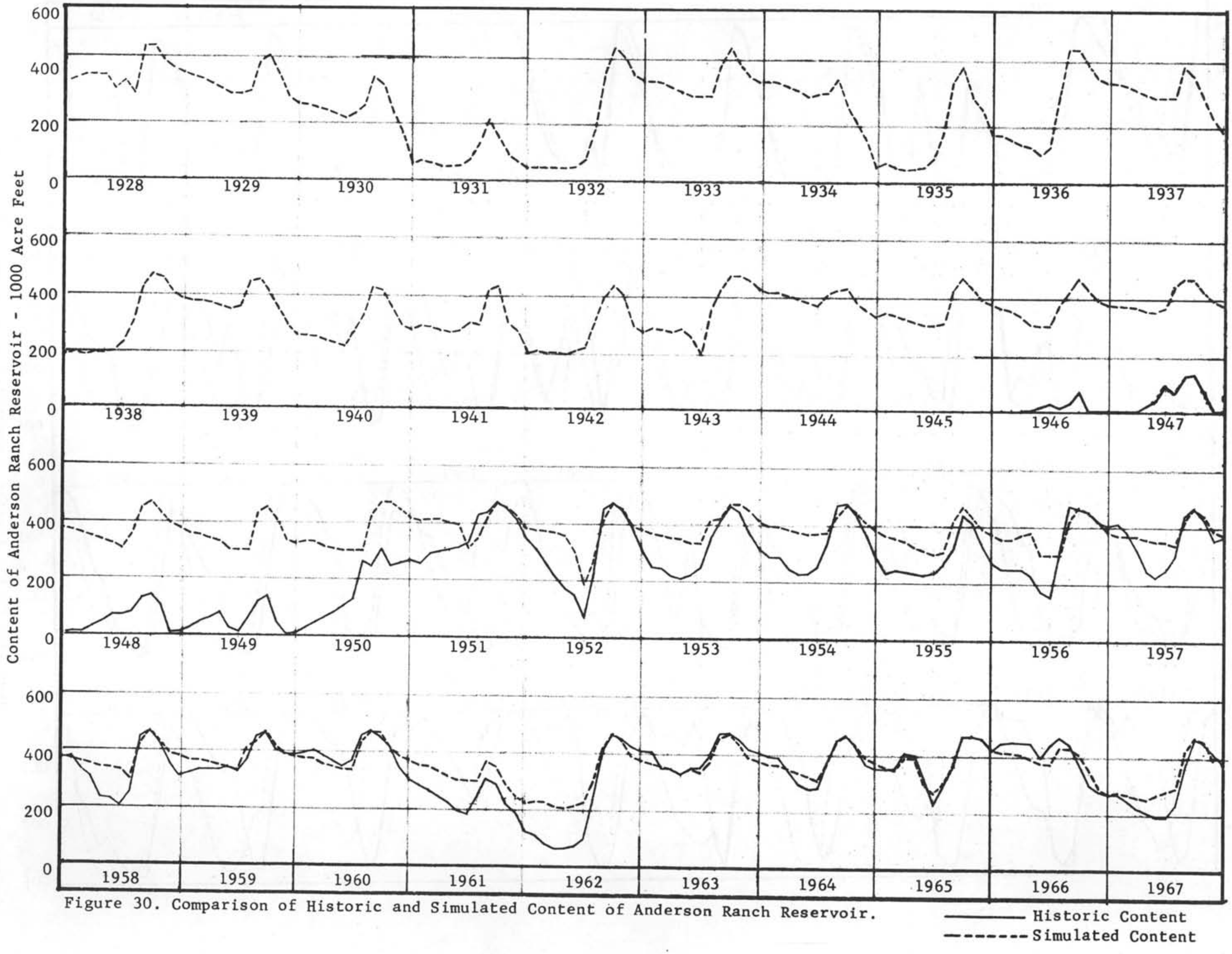


Figure 30. Comparison of Historic and Simulated Content of Anderson Ranch Reservoir.

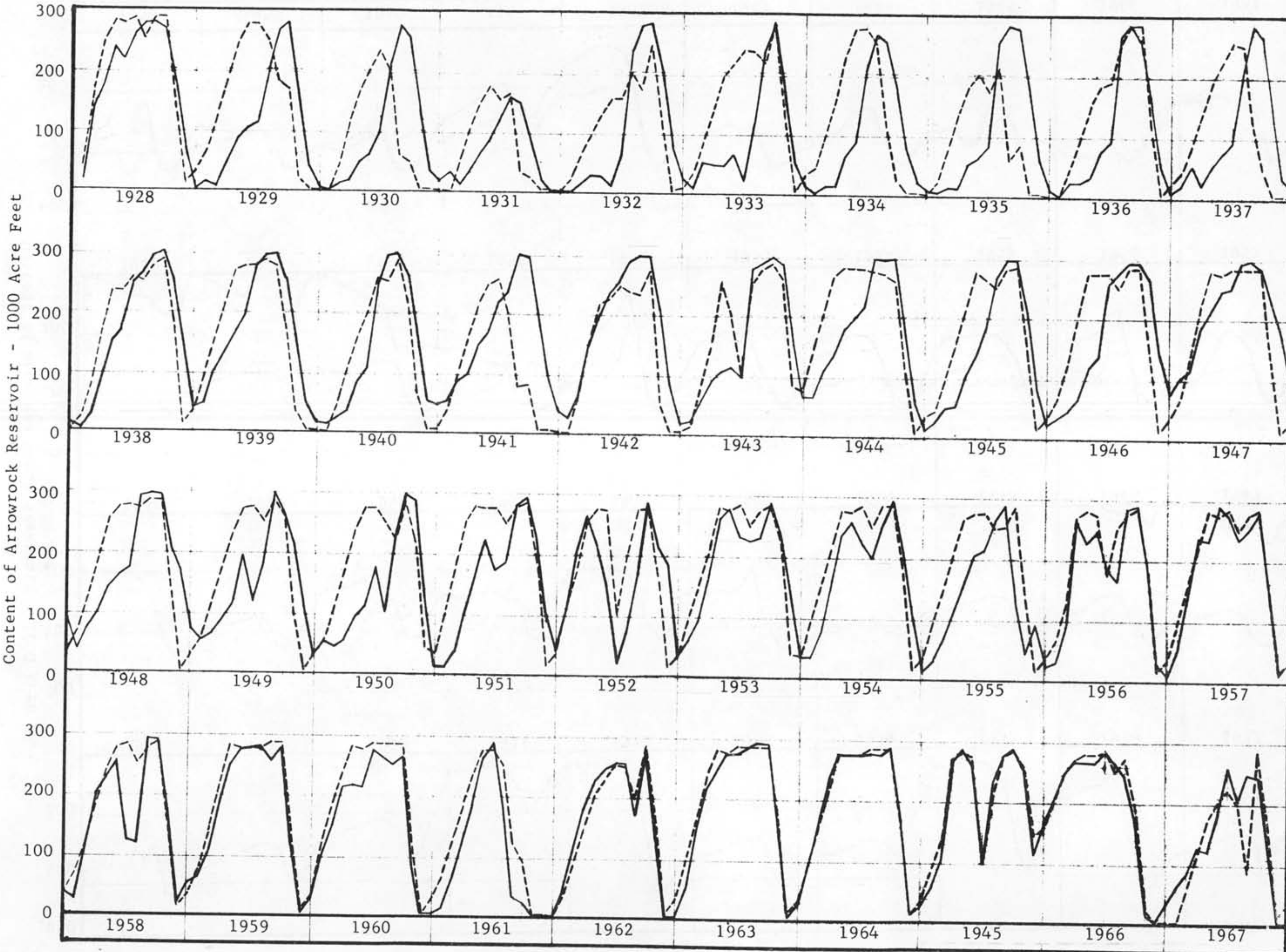


Figure 31. Comparison of Historic and Simulated Content of Arrowrock Reservoir

Historic Content
Sim[illegible]ed C[illegible]nt

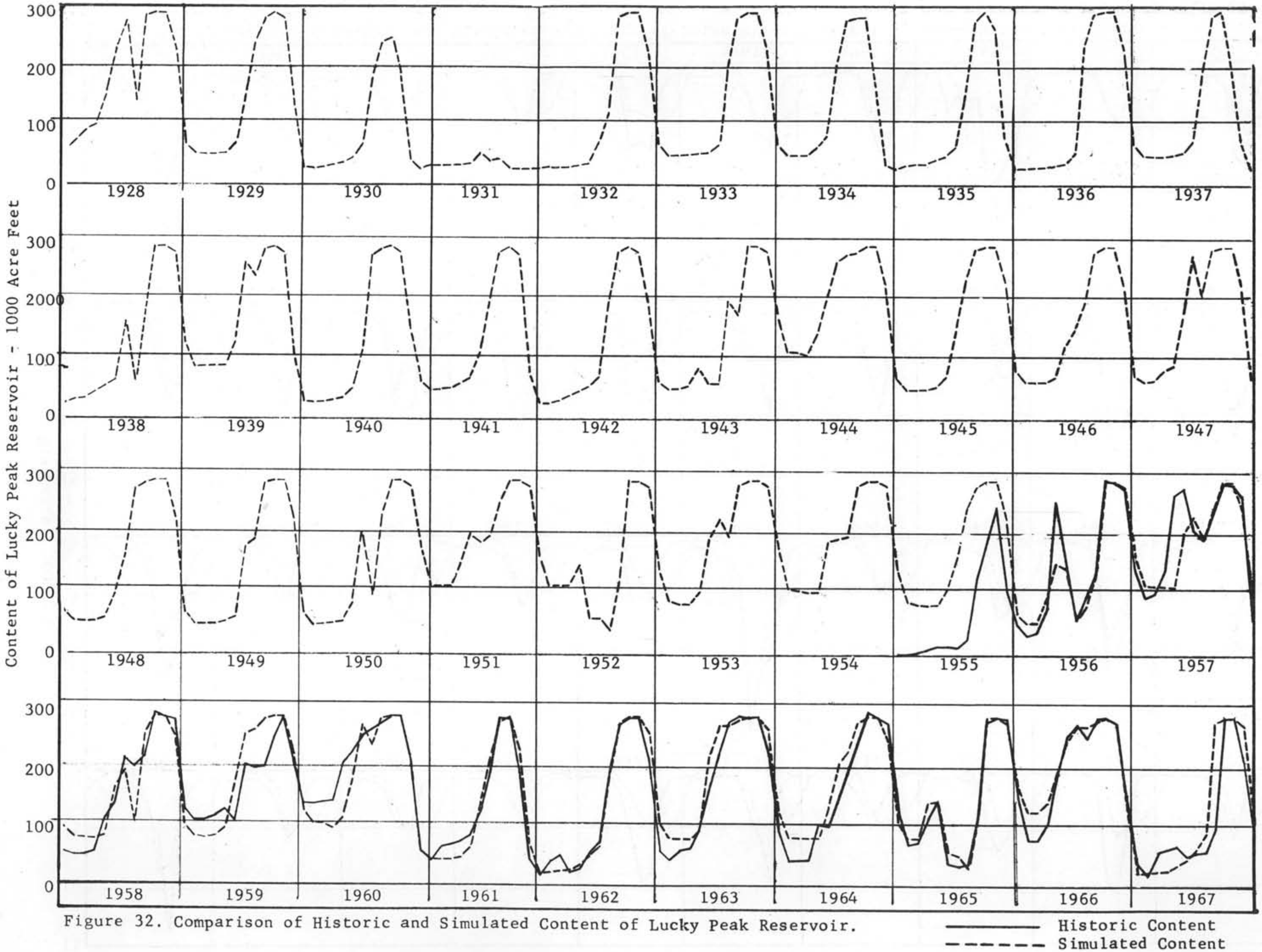


Figure 32. Comparison of Historic and Simulated Content of Lucky Peak Reservoir.

Figure 33. Comparison of Natural and Simulated Discharge of Boise River Near Boise.

——— Natural Discharge

- - - - Simulated Discharge with all Reservoirs in Operation

Assuming that water supply conditions experienced from 1928-68 were sufficiently varied to adequately reflect probable future runoff conditions, the reservoir operations shown in Figures 30, 31 and 32 are typical of those that will be experienced in the future. All reservoirs were emptied in one year, 1931, out of the 41 years of simulated operation. That year was the last year of a four year critical sequence in which the reservoirs failed to fill in three consecutive years. The study indicated that irrigation shortages to all canals receiving water from the Boise River would have been about 400,000 acre-feet, or about 20 percent of the total diversions.

As a result of the above reservoir operation, the monthly flow from each of the reservoirs was simulated for the same period. Figure 33 compares the 1928-67 simulated discharge of Boise River near Boise with the computed natural flow at the same location. These data show the effect that the reservoir regulation system has on the river below Lucky Peak Dam.

Further use of this model can be made to evaluate the effectiveness of present operation of both the Boise Project and the non-federal developments in utilizing the available water supply. Various management alternatives can be examined and compared to the present operation to determine possible improvements. Examples of alternatives which could be evaluated are: improved irrigation efficiencies, ground water pumping, longer maintenance of recreation levels, use of unallocated space, new reservoirs, minimum flows, and revised power operations. An aquifer model is being developed as a part of this sub-project and will be discussed in the GROUNDWATER section. Together these two models are capable of completely describing the effects of present day operations on the Boise Valley water supply and optimizing alternatives for river management.

BOISE VALLEY GROUND WATER

The lowland of the Boise Valley is a broad alluvial plain having low relief adjacent to the river channel. At the head of the valley there is the Broadway Terrace on the north side of the river, and on the south a series of terraces that form a transition belt of low scarps and benches (Whitney Terrace, Sunrise Terrace, and Gowen Terrace) that rise steplike to the level of the Mountain Home plateau. On the north and east the valley is bounded by low foothills, an area referred to as the Boise Ridge. On the west and south the valley merges with the main valley of the Snake River. Nace, et al. 1957, describe the underlying geology as follows:

> . . . Beneath the entire area, from the mountains north of Boise southwestward to the Owyhee Mountains, a huge basin is formed by a troughlike, impermeable floor of consolidated ancient rocks, the Idaho and Owyhee batholiths and associated older rocks. Within this trough is a great thickness of Tertiary stream and lake deposited sediments (Payette formation) and volcanic rocks (so-called) Owyhee rhyolites of Kirkham (1931) and Columbia River basalt). These rocks have generally low permeability but form a deep regional groundwater reservoir in which the water bearing beds are at depths of hundreds to perhaps thousands of feet. Resting on these materials is a younger group of sediments, the Idaho formation, which is quite varied in its water-bearing properties but is somewhat more permeable than the older sediments. The Idaho formation, consisting chiefly of clay, silt, and sand is a source of moderately deep artesian water in the Boise and Snake River valleys. On the ancient land surface formed by the Idaho formation, streams spread a thick sheet of permeable terrace gravel. Lava flows formed the Snake River basalt, which rests on the lower part of the gravel at some places and is covered by the upper part of the gravel at other places. Basalt accumulated chiefly on the Mountain Home plateau

and in the south-central part of the Boise Valley, only a few sheets extending to the southern edge of the eastern part of the valley. The Snake River then cut a deep canyon through the basalt and sediments, forming the present course of the Snake River. Meanwhile the Boise Valley was formed by alternative stream erosion and deposition, which formed terraces underlain by permeable younger terrace gravel, and bottom land occupied by highly permeable recent alluvium. Recent lava flows are interbedded with terrace gravel at a few places. Thus the younger water-bearing deposits in the Boise Valley occupy a partly closed basin that was eroded in older terrace gravel and Idaho formation."

For detailed reports, the following give more geologic information especially at the borders of the basin; Dion (1972), Kirkham (1931), Lindgren (1898), Lindgren (1904), Mohammad (1970), Savage (1958), and Toron (1964).

Nature of Ground Water Occurrence and Recharge

The geologic description speaks of the older and deeper formations and writers tend to refer to two aquifer systems, the deeper aquifer of lower permeability sometimes referred to being in the Glenns Ferry Formation of the Idaho Formation and the shallower system of older terrace gravels, basalts of the Snake River Group, the younger terrace gravel, and Quaternary alluvium. The deeper aquifer is quite commonly under artesian pressure. The upper or shallow aquifers appear to be complex, but are often treated as a single hydrologic unit. Superimposed on this are perched water tables caused by caliche layers.

Before the period of irrigation, recharge was from the limited precipitation, seepage from the intermittent local streams, and some leakage from segments of the river just east of Boise. Indications are that the depth to the water table was in excess of

100 feet. Dion (1972) indicates the recharge at present comes from the leakage from irrigation canals, the downward percolation of applied irrigation water and precipitation, and by downward percolation of domestic waste water from septic tanks, losses from the local intermittent streams and the segments of the Boise River. He also mentions upwork leakage from the deeper aquifer.

Definitely there has been a rise in the water table of these upper aquifers. This is illustrated by the hydrograph of a long-time well record presented as Figure 34. The most rapid change apparently occurred in the period from 1911 to 1935. Carter in the Fourth Biennial Report of the Idaho Department of Reclamation (1926) noted that beneath 125,000 acres of land in the Boise Valley (more than one-third of the irrigation area) the water table was less than 15 feet below the land surface. The report of Dion (1972) indicates rather minor change in water table conditions from 1953 to 1970.

Three recent M.S. theses from the Geology Department of the University of Idaho give further detail on the ground water occurrence. Toron (1962) treated an area in the vicinity of Boise City. Mohammad (1970) studied an area near the foothills of the Boise Ridge on the north side of the Boise River. His study had limited information on the flow system of the Glenns Ferry Formation. He concluded that the regional ground water flow system in that vicinity near the Boise Ridge does not have much natural recharge along the Boise River, but must extend discharge further south in the Idaho Formation. Williams (1973) reported on studies in the

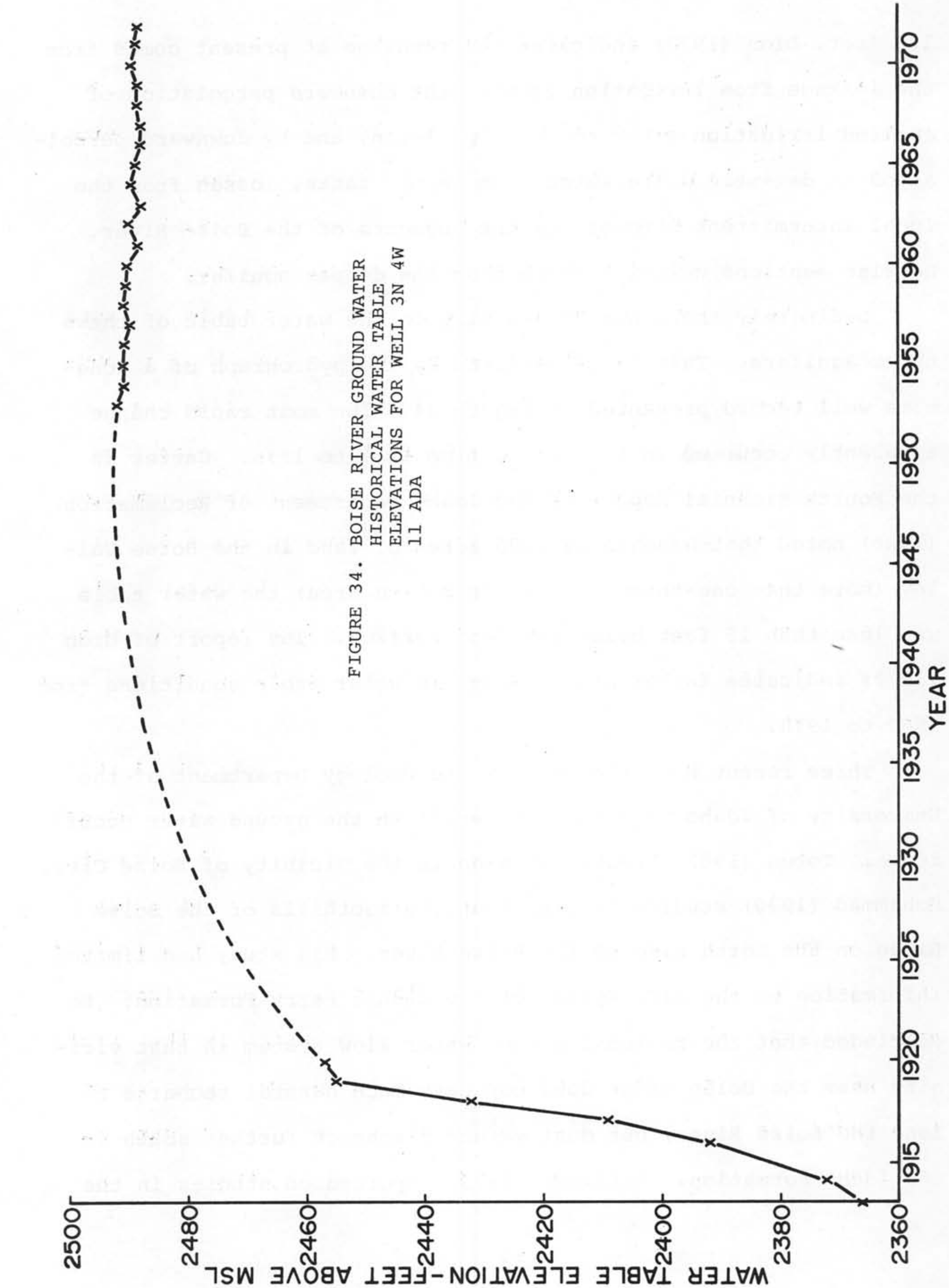


FIGURE 34. BOISE RIVER GROUND WATER HISTORICAL WATER TABLE ELEVATIONS FOR WELL 3N 4W 11 ADA

central portion of Canyon County and presented some updated water level data in connection with his research on location of land areas appropriate for the disposal of waste waters. Dr. L. Mink of the Idaho Bureau of Mines and Geology has continued studies on locations of land areas for waste water disposal extending into most of the lowlands of the Boise River Basin.

Apparently the upper aquifer has reached a somewhat stable condition. Indications in several reports refer to waterlogging that has occurred in the basin and an extensive system of drains has been advocated by studies to alleviate the condition. An early study of the drainage problem was covered by a brief report by Keener (1920) and a supplement by Keener (1921) in February of 1921. The first report gives one of the early maps of depth to ground water in detail. Locations of wells are also identified in another map. These reports mention the problem of lack of identity of the ground elevations at the wells. Tabulations are shown indicating rates of ground water rise by year and predictions were made as to when water logging would likely occur.

The report of Carter (1936) as Exhibit A in the U.S. Bureau of Reclamation report by Riter and Keimig (1936) gives interesting comments on pumping of ground water for drainage and to serve as a supplemental water supply. A ground water map prepared by Carter for the State Water Conservation Board is reproduced as U.S. Bureau of Reclamation Map 3-D-433. This map gives depths to the water table over much of the lowland portion of the basin.

A particular area witnessing high water table problems was the Whitney Terrace area to which West (1955) devoted a special study. Open drains constructed in the valley during the period 1914 to 1921 were reported as 127 miles in length, and Nace, et al., estimated the Mileage as of 1957 to be more than 325. The Pioneer Irrigation District and the western portion of the Nampa-Meridian Irrigation District have developed many drainage wells. Much of the drainage water is reused in the lowland portion of the basin. This reuse of water has made it very difficult to make water balance studies of the basin.

The natural hydrologic pattern of rise and fall of the water table would normally occur with highest levels in the spring, but because of the great effect of irrigation on recharge, the annual peaks always occur at the end of the season, in September and October. Examples of these seasonal fluctuations are reported by Nace (1957) and by Mundorff (1964), but a more up-to-date example of this is shown in Figure 35.

Nace, et al. contended that with the apparent filling of the upper ground water aquifer a stabilized condition evolved where ground water discharged by drains from the aquifers and upper alluvium far exceeds the amount of ground water withdrawn from wells. However, recent well development may have changed this relationship to some extent.

Water Table Conditions

Various attempts have been made to characterize the water table since the Boise Project has been under development. This

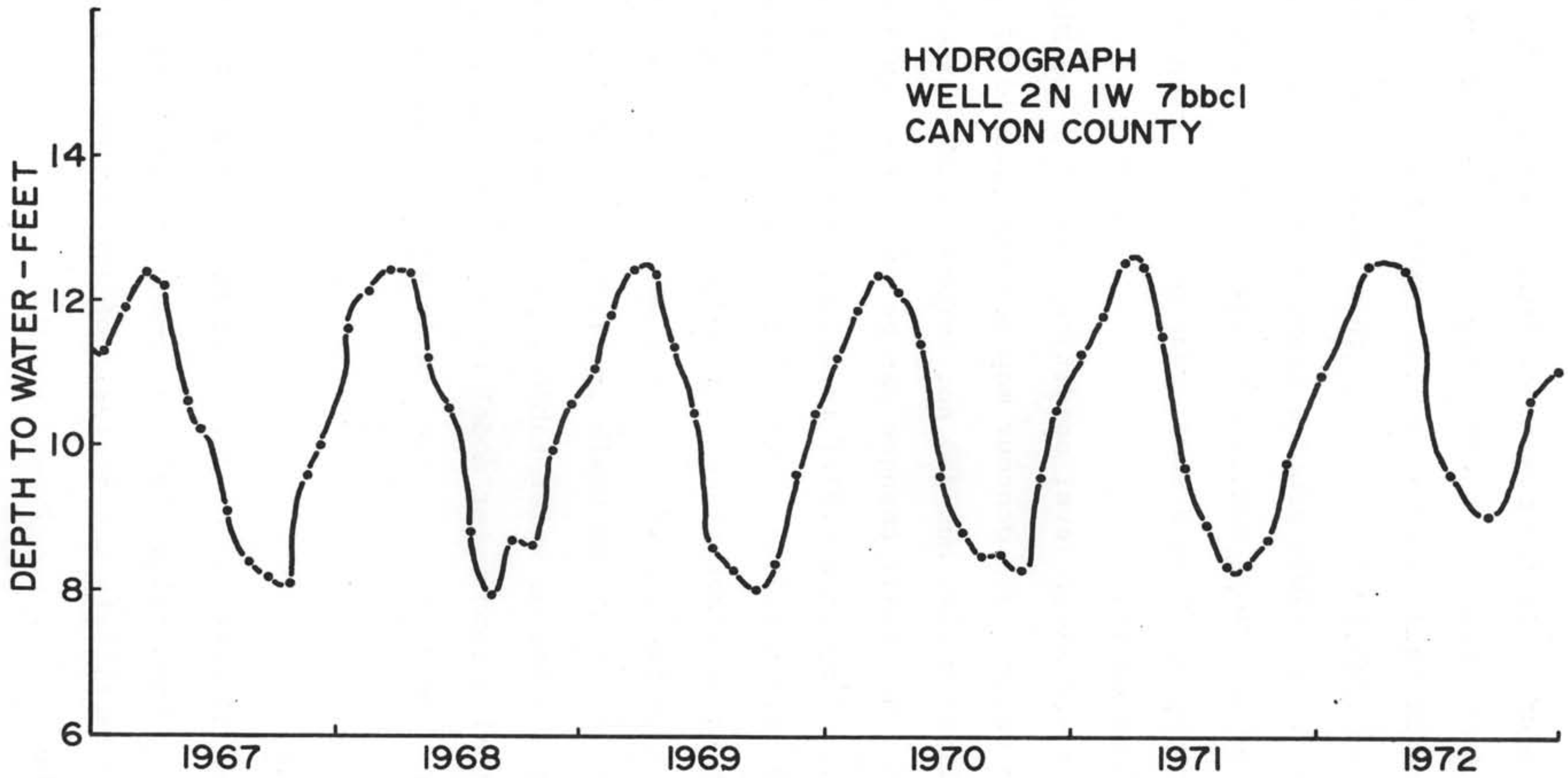


FIGURE 35. WATER TABLE SEASONAL FLUCTUATIONS

research forms a good basis for making evaluations pertinent to the use and control of water. An early depth to water map representing conditions of 1914 is presented as Plate 6 of U.S. Geological Survey Water Supply Paper 1376. This report also indicates several high water table problem areas in the valley. In particular areas of the Nampa-Meridian Irrigation District were affected by waterlogging as were some areas of the Whitney Terrace between Meridian and Ustick.

Nace (1957) gives water level conditions for 1953 and Dion (1972) presents a water table contour map for the year 1970. The latter study utilized wells, but did not extend to the western boundary of the basin. Small changes can be noted from 1953 to 1970. Measurements reported by Dion (1972) in 42 wells measured by both studies indicated only a 0.2 foot average decline, which the author concluded was not significant since year to year changes were as great or greater than the reported average decline. An updated ground water contour map of the basin utilizing 210 wells in the basin and correlating all previous water table maps has been prepared for use in a digital ground water model which is part of this subproject study. Figure 36 is the water table map prepared for the study.

Ground Water Model

A digital ground water model developed by de Sonneville (1972) and Brockway and de Sonneville (1972) is being adapted to the Boise Valley aquifer to facilitate the analysis of irrigation on the ground water system.

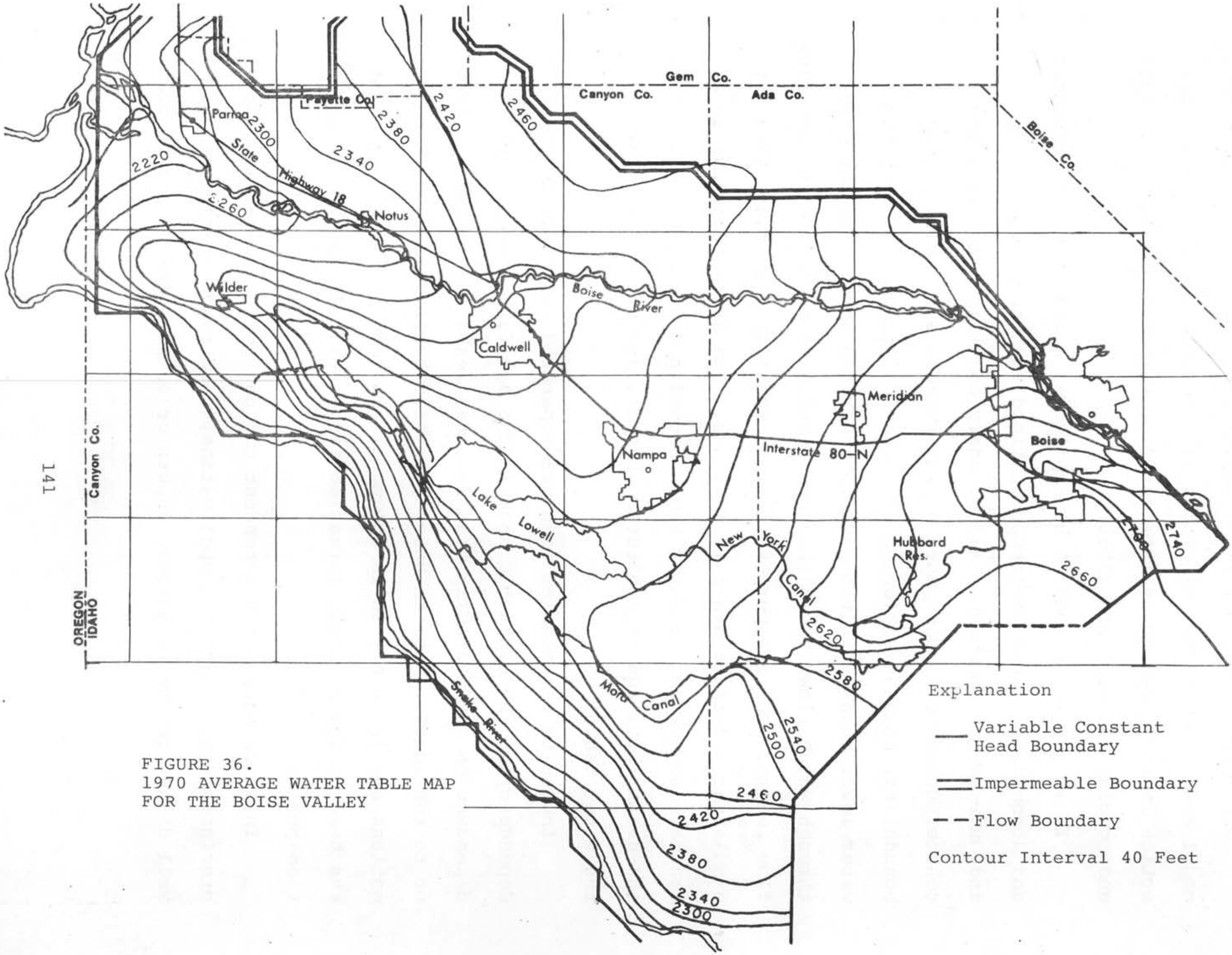


FIGURE 36.
1970 AVERAGE WATER TABLE MAP
FOR THE BOISE VALLEY

The mathematical model developed is a finite difference digital model and, like models of Pinder (1969), uses the alternating direction implicit method as introduced by Peaceman and Rachford (1953) and Douglas and Rachford (1956).

It is general enough to be applied to a wide range of aquifers and accomodates non-homogeneous confined and unconfined, leaky and non-leaky aquifers. All boundary conditions normally encountered can be handled such as impermeable and constant head boundaries; boundaries formed by lakes and streams in which the water level changes in time are incorporated and a flow boundary through which flow is variable and a function of the 'upstream' flow flow regime. For the purpose of management studies and option for simulating a surface drain is included. The drain functions as a constant head when the water table around the drain is higher than the drain level and is neglected when the drain level is above the water table.

Inputs to the modeled area are separated according to their dependency on the hydraulic head in the aquifer. Input which is dependent on the hydraulic head includes leakage (if present) from or to the aquifer from an underlying or overlying water bearing formations and is generated in the model program. It is assumed that the head in the adjacent formation is constant during the simulation period.

Input or output not dependent on the hydraulic head include precipitation, irrigation application, crop evapo-transpiration, well discharges or recharges, inputs or outputs due to change of average water content of the soil profile above the water table and canal seepage. Canal seepage is normally dependent on the water table levels and can be calculated in the model program as such, but in many cases unsaturated flow exists below the canal invert and canal seepage can be treated as a constant factor.

The Boise Valley aquifer has many different irrigation districts in which input due to irrigation practices varies substantially and with a spatially varying geology, rise of the water table may vary substantially from location to location. Maximum rise for all node locations may not occur at the same time. To make a reasonable simulation of the hydrogeological system it is considered necessary to approximate as accurately as possible inputs for each node at each time-step. Therefore, in a separate input program, data on climate, soils, crop distribution, irrigation diversions, distribution losses and irrigation practices are utilized to calculate a three dimensional input term for which a tape is generated. This tape serves as an input to the mathematical model program.

The data for a study area is composed of (1) data directly related to the water management of the study area. These data are used to generate the source term for the model program. (2) Other information is data related to the geo-hydrological properties of the aquifer such as the hydraulic conductivity values, the storage coefficient, the aquifer bottom elevation, the impedance of the leaky aquifer, the initial head difference between aquifers, and the initial water table values.

Except for water table data for which historical records are available from wells, information about the geo-hydrological parameters is extremely scarce for most aquifers. This is especially true for the Boise aquifer. With scarce geological or hydrologic input data, simulation of historical behavior can only be achieved with calibration. Hydrologic inputs to the Boise aquifer are considered to be better defined than geological parameters such as conductivity, storage coefficient, impedance of leaky aquifer and a trial and error calibration is cumbersome and the results doubtful. Therefore, a calibration routine which adjusts the hydro-geologic parameters systematically to achieve the proper aquifer response is included in the model program.

Water level data for 420 wells in the Boise Valley was acquired from U.S. Geological Survey and the Idaho Department of Water Administration files. Sixty of these were U.S.G.S. observation wells and the remainder were U.S.G.S. inventory wells. Two hundred fifty three well logs were obtained from the Department of Water Administration. Additional data for 71 wells was available in U.S.G.S. publications and in research theses from the University of Idaho. These publications also provided geologic and hydrologic data describing and helping to define the hydrologic units of the study area. Information on acreages served by ground water and by pumping from the Snake River were supplied by the Idaho Water Resource Board. Maps and publications defining irrigated lands and the water delivery systems were furnished by the Boise Project Board of Control, the Boise River Watermaster, and the Soil Conservation Service.

Water level data is most extensive for the year 1970 and for that reason, the 1970 calendar year has been selected as the base for the program. Water level contour maps have been computed for 1970 in order to examine the water table and to precisely define the boundaries of the model. Model boundaries have been established as; the Boise River from Diversion Dam to Eagle, the highlands north of the Boise River to confluence of Boise and Snake Rivers, the Snake River from its confluence with the Boise to longitude 116°30 (border of Ada and Canyon Counties) and a tentative boundary line drawn northeast to Diversion Dam excluding non-irrigated lands (Figure 35).

Surface water data was acquired from the Boise Project Board of Control, the Boise River Watermaster, Army Corps of Engineers, and extensive data from the Black Canyon Irrigation District Office at Notus, Idaho. The lands within the Board of Control were broken down into divisions which are combinations of two to three ditchrider rides for input to the model. All other irrigated lands were divided into convenient divisions subject to restrictions of available data. The twenty-five divisions average about 15 square miles and vary from eight to forty-five square miles.

The Corps of Engineers has supplied extensive data on the stages of the Boise River and its tributaries for various flows. This will be used in establishing the variable constant head boundary between Diversion Dam and Eagle and to refine the water table maps. Data on irrigation application is being prepared for the input model.

This model has been applied to the Snake River Fan aquifer in southeast Idaho and showed very satisfactory results. Boundaries which were satisfactorily simulated included constant head boundaries, variable head, impermeable boundaries and flow boundaries with prescribed or variable flow. A surface drain simulation was also achieved. The model was applied to the area despite scarce geological data. With the calibration routine included in the model program even with scarce geological data the model was capable of simulating historical behavior of the aquifer in the study area. The standard deviation from measured values was 1.25 feet for the priority timestep, while the average rise of the water table for this timestep was 35 feet. The ability to simulate historical behavior and the input flexibility makes the model very convenient for studying effects of management changes on aquifer behavior and will upon completion provide a workable tool for evaluating the effects of irrigation on the ground water in the Boise Valley.

CONCLUSION AND RECOMMENDATIONS

This study was intended as an evaluation of water use and water control of a major federal water development and the following conclusions are presented:

1. The study has met the project objective in presenting a valuable collection and cataloguing of hydrologic, water use and water control data for use by future investigators. It should be a valuable reference aid in water resources studies and in particular in evaluating the economic, social and environmental impacts of water resource development in the Boise River area.
2. Irrigation delivery records reveal that the irrigation diversion rates on federal project lands are presently lower than the non-federal entities as a whole. Use rates per acre appear to be stabilized and the federal project storage has provided a comparatively risk-free supply. More analysis is needed to provide a basis for indicating how well the system is achieving an optimum use of the water in a hydraulic and meteorological sense.
3. Irrigation return flows into the Boise river and reuse of return flows by downstream users greatly affect the management and diversion that are made in the system. Data on interchange of return flow water between districts is lacking as are winter return flow measurements.

4. The evolution of surface water rights has developed rules for allocation of natural flow which, if consistently administered, should provide equitable water distribution. Quantification of actual ground water withdrawals and applicable diversion rights is lacking.

5. Flood studies indicate that the flood control operations have successfully reduced peak flows below maximum channel capacities in the Boise area. However, it appears that this regulation may not have been achieved by strict application of the criteria outlined in the Corps of Engineers Reservoir Regulation Manual.

6. Mathematical simulation of the ground water of the basin offers the greatest potential for evaluating the interrelationships of irrigation applications, water table levels and return flows. Successful simulation of the ground water system will assist in evaluation of the effects of irrigation development and possible changes in water management on the water resource in the basin.

Several recommendations are made which if implemented could assist user groups, planners, and operating agencies in understanding and operating the system. These recommendations primarily in the form of data needs are as follows:

1. Determination of regulated flood frequency curves should be completed for the entire period of record considering present facilities and management. The available curves are not adequate and determination of flood damage potential

with the reservoir system in operation depends on reliable regulated flood frequency curves.

2. Boise River channel capacities should be re-evaluated. Normal aggradation has probably occurred since the 1939 determinations and re-evaluation would be helpful in flood control decisions as well as flood damage studies.
3. An attempt should be made by operating agencies to standardize runoff forecast procedures.
4. The Corps of Engineers - Reservoir Regulation Manual and the Flood Control Operation Agreement should be re-evaluated in light of current conditions. Specific topics which should be considered are criteria for determination of storage space requirements, integration or irrigation canal diversions in flood control operations and effects of pre-regulation season canal diversions on flood control.
5. Differences in water diversion rates between different types of systems operating in the Boise River area are influenced by many factors including governmental control, water rights, geographical location, and other factors. The magnitude of the effects of these influences could be determined by a study of water diversion and delivery rates, return flow, and conveyance losses for the four types or patterns operating in the basin, namely: (1) the old decreed right canal systems having non-federal affiliation, (2) the Boise Board of Control system lands that involve an old private irrigation system upon which

has been superimposed a federally designated and operated reservoir system, (3) the newer Black Canyon Irrigation District system which was designed and built by the U.S. Bureau of Reclamation and operates with water supplied from a federally operated trans-basin diversion, and (4) an area of new lands that are being privately developed and involve sprinkler irrigation systems and minimal influence from governmental control.

6. A continuing program of return flow measurement should be implemented to monitor the distribution and reuse of return flow between irrigation districts. A program for measurement of return flows during the nonirrigation season should be implemented. This data would assist in evaluating water use and water supply requirements and would add to the present limited knowledge of the hydrologic system.

7. A gaging station at Star on the Boise River should be installed. Measurements at this point will allow accurate determinations of return flow distribution and assist in the regulation of the river for irrigation.

8. An extensive survey of actual surface and ground water irrigated land should be made including areas adjacent to the Boise River drainage, but tributary to the Snake River. This survey will assist in ascertaining the effect of urbanization and conversion to sprinkler systems on the water requirements and on the aquifer system.

9. With the four reservoir system, the possibility of applying new techniques for reservoir operation optimization should be considered. Twenty years of operational data on the system should be sufficient for application of probabilistic techniques to operational studies on the Boise River system. Techniques such as those outlined by Morris (1965) should be applicable.

10. Continued studies should be pursued toward development of the ground water model with integration of return flows and river reach gains.

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