Review of

Boise River Flood Control Management

November 1974

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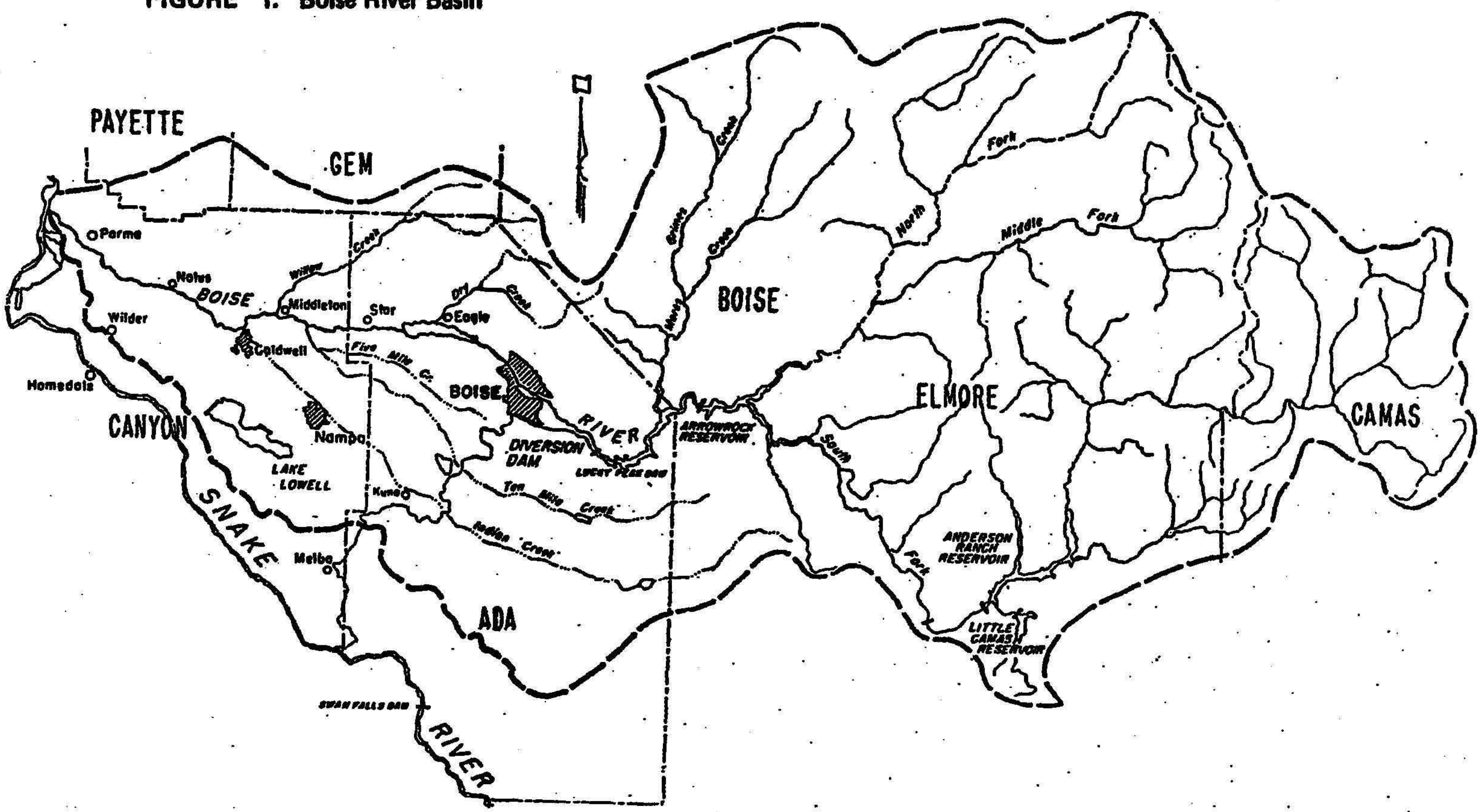
BOISE RIVER FLOOD CONTROL MANAGEMENT

IDAHO DEPARTMENT OF WATER RESOURCES
STATEHOUSE
BOISE, IDAHO 83720

NOVEMBER 1974

FIGURE 1. Boise River Basin



FOREWORD

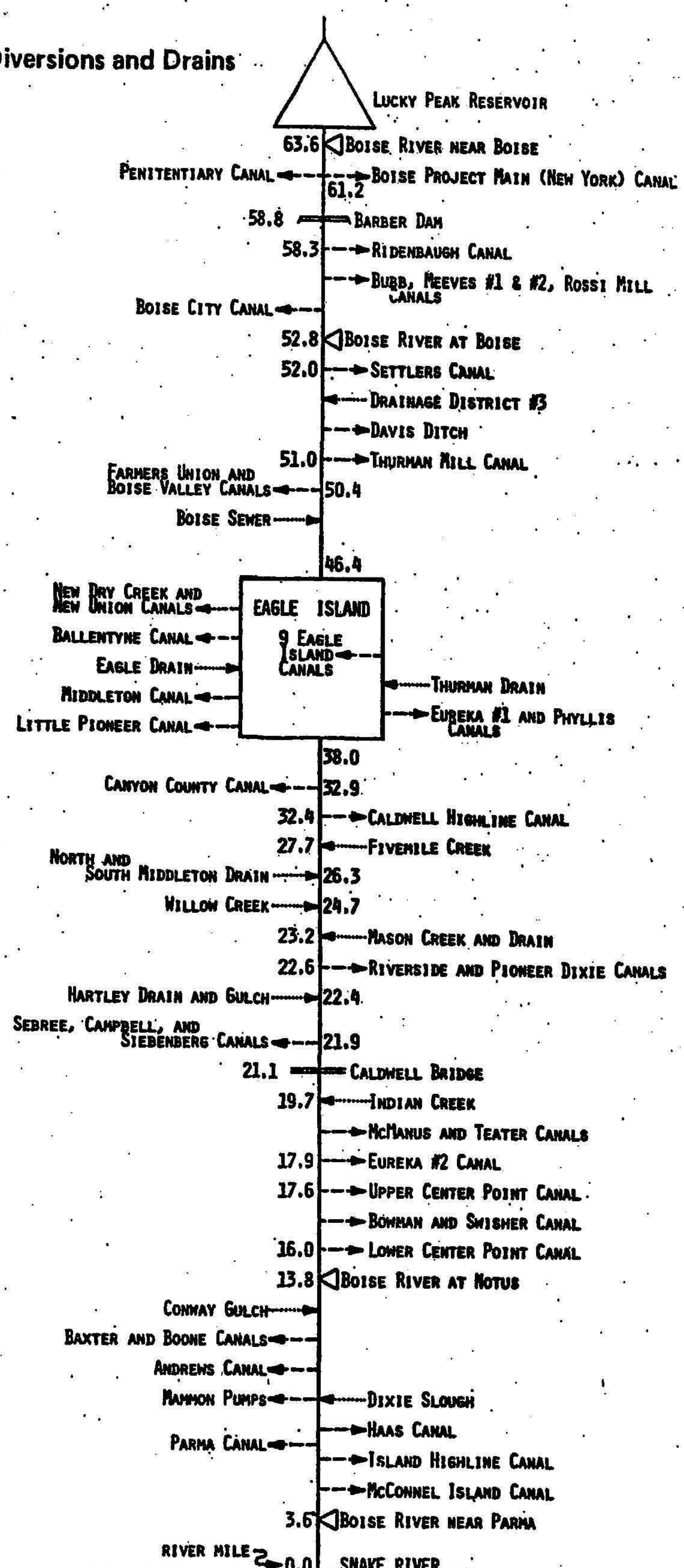
In May 1974, Governor Andrus requested that the flood control operations on the Boise River be reviewed and the possibilities for improved operations examined.

This report is a study of the flood control operation of the Boise River. The river system of dams and reservoirs is operated mainly for irrigation, power, recreation and flood control; however, irrigation, power and recreation uses are not discussed except as they relate to flood control management.

Present management agreements, runoff forecast methods, and flood frequencies are presented. The procedures which established the water releases from Lucky Peak, Arrowrock and Anderson Ranch reservoirs are reviewed.

The report identifies problems, examines the potential of various alternatives, and presents recommendations which would lead to improved operation.

FIGURE 3. Boise River Diversions and Drains



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INTRODUCTION

THE PROBLEM

Boise River flows are controlled by the federal system of reservoirs which were constructed for irrigation, flood control, recreation, and power. Since completion of Lucky Peak Reservoir in 1954, flows have been almost completely regulated. A formalized flood control procedure was instituted at that time which specified how the reservoirs were to be managed during the flood control season. The system has operated successfully with that procedure for about twenty years generally controlling all floods to within the original objective of a regulated flow of 6500 cfs through the city of Boise.

Conditions have changed in the intervening years. More use is now made of lands along the river between Lucky Peak Dam and the mouth. In some areas encroachments have been made on the channel by levees, farming activities, roads, and home construction. Channel capacities may also have changed from natural causes associated with the more complete flow regulation.

In recent years landowners along the river have frequently complained about high flows during the springtime flood regulation period. Other complaints have been made about flows which were too low at times.

In response to these complaints Governor Andrus requested a review of the reservoir operation procedures. His memorandum of May 1974 to the Department of Water Administration and the Water Resource Board (now consolidated into the Department of Water Resources) is quoted below.

> "Numerous landowners affected by the high levels of Boise River water have contacted this office to determine whether a more efficient method might be incorporated into the operation of the controlling reservoirs.
>
> "Please conduct a comprehensive review of the procedures which established the water releases from Lucky Peak, Arrowrock and Anderson Ranch reservoirs.
>
> "Extremely low flows preceding recent high releases have drawn criticism to the methods employed in regulating the river flow. Landowners ask why releases of Boise River water were not made at an earlier date last winter in anticipation of this year's high runoff.
>
> "Make public the results of the review."

This report is in response to the Governor's directive. Following sections will describe the Boise River system, its operation, and the potential for changes which may alleviate some of the downstream problems.

Aspects of the operation not directly related to flood problems will be treated only to the extent necessary to clarify flood control operations. Substantial information for this report describing the system and its operation was obtained from the Corps of Engineers and Bureau of Reclamation, the operating agencies.

RELATED STUDIES

Other studies have analyzed present and alternative methods of management of the Boise River and adjacent land areas. Following are brief descriptions of recent studies which are related to the subject of this report. These studies are in various stages of completion.

Boise Valley Regional Water Management Study

This study is being conducted jointly by the Ada Council of Governments, Canyon Development Council, and U. S. Army Corps of Engineers, Walla Walla District. It was begun in 1973 and will be completed in June 1976. The study will develop plans for management of wastewater, recreation, and domestic water supply. In addition, programs will be recommended for urban flood damage reduction.

Wastewater management analyses will include studies of various combinations of flow augmentation and wastewater treatment which meet Environmental Protection Agency and State of Idaho water quality criteria. Results will include comparisons of waste loads, required flows, and associated costs. Preliminary studies have been made to determine the frequency of availability of flow from the unallocated space in Lucky Peak Reservoir. Results indicate that when combined with the space allocated to the Idaho Fish and Game Department, a release from Lucky Peak of 120 cfs could be made during the non-irrigation season in 95 percent of all years; and a release of 150 cfs could be made in 85 percent of all years.

Boise Post Audit Hydrology Subproject

This study is part of a University of Idaho project entitled "A Case Study of Federal Expenditure on a Water and Related Land Resource Project, Boise Project, Idaho and Oregon." The project was funded by the Office of Water Resources Research for the fiscal year 1974. The intent of the case study is to evaluate the social, economic, and physical impact of the federally funded Boise Project. The Hydrology Subproject was organized to provide background information on past and present water supply management and hydrologic conditions. The information will be used to support later phases of the case study.

The Hydrology Subproject draft report was completed in June 1974. It contains descriptions of runoff, flood frequencies, water rights, irrigation operations, return flows, reservoir operations, and groundwater in the Boise drainage. The descriptions and data contained in this study relate directly to a review of Boise River management and some of the material is used in this report.

Lucky Peak Dam and Lake Environmental Impact Statement

This report is being prepared by the Corps of Engineers for submission to the Council on Environmental Quality. The purposes of the report are to describe the environmental setting of Lucky Peak Reservoir, the impact of the reservoir on the environment, and to examine possible alternatives of reservoir management. A draft report was completed in March 1974 and comments from agencies, organizations, and individuals have been requested.

A description of the operation of Lucky Peak Reservoir for irrigation, flood control, and recreation is given in the report. Impacts of the operation on recreation, water quality, and animal life are discussed. Management alternatives presented by the report are:

(a) Do nothing;
(b) Use Anderson Ranch Reservoir storage to supplement Lucky Peak recreational water levels;
(c) Increase downstream flood control measures;
(d) Use dead storage to augment winter flows;
(e) Supplement municipal and industrial water supplies from Lucky Peak storage;
(f) Add Lucky Peak power generation capacity;
(g) Coordinate Lucky Peak levels with fish and wildlife requirements;
(h) Use weather modification techniques to control runoff.

The draft statement rejected the last two alternatives because of inadequate data. In considering the other alternatives the recommended course of action was to adopt the first alternative, or "continue with present operation, maintenance and management practices according to the existing system agreement." It is stated that selection of management alternatives is limited by established physical and cultural factors.

Boise Valley (Ada County) Levee Restudy

A continuing study initiated in 1973, this study is an evaluation by the Corps of Engineers of the present levee system along Boise River in Ada County. Alternative solutions that are to be examined are new and rebuilt riverfront levees, set-back levees, channel enlargement, flood plain management, flood insurance programs, and no further action. An increase in channel capacity would affect the reservoir flood control operations; therefore, decisions made as a result of this study will influence the entire river system management. Two public meetings have been held to present this study to the public and gain input. No conclusions have yet been reached. The study is scheduled for completion in 1975.

Flood Plain Information, Boise, Idaho and Vicinity

The flood plain of the standard project and intermediate regional floods from Barber Dam to the Ada-Canyon County line are defined in this report. It was prepared by the Corps of Engineers and completed in October 1967. The report contains descriptions of historic floods and their effects.

The intermediate regional flood, having an average frequency of occurrence of one in 100 years, was estimated as 15,000 cfs at Boise. The standard project flood, which "can be expected from the most severe combination of meteorological conditions," was estimated at 27,500 cfs at Boise. These discharges reflect upstream reservoir regulation. Detailed maps are included of the areas which would be inundated by these flows. No attempt was made to present alternatives for solving flood problems, as the report was intended for use as a guide for land use controls by the city and county governments.

Flood Hazard Report, Caldwell, Idaho and Vicinity

The Corps of Engineers has recently initiated a study of flood prone areas along Boise River through Caldwell. The study will be completed in 1974 and will present information similar to that included in "Flood Plain Information, Boise, Idaho and Vicinity."

Southwest Idaho Water Management Study

The Bureau of Reclamation's Southwest Idaho Water Management Study includes the drainages of the Boise and Payette rivers and the lands north of the Snake River and west of King Hill. The study will evaluate the problems, needs, and alternative solutions for improved management of the water resources in these areas.

One primary purpose of the study is to find means to more efficiently utilize the storage and conveyance facilities of the river and canal systems. This would include an analysis of the current operating procedures and their effects on flood control, storage yields, recreation, and other uses. Canal systems will be studied to determine if current functions, including the bypassing of some floodwaters, can be improved.

The study will include further analyses of the unallocated space in Lucky Peak Reservoir. Potential uses of this space, the possibility of more extensive multiple use of present storage, and the effect on reservoir regulation and/or downstream release procedures will be evaluated.

Additional uses and needs for Boise River water include instream flows, water quality flows, and municipal water supply. The means which are finally adopted to satisfy these needs could have an effect on the sequence of storing and releasing water. Transbasin diversion, re-use of water, and exchanges in water supplies are potential new water sources. Urbanization in the Boise Valley may have created a significant water supply available for exchange. These possibilities will be studied to determine the best water management alternatives.

A status report on the Water Management Study will be prepared in 1976. Alternatives requiring early action will be identified and recommended for detailed study and/or possible implementation.

Lucky Peak Flow Maintenance Study

The Corps of Engineers has begun a study with the primary purpose of finding a feasible plan to correct the Lucky Peak flow shutdown problem. The study will consider alternatives including passing water around, through and over Lucky Peak Dam, or any other alternatives to maintain a flow below Lucky Peak. The study will also consider changing reservoir regulation emphasis in light of public concern over downstream flooding.

Study of water passage over or through Lucky Peak will include consideration of adding power generation. Inclusion of power as a project purpose at Lucky Peak would necessitate study of a revised operation procedure and downstream reregulation. A cursory consideration of raising the dam or adding spillway gates to increase storage capacity will also be made. Increased storage capability could be used for increased flood control, low flow maintenance, and/or power head.

A series of public meetings is being held to encourage public participation. The first of these was held on October 17th.

Environmental Planning Report No. 8

This study is being conducted by the Ada Council of Governments to provide background information on the water resources of Ada County for water quality planning. Sections of the report on "Potential Waste Water Sources" and "Water Use" have been completed with a section on "Water Quality Monitoring" to follow.

While the report focuses primarily on waste water sources, discussion of the effects of regulation on water quality and aquatic life is also included.

Current and Projected Recreational Demand on the Lower Boise River

This study, which is being prepared by Boise State University and the College of Idaho for the Corps of Engineers is scheduled for completion in March 1975. An Interim Report on review of literature, survey of spring and summer recreational activity, and a general population survey has been completed. The final report will include a fall and winter use assessment, projection of trends, and conclusions and recommendations.

BASIN DESCRIPTION

RUNOFF CHARACTERISTICS

RESERVOIRS

IRRIGATION

FLOOD FREQUENCY

FLOOD DAMAGE

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 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 and drainage areas are:

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

The 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.

RUNOFF CHARACTERISTICS

The pattern of natural streamflows in the Boise River is characterized by low flows from late July through February, increasing flows during March, and high flows in April, May, and June. Occasionally this pattern is interrupted by high flows of short duration during the winter months caused by rainstorms. Flood flows would, without regulation by reservoirs, occur annually in the snowmelt runoff season which normally extends through April, May and June.

The majority of the runoff is generated above Lucky Peak Dam. The yield from natural runoff below Lucky Peak is minor as there are no perennial streams, other than irrigation

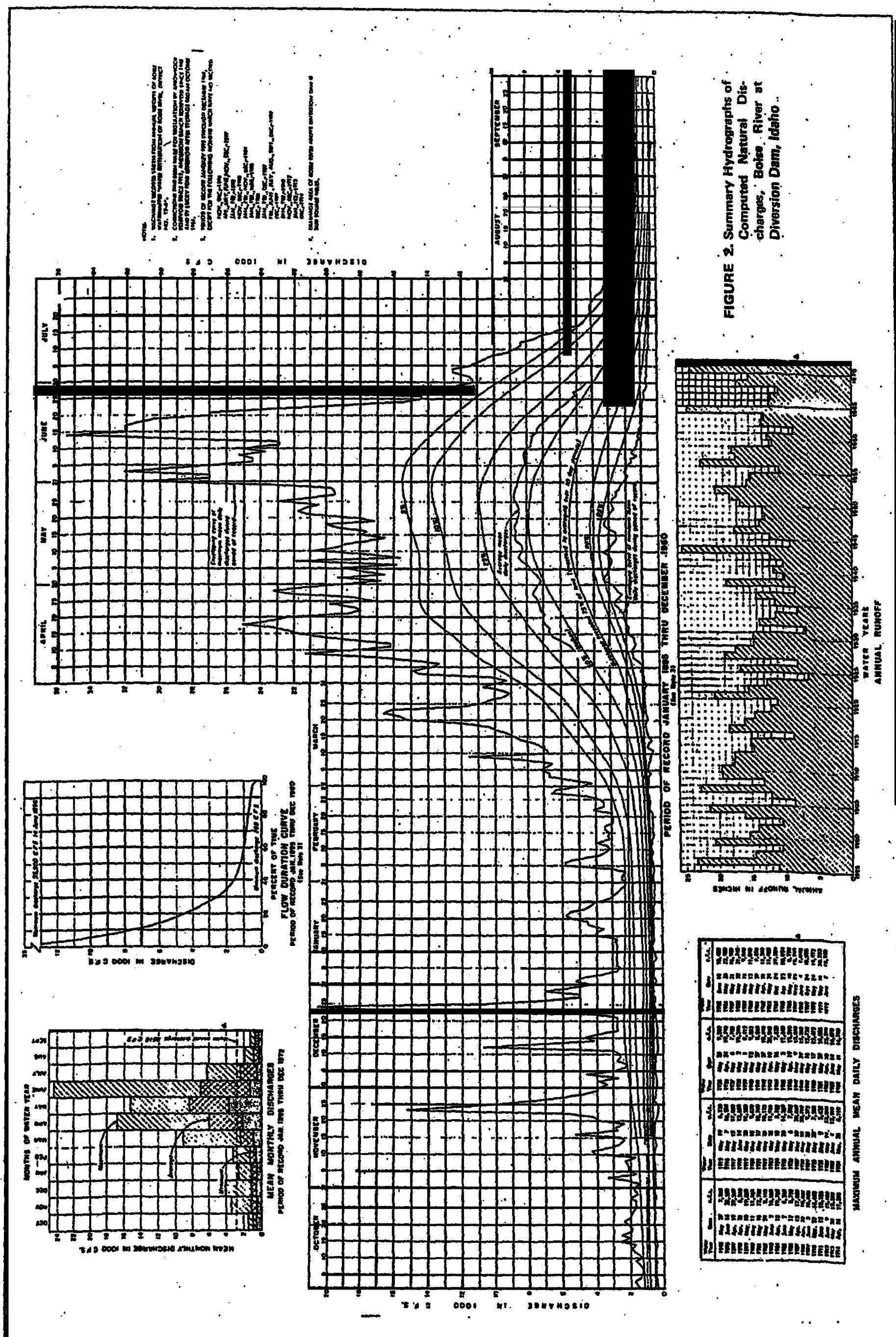


FIGURE 2. Summary Hydrographs of Computed Natural Discharges, Boise River at Diversion Dam, Idaho.

drains, which enter the river. Records of runoff have been kept in the vicinity of Lucky Peak Dam since 1895. This location is usually identified as "near Boise" or "at Diversion Dam."

Natural runoff characteristics are shown on Figure 2. Average discharge near Boise is about 2750 cfs or 2 million acre-feet per year. Maximum recorded mean daily discharge was 35,500 cfs on June 14, 1896, and the maximum instantaneous discharge, estimated at 44,000 cfs without regulation, occurred on December 24, 1964. The latter flow resulted from a short duration rainstorm.

RESERVOIRS

There are four major reservoirs in the Boise River system, which were federally constructed, and also some minor privately developed reservoirs. The major reservoirs are shown in the following table.

		Capacity		Construction	
Reservoir	Stream	Gross (ac-ft)	Active (ac-ft)	Agency	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

Reservoir Functions

The three Boise River reservoirs, Anderson Ranch, Arrowrock, and Lucky Peak, with the off-stream reservoir Lake Lowell, have evolved into a system operated for 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.

Reservoir Water Rights and Storage Allocations

The water rights that permit storage in the three Boise River reservoirs are listed as follows.

Date of Priority	Reservoir	Amount
January 13, 1911	Arrowrock	8,000 cfs
June 25, 1938	Arrowrock 1/	15,000 acre-feet
December 9, 1940	Anderson Ranch 1/	493,161 acre-feet
April 12, 1963	Lucky Peak 2/	307,000 acre-feet

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

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

The storage rights shown above were obtained by the U. S. Bureau of Reclamation mainly for irrigation water supply. Contracts were then made between the Bureau 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 reservoirs are shown in Table 1.

TABLE 1

SPACE ALLOCATIONS IN BOISE RIVER RESERVOIRS, 1974 STATUS

(acre-feet)

District or Company	Arrowrock	Anderson Ranch	Lucky Peak
Boise Project Board of Control	232,871	359,934	
Pioneer Irrigation District	21,018	25,582	16,000
Ridenbaugh Canal Company	3,832	15,137	35,000
Farmers Union Ditch Company	2,874	5,727	10,000
Settlers Irrigation District	1,778	5,810	10,000
Farmers Co-op Canal Company	1,227		
Hillcrest Irrigation District	23,000		
Power		5,200	
Pioneer Ditch Company		2,174	500
New Dry Creek Ditch Company		1,296	3,000
Boise Valley Ditch Company		961	2,500
South Boise Mutual Company		543	500
Capitol View Irrigation District		460	300
Ballentyne Ditch Company		376	1,300
Idaho Fish and Game Department			50,000
Eagle Island Water Company			7,650
Middleton Irrigation Association			6,380
Canyon County Water Company			6,000
Middleton Mill Ditch Company			4,620
Eureka Water Company No. 1			2,800
Davis Ditch			1,500
New Union Ditch Company			1,400
Boise City Canal Company			1,000
Thurman Mill			800
Rossi Mill			700
Unallocated			116,250
TOTAL ACTIVE SPACE	286,600	423,200	278,200

IRRIGATION

The location and names of major canals are indicated on Figure 3. The total capacity of the more than 40 canals diverting water from the Boise River is approximately 6700 cfs.

Boise Valley can be divided into three general irrigated areas. The largest is the Boise Project which is served mainly by diversion from the Main (New York) Canal. This canal diverts water from the Boise River at Diversion Dam to irrigate the area above and below

Lake Lowell. Boise Project is administered by the Boise Project Board of Control. The Bureau of Reclamation has estimated that 1973 gross crop value from the Project averaged $62.50 per acre foot of water diverted.

The second area lies immediately north and south of the Boise River between Diversion Dam and the Snake River. This area includes older privately developed irrigation districts which divert directly from the river.

The northwest portion of the valley is irrigated with water diverted from the Payette River. Irrigation of this area does not significantly affect flows of the Boise River and, therefore, will not be discussed in this report.

Acreages and Water Use

The Boise Project can be divided into the upper and lower system. The upper system, 116,300 acres, includes the area served directly from Boise River, mostly by the Main (New York) and Ridenbaugh canals. The lower system, 50,600 acres, includes the area that receives water after it has first been stored in Lake Lowell. The present average annual farm delivery of the Boise Project is about 3.75 acre-feet per acre. The average annual diversion of the Main (New York) Canal is about 925,000 acre-feet. The normal maximum diversion rate at the head of the canal is about 2850 cfs.

The remainder of the canals diverting from the Boise River supply approximately 160,000 acres of land. The average annual diversion rate computed from total diversion from the river, is six acre-feet per acre. Insufficient data exists to determine farm delivery rates. Normal maximum diversion rates during the summer are 600 cfs from Diversion Dam to Boise, 1400 cfs from Boise to Star, 850 cfs from Star to Notus, and 175 cfs from Notus to Parma. The actual magnitude of the diversions has a great effect on Boise River flows, in particular above Star, where diversions may range from zero to 2000 cfs.

Diversion Rights

The early water right decrees on the Boise River were preceded by many court cases involving claims of different individuals and companies contending harm from the over-allocation of the Boise River waters. All decreed rights are now governed by the Stewart Decree of 1906 and the Bryan Decree of 1929 which state the priorities, amounts and procedures by which each canal receives water. These rights are administered by the Boise River Watermaster who acts under the authority of the Department of Water Resources. The Watermaster is responsible for the measurement and distribution of water according to all decreed and licensed rights.

FLOOD FREQUENCY

Unregulated Floods

Natural or unregulated annual maximum daily discharges in excess of 20,000 cfs have occurred on 10 occasions since 1895 in Boise River at Diversion Dam. In most of the years, the natural flow exceeded the amount which causes some flooding along Boise River under present conditions. Winter rainstorms resulted in natural flows of 20,600 cfs and 44,000 cfs in December 1955 and December 1964. Since winter rainstorm flood volumes are much less than snowmelt flood volumes they are more easily regulated by the reservoirs. Rainstorm floods are not included in the flood frequency discussion which follows.

TABLE 2

ANNUAL SPRINGTIME MAXIMUM MEAN
DAILY NATURAL FLOW OF THE BOISE RIVER

Water Year	Day	Flow (cfs)	Water Year	Day	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	18,810
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	14,070
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	6,227	1955	Jun 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	May 21	10,940
1925	May 20	14,350	1965	Apr 23	20,850
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	6,100	1974	May 9	18,500

1895-1916 Flows are recorded maximums, Boise River near Boise.
1917-1954 Boise River at Dowling Ranch + Mores Creek near Arrowrock + storage changes.
1955-1973 Boise River near Boise + storage changes.

The exceedence probability of unregulated annual maximum flood discharges is shown graphically on Figure 4. The unregulated curve represents the percent chance of exceedence of various discharges at Diversion Dam without upstream storage. For example, without reservoir regulation a flow greater than 12,800 cfs could be expected in 50 percent of the years or on the average, once in every two years.

Regulated Floods

The discharges shown in Table 2 prior to 1915 are identical to those that were actually observed at Diversion Dam. After 1915, floods at Diversion Dam were regulated by storage at Arrowrock (1915), Anderson Ranch (1945), and Lucky Peak (1954) reservoirs. To illustrate the magnitude of flood peak reduction accomplished by the three reservoirs, Table 3 lists the regulated annual maximum mean daily discharge at Diversion Dam with the corresponding unregulated discharge. Also shown is the same data for the discharge at Boise which is much less because of upstream irrigation diversions. Only the period 1955-74 is shown when all three reservoirs were in operation.

TABLE 3

ANNUAL MAXIMUM MEAN DAILY DISCHARGE OF BOISE RIVER

(cfs)

Year	Unregulated at Diversion Dam	Regulated at Diversion Dam	Regulated at Boise
1955	10,480	5,110	1,740
1956	22,950	9,470	6,840
1957	16,930	10,600	6,870
1958	21,750	10,000	6,320
1959	9,040	5,390	1,800
1960	11,840	8,200	5,710
1961	7,830	5,360	1,560
1962	11,340	5,320	1,540
1963	11,480	9,820	5,870
1964	10,940	7,230	4,630
1965	20,850	11,600	7,170
1966	8,220	4,960	1,760
1967	15,600	5,270	1,640
1968	7,050	5,130	1,800
1969	15,930	8,660	5,280
1970	14,850	8,500	5,030
1971	20,250	10,800	6,850
1972	19,600	10,200	6,710
1973	9,550	4,760	1,460
1974	18,500	10,815	7,350

Frequency curves of regulated floods below Diversion Dam and at Boise are also shown on Figure 4. These curves, which were provided by the Corps of Engineers, represent the best available estimates of regulation achieved by the Boise River reservoirs under the present method of operation. They indicate that the system successfully regulates floods to the allowable release rate (about 7200 cfs through the city of Boise) in 97 percent of the years. In approximately one year in fifty a flood flow greater than 10,000 cfs can be expected to occur at Boise. A flow greater than 15,000 cfs will occur once in 100 years. Damages associated with these and other flows are discussed in the following section.

FLOOD DAMAGE

Channel Capacity Changes

In recent meetings with landowners along Boise River, there were claims that the capacity of the Boise River channel is decreasing. Landowners cited examples of drains being ineffective because of increased water surface elevations. While insufficient information is available to draw any firm conclusions, it may be that the channel capacity varies with time from location to location. Changes in flow regime caused by flood control operations provide for periodic long durations of moderate flows which may have made the channel more unstable. This instability may allow creation of local bars in the riverbed, thereby raising water surface elevations. Construction of levees across high-flow channels in the lower river during recent years has decreased channel capacity. This activity forces the flow into a narrower, more confined channel, thus increasing the water surface elevation adjacent to and upstream from the levees.

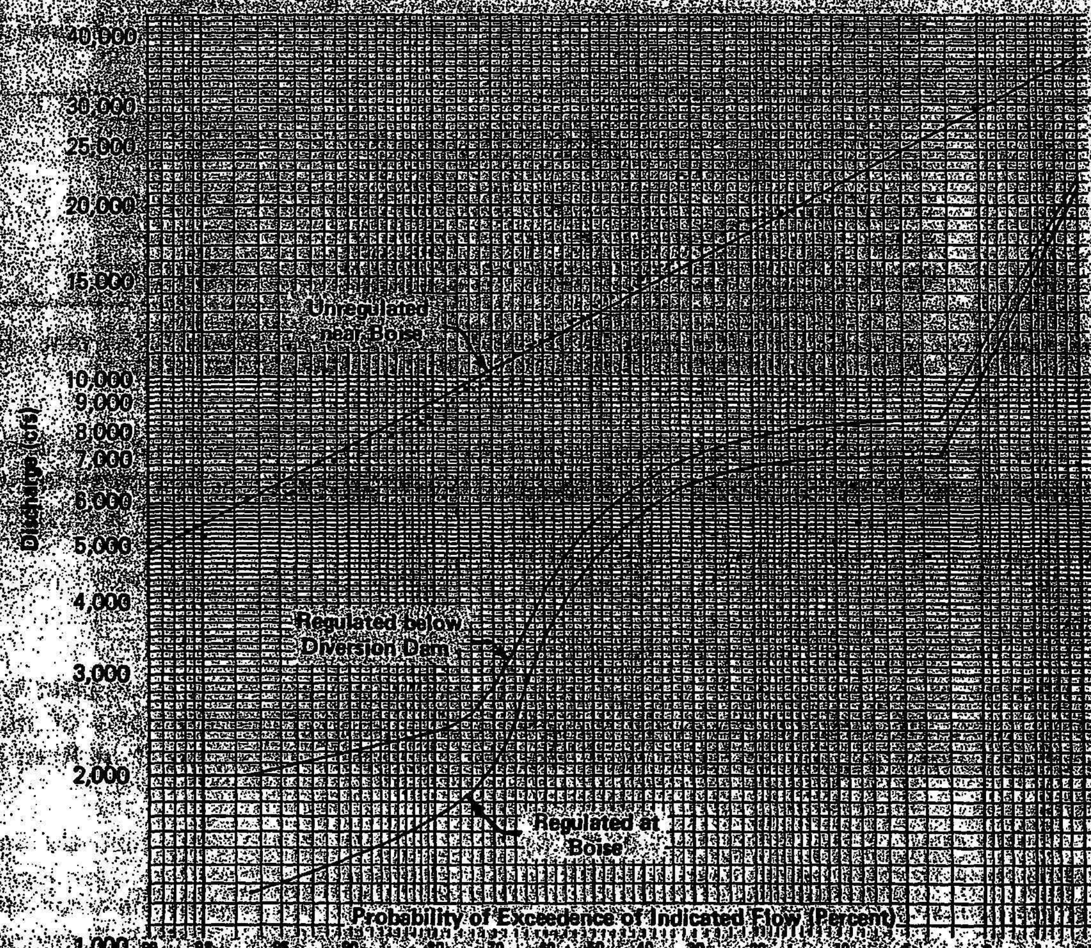
In a study made in 1972 by the U. S. Geological Survey, a considerable decrease in stream capacity was noted at the stream gaging stations at Notus and Boise. Records show that at the same stage of the river, flows at Notus were 11,800 cfs in 1938 and 8000 cfs in 1972. Flows at the same stage at Boise were 9600 cfs in 1943 and 7700 cfs in 1972. In terms of stage, an 8000 cfs flow at Notus would now be about 2 feet higher than in 1938 and 7700 cfs at Boise would be about 1 foot higher.

Reservoirs upstream also have some positive effects on stream channel capacity. Sediment retention by the reservoirs results in increased capacity of the released flows to degrade the downstream channel. In comparing river surveys taken in 1938 with surveys in the mid-1960s and later, there are numerous locations that show significant degradation of the river thalweg, the lowest point of the channel. Cross sections of the Boise River through Caldwell, taken in 1973, show a considerably lowered channel from the 1938 topography.

A comparison was made by the Corps of Engineers of channel capacity of the Boise River at similar flows at two separate time periods. The comparison was made from photo mosaics of the Boise River on February 17, 1965 and April 17, 1974. The similar flows on these two days are listed below:

Gage	17 Feb 65	17 Apr 74
Lucky Peak	7,070 cfs	8,118 cfs
Boise	6,430 cfs	6,450 cfs
Notus/Parma	7,000 cfs	6,670 cfs

FIGURE 4. Frequency Curves: Annual Maximum Daily Springtime Flows, Boise River



Approximately 49,000 feet of levees were constructed in the period of February 17, 1965 to April 17, 1974. The new levees are primarily of gravel construction and were privately built. In some instances, these levees have maintained the river in its banks, and hence have resulted in more intensive farm use, usually in the form of grazing land being converted to native hay, alfalfa, or improved pasture land. In other cases, the levees have been used to cut off meander channels with varying success.

In comparing flooded areas in 1965 and 1974, approximately 255 acres were partially or completely inundated on February 17, 1965 that were not on April 17, 1974; and 25 acres, which do not include gravel operations, were inundated on April 17, 1974 but not in 1965. Much of the change in inundation was due to the construction of the levees mentioned above.

A comparison was made of the April 17, 1974 mosaic with photos taken on June 12, 1974. Respective flows were:

Gage	12 Jun 74	17 Apr 74
Lucky Peak	7,800 cfs	8,118 cfs
Boise	4,182 cfs	6,450 cfs
Parma	4,200 cfs	6,670 cfs

There were no appreciable differences in flooded areas at these flows. Areas that were inundated at the higher flows were also inundated at the lower flows.

Low flow channels were defined at both conditions. The land area that is no longer inundated or no longer has flows in the meander channels at the lower flow condition was approximated by the Corps of Engineers to be 1400 acres. This land is used as grazing or holding land for most of the year during low flows.

Changes in Flood Plain Development

Changes in the period from 1965 to 1974 in agricultural use of the flood plain have resulted from the building of levees mentioned previously. These examples of more intensified farming are few, and the overall changes in agriculture along the Boise River are minor.

Construction in the flood plain over this nine-year period has been relatively light. Building close to the river has been minimal; only a few gravel operations have been located along the banks of the river. The majority of development has occurred on the outer edges of the 27,500 cfs flood plain. New construction includes a few farm buildings, homes, and trailer courts near Eagle Island, and several new homes and a few commercial structures in the Boise area.

Discharge-Damage Relationships

Discharge-damage relationships presented here are based on a flood plain inventory conducted in the spring of 1974 by the Corps of Engineers. Figure 5 shows discharge-damage curves for three reaches of the Boise River. These reaches are (1) Boise, extending from Glenwood Street Bridge upstream to Broadway Bridge, (2) Ada County, from the Canyon-Ada county line to Lucky Peak Reservoir, excluding the Boise reach, and (3) Canyon County, from the mouth of the Boise River upstream to the Canyon-Ada

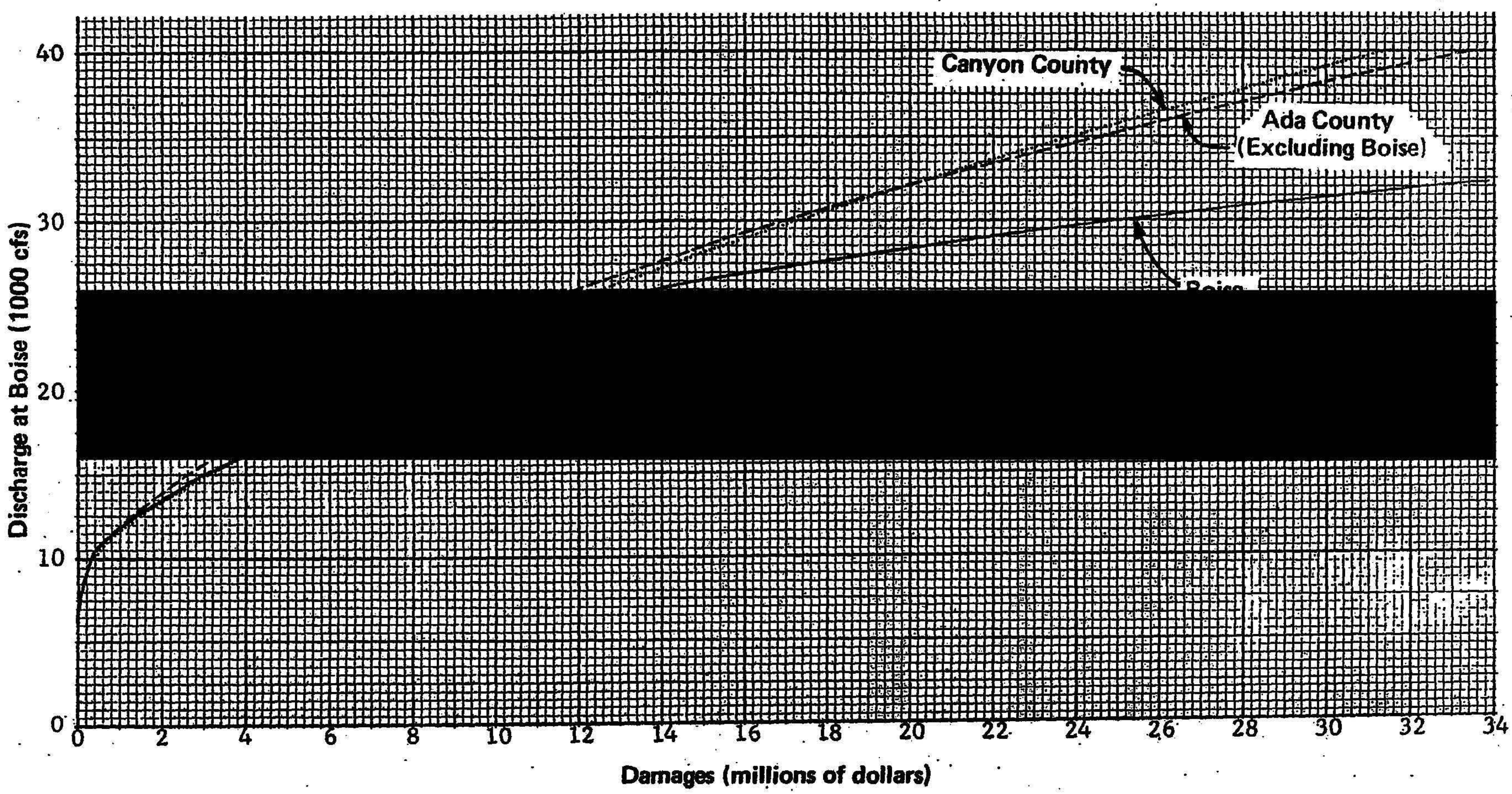


FIGURE 5. Discharge-Damage Relationships, Boise River

county line. From the curves, damages for 1974 price level and development for various flows for the three reaches are shown in Table 4.

TABLE 4

DISCHARGE-DAMAGE RELATIONSHIPS, BOISE RIVER

Flow (cfs)	Boise ($)	Ada Co. Excluding Boise ($)	Canyon Co. ($)	Total ($)
6,500	2,000	13,000	25,000	40,000
10,000	270,000	270,000	410,000	950,000
15,000	3,080,000	2,600,000	3,150,000	8,830,000
30,000	25,000,000	17,000,000	17,300,000	59,300,000
40,000	63,000,000	33,500,000	31,500,000	128,000,000

Damages in Boise from a release of 6500 cfs, the operating objective, are only five percent of the total occurring along the Boise River. For large floods damages which would occur in Boise approach fifty percent of the total. Damages in rural areas are relatively large for the lower flows but do not increase with flow as rapidly as in Boise.

By comparing the average annual flood damages expected without any regulation to the damages with current regulation, the flood damage reduction attributable to the existing projects can be estimated. Average annual damages without regulation would be $16.3 million at 1974 levels of price and development. With present regulation, the average annual flood damages are $0.53 million. This is $15.8 million less than they would be without any control under existing conditions of development.

The effective damage reduction attributable to the existing project operation can also be demonstrated by showing the reduction of damages in the larger floods of recent times. Estimates of flood damages that would have occurred along Boise River if there had been no regulation are compared in Table 5 to those that did occur during the five largest floods in the last ten years.

While the amount of flood damage reduction provided by the existing system is impressive, the remaining potential flood damage is also significant. The major reason for this is the fact that the existing projects are not adequate to afford complete flood regulation. For large, rare floods the reservoirs would fill and pass flows that would cause very large damages. For example, there is a two percent chance each year that flows in Boise will exceed 10,000 cfs. Stated another way, on the average once every 50 years major flooding can be expected in Boise with the current flood control operation on Boise River. Damages associated with this flooding would be greater than $950,000 (Table 4).

The flood damages that might be expected in the future are highly dependent upon control of flood plain development exercised at the local level. If homes and other structures are allowed in the flood plain, the increase in damage potential will be substantial. At the present time the Corps of Engineers estimates future flood damages assuming that the National Flood Insurance program will be in effect. That is, assuming effective flood plain zoning. Using this assumption, it is projected that flood plain growth will be limited to about one percent annually. The current average annual flood damages of $530,000 will grow to $872,000 in the year 2024. Discounting this growth to present terms by the current federal interest rate of 5-7/8 percent, the average annual damages over the 50-year period would amount to $620,000.

PRESENT REGULATION

RESPONSIBILITY AND AUTHORITY

FLOOD CONTROL

IRRIGATION

STREAM FLOW MAINTENANCE

POWER

PRESENT REGULATION

RESPONSIBILITY AND AUTHORITY

Responsibility for the operation of the Boise River system is shared by the Corps of Engineers, Bureau of Reclamation, Boise Project Board of Control, and Boise River Watermaster.

The Bureau of Reclamation has administrative responsibility for operation of the Boise River system for irrigation and is directly responsible for the physical operation of Arrowrock, Anderson Ranch, and Diversion dams. The Corps of Engineers has responsibility for physical operation of Lucky Peak Dam.

The Boise Project Board of Control is the operating agency for the irrigated lands of the Boise Valley which were developed by the federally supported Boise Project. The Board is composed of directors representing the various irrigation districts of the Boise Project. Operation and maintenance of facilities including Lake Lowell, the New York Canal, and associated canals, laterals and drains, is the responsibility of the Board of Control.

The Boise River Watermaster administers all water rights for diversion or storage according to Idaho water law.

Two flood control districts were organized to combat local flood problems on the lower Boise River. District 10 includes areas along the river from the western edge of Garden City to Caldwell and District 11 extends from Caldwell to the mouth.

Flood control management of the Boise River reservoirs is the responsibility of the Corps of Engineers and the Bureau of Reclamation. The division of responsibility and the plan of operation are given in the "Reservoir Regulation Manual for Boise River Reservoirs." The Regulation Manual, prepared in 1956 by the Walla Walla District Corps of Engineers, contains a detailed flood control plan of operation including forecast procedures, parameter curves for space evacuation, allocation of space among the three reservoirs, an operating procedure for floods which are too large to fully regulate, and organizational responsibilities.

Memorandum of Agreement

A Memorandum of Agreement, which is contained in the Regulation Manual as Appendix A, committed the existing irrigation reservoirs (Arrowrock and Anderson Ranch) to a system flood control operation with Lucky Peak Reservoir. The Agreement was made upon completion of Lucky Peak Reservoir to protect the existing irrigation use of Anderson Ranch and Arrowrock reservoirs during flood control operations, and to commit the space in Lucky Peak Reservoir to irrigation as well as flood control use. The elements of the agreement provide the true plan of operation of the three reservoirs since it is the only part of the Regulation Manual that was formally agreed to by the Departments of the Army and Interior. The plan of operation adopted by the Corps of Engineers in the Regulation Manual was not agreed to by the Bureau of Reclamation. Important features of the Memorandum of Agreement include:

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

(2) Specification of flood space parameter curves to be used from January 1 to July 31 with agreed upon forecasts of runoff to determine evacuation requirements and allowable refill.

(3) Protection of space allocations 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 during the reservoir refill period. This flow may be exceeded if diversion rates assumed in the derivation of the flood space parameter curves are not made.

(6) Provision of evacuation and refill sequence among the three reservoirs.

(7) Provision for releases during the refill period greater than 6500 cfs below Diversion Dam when forecasts of runoff require more than 983,000 acre-feet, the total active system space, to be provided for flood control. 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 or until September 15 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. Such modification shall take place only after consultation with the state of Idaho Reclamation Engineer, Boise River Watermaster, and Boise Project Board of Control Manager.

The above plan was developed jointly by the Bureau of Reclamation, Region 1, Boise, Idaho, and the Corps of Engineers, Walla Walla District. With respect to item 9, allowable releases below Diversion Dam (item 5) have been modified as discussed in a later section to approximately 7500 cfs when irrigation diversions are sufficient to reduce the flow to 6500 cfs below Boise. Adequacy of the Memorandum of Agreement is examined in a later section of this report.

FLOOD CONTROL

Runoff Forecasts

Successful flood control operations on the Boise River are very dependent on the accuracy of runoff forecasts. Snow water content, precipitation, and other hydrologic data are used to estimate subsequent flood volumes. The Memorandum of Agreement requires forecasts of runoff volume of Boise River at Diversion Dam from the first of January through June of each season. Forecasts are made at various times throughout the runoff season by the Soil Conservation Service, National Weather Service, Bureau of Reclamation, and the Corps of Engineers. The following discussion centers on the January to April period since this is usually the period of maximum snow accumulation.

In general, only the forecasts made by the Bureau of Reclamation and Corps of Engineers are used for flood operations, although all forecasts are examined. An April through July operating forecast is agreed to by both agencies after individual April 1 forecasts are made. Prior to April 1, separate forecasts are made and used to prepare proposed operations. The agencies then discuss and agree on a common operating plan.

The forecast procedure developed by the Corps of Engineers, as described in Appendix B of the Reservoir Regulation Manual, utilizes a complex method that includes snow water content data for five sites, and precipitation totals for six stations. The basic forecast was developed for the April - July period using April 1 snow course data and October through March precipitation totals. Forecasts of April through July runoff are made on the first day of January, February and March using the basic forecast equation. Adjustments are then made to obtain the actual date through July forecasts.

The forecast procedure developed by the Bureau of Reclamation utilizes data from five snow courses, four precipitation stations, and the antecedent natural flow of the Boise River. Forecasts are made on the same dates as the Corps of Engineers procedure.

Forecasts are least accurate for the January 1 forecast date, with monthly improvements until the April 1 forecast. This improvement is to be expected since the maximum snow accumulation at higher elevations does not usually occur until April, and the total volume of runoff is best estimated by sampling the total volume of water stored as snow in the basin. A measure of forecast accuracy is given by the correlation coefficient (r), obtained when observed and predicted values are compared using linear regression techniques. As the r value approaches 1.0, predicted values better represent observed values. Table 6 compares recent January through April runoff forecasts of the Corps of Engineers and Bureau of Reclamation to actual runoff. Correlation coefficients varied from 0.870 to 0.947 for the Corps of Engineers forecast, and from 0.840 to 0.965 for the Bureau of Reclamation forecast.

The relative accuracy of the Bureau of Reclamation forecast was greater than that of the Corps of Engineers for the January 1 and February 1 dates. The Corps forecast was more accurate for the March 1 and April 1 forecast dates.

Data for the five lowest runoff years (1955, '61, '66, '68 and '73) show that both the Bureau and Corps methods overestimated the actual runoff in four out of the five years for every forecast date. Part of this inaccuracy is due to the fact that other factors (such as soil

TABLE 6

COMPARISON OF FORECASTS WITH ACTUAL RUNOFF, BOISE RIVER AT DIVERSION DAM

(1,000 acre-feet)

Year	January 1 - July 31			February 1 - July 31			March 1 - July 31			April 1 - July 31		
	Actual Runoff	Bureau of Reclamation Forecast	Corps of Engineers Forecast	Actual Runoff	Bureau of Reclamation Forecast	Corps of Engineers Forecast	Actual Runoff	Bureau of Reclamation Forecast	Corps of Engineers Forecast	Actual Runoff	Bureau of Reclamation Forecast	Corps of Engineers Forecast
1950	2032	1624	1480	1969	1641	1810	1894	1583	1615	1741	1717	1967
1951	2184	2031	1730	2114	1948	1940	1988	2045	1975	1866	1931	1925
1952	2526	2726	2240	2460	2587	2490	2379	2685	2445	2276	2507	2413
1953	1869	1584	1260	1768	1719	1800	1680	1670	1675	1554	1464	1412
1954	1814	1877	1460	1750	1822	1830	1655	1726	1660	1506	1534	1708
1955	1218	1153	1170	1171	821	950	1131	737	870	1074	749	940
1956	2720	2752	2185	2570	2661	2460	2477	2743	2415	2250	2249	2279
1957	2124	1871	1595	2074	1606	1520	1976	1786	1695	1790	1754	1708
1958	2222	1930	1750	2166	1812	1870	2035	1816	1800	1915	1787	1800
1959	1342	1556	1310	1265	1401	1330	1193	1397	1300	1099	1237	1264
1960	1489	1397	1120	1436	1119	1055	1371	1264	1160	1191	1124	1067
1961	969	1439	1350	927	1048	1055	868	1013	1050	774	1002	1010
1962	1647	1980	1970	1592	1607	1740	1512	1596	1590	1426	1542	1605
1963	1532	1398	1380	1488	1103	1240	1338	1102	1070	1244	881	985
1964	1511	1739	1550	1456	1751	1800	1400	1330	1325	1326	1378	1280
1965	3141	2639	2505	2972	2821	3030	2794	2383	2600	2606	2046	2330
1966	1049	1505	1570	984	1224	1295	936	949	950	831	834	893
1967	1565	1579	1510	1499	1680	1850	1439	1425	1500	1352	1276	1379
1968	1052	1371		1004	1079	1120	904	1160	1110	783	846	816
1969	2300	2327	2000	2168	2486	2625	2076	2496	2350	1926	2056	2150
1970	1971	1346		1842	1933	2290	1737	1745	1920	1585	1546	1637
1971	3032	2585	2300	2870	2717	2770	2699	2564	2417	2482	2591	2495
1972	2806	2344	2150	2701	2489	2695	2586	2650	2400	2129	2071	2103
1973	1049	1672	1615	976	1498	1535	916	1229	1210	824	936	962
1974	2821	2696	2295	2692	2533	2320	2601	2500	2115	2344	2468	2420
		0.870	0.840		0.914	0.891		0.933	0.942		0.947	0.965

(such as soil moisture deficiency) affect the amount of snow water that eventually becomes runoff. Even if snow water equivalent and precipitation were the only factors influencing runoff, some error would be expected in a forecast since the measured data only represents point samples of the quantities, not the actual quantities as they exist on the entire basin.

A similar examination of data for the five highest runoff years (1956, '65, '71, '72 and '74) shows that for the January 1 and February 1 forecasts, both methods consistently underestimated the actual runoff. For the March 1 date, the Bureau forecast values were more normally distributed about the actual value, while the Corps forecast was consistently below the actual runoff value. For the April 1 date, both forecasts were normally distributed about the observed value. Data for the years 1950 through 1974 are shown in Table 6.

Determination of Flood Space

Releases at Lucky Peak during the flood control season result from the amount of flood space required as specified by the Memorandum of Agreement. Figure 6 is Plate A-2 of the Agreement which specifies the flood space required as a function of date and forecast runoff. These curves are called "flood storage allocation parameter curves" and are the primary determiner of flood operations after an operating forecast is agreed upon.

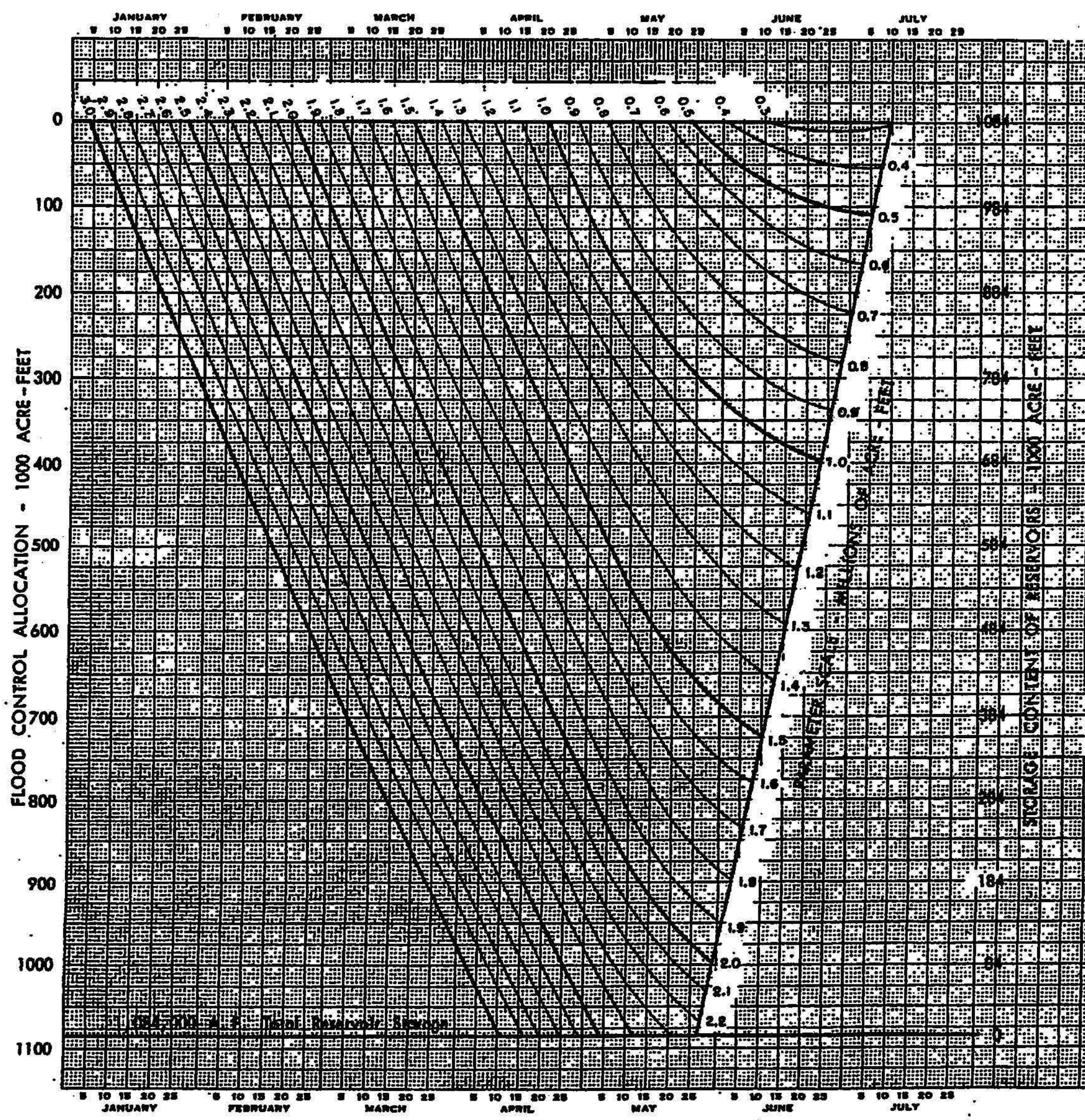
The storage allocation parameter curves were developed from analyses of past floods. Flood season runoff for each year of record prior to 1950 was analyzed for the total storage reservation that would be required to control the runoff to the allowable discharge in Boise River. Allowable discharge at Lucky Peak was then defined as 6500 cfs below Diversion Dam plus the diversions into New York Canal (1365 cfs in March and 2820 cfs from 1 April through 31 July). Parameter curves representing 100,000 acre-feet of runoff were sketched as approximate enveloping lines, and generally encompassed the maximum required storage reservation on any date for any of the floods studied. The parameters were then modified to provide margins of safety in reservoir space evacuated for flood control to compensate for errors in forecasts. The magnitude of the margin of safety was varied with the time of the season and with the magnitude of runoff as shown in Table 7.

TABLE 7

APPROXIMATE SAFETY MARGINS FOR FORECAST ERROR
USED IN CONSTRUCTION OF FLOOD SPACE PARAMETER CURVES

Forecast Parameter (million ac-ft)	Safety Margin (1000 ac-ft)				
	Feb. 1	March 1	April 1	May 2	June 1
3.0	400	360	300	–	–
2.5	400	330	270	–	–
2.0	–	300	200	160	–
1.5	–	–	140	40	–
1.0	–	–	–	80	0
0.5	–	–	–	–	70

FIGURE 6. Flood Storage Allocation Parameter Curves from Memorandum of Agreement



NOTE:

Parameters represent runoff volume anticipated at Diversion Dam between forecast date and July 31. Their spacing is based on following releases at Lucky Peak: January and February 6,600 c.f.s., March 7,865 c.f.s., April through July 9,320 c.f.s.

To determine total vacant space required on any forecast date in all three reservoirs, select parameter corresponding to predicted runoff between that date and July 31, then read the ordinate of this parameter corresponding to forecast date. This ordinate is the total space required to control the predicted runoff at Diversion Dam.

The following allocation has been made of the acre feet of storage capacity available:

Reservoir	Flood Control	Dead	Total
Anderson Ranch	418,000	75,000*	493,000
Arrowrock	285,000	0	285,000
Lucky Peak	280,000	26,000	306,000
Total Space	983,000	101,000	1,084,000

* Additional drawdown of 5,000 acre feet may be made for power production.

At least sixty percent of this flood control space must be available in Lucky Peak and Arrowrock Reservoirs. Lucky Peak must contain a minimum of 20,000 acre feet of flood control space from November 1 to March 1 each year.

Curves taken from Plate 2 of Memorandum of Agreement.

RESERVOIR REGULATION MANUAL
BOISE RIVER RESERVOIRS

FLOOD STORAGE ALLOCATION PARAMETERS
THREE RESERVOIR SYSTEM

Corps of Engineers, Walla Walla District
Water Control Section

Prepared: K.W.W. Date: Aug. 1956
Checked: M.J.O.

Use of the parameter curves can be discussed in two stages, the period of evacuation and the period of fill. The evacuation period begins in January as soon as the first forecast is made and continues until the natural inflow exceeds the release at Lucky Peak. The release at Lucky Peak is that which is necessary to obtain the required flood space at the end of the evacuation period. Beginning in January, the release is calculated using April 15 as the tentative date for the end of the evacuation period. The forecast runoff from April 15 through July 31 is used with Figure 6 to determine the required flood space on April 15. As new forecasts become available, space requirements and releases are revised. Table 8 shows an example calculation of required release at Lucky Peak Dam during the evacuation period using March 1, 1974 actual data. As used in this and later sections dealing with the evacuation sequence "required release" refers to the average release necessary to obtain the April 15 required space. The Agreement appears to "require" this release, but the operating agencies interpret this section of the Agreement to be not mandatory and have normally used it only as a guide.

TABLE 8

EXAMPLE CALCULATION: REQUIRED LUCKY PEAK RELEASE DURING EVACUATION PERIOD

Date: March 1, 1974

March 1 to July 31 forecast runoff:	2,129,000 ac-ft 1/
Average probable inflow until April 15:	430,000 ac-ft 2/
April 15 to July 31 forecast runoff:	1,699,000 ac-ft

Number of days until April 15 = 45 days

(1)	Reservoir contents on March 1	509,700 ac-ft
(2)	Space required on April 15	415,000 ac-ft 3/
(3)	Space available on March 1	478,400 ac-ft 4/
(4)	Required evacuation	-63,400 ac-ft 5/
(5)	Probable inflow March 1 – April 15	421,000 ac-ft
(6)	Release required to April 15	357,600 ac-ft 6/
(7)	Average daily release (45 days)	7,946 ac-ft
(8)	Average release required	4,000 cfs

1/ Average of Bureau of Reclamation and Corps of Engineers forecast.

2/ Based on relationship with March-July forecast.

3/ From April 15 – July 31 forecast and Figure 6.

4/ Maximum content = 988,100 acre-feet.

5/ Item (2) minus item (3).

6/ Item (4) plus item (5).

Filling operations immediately follow the period of evacuation. The parameter curves in Figure 6 are used to determine the releases, but releases are planned on the basis of short term forecasts of reservoir system inflow. This is a continuing process and forecasts and releases may be revised daily. The Agreement states that releases cannot exceed the allowable release during the filling period unless the forecast indicates a space requirement greater than the total active storage capacity of the system.

Allocation of Flood Space

Current flood regulations specify that at least 60 percent of the required flood space allocation be provided in Lucky Peak and Arrowrock reservoirs. This means that space in Anderson Ranch in excess of 40 percent of the total cannot be counted as flood space. The space distribution between upstream and downstream reservoirs was based on the relative inflow upstream and downstream from Anderson Ranch Dam. Preliminary Bureau of Reclamation studies indicate that the 40 percent space limitation in Anderson Ranch Reservoir may be increased without reducing the system flood control effectiveness. The space distribution has been modified on a temporary basis by mutual agreement between the Corps and the Bureau. Feasibility of changing the 40 percent limit at Anderson Ranch is discussed in a later section.

Throughout the evacuation period, releases from individual reservoirs are scheduled such that space is provided in the following order: first, from Lucky Peak; second, from Arrowrock; and last, from Anderson Ranch. The reverse order is followed during the filling period so that flood space is maintained low in the system.

Allowable Release

At the time the Memorandum of Agreement was written the allowable release was selected to limit inundation to pasture lands. Strict interpretation of the Memorandum of Agreement would place the allowable release at 6500 cfs flow below Diversion Dam. However, it is apparent that the intent was to limit flows to 6500 cfs in the channel below the city of Boise. Because there are significant diversions in the reach below Diversion Dam, and because the channel capacity for that reach is significantly more than 6500 cfs, the Corps and the Bureau have been interpreting the allowable release to be 6500 cfs below the city of Boise instead of at Diversion Dam. This interpretation compensates in part for the diversion assumptions of New York Canal which have often proved to be higher than actually experienced. Releases of up to 8000 cfs below Diversion Dam are made during flood control operations if irrigation diversions are sufficiently large. This would result in flows through the city of Boise as high as 7200 cfs.

The allowable release as referred to in this report will be considered to vary from 6500 cfs below Diversion Dam before irrigation begins, to a maximum of 8000 cfs when all canals are diverting at or near capacity.

Major Floods

Although most floods are regulated to the allowable release by use of the storage allocation parameter curves, Boise River is occasionally subjected to floods much larger which cannot be so regulated. With present downstream channel capacity, there is insufficient reservoir capacity in the system to fully regulate the standard project flood or maximum historical floods. Also, heavy precipitation and consequent snow accumulation may develop late in the season, leaving insufficient time to evacuate reservoirs to obtain required space for complete regulation. For these floods, operation of the reservoir system to permit releases above the allowable could materially reduce the magnitude of the peak discharge later in the flood season.

The Boise River Regulation Manual contains a procedure developed by the Corps of Engineers for definition and regulation of major floods. The procedure contains major flood parameter curves which would replace the allowable release method during a major flood. This procedure would result in releases greater than the allowable, thus retaining space for control of the major flood peak. The method has received formal approval by the Corps of Engineers, but it has never been formally agreed to by the Bureau of Reclamation.

The plan of operation agreed to by the Corps and Bureau (in the Memorandum of Agreement) is interpreted by both agencies to preclude use of the major flood parameter curves if the storage required for control of floods to the allowable release is less than 983,000 acre-feet, the total system flood space. This interpretation is based on the following quotation from the Agreement:

> "From the date of the governing forecast each year through July 31 of that year, . . . the combined reservoir content, as determined from the parameter chart (Plate 2), will be maintained except when irrigation requirements necessitate a drawdown below such total content, but will not be exceeded except when total storage above such content is required to limit the releases to allowable flows (as determined by downstream channel capacity and irrigation diversions) at Diversion Dam. However, when the forecasted runoff indicates extraordinary flood flows, requiring storage capacity for flood control in excess of the total active storage capacity of the reservoir system (983,000 acre-feet), temporary releases will be made at a rate so as to minimize the peak rate of flow in the river channel below the Diversion Dam. The rate of such releases shall be specified by the Chief of Engineers after consultation with the Commissioner of Reclamation to the extent consistent with paragraph 6g herein."

The above quote defines the condition under which the major flood parameter curves might be used, but appears to apply only to the filling period. Releases greater than allowable under any other condition during the filling period would be in violation of the Agreement.

IRRIGATION

Refill of storage space follows generally the reverse order from that used in drafting storage but for the same general reasons. Water is stored in Anderson Ranch first for the purpose of maximizing upstream storage and increasing the head on Anderson Ranch powerplant. Arrowrock is filled next and Lucky Peak, which controls the greatest tributary area, is filled last to insure maximum flood control space in the reservoir most capable of controlling floods.

Irrigation diversions usually begin on April 1 and gradually increase throughout the month. The amount of water to be released at Lucky Peak for irrigation is determined by the Boise River Watermaster and the Boise Project Board of Control Manager. Release of storage from individual reservoirs is determined by the Bureau of Reclamation.

Withdrawals of stored water for irrigation are made first from Arrowrock Reservoir. Paragraph 6h of the Memorandum of Agreement states that:

> "In order to enhance the recreational value of Lucky Peak Reservoir after recession of the flood each year, that reservoir will be filled, if not already full from flood water storage or natural flow, by transfer of water from Arrowrock storage, and will be held full through September 15 each year except when Arrowrock Reservoir has been drawn down to a level from which it can no longer supply the irrigation requirements prior to that date, . . ."

Current operation procedures limit the irrigation season drafts of storage from Anderson Ranch to amounts that can be utilized through the powerplant to the extent practicable. Thus it is the policy to make storage releases first from Arrowrock, second or concurrently from Anderson Ranch with the above limitations, and third from Lucky Peak Reservoir.

Irrigation diversions can significantly reduce the flow in Boise River thus allowing greater releases at Lucky Peak after April 1 when irrigation begins. In derivation of the flood control parameter curves it was assumed that the New York Canal diversion would provide a conservative estimate of irrigation diversion effectiveness during floods. Assumed diversions for the canal were 1365 cfs in March, and 2820 cfs April through July.

The assumed diversion of 1365 cfs by the New York Canal in March was based on the normal diversion for storage in Lake Lowell. This assumption also assumed release of water to Snake River through the wasteway system. Recent experience indicates that rather substantial rehabilitation of the wasteways would be required to pass any appreciable amounts of water directly to Snake River. In some recent years, there was no diversion to the New York Canal in March.

During the actual flood runoff (filling period) in April, May, June, and July, any deficiency in diversions from those assumed for parameter curve construction would limit flood regulation ability. In some years irrigation diversions do not begin until about April 15. Diversions by the New York Canal do not always average 2820 cfs as was assumed in development of the plan. However, the diversions to all canals between Lucky Peak and the western limits of Boise generally average considerably more than the 2820 cfs through the flood period (between the date of the governing forecast, when runoff first exceeds 9320 cfs, until the flood is past).

Canals of the Boise River divert almost all of the water from the river above a point near Star during the irrigation season when flood releases are not being passed. Similarly, canals at Caldwell often divert nearly all of the Boise River flow. This results in flows which are often less than 100 cfs at these locations.

A second low flow condition occurs from October 15 until flood releases begin or irrigation resumes. Discharge from Lucky Peak is 100 cfs or less during this time in all years. When flood releases become necessary, flows are often rapidly increased to 4000 cfs or more. In terms of stream resource maintenance, the effects of this operation are twofold. First, the extended period of low flows reduces the waste assimilation capacity of the river and often results in very high downstream waste concentration. The small flow, together with waste loadings, has created a poor game fish habitat. Secondly, the wide fluctuation in flows is damaging to aquatic life in the river. The fluctuations cause a less stable environment for fish and, consequently, a smaller fish population.

The following discussion describes the operational reasons for the occurrence of low flows. This report includes potential solutions to the problem of low flows only insofar as changes in flood control operations may tend to alleviate the problem. Potential solutions are currently being analyzed, however, by the Corps of Engineers in their "Boise Valley Regional Water Management" and "Lucky Peak Flow Maintenance" studies.

Reservoir Shut-off

Current operating procedures provide some flow in the river below Anderson Ranch Dam and below Lucky Peak Dam most of the time. Requirements for inspections or maintenance, however, occasionally require that the flow be shut off for limited periods of time. This happens at both dams whenever it is necessary to de-water the outlet tunnel which is the only means for releasing water when reservoir pool levels are below the spillway crests. At Lucky Peak, maintenance has required releases to be curtailed for periods up to six weeks.

Allocated Space

Under current procedures, 50,000 acre-feet of storage capacity in Lucky Peak Reservoir is used for flow maintenance below Lucky Peak Dam. Releases are made in accordance with schedules provided by the Idaho Fish and Game Department. The basis for use of the 50,000 acre-feet of Lucky Peak was established under the water right permit for Lucky Peak Reservoir storage which was issued by the State of Idaho to the Bureau of Reclamation on March 20, 1964. Each year in October when releases for irrigation have stopped, about 110 cfs is released at Lucky Peak from this storage. 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 Bureau of Reclamation may be made to make releases from unallocated space in

Lucky Peak. When the amount of water remaining in the unallocated space is less than average, this agreement would probably not be made and releases would then approach zero.

POWER

Under the current operating plan, the power operation at Anderson Ranch Dam is secondary to both the operation for irrigation storage and for flood control. During the irrigation storage draft season, releases from Anderson Ranch Dam are scheduled to permit utilization for power production but are limited to amounts expected to be required for irrigation. The overall objective is to retain as much of the system storage in Anderson Ranch Reservoir as possible for the purpose of maximizing power head and system storage yields. Maintaining storage in Anderson Ranch reduces the risk of spilling at the downstream reservoirs the next year without filling Anderson Ranch.

Power production during late fall and early winter is limited to a minimum of 10 megawatts (MW) which is required for firm power production. This requires releases of about 450 cfs. During the January-June period, power production is also limited to 10 MW unless streamflow forecasts indicate that expected inflow is more than adequate to assure reservoir fill. In this case maximum production capability of 35 MW is reached. Power production during the spring flood runoff period may further be limited by flood control operations. The principal objective is to avoid premature fill of the downstream reservoirs and loss of control of flood inflow below Anderson Ranch Dam.

RECENT FLOOD OPERATIONS

FLOOD REGULATION 1971 THROUGH 1974

OPERATIONAL PROBLEMS

EVALUATION

RECENT FLOOD OPERATIONS

FLOOD REGULATION 1971 THROUGH 1974

Since completion of Lucky Peak Dam and Reservoir in 1954, the Boise system has achieved its regulation objective each year. Natural inflows, which have been as high as 44,000 cfs, have been reduced to 6500 cfs or less in the lower river. The operation has caused flows in the lower river to remain near 6500 cfs for several months, however, and has created much public discontent because of inadequate channel capacity in some locations. This section will discuss the actual flood operations in four recent years (1971, 1972, 1973, and 1974) so that the effectiveness of the present operation can be illustrated and evaluated. The years 1971, 1972, and 1974 were of above average runoff, and 1973 was a year with below average runoff.

Figures 7, 8, 9, and 10 present a summary of the Boise River system operation in 1971, 1972, 1973, and 1974, respectively. Included are the space requirement for flood control as indicated by the parameter curves (Figure 6), the actual system storage, the natural inflow to the reservoirs, Lucky Peak release, and the flow at Boise. In general, it can be noted that in each year except 1973 the system had less space available on April 15th than required by the flood control parameter curves. However, the required space was in each case gained during the month of May.

Evacuation Period

During the evacuation period, January 1 to April 15, the space required by the Agreement must be determined by projecting the releases necessary to attain the required space on April 15. Therefore, a short analysis of January through March releases required by the Agreement was made using the average of the Bureau of Reclamation and Corps of Engineers' forecasts. These releases were calculated as shown previously in Table 8. The releases are compared in Table 9 to the average releases that were actually made from the date of the forecast until the next forecast was available. In all four years the actual release was smaller than that required during January and February. In 1971, 1973, and 1974 the releases were greater in March than actually required.

The space that would have resulted from the required releases is also shown on Figures 7 through 10, as well as the required releases. These releases are similar only in January to those shown in Table 9, because the releases in Table 8 were calculated using the observed beginning of month reservoir contents in order to show comparisons with the actual

TABLE 9

COMPARISON OF ACTUAL FLOOD RELEASES WITH RELEASE REQUIRED BY AGREEMENT DURING EVACUATION PERIOD

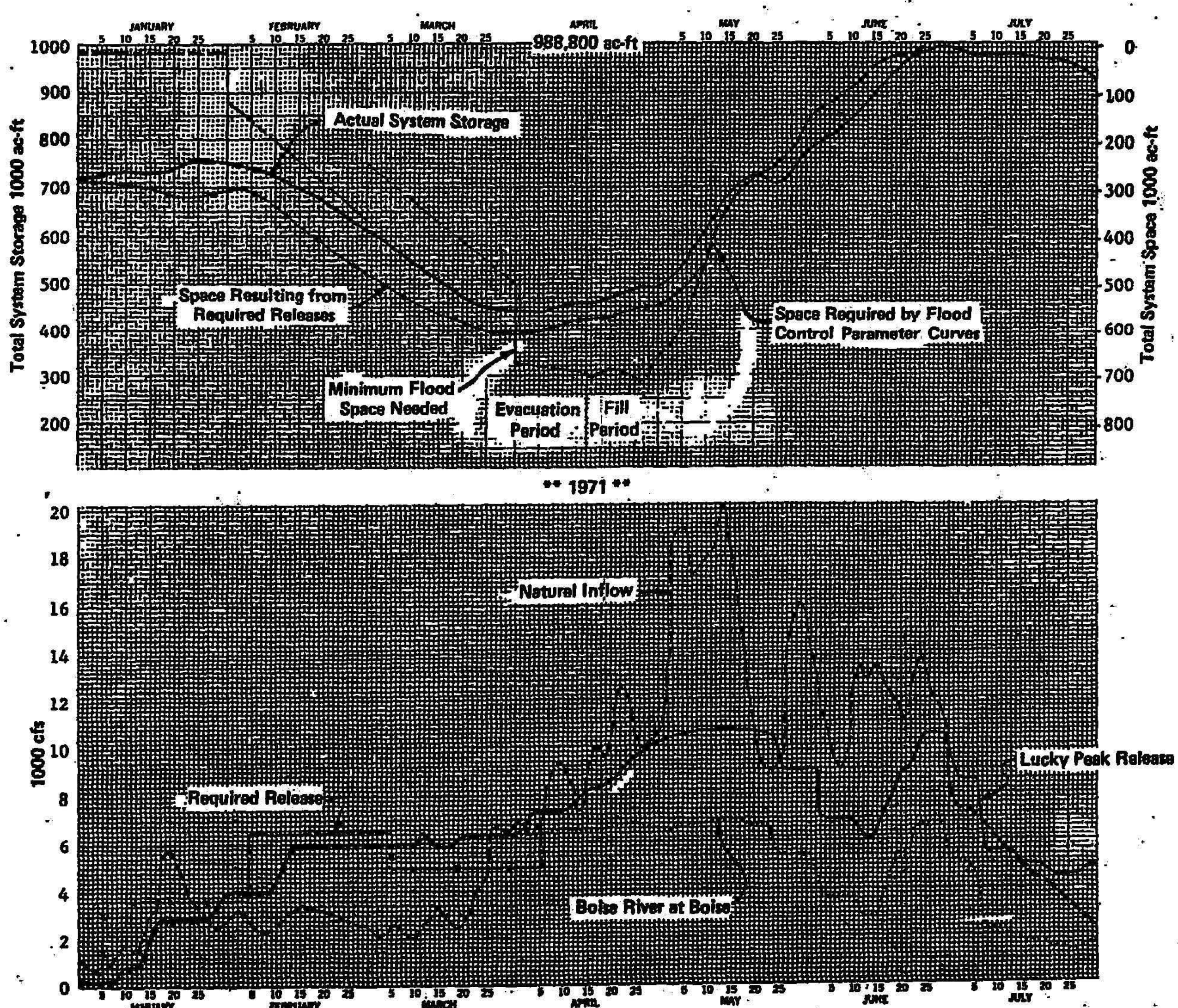
Year	Month	April 15-July 31 Forecast 1/ (1000 ac-ft)	Average Daily Release Required 2/ (cfs)	Actual Average Release until next Forecast (cfs)
1971	January	1710	3506	2598
	February	1950	6500	5380
	March	1815	5964	6251
1972	January	1670	3497	2411
	February	1985	6500	5600
	March	2021	6500	6197
1973	January	1246	938	142
	February	1145	545	197
	March	974	71	523 3/
1974	January	1778	2594	358
	February	1702	4100	3090
	March	1699	4008	4469

1/ *Average of Corps of Engineers and Bureau of Reclamation forecasts.*

2/ *Limited to 6500 cfs channel capacity below Boise.*

3/ *Release made for transfer of storage to Lake Lowell.*

operation for the later months. Had the required releases been made, different reservoir contents would have resulted as shown in the four graphs. With the required releases, space closer to that required on April 15 would have been achieved in the three high runoff years. In each case, early releases would have been greater, but the need to pass flows of 6500 cfs or more through Boise would not have been eliminated. In 1972 the duration of flows at 6000 cfs would have been greater. In 1974 maximum releases prior to April 1 would have been reduced from over 4000 cfs to 3000 cfs or less.



Units in Acre-Feet

Date of Forecast	Apr 15 - Jul 31 Forecast Runoff
Jan 5	1,710,000
Feb 4	1,950,000
Mar 5	1,815,000
Apr 7	2,110,000

Apr - Jul Operating Forecast	Apr - Jul Actual Runoff
2,350,000	2,463,000

FIGURE 7. Boise River System Regulation - 1971

An additional line labeled "minimum flood space needed" is shown on the regulation graphs. This line represents the space necessary to control floods within the capacity of the Boise River as determined directly from the parameter curves on Figure 6. The minimum flood space needed was zero in 1973, and is not shown on Figure 9. In all four years the actual space was greater than minimum space needed prior to April 1. It is evident that actual operation during evacuation lies somewhere between the minimum flood space needed and the space resulting from required releases.

The system could be operated anywhere below the space needed line and be in no danger of having to exceed the allowable release unless (1) a runoff sequence more unique than those used to derive the parameter curves occurred, or (2) forecast error exceeded the safety margin shown in Table 7. However, operating the system along the space needed line would result in delaying releases until later in the evacuation period and tends to maximize the duration of flows at the allowable release. In fact, the space needed line assumes the maximum allowable release will be made during the remainder of the flood season. This operation would provide maximum assurance of total system refill. Operation along the required release line averages the release over a longer period, thus tending to increase early releases and decrease the duration of maximum allowable releases. This operation provides a lesser assurance of total system refill.

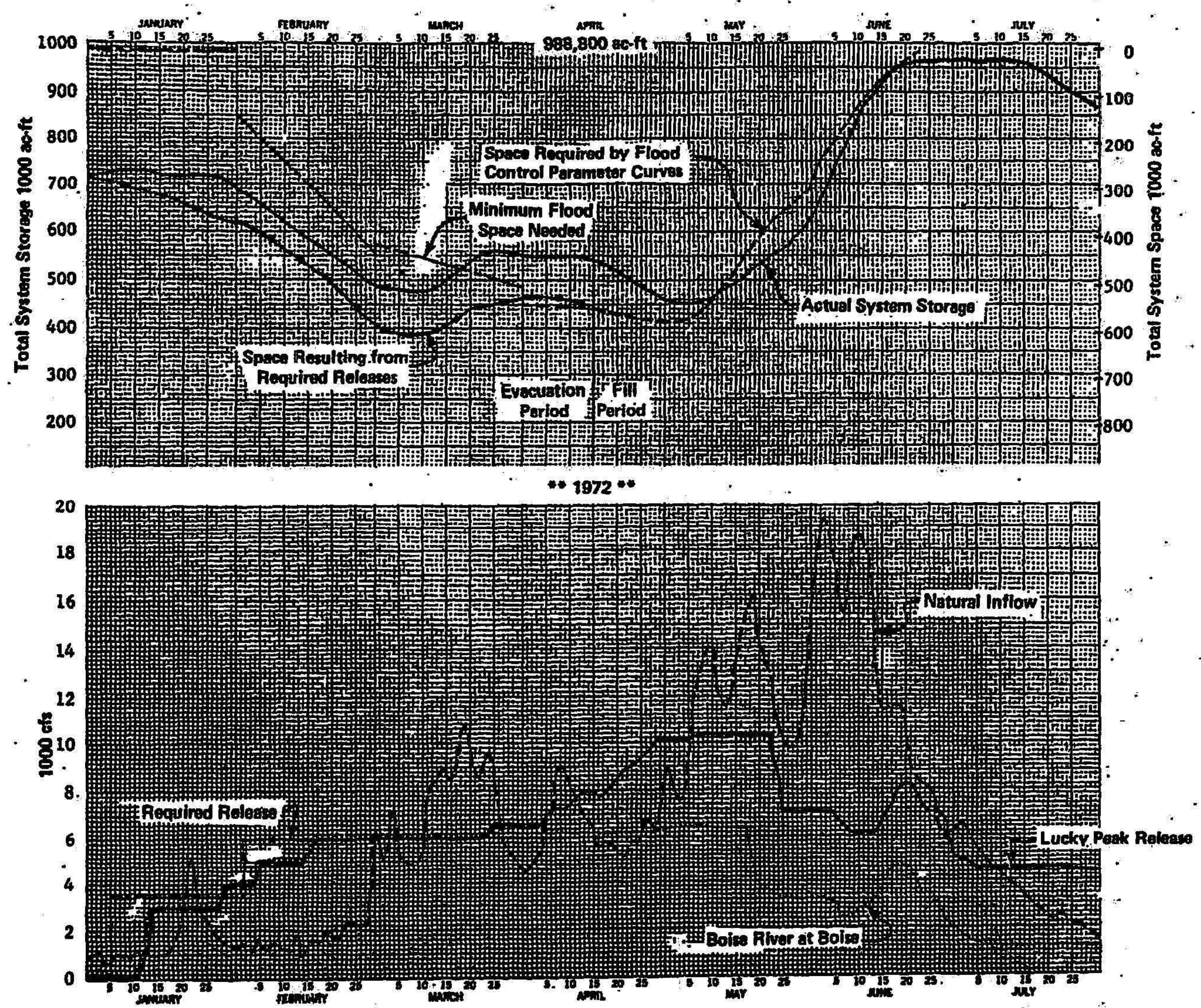
From the preceding analysis it is concluded that in 1971, 1972, and 1974 the failure to provide the April 15 required space resulted in part from insufficient releases. In 1971 and 1974, the required releases would not have provided the April 15 required space because of the heavy March snowfall which was not reflected in a forecast until after April 1. The actual April 15 required space is not determined until that date, and, therefore, not having the space available on that date does not necessarily violate the Agreement.

In 1973, provision of the required release in January and February would have reduced the amount of storage in the Boise system by about 70,000 acre-feet. That year the maximum storage attained was about 918,000 acre-feet. As shown on Figure 9, maximum storage with the required releases would have been about 848,000 acre-feet. Because Lucky Peak Reservoir allocations are junior in priority, the effect of this would have been that each storage use in Lucky Peak (see Table 1) would have received only 50 percent of their allocation, 25 percent less than actual. This, however, would not have been significant since less than 20 percent of Lucky Peak storage allocations were used in 1973, and 1974 was an above average runoff year. If 1973 had been followed by a critical series of below average runoff years, shortages would have been 70,000 acre-feet greater.

The releases calculated above assumed ideal operating conditions. In reality, various operational constraints cause the operation to be somewhat less than ideal. Examples of these constraints and their impacts are discussed in a following section.

Filling Period

While flood operations during the evacuation period are governed by an April 15 target date, space requirements throughout filling can be determined directly from the flood parameter curves (Figure 6) using the current runoff forecast.



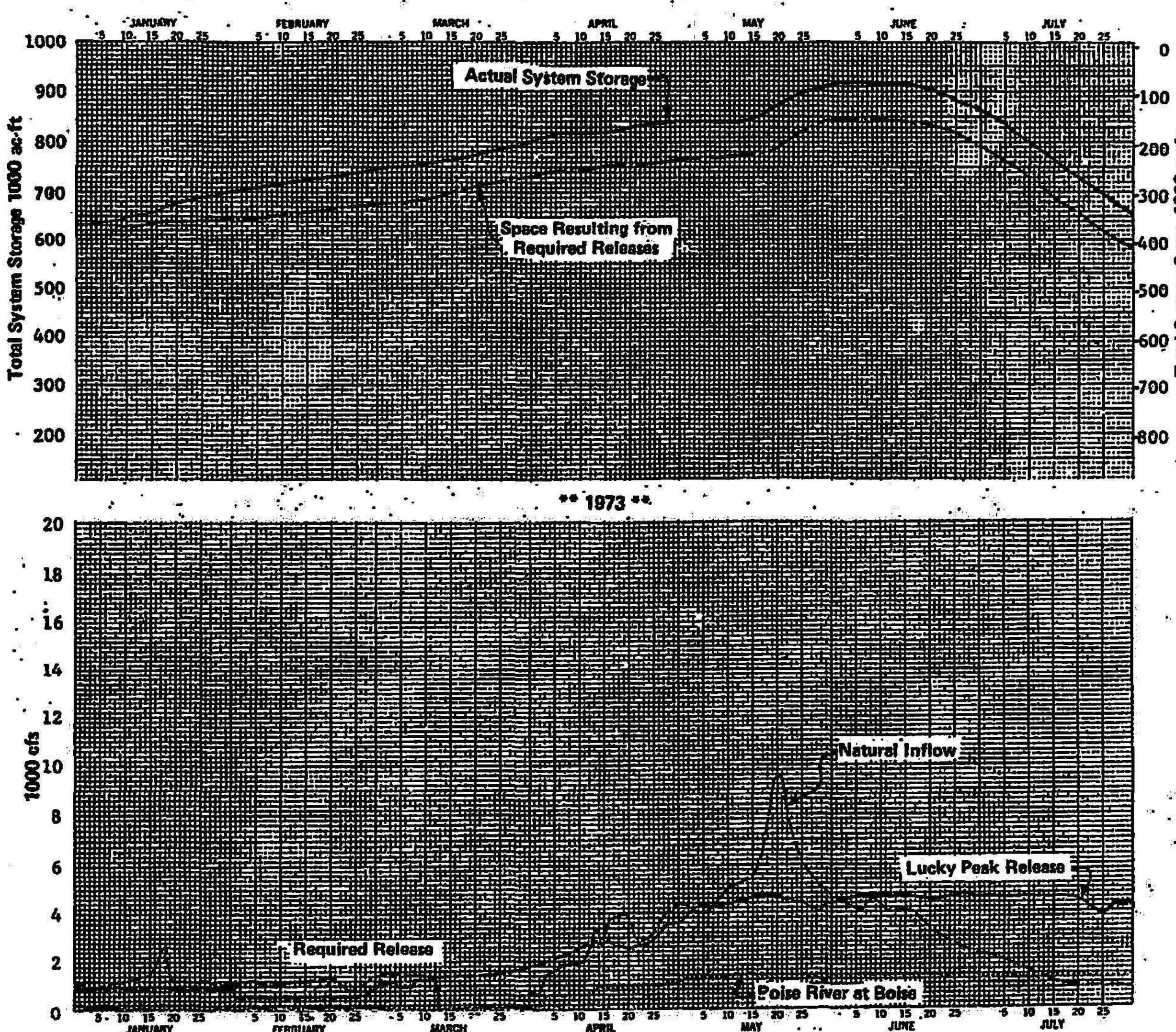
Units in Acre-Feet

Date of Forecast	Apr 15 - Jul 31 Forecast Runoff
Jan 5	1,670,000
Feb 3	1,985,000
Mar 3	2,021,000
Apr 5	1,925,000

Apr - Jul Operating Forecast	Apr - Jul Actual Runoff
2,100,000	2,101,000

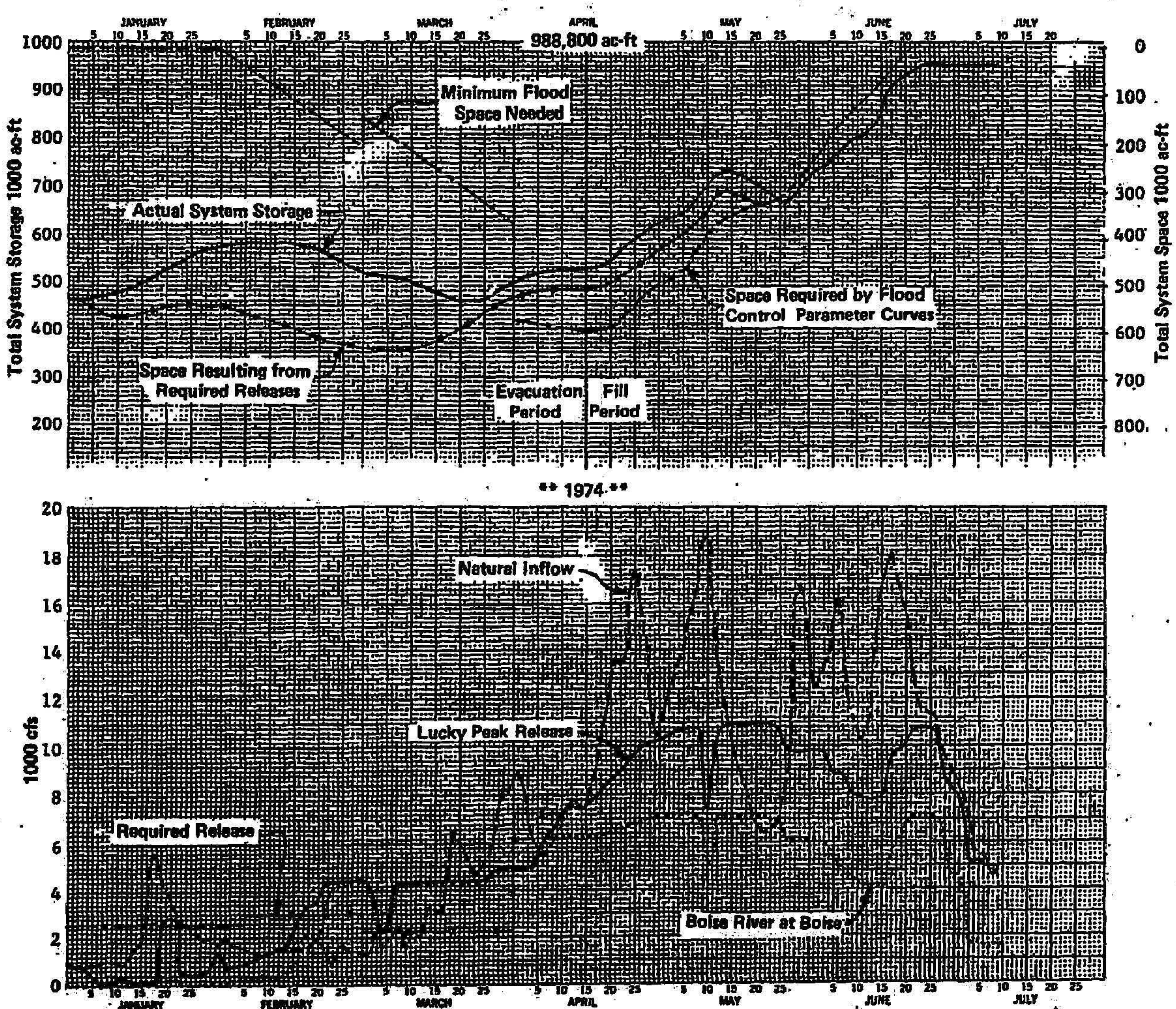
FIGURE 8. Boise River System Regulation - 1972

FIGURE 9. Boise River System Regulation - 1973



Units in Acre-Feet

Date of Forecast	Apr 15 - Jul 31 Forecast Runoff
Jan 1	1,246,000
Feb 1	1,145,000
Mar 1	974,000
Apr 1	852,000
Apr - Jul Operating Forecast	Apr - Jul Actual Runoff
Not needed	824,200



Units in Acre-Feet

Date of Forecast	Apr 15 - Jul 31 Forecast Runoff
Jan 1	1,778,000
Feb 5	1,702,000
Mar 1	1,699,000
Apr 1	2,070,000
Apr - Jul Operating Forecast	Apr - Jul Actual Runoff
2,200,000	2,344,000

FIGURE 10. Boise River System Regulation - 1974.

When the space available is less than the required space, the maximum allowable release is made. Examination of Figures 7, 8, and 10 show a lowering of outflow from Lucky Peak during the latter part of May when the space available was greater than required by the flood parameter curves and subsequent increase in outflow during June when the available space approaches the required space indicated by the parameter curves. This type of operation will be characteristic as long as the current plan of operation is in force. Adjustments in release must be made during the filling cycle if the reservoir space is to follow the parameter curves.

During 1971, the reservoirs had essentially filled by the Ist of July when preceding inflows had been quite high. It is evident that the system nearly lost the ability to control flows to the maximum allowable release that year. It is also evident that during the month of June the system was operated according to the Agreement. The 1971 operation indicates that there is little factor of safety for flood control in the system using the existing Agreement. It is noted that in 1971 additional space could have been gained by higher releases during the latter part of May and the first three weeks of June, as is also generally true for the years 1972 and 1974. To do so would have been in violation of the Agreement and in some years would prevent complete filling of the total storage.

OPERATIONAL PROBLEMS

Many intervening factors prevent executing flood control operations in an exact fashion. Often these factors can be anticipated, but more commonly, they cannot.

Operations during 1974 included typical examples of unexpected constraints. As shown on Figure 10, releases from Lucky Peak were reduced twice, once for dike construction and once to aid in the search for a drowning victim. In particular, the second occurrence came at a time when additional space for flood control was needed.

Many of the diversion structures in the lower Boise River are temporary earth dams in the river channel and must be reconstructed each year. Often requests are received at the beginning of the irrigation season for the flows to be lowered so that this work can be accomplished. When these requests are granted, the provision of flood space may be hampered.

Delays can be experienced in receiving and processing snow course data. Normally snow measurements are made on the first day of each month, but often several days pass before an actual forecast becomes available. This can be the result of difficulty in obtaining the measured snow data and in agreeing on an operating forecast between the agencies. The time lost can be critical, especially late in the season and if the accumulated snowpack has greatly changed.

Other problems that arise are similarly unique. They are generally related to activities in the lower river and may occur only a single time, but they do have an impact on flood operations.

EVALUATION

Examination of 1971 through 1974 Boise River operation points out problems characteristic of the system, namely:

- Because of the relative inaccuracy of early forecasts, there is a reluctance to make required releases early, thus having a greater assurance of total refill.
- Capability to evacuate required flood control space is marginal during some years because of the 6500 cfs limitation for flows in the lower Boise River.
- More reliable forecasts are needed, especially during the evacuation period, January through March.
- More frequent forecasts are needed during the evacuation period to facilitate a system operation which is more sensitive to changing conditions.
- Lack of a common forecast procedure causes uncertainty in flood operations.
- The flood parameter curves are conservative for refill of the reservoirs, but not conservative for flood control, especially during the month of June. This means that a lower risk of refill is achieved at the expense of a higher risk for large flood damage.
- Control may be lost during some future years when required flood control space is less than the total space because of the above considerations.

POTENTIAL FOR IMPROVED OPERATION

RUNOFF FORECASTS

FLOOD SPACE PARAMETERS AND ASSUMPTIONS

CRITERIA FOR MAJOR FLOOD REGULATION

FLOOD SPACE DISTRIBUTION AMONG RESERVOIRS

CHANNEL CAPACITY

FLOOD PLAIN ZONING

ADDITIONAL STORAGE

POTENTIAL FOR IMPROVED OPERATION

It is a conclusion of this report that regulation of the Boise River has been very effective in controlling floods in the Boise Valley. The system could, however, be operated in many other ways and remain as effective, or become more effective in control of floods. Whether or not a change in operation can be classified as an "improvement" depends in large part on the value placed on the various uses of water. Some operational alternatives involve using more advanced technology and can be accomplished by expending time, manpower, and funds to do the work. Other alternatives involve reallocation of functional uses of the projects based on changing social values. Some alternatives lie between the above extremes.

This section will identify "problems" and present alternatives, and will evaluate the potential for changing the present system regulation, based on the investigations presented in the preceding sections. The problems discussed will be limited to those related to flood control, but the effects on other functions (irrigation, recreation, etc.) will be discussed as thoroughly as possible.

The implementation of some alternate operations involve physical, legal, and social constraints. In particular, the Memorandum of Agreement between the Bureau of Reclamation and the Corps of Engineers would have to be modified to effect many of the changes described in this section. In discussing the potential for alternate operational procedures, the Agreement will not be considered a constraint. The report concludes with a discussion of processes involved in changing the Regulation Manual and instituting other changes.

RUNOFF FORECASTS

Because runoff in the Boise River results primarily from snowmelt, forecasts of runoff volume can be made with a reasonable degree of accuracy. However, relatively small errors in forecasts can result in significantly different flood operations. Although forecasts of the various agencies often differ among themselves, there is no consensus among agencies concerning the accuracy of the methods. A previous section (see Table 6) displays the relative accuracy of forecasting procedures of the operating agencies. This section describes one possible method for improving runoff forecasting.

The Northwest Watershed Research Center of the Agricultural Research Service (ARS) recently developed a procedure that holds promise as a forecasting tool. The procedure uses a linear model incorporating snow course and precipitation data that is quite similar to the existing forecast models. For most models, the coefficients which best fit the observed values are determined using the "least squares" method. The ARS method utilizes a "pattern search" optimization technique which minimizes the errors for a given forecast period by searching for the optimum values of coefficients. The validity of the procedure is not reduced by the use of independent variables (snow course and precipitation data) that are highly correlated, as is the case with the least squares method.

The pattern search method is easy to apply to a variety of models. A separate optimization can be performed for each forecast date, allowing available data to be more fully utilized. This allows the importance of the snow courses to vary from one forecast date to another since they represent samples of snow water equivalent on different zones of the watershed.

The ARS forecast method was modified for this study to allow inclusion of precipitation station data and was used to develop a forecast procedure using data from the period 1950-74. Forecasts were calculated for each forecast date (January 1 to April 1). The number of snow courses used depended upon data available for that forecast date, and varied between four and ten, while three precipitation stations were used for every forecast date.

Use of the above forecast method yielded higher correlation coefficients (r) than the operating agency methods for every forecast date. The r values obtained were 0.901, 0.918, 0.962, and 0.980 for the January 1, February 1, March 1 and April 1 forecast dates. The correlation coefficient represents the fit of the observed and predicted data for the entire 25-year period, with the exception of January 1 forecast which uses a 17-year period. Comparison of ARS forecast method with the existing forecasts for the five highest and five lowest runoff years showed errors in the same direction, but with improved accuracy. No forecast was consistently high or low relative to the others. The ARS forecast method more accurately predicted actual runoff on the average. Therefore, it is concluded that present forecast procedures can be improved.

The development of a single forecast method would lead to the adoption of the best procedure. This is true because the best procedure is a technically determinable fact. Whatever set of criteria are used to judge the method, there is one best method. A single forecast procedure also permits the operational forecast to be determined by anyone, not just the operating agencies. The single forecast method allows the decision making processes involved in reservoir operation to be seen in a clearer, more straight forward manner.

There is a need for flexibility in flood operations apart from forecast computations to permit judgment to enter the process at some point. The adoption of a single forecast procedure would not preclude the use of judgment. In fact, operational decisions would be enhanced because of a better forecast; but these decisions should take place separately from forecast determination.

The effect of major storms is not reflected in runoff forecasts until the following month. More frequent forecasts would provide better quantification of snowpack changes, and, therefore, result in improved system operation. Mid-month data are taken on only a few snow courses. In the long range there appears to be a potential to improve the flood control operation by expanding the mid-month snow data program. Existing mid-month data should be analyzed to determine potential for updating first of the month forecasts.

Daily streamflow models have the capability to estimate potential runoff sequences provided that an adequate continuous data reporting system exists. Models such as these could eventually replace the monthly forecast equations now used. Continuous monitoring and reporting of snowpack conditions would be one of the requirements of such a system.

FLOOD SPACE PARAMETERS AND ASSUMPTIONS

Once forecasts of runoff have been made, operation of the Boise River reservoirs for flood control becomes dependent on the flood space parameter curves shown on Figure 6. These curves are used by the operating agencies, the Bureau of Reclamation and the Corps of Engineers, during the evacuation and fill periods to judge the releases that should be made to provide the required flood space. As illustrated in the review of 1971 through 1974 operations, the procedure for use of the curves during the evacuation period as stated by the Agreement is not strictly followed; and there is little safety margin for flood control during the refill period.

The curves on Figure 6 were constructed in 1950 prior to the construction of Lucky Peak Dam. More than 15 years have now passed with the entire system in existence. It is now appropriate to re-examine the parameter curves for possible modification. This section discusses the potential for such modification as well as that for using alternate parameter curves.

Use of Recent Flood Data

The present flood space parameter curves were derived using the hydrologic data from 1895 through 1949. Since 1949, several years of above average runoff have occurred. By including this data in the analysis of flood space parameter curves, a better judgment can be made of the adequacy of the curves. Flood space requirements for the five largest flood years since construction of Lucky Peak Dam were derived based on the allowable releases stated in the Agreement. These space requirements were then compared to the original enveloping curves constructed before safety margins for forecast error were added. It was found that the original curves satisfactorily enveloped the space requirements for the five flood seasons. It was, therefore, concluded that the existing enveloping curves adequately represent all available flood data assuming the allowable releases are as stated in the Agreement.

Safety Margin for Forecast Error

Table 7 listed the approximate runoff forecast safety margins applied to the various magnitudes of runoff to obtain the parameter curves on Figure 6. The margins allowed for forecast error decrease with advancing forecast date. Toward the end of the flood season, safety margins for forecast error approach zero. The margins of safety were chosen in this manner to assure complete system refill.

There appears to be a definite potential to provide greater flood protection on Boise River by including greater safety margins for forecast error for all forecasts late in the flood season. For example, the safety margin for forecast error on June 1 for forecasts greater than 1 million acre-feet is near zero; but forecasts in this range can be in error by ten percent or more. To increase the safety margin would mean that a greater risk would be taken for complete system refill. Other effects of refill risk are discussed in a following section.

Available Refill Volume

One of the characteristics of Boise River regulation that brought about this review is the extremely low fall and early winter releases followed by large releases for flood control. This section examines the potential for making releases earlier and thus minimizing the fluctuations that now occur.

Hydrologic data from 1928 through 1973 were examined to determine the amount of water that would be available for refill of storage space each year under the present system operation. This volume is equal to the total natural runoff less required releases for irrigation and flow maintenance from a given date until the reservoirs reach maximum content for the year. The volume, or "available refill", was derived for each year of the 46-year period from November through July. By determining the frequency of occurrence of various volumes of available refill, one possible procedure was developed to effect earlier season releases.

The low regulated flow period below Lucky Peak Dam begins each year in late October when irrigation diversions are stopped. Frequency analysis for November shows that 98 percent of the time, the amount available for refill will be greater than 225,000 acre-feet. Using a total active space of 988,000 acre-feet, this means that reservoir contents in excess of 763,000 acre-feet on November 1 could be released with 98 percent probability of refilling the entire space that year. Similarly, using the total allocated space (see Table 1) of about 872,000 acre-feet, storage in excess of 647,000 acre-feet could be released with a 98 percent chance of refill. Reservoir contents necessary for 90, 95, and 98 percent assurance of refill are shown in Table 10 for refill of (1) the total system space, (2) the allocated space, and (3) the total space excluding Lucky Peak Reservoir. Results are shown for the beginning of November, December, and January.

Total active space filled on November 1 rarely exceeds 600,000 acre-feet and averages less than 300,000 acre-feet. Therefore, it is evident that making any early season release will

TABLE 10

RESERVOIR CONTENTS REQUIRED FOR ASSURANCE OF REFILL OF BOISE RIVER SYSTEM

Space to be Refilled 1/	Percent Chance of Fill	Required Contents at Beginning of Month (ac-ft) November	December	January
Total Capacity (988,000 ac-ft)	98	760,000	790,000	820,000
	95	700,000	730,000	765,000
	90	630,000	645,000	705,000
Allocated Space (871,500 ac-ft)	98	654,000	675,000	705,000
	95	585,000	615,000	650,000
	90	515,000	550,000	590,000
All Space Excluding Lucky Peak (709,800 ac-ft)	98	485,000	515,000	545,000
	95	425,000	455,000	490,000
	90	355,000	390,000	430,000

1/ Does not include dead storage.

cause some risk to refill of the entire space. However, by examination of Table 10, it can also be seen that assigning some risk to refill of the entire space imparts a much less risk of refill to all space excluding Lucky Peak; and assigning some risk to the allocated space similarly imparts less risk to refill of all allocated space other than that in Lucky Peak.

Possible use of the data in Table 10 is illustrated in Table 11 for the years 1971 through 1974. Additional releases that would have been made in November and December are calculated assuming a five and ten percent risk of refill of the allocated space (871,500 acre-feet). In three of the four years, additional releases ranging from 240 to 1340 cfs would have been made with a ten percent risk. In 1973, a year when the system did not totally fill, about 80,000 acre-feet would have been released. This would have caused the system to fill only to 840,000 acre-feet, about 30,000 less than the total allocated space. Making such releases in November and December would risk filling the space in Arrowrock, Anderson Ranch, and Lake Lowell, but the risk would be very small. In the above example, a one percent chance of not completely filling the other reservoirs would exist.

After January 1 when forecasts of runoff are made, the frequency of occurrence of available refill can be predicted with greater certainty by relating the refill volume to the forecast. To test such a procedure, estimated monthly forecasts from 1928-74 were

TABLE 11

EXAMPLE USE OF ASSURED REFILL OF BOISE RIVER SYSTEM
USING PERCENTAGE RISK ON TOTAL ALLOCATED SPACE

Risk of Refill	Date	System Contents (ac-ft)	Required[1/] Contents (ac-ft)	Excess (ac-ft)	Average Additional Release (cfs)
	Nov 1, 1971	543,600	515,000	28,600	480
	Dec 1, 1971	606,600	550,000	56,600	920
	Nov 1, 1972	594,700	515,000	79,700	1340
	Dec 1, 1972	573,000	550,000	23,000	370
10%					
	Nov 1, 1973	578,500	515,000	63,500	1070
	Dec 1, 1973	564,500	550,000	14,500	240
	Nov 1, 1974	353,100	515,000	0	0
	Dec 1, 1974	439,800	550,000	0	0
	Nov 1, 1971	543,600	585,000	0	0
	Dec 1, 1971	635,200	615,000	20,200	330
	Nov 1, 1972	594,700	585,000	9,700	160
	Dec 1, 1972	643,000	615,000	28,700	470
5%					
	Nov 1, 1973	578,500	585,000	0	0
	Dec 1, 1973	628,000	615,000	13,000	211
	Nov 1, 1974	353,100	585,000	0	0
	Dec 1, 1974	439,800	615,000	0	0

1/ From Table 10.

correlated with the January through April available refill. Results are shown in Table 12 for the 95 percent assurance of refill (five percent risk) for three different volumes to be refilled. An example calculation using this data for the year 1971 through 1974 is shown in Table 13. The calculations in this table are consistent with those for the 5 percent risk of refill of the total allocated space in Table 11. Because of the extremely large forecasts in 1971, 1972, and 1974, almost the entire contents would have been available for release on January 1 with little danger to refill. In these three years the flood parameter curves of Figure 6 should govern releases beginning January 1. In the 1973 example in Table 13, about 87,000 acre-feet would have been available for release in January; again, this release would have caused some allocated space in Lucky Peak not to fill.

TABLE 12

RESERVOIR CONTENTS REQUIRED FOR 95% ASSURANCE OF REFILL

(ac-ft)

Space to be Refilled 1/	1st of Month - July 31 Forecast	Required Contents at Beginning of Month (ac-ft) January	February	March	April
Total Capacity (988,000 ac-ft)	1,400,000	910,000	840,000	720,000	640,000
	1,600,000	720,000	680,000	560,000	480,000
	1,800,000	540,000	530,000	390,000	330,000
	2,000,000	370,000	370,000	230,000	180,000
	2,200,000	190,000	190,000	80,000	20,000
Allocated Space (871,500 ac-ft)	1,400,000	790,000	720,000	600,000	520,000
	1,600,000	600,000	560,000	440,000	360,000
	1,800,000	420,000	410,000	270,000	210,000
	2,000,000	250,000	250,000	110,000	60,000
	2,200,000	70,000	70,000	0	0
All Space Excluding Lucky Peak (709,800 ac-ft)	1,400,000	630,000	560,000	440,000	370,000
	1,600,000	440,000	400,000	280,000	200,000
	1,800,000	260,000	250,000	110,000	50,000
	2,000,000	90,000	90,000	0	0
	2,200,000	0	0	0	0

1/ Does not include dead storage.

TABLE 13

EXAMPLE USE OF ASSURED REFILL WITH A 5% RISK OF COMPLETE FILL OF TOTAL ALLOCATED SPACE

(ac-ft)

Date	Date-July 31 Forecast	System Reservoir Contents	Required 1/ Contents	Available for Release
Jan 1, 1971	2,255,000	705,500	30,000	675,000
Jan 1, 1972	2,242,000	674,500	30,000	644,500
Jan 1, 1973	1,686,000	617,200	530,000	87,200
Feb 1, 1973	1,520,000	599,100	630,000	0
Mar 1, 1973	1,224,000	645,600	750,000	0
Apr 1, 1973	952,000	707,000	870,000	0
Jan 1 1974	2,383,000	460,300	0	460,300

1/ Interpolated from Table 12.

The above examples illustrate that there is a potential to make earlier releases from the Boise River system if more risk is accepted for total refill. They show only a few of the many operations that could be adopted. As the risk of refill is increased and the volume of storage to be refilled is decreased, larger and earlier releases can be made. Prior to the availability of forecast data (November and December), releases impart a greater risk to refill. After forecasts become available, releases can be made with very small risk to refill when forecasts are above average.

Probable Runoff

A critical factor in flood regulation with the Boise system is evacuation of stored water during the months from January through March. To make the required releases, an estimate of probable runoff from the forecast date to April 15 must be made (see line 5, Table 8). The estimate of probable runoff is an average based on a relationship with forecast runoff to July 31 given in the Memorandum of Agreement. An inaccurate estimate of the probable runoff to April 15 can contribute to the failure to provide the required evacuation space. For example, in 1972 the required evacuation space was not attained, and the January through March runoff was much greater than the assumed average. A revision of the probable runoff relationship could include a greater degree of safety during the years of high runoff.

Recession Volume

Late in the refill period of flood regulation, operation is based on the minimum space needed to control the remaining runoff to the maximum allowable release. An alternate method of space reservation late in the flood season could be based on the ability to refill with recession flows which are smaller than channel capacity, yet larger than irrigation requirements. Cursory studies by the Corps of Engineers indicate that in twenty of the years from 1941-74 recession volumes varied from 14,000 to 122,000 acre-feet. An amount of space equal to the expected recession volume would be reserved until the flood peak had occurred. Estimation of recession volume from other parameters, such as snow, should be made to fully evaluate the potential of this type of operation.

Risk for Refill

As the Boise River system is now operated, there is little risk taken for refill of the system. Releases are made as late as possible in the evacuation period, and flood space requirements late in the fill period have no margin of safety. As shown previously in Table 7, it is also assumed that little forecast error exists at the end of the flood season. In 1971, 1972, and 1974 when runoff was far above average, the system was filled as early as possible. As discussed earlier, there is a large amount of storage which is unallocated and is usually not used, especially in years of high runoff. In most of the high runoff years, much of the allocated space also remains unused. Greater flood protection could be achieved by taking some risk on the refill of this space, and by including a safety margin for forecast error in the late refill season.

A previous section on "Available Refill Volume" has discussed an application using refill risk from the end of the irrigation season throughout the evacuation period. By making releases during the evacuation period as required by the regulation manual, a greater risk for refill would be taken. Making late season releases according to the probability of occurrence of recession hydrograph volumes, as discussed in the previous section, could also be used to provide a risk to refill.

The risk taken for total refill could be varied to any degree. More detailed studies would be necessary to identify the exact consequences of any proposal. However, taking some risk on refill would reduce the total amount stored in the Boise system in some years. If such a year were the first of a critical sequence of dry years, shortages would occur sooner. Late in the summer, Lucky Peak Reservoir would be drawn down earlier in some years with a loss to recreation. Releases from Lucky Peak Reservoir would tend to be greater and occur earlier in the flood control season.

Allowable Release

Important in the derivation of the flood space parameter curves is the allowable release. The amount of flood space required increases as the allowable release decreases. The allowable release presently used is that flow which limits the flow in the Boise River below Boise to 6500 cfs. Alternate operations could either increase or decrease the allowable release. The main consideration of such a change is the flood damage that would occur under alternate operations.

At the present time, complaints about the Boise River flood control operation are generated by the problems caused by river flows on the order of 7000 cfs or less. Even though the total flood damages at these flows are not great (see Table 4), the individuals having bank erosion or flooding are very concerned. To further complicate the situation, the extent of flooding for flows down to about 4200 cfs is nearly as great as that of 7000 cfs. Thus, in order to eliminate all flooding considered to be serious, flows on the Boise River would need to be maintained below 4200 cfs. If this were done, the probability of having large floods would increase markedly. Because these large floods cause extensive flood damages, operating the existing reservoirs with lower releases would increase average annual flood damages.

The greatest potential increase in flood damages that would occur by shifting to an operation with lower releases would be in Boise, although this type of operation would increase the average annual flood damages throughout the Boise River. In effect, by lowering the releases from Lucky Peak, flood damages in most years would be eliminated; but the probability of much larger flows than have been experienced since Lucky Peak was constructed would be increased.

In fact, to minimize average annual flood damages with existing channel conditions, it would be desirable to increase the flow objective below Boise to something on the order of 10,000 cfs. If this were done, average annual flood damages based on current conditions of development and price level would be reduced approximately $350,000. The reason for this is the same as discussed above; that is, by having higher releases, the chance of the reservoirs spilling so that the peak of a large rare flood must be passed is substantially reduced. For example, at Boise under the existing operating plan, there is a two percent chance each year that flows in excess of 10,000 cfs will be experienced, or on the average once every 50 years flows at Boise will exceed 10,000 cfs. However, if the allowable releases were increased to 10,000 cfs below Boise, flows exceeding 10,000 cfs could be expected to be more infrequent than once every 200 years. While the higher release would provide more average annual benefits at Boise than the remainder of Ada County or in Canyon County, there would also be an increased average annual flood damage reduction in the other two reaches.

The above discussion illustrates that there is little potential to reduce the allowable release below 6500 cfs in the lower Boise River. To do so would increase the average annual damages caused by flooding. Even if the risk of refill were greatly increased to afford present level flood protection at a lower allowable release rate, average annual damages would still be greater at the lower rate. There is, however, potential to increase the allowable release rate. Doing so would increase the frequency of minor flood damage to some areas along the river, but it would reduce the risk of a major flood which would be more costly in terms of average annual damages. The maximum allowable release that should be considered is approximately 10,000 cfs in the lower river.

Dependability of Diversion

In the derivation of the flood space parameter curves, the allowable release was derived assuming diversions to the New York Canal of 1365 cfs in March and 2820 cfs from April through July. As discussed earlier, these diversions are often not made or are less than that assumed.

The Memorandum of Agreement states that "diversions to the New York Canal may infrequently be reduced below the diversion figures indicated above. When the above decreased diversions are required, it may be necessary to increase flow in Boise River below Diversion Dam." In the last ten years, 1965-74, diversions have averaged 185 cfs in March and 1510 cfs in April. Although the Agreement does permit increasing the release to compensate for the small diversions, there has been a reluctance to do this in March and early April because of the increased flooding it would cause. By the end of April diversions to other canals near Boise effectively reduce the flooding caused by releases greater than those originally assumed. In recent flood years the allowance for diversions in the allowable release has been as much as 4300 cfs in May and June.

The flood space parameter curves should be revised to reflect present diversions above Boise during the early irrigation season. In above average flood years the small March and early April diversions could limit evacuation capability. Even though present operation may try to compensate for reduced diversions, a more accurate estimate of the space required should be made.

CRITERIA FOR MAJOR FLOOD REGULATION

As stated previously, the reservoir system on Boise River does not provide complete flood protection and there is a two percent chance each year that a flood of 10,000 cfs or more will occur. While the Corps of Engineers' Regulation Manual contains a procedure for major flood regulation, no such procedure has been agreed to by the Bureau of Reclamation.

The Agreement states that major flood operations can begin when the forecast calls for space requirements greater than the total system flood space. A more comprehensive definition of an impending major flood is needed to cover all possible occurrences. Major flooding could occur when space requirements are less than the total system flood space if the space available is much less than that required. Under such circumstances it may be desirable to increase the releases above that presently allowed, to prevent passing a much larger flood peak.

If a major flood did occur, and the system did exceed the maximum allowable release, the expertise to regulate the flood to the minimum possible discharge is available in the Corps of Engineers. If this occurred, data such as soil moisture content, available storage, streamflow, and weather forecasts would be used in simulation models to choose the best operation. What is lacking is an adequate procedure between the operating agencies for defining major flood conditions and who should have control over the subsequent operation. The procedure in the Agreement for major flood operation is poorly defined and very vague.

The formulation of major flood criteria is considered to be one of the most urgent needs for improving flood operations of the Boise River. Although such criteria would not be used most of the years, it has perhaps the greatest potential to afford better overall flood protection for the Boise Valley.

FLOOD SPACE DISTRIBUTION AMONG RESERVOIRS

Of the total flood space required in the three reservoir Boise River system, no more than 40 percent can be provided at Anderson Ranch Dam. In some years power production at Anderson Ranch may be limited because the resulting space provided from power releases cannot be counted as flood space. There are indications based on preliminary studies by the Bureau of Reclamation that the percent of flood space effective at Anderson Ranch could be varied with runoff potential. These studies show that for low runoff years, the percent effective space in Anderson Ranch could be increased.

A set of parameter curves similar to those used to establish system flood space requirements could be used to control the space distribution among reservoirs. These parameter curves would relate forecast runoff and/or other variables to the expected inflow below Anderson Ranch Dam in excess of the downstream channel capacity with sufficient factors to allow for forecast errors.

A study should be made to determine the maximum percent effective space that can be provided at Anderson Ranch. Once this information is available, the consequences of adopting new flood space criteria should also be analyzed. Preliminary estimates are that there is potential for an average increase of 10 MW in power production during the three month period March-May. Studies should include the impact on the change in reservoir contents of Anderson Ranch Reservoir and its refill capability. Although this alternate operation could improve power production, there would be no potential for providing increased flood protection.

CHANNEL CAPACITY

In a previous section, the problems associated with reducing reservoir releases to meet existing channel capacities were discussed. The alternative exists to physically change the capacity of the Boise River channel so that greater major flood protection can be made available with no increase in local flooding. Increasing the capacity of the channel to carry more flow can be accomplished by clearing and enlarging the existing channel, building levees, or a combination of the two.

The maximum channel capacity that should be considered is about 10,000 cfs, the approximate capacity of Boise River through Boise. Because of bridges, utilities, and other developments across and adjacent to the river, it is impractical to consider enlarging the river through Boise. In addition, if there were sufficient capacity in the river to release 10,000 cfs, the upstream reservoirs could be operated to significantly reduce the chance of greater floods occurring.

Enlarging the Boise River from Boise to the mouth would involve large costs and cause major environmental alterations. Channel enlargement would eliminate many islands used by wildlife, destroy fish habitat, and adversely affect all semi-aquatic birds and mammals. Enlargement would provide greater flood damage reduction than levees because flows could be carried at a reduced height which would help alleviate high groundwater conditions adjacent to the river. Channel enlargement would not be permanent because the river would continue to shift and build up a gravel base which would have to be removed to maintain the channel capacity. Nearly continuous riprap would be required to avoid bank erosion.

Seventy percent of the river below Boise has levees of various kinds. These have been built by local people and by the Corps of Engineers during emergency flood situations. In many cases the levees are inadequate to withstand other than minor flood flows. Levees might be constructed on the river bank or set back from the river. Continuous levees constructed along the river bank would have to be riprapped, thus destroying streamside vegetation. In addition, the riprap would be placed below the river channel to avoid being undermined; consequently, the channel would have to be disturbed during construction.

Offset levees could be beneficial to fish and wildlife habitat. It would be necessary to reserve the area between the river and the levees for cattle grazing or other uses that could withstand flooding with minimum damage. Much of the wildlife habitat would be protected as opposed to the present situation where this habitat is being cleared away to provide for more intensive agriculture.

From a practical standpoint, it appears that any efforts to increase channel capacity would involve a combination of channel clearing, streambank levees and offset levees. Channel clearing should be restricted to a few locations where the capacity has been severely limited. Streamside levees should be restricted to those reaches where the existing ones are rather adequate. In the remaining reaches the levees would be set back from the river. To effectively allow modification of reservoir operations, channel capacity changes would have to be made along the entire river. To do otherwise would result in increased frequency of flood problems for the unprotected areas.

There is potential to increase flood protection along Boise River by increasing the channel capacity. Areas along the entire river below Lucky Peak would benefit by greater flood protection. This includes additional protection through Boise as well as in the reaches where the actual enlargement would be made. For this reason economic evaluation of the levees should involve crediting of damage reduction through Boise to the downstream levees. Overall feasibility of channel enlargement will be determined by the Corps of Engineers in the Levee Restudy which will be completed by the summer of 1975.

Regardless of results of the Levee Restudy, private levee construction will continue. In order to prevent further restriction of channel capacity, a plan for proper placement of these levees is needed. Such a plan could best be prepared by the flood control districts with assistance of the Idaho Department of Water Resources and the Corps of Engineers.

FLOOD PLAIN ZONING

Potential increases in future flood damages on Boise River could be controlled by enforcement of flood plain zoning. However, the flood damages that have been experienced in recent years will not be substantially affected by zoning. Most of the recent flooding has been on agricultural land and zoning would not affect the continued use of the flood plain for agriculture. Zoning would control the addition of flood-prone structures. As there is limited structural development in the flood plain outside of Boise, adopting and enforcing flood plain zoning could be very effective in preventing future escalation of structural flood damage.

The National Flood Insurance Program administered by the U. S. Department of Housing and Urban Development makes flood insurance available at reasonable costs to those located in flood-prone areas. However, for residents to qualify for this insurance it is necessary for the governing body having zoning jurisdiction to adopt flood plain control measures. No later than one year after identification of a flood hazard area, all lending institutions under Federal supervision must require flood insurance for structures located in that area before making loans. However, this insurance is largely limited to structures and their contents and does not, for example, provide flood insurance for crop losses.

The major flood areas below Lucky Peak Dam are located almost entirely in Ada and Canyon counties. The Corps of Engineers' reports "Flood Plain Information, Boise, Idaho and Vicinity" and "Flood Hazard Report, Caldwell, Idaho and Vicinity", will adequately define flood prone areas along Boise River from Barber Dam to the Canyon County line and through Caldwell. This information will be used by the Department of Housing and Urban Development to prepare flood hazard area maps for the cities and counties. Maps already prepared include the cities of Eagle, Garden City, Middleton, Caldwell, Parma, Nampa, and Boise.

Once flood hazard maps are presented to the cities and counties, they must resolve within one year to use the maps in evaluating the issuance of building permits in the flood plain in order for builders to qualify for flood insurance and thus qualify for loans from federally supervised lending institutions. At present none of the mapped cities have passed such resolutions. Zoning is particularly important in the city of Boise where flood plain encroachment has occurred. The major reason for official reluctance to zone for floods is fear that property values in flood hazard areas will decrease. The Idaho Department of Water Resources, as the state coordinating agency for flood insurance, has encouraged cities and counties to adopt resolutions or zoning regulations necessary to qualify for insurance. This has been done in cooperation with the Department of Housing and Urban Development and the Corps of Engineers through public workshops and other information programs. The effort will be continued so that local authorities will be kept informed of the benefit and consequences of flood plain management programs.

ADDITIONAL STORAGE

Additional flood storage could be gained by constructing another reservoir on Boise River. For example, the Corps of Engineers has proposed a reservoir on the Boise River with an active capacity of 490,000 acre-feet. Such a reservoir could be used to provide present level flood protection at a lower allowable release, greater major flood protection at the present allowable release rate, or some alternative between these two.

The major disadvantage of construction of another reservoir is the loss of a free-flowing portion of the Boise River. The net effect on fish and wildlife resources would most likely be detrimental. Further study of new reservoirs on Boise River should not be made until all nonstructural alternatives such as zoning and reservoir re-operation have been improved to the maximum possible extent.

Additional flood storage could also be provided by enlarging the existing reservoirs. The possibility of raising Lucky Peak Dam or Arrowrock Dam is presently being studied by the Corps of Engineers.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS AND RECOMMENDATIONS

Of the alternative operations described in this report, some could be adopted under the existing Agreement. Included among these are the use of a common runoff forecast procedure, strict interpretation of the Memorandum of Agreement, modification of allocated flood space, and modification of the maximum allowable release. Changes concerning these items are allowed by the Memorandum of Agreement between the operating agencies. Instituting a change would, however, be difficult. Agreement would have to be reached between the Corps of Engineers and the Bureau of Reclamation on the desirability of a change and the exact form of the change. Recommendations of this report on short term changes can only urge the two agencies to modify present operation.

Other management alternatives require revision of the Memorandum of Agreement, the completion of new studies, or both. Revision of the flood space parameters and addition of major flood criteria involve revision of the Operating Manual and the Agreement. This process would be lengthy not only because of the studies that would have to be completed, but also because agreement between the Corps of Engineers, Bureau of Reclamation, and possibly, the State of Idaho, would have to be reached. Agreement between the agencies would be difficult because the Bureau of Reclamation is chiefly concerned with assuring maximum reservoir fill for irrigation, while the Corps of Engineers has more adequate flood control as a primary goal.

Both agencies do agree, however, that Regulation Manual revision is needed, and that the present manual could be improved. It is the principal recommendation of this report that preparation of a new Regulation Manual and Agreement be initiated as soon as possible, and the subjects treated in this report be incorporated in the revision. The manual should be prepared jointly by the Corps of Engineers and the Bureau of Reclamation with the consultation of the State of Idaho. To eliminate the present confusion concerning the differences between the Regulation Manual and the Agreement, a new Agreement should recognize the Regulation Manual as the determiner of all reservoir operations. Provision should be made for frequent updating.

Structural alternatives, such as channel clearing, new or rebuilt levees, and new reservoirs are much longer range than operation revision. Extensive study and public authorization of such projects would be necessary. In addition, the Idaho Water Resource Board has stated as a water planning objective "the preference of management over structural alternatives in reducing or preventing flood damages." New reservoirs, because of public attitudes, are not desirable at the present time. The social and economic feasibility of a combination of channel clearing and levee construction will be much better defined upon completion of the Corps of Engineers' "Boise Valley Levee Restudy."

The various sections of this report contain conclusions concerning present and future flood operations on Boise River. Many of these are technical in nature and are not repeated here. The report was prepared as a result of inquiries regarding the sequence of low fall flows followed by relatively high spring releases. That flow sequence occurs because it is impossible to forecast seasonal runoff until information on the accumulating snowpack becomes available in January. In years of large runoff the January forecast may indicate the need to begin reservoir evacuation for flood control. The allowable release which now occurs during the flood regulation season was apparently the principal cause of the complaints regarding the flood control operation. Recommendation number four, below, does not satisfy the desire of some landowners for a lower regulated release. The capability to evacuate required flood control space is marginal during some years because of the 6500 cfs allowable release. The allowable release is discussed on pages 56 and 57.

The report concludes (page 56) that increased releases in the fall months could be made only by accepting a greater risk of refilling the system. Various levels of risk associated with increased fall releases were presented in Tables 10 and 11. These early releases could shorten the period during which maximum allowable releases (6500 cfs) are required, but would not eliminate the need for such releases in most years.

The effect of taking a greater refill risk on irrigated agriculture and reservoir recreation has not been evaluated. The purpose of this report has been to examine the various potentials for improving the flood control operation but not to select a preferred operation. Several levels of refill risk have been discussed and each would have a different impact. In the detailed studies for manual revision, the trade-offs between flood control and other reservoir uses should be evaluated before a new operating plan is selected.

It is concluded that the flood control objective of 6500 cfs on the Boise River system has been successfully met since the present operating plan became effective in 1954. During that period, there would have been four springtime floods of greater than 20,000 cfs if there had been no reservoirs in the system.

Following are major recommendations concerning Boise River flood control.

(1) A new Reservoir Regulation Manual should be prepared with appropriate supporting Agreement.

(2) Beginning in 1975, releases during the evacuation period should be determined by averaging the computed release over the remainder of the period as defined in paragraph 6c of the present Agreement.

(3) A procedure should be developed to use a portion of the space in Lucky Peak Reservoir to provide greater flood protection for the occurrence of a major flood. Decisions must be made regarding the degree of flood protection desired in relation to reservoir refill risk.

(4) The present maximum release from Lucky Peak Reservoir of 6500 cfs below Boise should not be decreased. Consideration should be given for an increase in the maximum release.

(5) A single forecast procedure for reservoir operation should be developed and put into use as soon as possible. Feasibility of automating the existing snow course network for continuous monitoring should be examined.

(6) The cities and counties within the Boise River flood plain should take the necessary steps to qualify for flood insurance. This should be accompanied by programs to develop public awareness of flood hazard areas.