ANALYSIS OF WATER FLOW PROBLEMS IN THE HELLS CANYON REACH OF THE SNAKE RIVER

A Thesis

Presented in Partial Fulfillment of the Requirements for the

DEGREE OF MASTER OF SCIENCE

Major in Civil Engineering

in the

UNIVERSITY OF IDAHO GRADUATE SCHOOL

by

JEFFREY HART COFFIN

June 1977

AUTHORIZATION TO PROCEED WITH THE FINAL DRAFT:

This thesis of Jeffrey Hart Coffin for the degree of Master of Science with major in Civil Engineering and titled "Analysis of Water Flow Problems in the Hells Canyon Reach of the Snake River," was reviewed in rough draft form by each Committee member as indicated by the signatures and dates given below and permission was granted to prepare the final copy incorporating suggestions of the Committee; permission was also given to schedule the final examination upon submission of two final copies to the Graduate School Office:

Major Professor [signature] Date 6/3/77

Committee Members [signature] Date 6/9/77

[signature] Date 6/3/77

[signature] Date 6/3/77

REVIEW OF FINAL DRAFT:

Department Head [signature] Date 6/29/77

FINAL EXAMINATION: By majority vote of the candidate's Committee at the final examination held on date of June 15, 1977 Committee approval and acceptance was granted.

Major Professor [signature] Date 6/15/77

GRADUATE COUNCIL FINAL APPROVAL AND ACCEPTANCE:

Graduate School Dean ____________________ Date __________

ACKNOWLEDGMENTS

The study reported in the present thesis would quite likely have remained incomplete without the help of many individuals who assisted the author at various stages of the research and preparation of the manuscript. It should be noted that, while many persons contributed, any opinions expressed in the thesis are those of the author alone.

First, the author is very much indebted to the members of his committee, Dr. Frederick Watts, Dr. Myron Molnau, and Mr. Alan Robertson, for their reviews of the drafts and their suggestions for improvement. In addition, Mr. Robertson's taking time out from his busy Idaho Department of Water Resources schedule to sit with the committee and his furnishing of extensive Department streamflow data, as well as Dr. Molnau's assistance with computer programming problems, have been much appreciated.

Second, other useful data were provided by several parties. Herman Ray and Robert Harper of the U.S. Geological Survey in Boise sent copies of several USGS stream gage recorder charts, which were helpful in background work. C.E. Bissel, an Idaho Power Company engineer in Boise, furnished useful information from the company's reregulating dam study, discussed in Chapter VIII. Also, conferences with several engineers in the Walla Walla District office of the Corps of Engineers in the early phases of the study were quite beneficial.

Third, the financial support, without which the author would not have been able to undertake the necessary research for the thesis, is gratefully acknowledged. The project was funded through the Idaho Water Resources Research Institute by the Office of Water Resources Technology in the U.S. Department of Interior, Project B-037-IDA in the matching grant program, short-titled WR-Hells Canyon.

The advice on preparation of the final manuscript given by the Idaho Water Resources Research Institute secretaries Greetis, Jennie, Meredith, and Diane, was very helpful.

Moral support from the author's wife Wendy, a fellow civil engineering student, was a necessary ingredient for his continuance and completion of the project.

Finally, the greatest gratitude by far is owed the author's major professor, C.C. Warnick, for his seemingly unending inspiration, guidance, and technical assistance in matters pertinent to the thesis, as well as to general academic affairs.

TABLE OF CONTENTS

ACKNOWLEDGMENTS iii

Chapter

I. INTRODUCTION 1

II. HISTORY OF HELLS CANYON DEVELOPMENT 8
Early Controversies 9
Later Controversies 20
Hells Canyon National Recreation Area 25

III. PREVIOUS STUDIES 27

Early Studies (Prior to 1962) 27
More Recent Studies 29
Army Corps of Engineers 29
Idaho Power Company 32
Idaho Water Resource Board 35
Pacific Northwest River Basins Commission . 39
Idaho Public Utilities Commission 41

IV. COMPETING USES FOR THE SNAKE RIVER 43

Irrigation 44
Power 46
Navigation 48
Recreation 53
Fish and Wildlife Enhancement 54

V. IDAHO POWER COMPANY SYSTEM 57

Resource and Load Characteristics 57
Middle Snake Projects 62
Description 62
Federal Power Commission license 66
Operation for navigation 69
Operation for flood control 73

VI. IDAHO'S FUTURE POWER NEEDS 78

VII. FUTURE AVAILABILITY OF SNAKE RIVER WATER 83

VIII. REREGULATING DAM BELOW HELLS CANYON DAM 86

IX. COMPUTER OPERATION STUDY OF BROWNLEE RESERVOIR RELEASES 101

Description of the River System 102
Upper Snake River Basin 102
Middle Snake projects 103
Description of Simulation Model 108
Input Data Used 111
Analysis Procedure 112
Results 114

X. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS 124

LIST OF REFERENCES 131

APPENDIX I. DESCRIPTION OF COMPUTER PROGRAM 136

APPENDIX II. DATA USED IN RESERVOIR REGULATION ANALYSIS 159

LIST OF FIGURES

1. Location Map--State of Idaho 2

2. Hells Canyon Vicinity 3

3. Typical Summer Weekly Power Demand--Idaho Power Company System 58

4. Reregulated 24-Hour Hydrograph--Maximum Condition 89

5. Gross Storage as Function of Surface Elevation--Idaho Power Company Study 91

6. A. Representative Shape of Layer Between Contour Intervals 95
   B. Representative Shape of Layer Below "Bottom" Contour 95

7. Gross Storage as Function of Surface Elevation and River Mile 98

8. Brownlee Reservoir Rule Curve and 1973 Contents . 106

9. Energy Generated vs. Required Release--100% Rule Curve 116

10. Energy Generated vs. Required Release--75% Rule Curve 117

11. Energy Generated vs. Required Release--50% Rule Curve 118

12. Energy Generated vs. Required Release--25% Rule Curve 119

13. Energy Generated vs. Required Release--0% Rule Curve 120

I-1. Listing of Reservoir Regulation Program 137

I-2. Sample Data Cards for Use with Computer Program . 148

I-3. Sample Computer Program Output--Monthly 155

I-4. Computer Program Output--Summary Results 159

LIST OF TABLES

1. Measured and Calculated Figures for Hells Canyon Reregulating Dam 96

2. Reregulating Dam Storage as Function of Surface Elevation and River Mile 97

3. Total Energy Generation, 1928-1968, Under Various Conditions (GWH) 115

4. Number of Months not Meeting Minimum Flow Requirement in Each Study 121

I-1. Formats for Input of Data to Computer Program . . 158

II-1. Historic Records Streamflow Data Used in Computer Operation Study 160

II-2. Present Conditions Streamflow Data Used in Computer Operation Study 161

II-3. Licenses and Permits Streamflow Data Used in Computer Operation Study 162

II-4. Licenses, Permits, and Applications Streamflow Data Used in Computer Operation Study 163

II-5. Future Conditions Streamflow Data Used in Computer Operation Study 164

II-6. Reservoir Characteristics for Brownlee Reservoir Used in Computer Operation Study 165

II-7. Evaporation Coefficients and Brownlee Power Plant Characteristics Used in Computer Operation Study 166

ABSTRACT

A series of three hydroelectric projects owned by one power company just upstream from Hells Canyon on the Snake River between Idaho and Oregon have been in competition with other water users in the river, both upstream and downstream. Upstream, extensive irrigated agriculture has developed, which has resulted in large reductions in the streamflow reaching the dams. Downstream, higher levels of streamflow are sought to benefit navigation, recreation, and fish and wildlife habitat. The power company's desire to retain water in storage, releasing lower flows, is in conflict with the other users' desires to have the downstream releases increased. Projections by the Idaho Water Resource Board indicate further expansion is likely in the amount of irrigated land upstream, promising greater reduction in the flows to the hydroelectric projects and more acute conflict over the levels of the power releases to Hells Canyon.

The thesis presents a synopsis of the history behind the controversial Hells Canyon developments, an examination of the nature of each use of the river, and consideration of alternatives for easing the antagonism between the power company and the other users. A computer model was used to make a simula-

tion study of reservoir and power plant operation under various hydrologic and hydraulic conditions to analyze the effect of different alternatives on energy production.

The fundamental conclusion was that a change will be necessary in future water use, either by decreasing the reliance on water for power production or by limiting consumption of the water by irrigated agriculture.

I. INTRODUCTION

Idaho's Snake River is a very important resource to the state. Its water is distributed over large land areas to help grow agricultural products; it is used by residents and tourists for recreation such as floating, hunting, fishing, and aesthetic enjoyment; it is used to obtain boat access to places otherwise accessible only with great difficulty; and it is used to generate electric power as it falls on its downhill flow to the sea. With so many users of essentially the same commodity, conflicts are inevitable. Indeed, conflicts over the Snake River have been very prevalent. Considering that the future holds prospects for an increasing number of people desiring incompatible uses of the Snake River waters, the controversy is most likely to intensify before subsiding.

In the middle of the dispute, quite literally, is Hells Canyon, a deep gorge in the middle reach of the Snake River. The upper Snake River Basin has extensive development of irrigated agriculture, indicated in Figure 1, a location map of the area under study. Downstream from this development are three hydroelectric dams, which lie in and just upstream from Hells Canyon (see Figure 2). Further downstream, in Hells Canyon and below, are stretches of the river used for

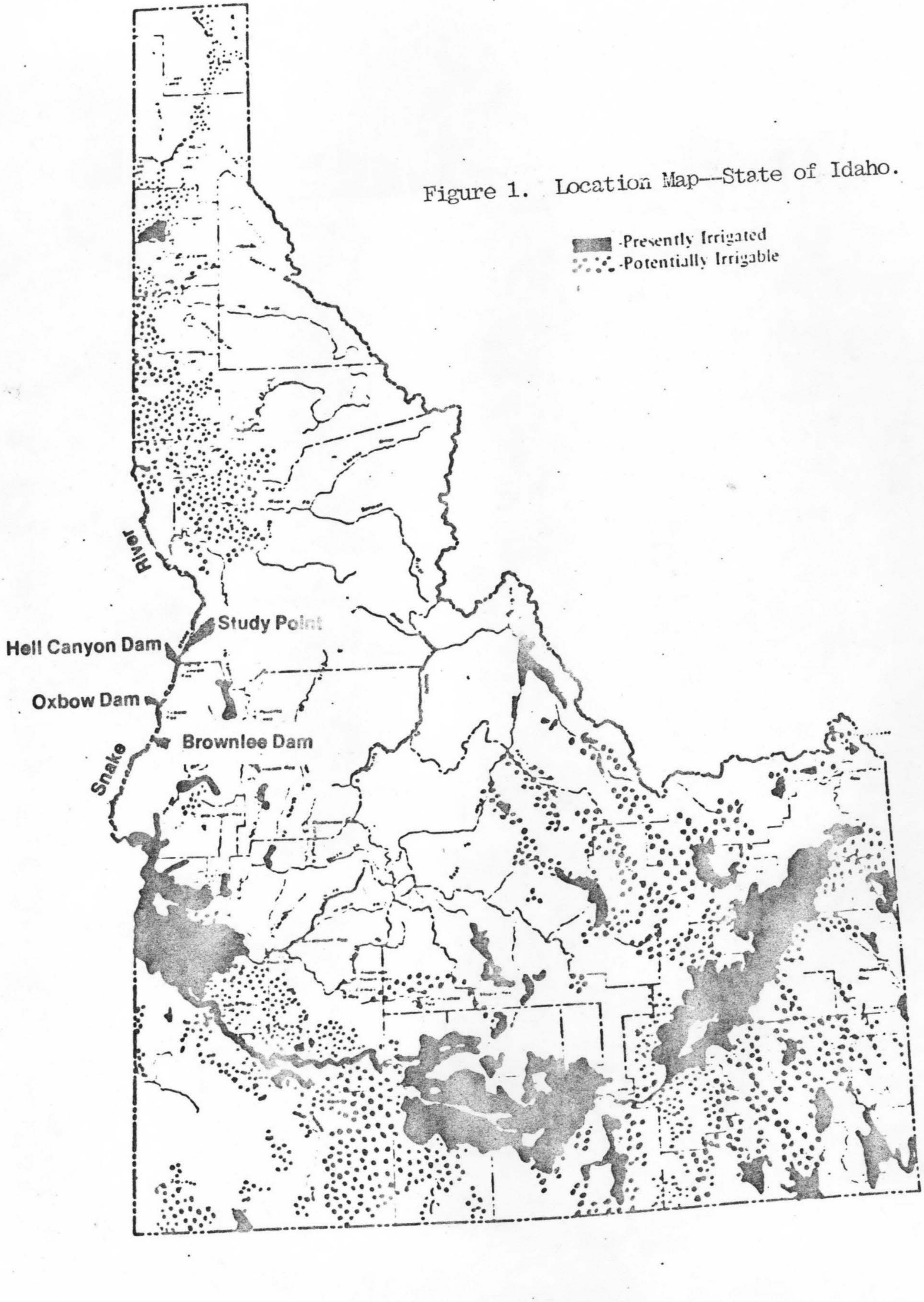

Figure 1. Location Map—State of Idaho.

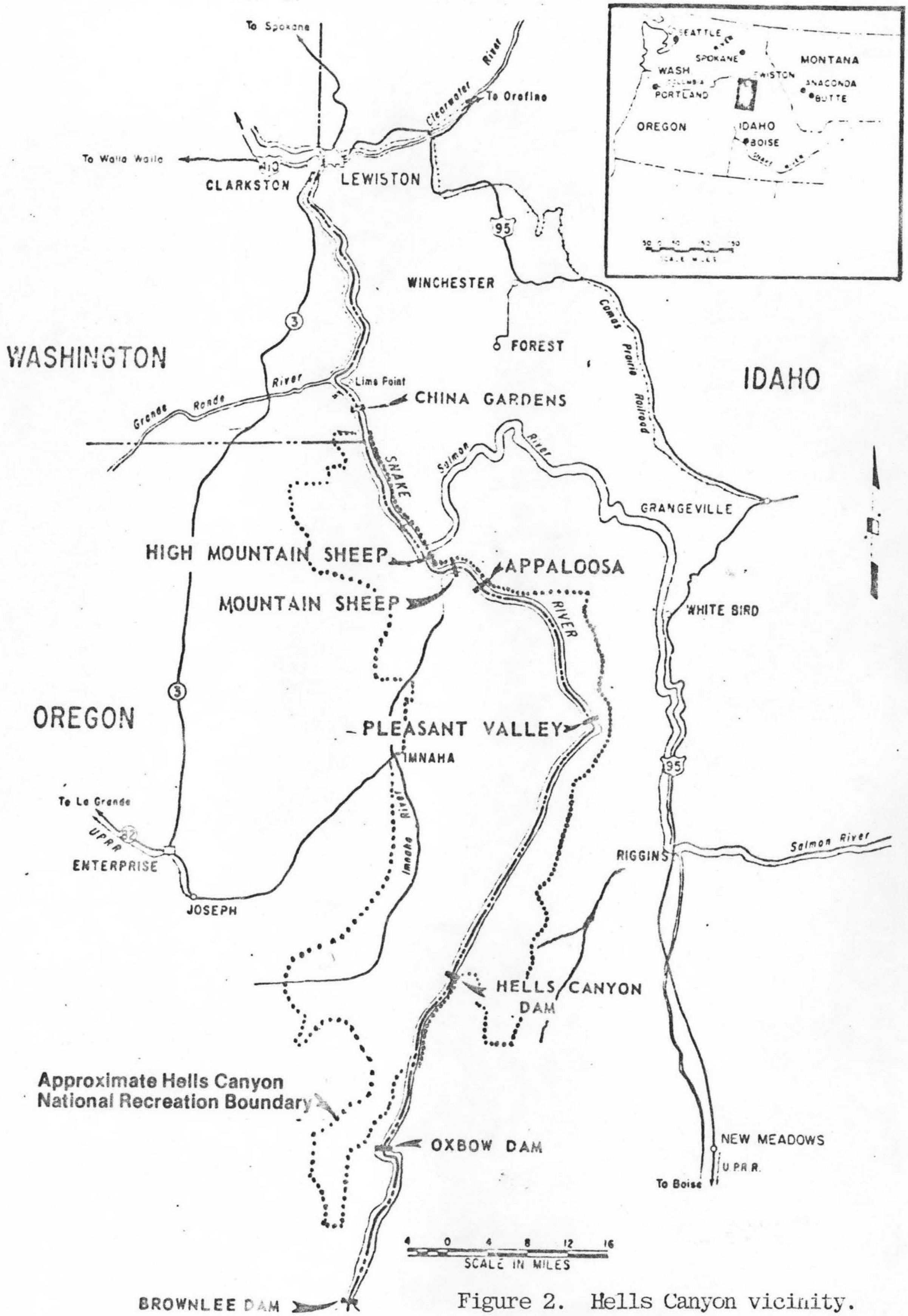

Figure 2. Hells Canyon vicinity.

navigation, fishing, and recreational pursuits. And at the dams, of course, power is generated. All of the user groups have tried to obtain water from the others to enhance their own applications. Most successful to date have been the irrigation interests because they are located upstream and as a group have been around the longest, plus as a group, they make the greatest contribution to the state economy. Of late, however, the other water use interests have been gaining in popularity and political power.

Since Idaho Power Company started building the three dams in its Middle Snake Project in the mid-1950s, it has met opposition almost constantly on one front or another. For many years, the fight was over who should do the building of a dam, then it was over whether to do the building at all, and now that the dams are all in and operating, there are constant battles over how the system should be operated. Due to generally low water supplies in the summer, at the time when the demand for water use is greatest, the problem has become quite acute, and the issue of Hells Canyon has been politically very touchy on state, regional, and national levels. At various times in recent history, Hells Canyon has been discussed and debated throughout the country as to what should be the future status of the area, both with respect to development and with respect to use. Some years ago, before the hydroelectric development of the canyon had been completed, Roy F. Bessey

(1964, p. 1), a prominent water resources planner regionally and nationally, saw the national interest in Hells Canyon as lying in a number of areas: "development and use of a national resource for national benefit in meeting expanding requirements for space, land, water, materials, and energy; the strengthening and balancing of the national economy in its functional and areal sectors; the advancement and effective use of principles and policies of national resources management."

One aspect of the issue which will be of great significance in determining future use patterns is the designation by the U.S. Congress of the Hells Canyon National Recreation Area in 1975 (89 Stat. 1117). This area, just downstream of the power company dams, will be administered by the Federal Government and will have no major construction projects permitted in it at all. This may be a very laudable achievement--having the area permanently dedicated to and preserved for recreation--but the consequences of such action should be examined. As the Pacific Northwest River Basins Commission noted (1971, p. 7), "The State of Idaho has an unusually large number of the nation's potential wild rivers. These rivers also have large potentials of development for flood control and irrigation storage, hydropower generation, and other purposes besides their free-flowing features. Careful analysis is required of opportunities foregone as wild and scenic rivers are established."

Thus, the present research is aimed at investigating the water problems currently encountered in and about Hells Canyon, the likely course of the problems in the future, and some potential means of alleviating the problems. Specifically, the objectives of this study are:

(1) To examine the nature of the opposing uses of the river;

(2) To analyze the value of the Middle Snake dams to the power company;

(3) To investigate for Idaho's future both the need for power production and the expected availability of water; and

(4) To develop a computer program to simulate the Hells Canyon hydroelectric system on the Snake River and analyze various operating schemes to determine their effects on power production.

The history of the Hells Canyon controversy, along with the National Recreation Area, is discussed in Chapter II. Chapter III looks at earlier work by federal, state, and private groups studying the canyon and river directly, or else studying subjects directly related to the canyon developments. The different river-user groups are analyzed in Chapter IV, while Chapters V, VI, and VII examine, respectively, the overall power generation and supply system of Idaho Power Company, the projected needs for electricity in Idaho in the near future, and the projected availability of adequate streamflows in the Snake River. Chapter VIII considers one of the alternatives originally contemplated for providing higher flow levels downstream, a dam for reregulation of flow below Hells Canyon Dam. The computer simulation study is discussed in Chapter IX, and Chapter X offers conclusions and recommendations for further study. A detailed description of the computer program and the data used in the computer study are presented in the appendices.

II. HISTORY OF HELLS CANYON DEVELOPMENT

While the actual development in Hells Canyon is not so long on the time scale, the history of the controversy related to the development is quite involved. The Hells Canyon reach of the Snake River, located on the Middle Snake, was first discussed in federal water resources plans for the region in the late 1940s. For the next two and half decades, opposition was expressed very strongly, often bitterly, on both sides of several issues, with Hells Canyon, the deepest canyon in North America, lying in the middle. The primary issues went essentially from federal versus non-federal construction of dams in the canyon to non-federal construction versus non-construction of dams. The current status of the "battle" is substantially a compromise--some non-federal dams have been built, but several others that had been planned have now been prohibited by federal law, and it appears very likely that the development in the canyon will not extend beyond its present level for some time into the future, if ever. The battle has not ceased, however, as will be seen in this chapter and later in Chapter IV.

A. Early Controversies

As mentioned above, the early "disputers" on both sides cited a need for dam construction, but they disagreed on who should build the dams. The start of the discussions was in the federal plans released in the late 1940s. A water resources plan for the Columbia River Basin, of which the Snake River Basin is a large part, was one of the Corps of Engineers' "308" Reports. The report done for the Columbia was completed in 1931, and it proposed ten dams on the Columbia proper (U.S. Congress 1931). The major plan, though, much more basin-wide, was completed in 1948. This report, also made by the Corps, included (a) existing projects, (b) projects underway, (c) additional projects forming a main control plan for early development, (d) proposed future projects, and (e) additional potential projects (Bessey 1964, p. 9). Therein mention was made of a proposed federal Hells Canyon Dam, a high dam to provide storage for control of floods and for generation of power.

The U.S. Bureau of Reclamation also made a large report at about the same time, in which they proposed construction of a similar high Hells Canyon Dam primarily to benefit irrigation interests. They desired to generate power at the dam and use revenues thus obtained to subsidize irrigation projects in southern Idaho. These two studies and plans, the

Corps' and the Bureau's, had been done independently, with no attempt to coordinate. In 1948, however, there was a major flood on the Lower Columbia River, after which President Truman directed the Departments of Interior and Army to work together on Columbia Basin planning. The agencies adopted an agreement in April 1949 such that with respect to the Snake, the Bureau would be responsible for development above the Salmon River confluence, and the Corps would be responsible for development below (Bessey 1964, p. 21). The Army portion, which consisted primarily of four navigation-power dams on the Lower Snake, was authorized by Congress in 1950, but the Bureau's plan, including Hells Canyon Dam, failed to be authorized.

The Idaho Power Company (IPC) had plans for eventually building five run-of-river projects on the Middle Snake, a plan which was later changed to one storage reservoir and two run-of-river reservoirs. In 1947 and 1948 there had been a fight in the Oregon state government over amendment of a 1931 state law permitting the state to recapture private power dams without going through condemnation proceedings. The amendment was supported by eastern Oregon counties, who had been told by Idaho Power that the company would proceed with Oxbow Dam if the bill were passed. The legislature passed the bill, then overrode the governor's veto, but when the Oregon Grange and others succeeded in getting the bill as a referendum in the general election of 1948, the voters rejected it by a large majority (Weatherby 1968, p. 47). Despite this loss, the company still sought construction of Oxbow and applied to the Federal Power Commission (FPC) to do so in late 1950.

A very diverse group of government agencies, citizen groups, and other organizations joined the FPC proceedings as interveners, either favoring Idaho Power's application or opposing it. At the start of the struggle, the opposing sides (within the FPC hearings or publicly outside the proceedings) were:

> organized labor at national AFL-CIO, state and local levels; a number of farm groups such as the Farmers Union at national, state, and local levels, Oregon and Washington state and subordinate granges and some local granges in other states; some regional and national supply cooperatives; some local chambers of commerce; national, regional, and local public and cooperative power associations; public utility districts; the widely-represented regional Hells Canyon associations; some individuals and groups in state government; a majority of the Pacific Northwest delegation in the U.S. Congress; and, until 1953, the federal Departments of Interior and Agriculture

favoring the federal plan (the high dam at Hells Canyon), and

> the U.S., state, and some local chambers of commerce, the National Association of Manufacturers; the Farm Bureau Federation at national, state, and local levels; some local units of the grange; the Idaho State Reclamation Association; some water-users groups; the governors of Idaho and Washington (Jordan and Langlie); and the privately-owned utilities, especially Idaho Power Company

opposing federal development (Bessey 1964, p. 28).

President Truman was also one of the opponents of the private development of the canyon. He had originally asked the Corps and the Bureau to work jointly on developing the river, and as noted earlier, the Bureau's Hells Canyon Dam proposal failed to receive Congressional authorization. Still, the Administration fought Idaho Power's efforts for its low-dam project because the President believed "that the site called for a high dam to ensure more power, adequate storage, and full resource development" (Moss 1967, p. 175). The federal Departments of Agriculture and Interior officially intervened in the FPC hearings, trying to dissuade the FPC from licensing the private project. When the Eisenhower Administration entered in 1953, however, matters changed significantly. In his inaugural address, Eisenhower set forward a policy of "partnership," pledging assistance to private enterprise. The Secretary of Agriculture withdrew almost immediately as an FPC intervener, and the Secretary of Interior withdrew that department's opposition in May.

With the loss of Interior as an ally, the several regional organizations felt the need for a national organization to continue the fight. The various groups, mostly public power, labor, and farm groups, combined resources in May 1953 to form the National Hells Canyon Association (NHCA), headquartered in Portland (Weatherby 1968, p. 89). Also in May 1953, Idaho Power Company revealed its three-dam plan, making application to the FPC for Brownlee and Hells Canyon Dams. The three-dam plan provided for two run-of-river plants and a one-million acre-foot multiple-purpose reservoir upstream. In contrast, the one-dam plan had a high dam located near the site of the proposed downstream power plant of Idaho Power, with a reservoir extending as far upstream as Idaho Power's three reservoirs and containing approximately 3.88 million acre-feet of storage.

The position of the interveners (i.e. NHCA) was based on sections 7(b) and 10(a) of the Federal Power Act (49 Stat. 838). Section 7(b) requires the FPC to deny a license for any project that would be better undertaken by the United States, then to recommend development of the project to Congress. Section 10(a) requires the FPC to license only projects best adapted to a "comprehensive plan for improving or developing a waterway or waterways for the use or benefit of interstate or foreign commerce, for the improvement and utilization of water-power development, and for other beneficial public uses, including recreational purposes. . . ." The proponents of the federal plan argued that the high Hells Canyon Dam was a "better" plan than Idaho Power's, since it would provide lower-cost power than private development, thus greatly aiding the regional economic development. They also said it was much better adapted to a comprehensive plan for the Basin since the Bureau of Reclamation and Corps of Engineers had each included the high dam as a significant unit of their existing comprehensive plans for the Columbia system. Moreover, construction of the Idaho Power three-dam project would preclude later development of the federal plan.

Idaho Power defended its case by asserting that "(1) expanding load requirements made immediate construction under its three-dam plan imperative. (2) Its project was, in fact, a multiple purpose development. (3) It was best adapted to a comprehensive plan for the development of the basin. (4) No facts justified a finding under the Federal Power Act that development should be undertaken by the U.S. (5) The project was economically feasible. (6) It could be financed and construction could proceed quickly" (Bessey 1956, p. 684). They also argued that the one-dam project had not been properly evaluated, and that if it had been, it would have been found economically unsound and infeasible.

In the state of Idaho, the primary concern had always been (in the southern part of the state, at least) to make certain that no project would have any interference with "upstream rights" to Snake River water for irrigation and other beneficial uses. A state permit granted to Idaho Power for its project stated that any rights it had to water were granted subject to the condition that the project should be operated so as not to conflict with future upstream diversion and use (Bessey 1956, p. 687). Initially, the Idaho interests did not oppose the federal project since it would have brought reclamation benefits and supposed protection of upstream water rights. In fact, official comments of the governors of the several Columbia Basin states were generally favorable to the federal "main control plan" at the end of the 1940s (Bessey 1964, p. 25). Later on, however, despite inclusion of language protective of the upstream rights in the Congressional bills, "the governors of Idaho have continued to oppose that legislation" (Bessey 1956, p. 687).

The Federal Power Commission hearing process involves an Examiner for the Commission listening publicly to the arguments for and against issuance of a license to the applicant. The Examiner then offers a decision on whether to grant the license or not, and passes his decision on to the Commission. The whole Commission then issues its final, binding decision, considering the evidence given by both sides and giving due weight to the decision of the Examiner. In the Idaho Power case, where the FPC had decided to consider all three dams as one single project (FPC Project No. 1971), the Examiner found that the federal dam was superior in most respects. But he also felt that Congressional authorization would be very unlikely, so he recommended that the FPC plan be licensed. The final FPC decision was issued in August 1955. They agreed with the Examiner that the project should be licensed, but they did not agree that the federal project would be a better one.

The essence of the Commission decision was that Idaho Power's project would be better suited to the comprehensive plan of development than the high Hells Canyon Dam project would be. They found fault with the interveners' economic reasons for federal Hells Canyon superiority. They noted (FPC 1955, 14 FPC 59) no provision in section 7(b) of the Act that federal development should be recommended if it could provide lower-cost power, and "if the supplying of power at the lower costs resulting from Federal development should be considered as a decisive factor, there would be few cases involving major power projects where private power could be licensed under the Act. . . ." The comparisons in value were made almost entirely on an economic basis, and the FPC emphasized that such comparisons should be made using the same means of financing, either private financing or federal financing for each project. The interveners had attempted to compare them with federal financing for the federal plan and private for the private plan, a comparison which "would be of little value in determining which plan would be more economic for either Federal construction or private construction." The Commission thus found that power considerations, which accounted for 85% of the total benefits under either plan, had a higher benefit:cost ratio with the three-dam plan (Federal Power Commission 1955, 14 FPC 59).[1]

The Commission also looked at each of the projects with

----

[1]Federal Power Commission cited hereinafter as FPC.

respect to navigation, recreation, irrigation, and flood control benefits, and effects on fish and wildlife. Navigation benefits were seen as relatively insignificant, economically, when compared with the overall benefits of either plan, and they were "so similar in amount as to have no discernible effect." It was felt that the federal project, with its greater size, would probably attract more out-of-state visitors, but that good access roads would make either area an important recreation attraction, so again they were comparable. While the federal dam project was intended to benefit farmers through subsidization of irrigation costs, the Commission felt that the matter of subsidies (whether and in what manner) was for Congress to decide, so they disregarded the irrigators' argument. The Commission also considered the Corps of Engineers' reliance on high Hells Canyon as part of the Corps' so-called main control plan to control floods on the Lower Columbia. The FPC noted that Brownlee Reservoir, containing about one million acre-feet of storage, which, combined with other dams in the Snake Basin, would total about 8.5 million acre-feet, about two-thirds of the average annual flow of the Snake River at Weiser at that time. In addition, they noted that the Department of the Army had no objections to Idaho Power's offering less storage than originally planned, and the Corps had, in fact, offered license conditions to the FPC under which Brownlee should be operated for flood control purposes. The Commission thus felt that the IPC plan was consistent with the Army's present plans to control floods on the Columbia River. As for the fish and wildlife aspect, either plan was judged to likely have an adverse impact, especially on anadromous fish, so the Commission felt that about five million dollars would be required to be spent for a fishery program. Thus, the Commission felt that "the public purposes such as flood control, navigation, and recreation could be effectuated to about the same extent under either plan of development." Finally, the private plan would serve these public purposes at no expense to the United States (FPC 1955, 14 FPC 62).

Rather expectedly, the interveners did not agree with the Commission's decision. They petitioned the FPC for a rehearing, which the FPC denied. They then appealed to the United States Circuit Court of Appeals, maintaining their position that the federal project was superior under sections 7(b) and 10(a) of the Federal Power Act. The court unanimously upheld the FPC decision, not wishing to judge what they considered a technical matter. The next step was a filing with the U.S. Supreme Court for a writ of certiorari. The High Court denied the writ in 1957, refusing to review the case, with no reason given.

With apparent confidence that the appeals would be denied, Idaho Power had begun construction of Brownlee Dam in

November 1955. Oxbow was started in the summer of 1958, and Brownlee was completed in the fall of 1958. Oxbow was completed in 1961. Construction of Hells Canyon Dam, begun in 1964, was complete in 1968.

After issuance of the FPC license in 1955, IPC, which had made applications for permits for its three dams with the Oregon Hydroelectric Commission, appeared at a public hearing considering the permits. The company took the position that it did not need a state license since it had already gotten one from the FPC, who had jurisdiction, but that it wished to maintain proper relations with the state. Opponents said that a state license was required, and the state Attorney General believed state law was being violated by IPC's proceeding with Brownlee construction. A precedent case was later discovered, however, which upheld the company's claims.

The Hells Canyon associations, particularly the National Hells Canyon Association, pretty much passed out of existence after 1957. They managed to muster a large letter-writing campaign in 1957, however, which likely helped bring about passage in the U.S. Senate of a bill in favor of high Hells Canyon Dam. The bill later died in committee in the House and with it the Association's hopes of halting construction of Idaho Power Company's three-dam hydroelectric complex. Ten years later, however, some one-dam advocates took consolation in the fact that Idaho Power had been forced to change its plans from its original five run-of-river dams, so their time and money had not all been for a losing cause (Weatherby 1968, p. 88). Though this was the end of attempts to stop project construction, it was not by any means the end of disputes over Hells Canyon.

B. Later Controversies

After construction of the three dams was "cleared" for Idaho Power, probably the largest thorn in the company's side was its requirement, under FPC orders, to mitigate adverse effects on anadromous fishes in the Snake River. The fish problem may have been the start of the "environmental" concern for Hells Canyon. The problem was that the dams blocked the migration of salmonid fishes, who swam downstream to the sea as smolts and back upstream a few years later as adults to spawn. Article 35 of its FPC license required the company to provide for fish-handling facilities to conserve these fish runs. They were also to act accordingly upon recommendations relevant to the fish problem from the Secretary of the Interior, the conservation agencies of Idaho and Oregon, or the FPC itself, as well as to pay a portion of the annual costs realized by the Idaho and Oregon Fish and Game Commissions with respect to operation and maintenance of related fishery facilities.

In November 1956, the Department of Interior submitted recommendations to the FPC for construction of fish conservation facilities, followed in the summer of 1957 by a letter recommending specific fish-handling facilities. In February 1958, the FPC issued an order prescribing a net arrangement in Brownlee Reservoir with skimming and trapping devices to capture migrating fish and permit their passage around the dams. The net idea apparently worked poorly, and in October 1963 Idaho Power Company, the U.S. Fish and Wildlife Service, and the fish and game agencies of Idaho, Oregon, and Washington jointly urged the FPC to amend its earlier order. The FPC did so, two months later, when it ordered that the net be abandoned, that a hatchery be constructed by Idaho Power on the Rapid River, a tributary of the Salmon River, and that the company make provisions for transportation of spawning fish and/or their eggs (Bessey 1964, p. 38). The Rapid River hatchery, as well as a few other hatchery facilities on the upper Salmon and Snake Rivers, have had limited success, but to date have still sustained the salmon runs to some extent.

A development closely related to the "Hells Canyon battle" was a series of hydroelectric developments proposed by power companies other than Idaho Power to be constructed downstream from IPC's Hells Canyon Dam. Pacific Northwest Power Company (PNPC), a coalition of four private utilities based in Washington and Oregon, filed an FPC application for a preliminary permit for two dams called Pleasant Valley and Mountain

Sheep (see Figure 2). The three-year preliminary permit was issued, but a license was denied by Commission order in January 1958. The last day of its three-year permit period, PNPC filed a license application for a high dam at the Mountain Sheep site. The FPC called for a hearing on the application, and six days before the scheduled hearing, an application for another dam called Nez Perce was received from Washington Public Power Supply System (WPPSS), a group of eighteen municipalities. The two applications were mutually exclusive, so the Commission provided a single hearing for both of them, running during late 1960 and 1961. The Presiding Examiner's initial decision, in late 1962, was to grant PNPC's license and deny WPPSS's, which was followed by a petition from the Secretary of Interior to intervene in the proceedings in order to urge development by the federal government. The Commission did, however, decide to grant the PNPC license and deny the WPPSS one, an order which was appealed by the Secretary of Interior to the Circuit Court of Appeals and the U.S. Supreme Court. The Supreme Court, in a significant decision in June 1967, remanded the case to the FPC so it could reconsider two principal questions: private versus federal development, and development versus non-development (Udall v. FPC 1967, 387 U.S. 428).

The Supreme Court decision, written by Justice Douglas, opened the way for individuals and groups with strong environmental concerns to begin making their case for preserving the canyon, i.e. not permitting any more development there beyond what Idaho Power had already done. The Hells Canyon Preservation Council, one of the more active of the groups, was incorporated in 1967 "for the specific, single purpose of saving the world's deepest river canyon from being drowned by additional dams" (Hells Canyon Preservation Council 1975, Newsletter Preface).[1] The Council published a newsletter three or four times a year between 1967 and 1975 to inform members of the issues pertinent to Hells Canyon, to report the progress of the various Hells Canyon bills in Congress, and to encourage active participation by its members. The Council gave its first annual award, given to "leaders of American public opinion who have taken up our cause" to Justice William O. Douglas for his writing of the Court's 1967 opinion in Udall v. FPC (HCPC 1973).

When the PNPC-WPPSS case went back to the FPC for further hearing, the two power entities agreed to join forces and make a single application for a Middle Snake project, applying for any one of three alternative developments in the reach between Hells Canyon Dam and the Grande Ronde River. Shortly thereafter, in late 1968, the Department of Interior sought to

----

[1]Hells Canyon Preservation Council cited hereinafter as HCPC.

join in on the project also, which would have required enabling legislation from Congress. Before that occurred, however, the new administration's Secretary (Hickel) withdrew the Department from consideration for the three-way coalition, and even proposed a moratorium on dam-building. With the continuation of the hearings, the Presiding Examiner again recommended issuance of a license for a Pleasant Valley-Mountain Sheep project, but he also recommended that construction not begin before September 12, 1975, so that studies could be made on including the Middle Snake River as a component of the National Wild and Scenic Rivers System. In February 1975, the Commission released a draft environmental impact statement on the project (FPC 1975), in compliance with the National Environmental Policy Act. Congressional action later killed all consideration for the project.

Several bills had been introduced into both houses of Congress since about 1968 by several of the representatives of the Pacific Northwest states. Idaho Senators Church and Jordan introduced a moratorium bill in 1968 and 1969 with little success, but it passed the Senate in 1970. The bill, intended to permit exploration of all possible alternatives and prevent construction until exploration was complete, subsequently failed in the House. Re-introduction in 1971 was also fruitless. Two bills introduced in 1970 proposed to designate the stretch of the Snake in question as a National

River to be administered by the Secretary of Agriculture. Oregon Senator Packwood introduced a bill in the Senate, and Representative Saylor of Pennsylvania introduced a separate one in the House. Neither was successful, including a reintroduction of Packwood's bill in the Senate in 1971. Several other bills in 1972, 1973, and 1974 attempted to create a national forest parklands area or a national recreation area, but none was successful until passage was secured on the last day of 1975 of an act establishing the Hells Canyon National Recreation Area (89 Stat. 1117), which was later signed by the President. A principal provision of the law creating the National Recreation Area (NRA) is prohibition of construction of any further development within the area, which cancels the PNPC-WPPSS project.

C. Hells Canyon National Recreation Area

The law which created Hells Canyon National Recreation Area was a great victory for "environmentalists." They had tried for many years to obtain a legal prohibition against further Hells Canyon dam-building. The Act designated certain lands along the Snake River below Hells Canyon Dam as wilderness, certain other lands in the vicinity as the NRA, and other neighboring areas as wilderness study area. In addition, portions of the Snake and Rapid Rivers were designated as Wild or Scenic Rivers. The tentative boundaries of the NRA in relation to existing and previously-proposed hydroelectric dams in the vicinity, are shown in Figure 2. The Act directs the Federal Power Commission not to license any project within the recreation area. It also directs the Secretary of Agriculture to determine final boundaries for the various areas, and to administer the whole area. Some protection is offered to the upstream irrigation and power interests, however. The law states that it shall not "in any way limit, restrict, or conflict with present and future uses of the waters of the Snake River and its tributaries upstream from the boundaries of the Hells Canyon National Recreation Area created hereby." Also, "no flow requirements of any kind may be imposed on the waters of the Snake River below Hells Canyon Dam. . . ." under the Act (89 Stat. 1118).

III. PREVIOUS STUDIES

The Hells Canyon reach of the Snake River has been studied for quite some time. It has been referred to as the most studied river in the country. Some studies have looked at it as a portion of the Columbia River Basin of the Pacific Northwest Region, while others have researched the canyon specifically. As noted in Chapter II, the area has been very controversial--there have long been parties eager to develop the canyon, and for almost as long, there have been others who have wanted to preserve it. The result has been numerous studies, to determine the best ways to develop, the restrictions on the development, how to preserve the river, and how best to compromise for all these.

A. Early Studies (Prior to 1962)

In 1924 the U.S. Congress directed the Chief of Engineers of the Army to take leadership in multiple-purpose surveys of major American river basins (U.S. Congress 1926). They requested a plan for improving navigation, waterpower, flood control,and irrigation in the Columbia Basin and its minor tributaries. The Corps of Engineers responded in 1931 with a report proposing ten dams to be constructed on the main stem of the Columbia. The Corps presented in 1948 a more basin-wide plan, however, in which it offered its "main control plan" (U.S. Congress 1948). This plan included several large multiple-purpose dams and reservoirs to be operated as a coordinated system in conjunction with lower Columbia levees for controlling main Columbia floods, improving inland navigation, and furnishing the main part of the power requirements for the Columbia Basin. Therein the federal plan for the high Hells Canyon Dam was first revealed. Coincidentally, the U.S. Bureau of Reclamation released at about the same time a study of the Columbia River Basin water resources in which it, too, had proposed development of a high dam near the Corps' Hells Canyon site.

After licensing of the Idaho Power Company Middle Snake project in 1955, the Corps drew up a manual to be jointly used by the agency and the power company for operating the three-dam complex for power, navigation, and flood control. This manual announced (U.S. Army, Corps of Engineers 1961, p. 36)[1] that

> Regulation studies and other investigations since issuance of the license have indicated to the Corps of Engineers that some of the provisions of Articles 42 and 43 need to be reviewed to insure adequate navigable water downstream and provide greater flexibility in flood control operations.

It was noted, though (Corps 1961, p. 36), that such a review

---

[1]U.S. Army, Corps of Engineers cited hereinafter as Corps.

would involve quite a bit of negotiation and time, so the preliminary operating plan, outlined in the manual, had been based on existing provisions and "practical integration of over-all operating objectives." The Chief of Engineers proposed thereafter to the Chairman of the Federal Power Commission that the company be required to release at least 8500 cubic feet per second (cfs) at all times, rather than just 5000 cfs, but a later letter withdrew the request and recommended that action on the license review be discontinued (Corps 1972, p. 7).

B. More Recent Studies

1. Army Corps of Engineers

After receiving a petition from the Lewiston, Idaho, and Clarkston, Washington, Chambers of Commerce in late 1967, the Federal Power Commission requested the Corps of Engineers to review and comment upon the petition. The petition had requested a modification of Idaho Power Company's license to require a release of at least 10,000 cfs (instead of 5000) at all times in order to benefit pleasure boating, commercial boating, and to preserve fish and wildlife on the Snake River downstream. The Corps requested extra time before commenting, so they could make a boating survey of the river reach. The Walla Walla District then released a brief staff paper (Corps 1969), summarizing the results of the initial phases of the study, which had consisted of analyzing the problem, conferring with the parties involved, investigating alternative solutions, and conducting the boating survey. Thereafter, they held public meetings in Boise and Lewiston in December 1970, and released the final report from the North Pacific Division a year later (Corps 1972).

The Corps recognized that current operating practices of Idaho Power's Middle Snake Project, combined with Snake River hydrology, often made navigation difficult in the river downstream of the power plants. The most troublesome condition was low streamflow, which Idaho Power could legally reduce to 5000 cfs at times. This was the situation the petitioners hoped to eradicate by increasing the minimum flow. Aside from the proposed changes in the license, the Corps also looked at other possible solutions to the boating problem. The alternatives initially considered were no change in the license, the requested license change, the requested license change (modified), a downstream dam for reregulation, provision of navigable flows during mail-run periods and weekends, restriction of navigation on the reach to licensed boats and operators, construction of channel improvements, provision of upstream storage for augmentation of flows for navigation, closure of the river to navigation, restriction of navigation above Lime Point to jet-type craft, and the Pleasant Valley-Mountain Sheep dam complex downstream (Corps 1972, p. 29). Most of them were considered unavailable at the present time or infeasible for some other reason, with the only realistic alternatives then being no change in the license, the proposed or the modified proposed license change, and maintaining increased minimum flows part of the time (i.e. for the mail boat and on weekends). The modified proposed change was to require 10,000 cfs to be released, except that the release would not have to exceed the inflow to Brownlee.

In discussing the proposed license modifications, the Corps noted that the requirement for 10,000 cfs at all times would require drafting storage from Brownlee at times, thereby wasting substantial amounts of firm energy both to Idaho Power Company and to the coordinated Columbia River system. Thus, the Corps confined its analysis to the modified proposal, which it examined in detail. The study actually considered 9500 cfs, rather than 10,000, since that flow would provide a channel above the Salmon River comparable to the channel below the Salmon at 13,000 cfs (Corps 1972, p. 36). The Corps discussed losses that the company (and the entire system) would suffer in terms of annual energy production and peaking capability. Evaluations made using a severe critical period as the criterion showed an average annual firm energy loss of 48,400 kilowatts, worth about $2.3 million per year. Using a less severe control period, the loss would not be as bad, about 12,000 kilowatts and $600,000 annually.

The conclusion reached in 1972 was that other uses of the river besides boating and power production would be affected by any license change increasing minimum flows. Among these other uses would be fish and wildlife habitat, water quality, recreational use of the river and adjacent land, recreational use of Brownlee Reservoir, and upstream irrigation. It should be noted that upstream irrigation interests were very adamantly opposed to increasing the minimum flow requirements. Ultimately, the Corps felt that it could not have evaluated the impacts on these uses within the scope of its study, and that a complete analysis of each should be made before deciding whether to modify the license, so the Corps recommended no change in the license at that time.

2. Idaho Power Company

Directly related to the aforementioned license change proposal and analysis, the Idaho Power Company itself released a study (Idaho Power Company 1970) on the effects of the license modification, and its reasons why it should not be modified. The company's analysis, presented in June 1970, was in response to the Corps' 1969 report which had made a preliminary recommendation in favor of the increased flow requirement. Idaho Power hoped to show "the Corps of Engineers and other interested parties the detrimental and perhaps disastrous effect that changing the license as proposed could cause" (IPC 1970, p. 4).

Idaho Power noted that the principal effect of increasing the minimum flow would be a loss of storable waters in Brownlee Reservoir. In years when the streamflow coming in was normal or above normal, the reduction would not be too great, but the advantage gained for navigation would also be very small since the water releases would be high anyway. In dry years, though, Brownlee's level would be lowered by not being able to refill, but even this reduction in the reservoir storage "would not increase downstream flows to the level that could be envisioned by the requirement of a 9500 cfs minimum flow" (IPC 1970, p. 15).

Though not a member of the Pacific Northwest Coordination Agreement (PNCA), Idaho Power Company is required by Article 39 of its FPC license to coordinate its Project 1971 operations both hydraulically and electrically with the Northwest Power Pool, which operates as a coordinated system under the PNCA. The company felt that increasing the minimum flow requirement would decrease its ability to benefically coordinate its operation. Reasons given (IPC 1970, p. 18) were:

a. Generation at downstream plants attributable to coordinated storage water releases from Brownlee Reservoir will be reduced about 50 percent from the level that was anticipated as a result of the minimum flows from Brownlee specified in the FPC license.

b. At site generation from stored waters will be reduced about 40 percent.

c. At site peaking capabiliity at the time of the system peak will be reduced about 300,000 kilowatts below the amount contemplated when Hells Canyon Dam was de-signed and constructed.

d. Flexibility of operation with the Northwest Power Pool will be reduced because of these restrictions.

The company did some regulation studies based on its required 5000 cfs release and also on the 9500 cfs requirement. They used the Corps of Engineers operating rule curve for Brownlee Reservoir which had been developed based on conditions during a critically dry 8-1/2-month period in 1936-37. The rule curve specifies the drawdown permitted so that the reservoir can refill using a specified release for power. With a 5000 cfs release, full drafting and refilling of Brownlee was possible, but 9500 cfs permitted drafting and refilling only 64 percent of full capacity, reducing the output of firm power at Brownlee, Oxbow, and Hells Canyon, and also at downstream power plants.

Idaho Power considered that alternatives to replace the lost capacity would be expensive for its rate payers. The alternatives mentioned were thermal peaking generation by gas turbine or coal-fired plants, purchasing from another company, for which Idaho Power would have to construct transmission facilities, or construction of a reregulating dam below Hells Canyon. To replace the projected 310,000 kilowatts of lost capacity, they would need to spend annually about $8 million for new peaking facilities, about $4 million for transmissinn lines, or about $4 million for the reregulating dam (IPC 1970, p. 25).

Finally, the company asserted that the economic impact of the proposed change would be substantial. They expressed doubts about meeting contractual obligations to supply power during dry years, and they anticipated serious legal and equitable problems if such a situation occurred (IPC 1970, p. 38).

3. Idaho Water Resource Board

As part of the Comprehensive Joint Plan of the Pacific Northwest River Basins Commission (PNWRBC) and the Idaho State Water Plan, the Idaho Water Resource Board did a study (Idaho Water Resource Board 1974)[1] to determine flow rates that would be desirable for aquatic life, recreation, and water quality in the Snake River, and also to project the availability of water in the future based on minimum flow requirements and future irrigation development. They selected four reaches of the Snake River for study between Marsing, Idaho, and the mouth of the Grande Ronde River. They then sought to determine what the flows would have been in these reaches if the present levels of upstream control and irrigation had existed throughout the 1928-1968 period of record used for analysis. In addition, they sought to determine the extent to which potential minimum-flow requirements are not being met now, what

----

[1]Idaho Water Resource Board cited hereinafter as IWRB.

the flows would have been in the 41-year study period if the levels of development projected for the year 2020 had existed throughout, and what deficiencies could be expected in meeting the potential minimum flows under the assumed future conditions. The flow requirements assumed were 6800 cfs from Marsing to Ontario; 8600 cfs from Weiser to Brownlee Reservoir; various levels from 9500 cfs to 16,000 cfs in the reach below Hells Canyon Dam; and 13,000 cfs above the Grande Ronde River, i.e. at Lime Point. The study, released in 1974, used a computer model of the Snake River to calculate the flows.

The study had two main parts--the Present Conditions study and the Future Conditions study. Noting that significant changes with respect to existence and/or operation of reservoirs and irrigation systems had taken place on the Snake in the period of record, the Present Conditions study made several assumptions to try to correct for these changes. First, "present" was understood to mean 1973 or the period preceding 1973 when the data or criteria being considered were at a stable condition. Further, all structured controls existing then (1973) were assumed to have existed throughout the study period, and their simulated operation was the same as the present type of operation.

In the Future Conditions aspect of the research, the level of development projected for the year 2020 was again assumed to have existed throughout the period. The projection was made by the Office of Business Economics and Economic Research Service (OBERS) based on population and food and fiber needs for the country with Idaho's irrigation development proceeding to meet the National Economic Development (NED) objective. A projection based on the Environmental Quality (EQ) objective was also made, which had the effect of maintaining higher instream flows. The actual growth rate occurring will probably be between the NED and EQ levels, so the water available in 2020 will probably be somewhat higher than that predicted by this study, which used the NED maximum development projection. The assumption was also made that the instream flow requirements (such as at Hells Canyon) would not hinder the irrigation development.

Reservoirs in the Snake River Basin consist of federal reservoirs constructed by the Corps of Engineers and the Bureau of Reclamation for irrigation, flood control, and power production, as well as some private dams and reservoirs. These reservoirs were "operated" in the simulation to serve their design purposes, based on current management practices and historic records of contents and releases.

The results of the Present Conditions study showed lowest flows occurring in July, August, and September, the same as historically. Flows at Murphy (above Marsing) were quite constant throughout the year, primarily because of groundwater discharge from the Snake River Plain at Thousand Springs. The Weiser and Hells Canyon reaches had greater seasonal fluctuations due to less regulation in the intervening tributaries (Boise and Payette Rivers). Deficits in meeting the minimum flow objectives occurred at Weiser in July and August, at Hells Canyon from 9500 cfs in May, June, July, and August, but mostly in July and August, and at Lime Point from 13,000 cfs in July, August, and September. A log-normal frequency analysis at each site for the winter period (September through March) showed that the probability of not meeting the objective was less than five percent at each site. In the summer, however, chances were much greater. There was a 40 percent chance that Hells Canyon's flow would be below 9500 cfs in July and August.

The Future Conditions flows were much lower overall and especially in July. Flows at Weiser, Hells Canyon, and Lime Point averaged about 5000 cfs less under future conditions in July than under present conditions. The primary reason was pumping from the Snake River for summer irrigation between King Hill and Murphy. Deficits from the flow objectives occurred generally in July, August, and September for Weiser's 8600 cfs, with July being the lowest month. The same was true at Hells Canyon Dam. At Lime Point, the 13,000 cfs was met in July, but deficits occurred in August and September. The study also analyzed the effect of future conditions on the major Snake River tributaries, projecting depletions therein, and noting that "with increased depletions elsewhere in the Snake River Basin, a larger portion of Brownlee Reservoir inflow would be supplied by the Payette River" (IWRB 1974, p. 22). The Payette enters the Snake about 15 miles upstream from Weiser, and about 25 miles above the upstream end of Brownlee Reservoir.

The major conclusions of the study were that flow objectives under the present conditions could not be met 100 percent of the time, and that future conditions caused even greater and much more frequent depletions in streamflows. Also, the most likely ways to supply water (in-stream) for 2020 and beyond were judged to be pumping groundwater into the river to increase the flow, or improving efficiency in irrigation systems to decrease the diversions.

4. Pacific Northwest River Basins Commission

In March of 1973, Keith Bayha and Charles Koski, under the auspices of the Pacific Northwest River Basins Commission, organized and coordinated a study by over 30 state and federal agencies and private entities to try to determine the optimal instream flow requirements for the Hells Canyon reach (Bayha and Koski 1974).[1] A group of 79 specialists worked on the

---

[1]This study is discussed hereinafter as the Pacific Northwest River Basins Commission study.

river at nine different sites for 10 days, monitoring the effects of five controlled flows--releases from Hells Canyon--on the biological community of the canyon and on non-consumptive uses of the river by man. Basically, they wished to assess water requirements in the reach for fish and wildlife, for water quality, for navigation, and for recreation. The study report, titled "Anatomy of a River," summarized the plan, methods, results, and conclusions (Bayha and Koski 1974).

Specifically, the items investigated were instream-flow needs for:

1. maintaining water quality,
2. supporting aquatic vegetation,
3. supporting benthic (bottom-dwelling) insects,
4. affecting catchability and feeding habits of fish,
5. supporting salmonid fishes,
6. supporting warm-water fishes,
7. supporting sturgeon,
8. stranding fish,
9. affecting wildlife in the area,
10. supporting recreation,
11. permitting or enhancing whitewater boating,
12. permitting or restricting navigation, and
13. permitting adequate power generation and water supply.

The researchers specified flows in a few cases that were the minimum acceptable for different activities. These are discussed in Chapter IV with the specific applications. The researchers noted that additional studies should be done to quantitatively evaluate requirements for other considerations, which was not possible in a short study such as theirs.

5. Idaho Public Utilities Commission

When Idaho Power Company expressed a need and desire to construct a coal-fueled generating plant about 25 miles from Boise, it was up to the state Public Utilities Commission (PUC) to evaluate the proposal. The Commission investigated the anticipated impacts of the proposed power plant, as well as the company's actual need for additional capacity. It was this latter aspect that Arthur D. Little, Inc., a consulting firm based in Cambridge, Massachusetts, was asked to research. The firm started its study in June 1975 and released its final report the following February (Arthur D. Little, Inc., 1976).[1]

Little looked at prospects for growth in Idaho Power's service territory, growth in both the population and the economy. They also looked at trends in consumption of electric energy and tried to project future demands, both

----

[1]Arthur D. Little, Inc., cited hereinafter as Little.

annual totals and peak demands. In addition, they considered the company's existing generating resources, as well as its plans for expansion by hydroelectric or thermal facilities and even possible expansion not formally contemplated by the company. Finally, they reviewed possibilites for purchases of power and energy, either by cash or on an exchange basis, from other utilities and power suppliers in the region.

Little's conclusion was that the company's electrical demand would grow about five percent per year, the company's hydrolectric generating resources had little room for expansion, and that obtaining energy from external sources (i.e. other companies) appeared doubtful on a reliable basis. A thermal plant would most likely be the best alternative. They mentioned that a base-load thermal plant would be preferable if the company could sell its surplus power in the winter. One or more peaking units would be better, though, if there were no market for the winter power.

IV. COMPETING USES FOR THE SNAKE RIVER

A United States senator from Idaho frequently used to call the Snake River "a working river" and "the lifeblood of Idaho" (Senator Len Jordan, in: U.S. Congress 1971, p. 18). Indeed, the river is vital to many citizens of the state, and it is very beneficial to others, and also to non-Idaho residents of the region and out-of-state tourists visiting the region. Unfortunately, however, the several different uses of the river are not entirely compatible: they cannot all be simultaneously optimized. From an economic standpoint, by far the biggest users of the river are those who use the water to irrigate crops and those who use the energy released by the falling water to generate electricity. There are other important uses of the river, though. It was in recognition of these, and perhaps in giving them higher priority than the two aforementioned uses, that the Chambers of Commerce of Lewiston, Idaho, and Clarkston, Washington, in 1967 petitioned the Federal Power Commission to require Idaho Power Company to release more water during minimum flow periods, as was discussed in Chapter III. Actions and results pertinent to the petition were discussed more fully in Chapter III, while the present chapter deals with the nature of each of the primary river uses--how each employs the waters of the Snake and how it affects the other uses.

The competing uses that will be examined are land-based agriculture, electric energy production, boating, recreation, and enhancement of fish and wildlife in and around the river environment.

A. Irrigation

Farming by means of irrigation has been widely practiced in the upper Snake River Basin since well before 1900. Development in some areas has been through private enterprise, while in others it has been largely government-supported. Irrigated crops in Southern Idaho consist of potatoes, sugar beets, and onions, among others.

More emphasis has been placed recently on obtaining irrigation water from groundwater supplies, but in some areas which were formerly only desert lands, there are now communities dependent on farming, and getting their water directly from the Snake River. The farming and food processing interests are quite powerful in the Idaho state government, and they are even influential in the federal government, as is evidenced by inclusion in the Hells Canyon National Recreation Area Act of a section prohibiting the Act or any related minimum streamflow requirement from being construed as a limitation on irrigation development in the Upper Snake Basin (89 Stat. 1118, Sec. 6).

Irrigated land in Idaho at present (1977) is about 3.8 million acres, all of which is in the drainage above Brownlee Reservoir, except for small portions near Salmon, Coeur d'Alene, Lewiston, New Meadows, and in the Bear River Basin. Projections by the Idaho Department of Water Resources in the State Water Plan (IWRB 1976) reveal expectations for development of nearly another one million acres by the year 2020. The new development is in turn expected to reduce the downstream water supply. While some of the water will make its way back into the river through return flows underground, greater application for irrigation will increase the consumption by increasing evapotranspiration from plants. Should new storage reservoirs be constructed and utilized, water surface evaporation will also be increased.

In Idaho Power's analysis of disadvantages in increasing the minimum flow requirement (1970, p. 34), the company noted that:

> The irrigation and water interests of southern Idaho are again opposed to the increase of minimum flow proposed by the Corps of Engineers. This opposition is based upon the very sound rationale that if the provision for passage of a minimum of 5000 cfs can be changed due to the request of a relatively few boaters and despite the vast expenditures of capital and the potential power displacements that may occur in complying with such a change, then it is only reasonable to realize that once a 9500 cfs minimum flow has been established, all boaters and users of the Lower Snake will resist reduction in flow for any reason. . . . There are many hundreds of thousands of additional acres of desert land that will be irrigated out of the Snake River and each of these developments must result in a diminution of the Snake River flows so that the minimum flow in a critical summer month

can be extremely low--much too low to comply with the desires of the boating enthusiasts.

B. Power

There are several dams with power-generating capability on the Snake River above Brownlee, mostly owned or operated by Idaho Power Company, but this section will be concerned mainly with power production at the Middle Snake dams. Hydroelectric power generation is a non-consumptive use of water--what water comes into the plant is released downstream. The reservoirs used just for power upstream from Brownlee do not affect very much the character or the quantity of the inflow reaching Brownlee, so they are not in competition with the three-dam complex for water.

Noting the general effects of reservoirs created and operated for power production, C.H.J. Hull (Hull 1967, p. 93), in a section entitled "River Regulation," wrote:

> Impoundments radically change the stream from a relatively shallow, high velocity one to a deep, sluggish lake. . . . Suffice it to say that some of these effects are beneficial while others are detrimental to other water uses. . . . A second result of flow regulation for power production is the increase of the average flows during the normal low-flow periods of the year. This seasonal stabilization of runoff is generally beneficial to all other types of water use, making more water available during the periods of critical drought flows. Still another effect of flow regulation for power generation is the relatively short-term fluctuations of flow in response to daily and weekly variations in power demand. These fluctiations tend to complicate some downstream water uses, and are therefore detrimental.

These observations are applicable to Idaho Power's Middle

Snake Project. The annual hydrograph is stabilized by storing the snowmelt runoff in the spring and making extra releases in the fall and winter for power production and flood control. Thus, the high spring flows are reduced, and the fall-winter flows are increased. The mid- and late-summer flows have been historically low, and may be increased somewhat by power releases, but the power company prefers to maintain a full storage reservoir and essentially release the daily average inflow.

Hydroelectric power generation has several advantages over thermal power generation. Installation costs for the dam and turbines may be higher than for a steam plant of comparable size, but operating costs are much less so the annual cost of production is usually less for hydropower. While steam turbines require quite a bit of time to go from "off" to full capacity production, hydroelectric turbines can be started and operated at full output quite quickly. Water power plants are "clean," i.e. there are no undesirable gaseous or liquid effluents to contribute to environmental pollution. There are disadvantages, too, however. The plant usually requires a dam and accompanying reservoir, causing inundation sometimes of valuable resources. Also, as mentioned above, operation of the units often requires fluctuating water discharges, which makes downstream use of the river difficult. In addition, power production is very dependent on the natural supply of water.

Due to the hydropower plants' ability to start and stop rapidly, they are very well employed as peak-generation plants. Ideally, from the power company's point of view, one or two power plants would be operated to provide electricity for the base load, the fairly constant level of generation required throughout the day. Then, the other hydro plants in the system could be turned "on" and "off" as the need arose for production from them. In Idaho Power's case, if it could do so without harming downstream users, the company would most likely prefer to completely shut down Hells Canyon Dam at times when the generation was not needed, then generate the power they require during the peak-load periods. Such a mode of operation, however, would be very undesirable for the other users below the dam.

C. Navigation

Use of the Snake River for navigation in and above Hells Canyon is not as great economically as is use for irrigation and power production, but for some people, it is just as vital. There are several homes, mostly ranches, along the river in the canyon reach below Hells Canyon Dam. These areas are very isolated, surrounding mountain grades are very steep, and there are few access points thereto by land transportaionn routes, so travel on the river provides the only practical way for most of the ranchers to transport themselves and necessary supplies into and out of the canyon. A few of the canyon-area residents have their own boats, but many rely on commercial operators from downriver, particularly on R.B. Rivers' Rivers Navigation Company. Rivers has owned the contract for mail delivery into the canyon since 1958, and he has also brought in cargo for the inhabitants from outside. His operation primarily consists of running up the river every Wednesday and back down on Thursday. He also offers a tour-boat service, transporting people up and down river to view the Hells Canyon area. This service is in addition provided by several other commercial operators stationed along the Snake from Hells Canyon Dam down to Lewiston.

One of the major responsibilities of the Army Corps of Engineers is overseeing navigation on the nation's navigable waters. Since the Snake River has been considered navigable below Hells Canyon Dam, the Corps has made provisions for maintaining the reach's navigability. First of these provisions was inclusion in Idaho Power's FPC license of several restrictions on operation of the complex to favor navigation. These restrictions mandate a certain minimum flow in the river at Johnson Bar, generally considered to be the head of navigation, another minimum flow below the Salmon River confluence, and a limitation on the rate at which the water level may be fluctuated at Johnson Bar. As noted earlier, these restrictions are quite undesirable from Idaho

Power Company's point of view, but they are considered by the Corps to be the absolute minimum conditions at which navigation may be considered safe. Actually, the Corps had recommended in 1961 that the minimum required flows be raised from 5000 cfs to 8500 cfs at Johnson Bar and from 13,000 to 16,500 cfs at Lime Point (below the Salmon River confluence), but the recommendation was later withdrawn. These higher flows would have provided a channel three feet deep over critical gravel shoals and rapids. The mail-boat, larger than most of the commercially-operated jet boats, may still require up to 8500 cfs for safe navigation during its two days of operation per week. The 1973 Pacific Northwest River Basins Commission study (see Chapter III) estimated the mailboat water requirements at 8500 cfs most of the time, and 10,000 cfs in the winter when cargo loads are greater. Winter flows are normally high anyway, so 10,000 cfs then offers little conflict with the power company. The smaller jet boats, which have become very popular and are now almost the only type of craft used above the Salmon River, have a draft of about one foot and consequently do not need as deep a channel.

Even though flows above 5000 cfs may not be <u>required</u> for navigation, higher flows would make the boating conditions safer and more desirable. Hence, the petition in 1967 requested an increase in the minimum Johnson Bar flow from 5000 cfs to 10,000 cfs, largely to improve navigation. The Corps studied the proposal for the FPC, modifying it to 9500 instead of 10,000 cfs. They noted that benefits to boating (and costs to power) would occur in two ways: "(1) Through increased Hells Canyon releases during the refill period to higher levels during years of low runoff. (2) Through increased minimum Hells Canyon releases and reducing fluctuations by restricting peaking operations, principally during the refill season in years of low runoff and during summer months with low prevailing flows." Essentially, if Idaho Power were required to release the lesser of 9500 cfs or Brownlee inflow, such a requirement would augment the power company-preferred discharges in dry years and raise the stream level above what it would normally be. However, Brownlee Reservoir may also be prevented from filling to capacity. The Corps notes that, in low runoff years, higher streamflows would be possible, but they would not always be up to 9500 cfs, since inflows to Brownlee are often less than 9500 (Corps 1972, p. 37).

During the summer, after Brownlee has been refilled, dry years could still be dry below Hells Canyon. Quite often the summer flows at Weiser (i.e. Brownlee inflow) are less that 9500 cfs, so the downstream release would not be helped then by the proposed license change. In the summer of 1961, for example, 68 out of 69 consecutive days had average flows at Weiser below 9500 cfs (Corps 1972, p. 38). During the fall and winter, flows are usually above 9500 cfs, and Brownlee is releasing storage then for flood control anyway, so the license modification would not have affected operation then, either. The other consequence of the proposed license change is that it would have drastically cut down the peaking operations of the power plants, which would have undoubtedly benefited boating. Peaking under the proposed requirements would have been very difficult for the power company when the average flow was below 9500 cfs, so the discharges would have been stabilized quite a bit at such times, times when the fluctuations are especially troublesome to boaters. Due to the serious consequences foreseen to Idaho Power and due to insufficient time to evaluate other impacts of the change, the Corps of Engineers recommended against the proposed change in the license.

In discussing detrimental effects of the proposed license modification, Idaho Power (1970, p. 30) cited examples of conditions that could result that would make navigation worse. The company claimed that navigation use on the three reservoirs far exceeded navigation use of the free river below Hells Canyon Dam. Thus, these interests should be considered as well. It was noted that Brownlee might not fill in dry years. Such a circumstance

> would reduce the convenience of boating and boaters to lose their desire to use the reservoir and decrease boating activities, a decrease which would be substantially in excess of any potential increase that might occur downstream as a result of the increased outflow.

The navigation on the reservoirs is actually more recreation-oriented than commercial, so it is apparent that the recreation groups compose another segment of society interested in Snake River water.

D. Recreation

The nature of recreational use on the Middle Snake River is widely varied. Some float downstream from Hells Canyon Dam in kayaks and inflatable rafts; some hike, picnic, or camp along the river in Hells Canyon; others journey upstream by boat to view the natural and historic wonders of the area; while still others use the reservoirs for swimming, fishing, boating, or water skiing. In the 1950s, when the FPC licensing proceedings for Idaho Power's project were going on, commercial navigation on the Snake River below Hells Canyon Dam was of primary concern. In the 1960s, though, and still continuing in the 1970s, activity for recreation on the reach has shown a substantial increase, so that it, too, is a major consideration.

According to the study by Idaho Power (1970, App. VIII, p. 3), over ten times as many people were using the reservoirs for recreation as were using the free-flowing river downstream. Further, the company's fish biologist and recreationalist expected "the factors of access and convenience alone" to widen the margin even further in the future (IPC 1970, Appendix VIII, p. 3). In addition, the company claimed that if it were required to release flows above 5000 cfs, then the reservoir-based recreation could be seriously affected. In low-flow years, if Brownlee Reservoir failed to fill, docks and boat-launching facilities would be lying on the bank rather than floating on the water, and muddy banks would be exposed. Many people could be expected to abandon use of the facilities, "thus depriving the people of southern Idaho, eastern Oregon, and the vast number of tourists who use the area of a full recreational use pattern. . . ." (IPC 1970, p. 26).

The PNWRBC minimum flow study (see Chapter III) judged that the best conditions for whitewater boating below Hells Canyon Dam occurred when the flow was about 12,000 cfs (Bayha and Koski 1974, p. 178). Below this flow, the activity became quite dangerous. Thus, in years of low Brownlee inflows, recreational boating below the dam would be one activity that would be severely hampered by lowering power plant discharges to 5000 cfs.

E. Fish and Wildlife Enhancement

The primary targets of fish enhancement efforts in the Middle and Lower Snake reaches are salmonid fishes, which are born in the upper areas, swim downstream to the ocean after rearing in fresh water, then return to their birthplaces a few years later to spawn. There are other fishes living in the

Middle Snake, such as bass and sturgeon, but these receive less attention than do the salmonids. Idaho Power reports that, "During the 1967 season there was a movement under foot to require increases in the minimum flow from Project 1971 for the express purpose of the anadromous fish run. . . ." The motivation at that time was to release more of the cooler reservoir water, thereby reducing the ambient temperature of the stream and making it more desirable for the fish to migrate upstream (IPC 1970, p. 32).

It was found in the PNWRBC study, discussed in Chapter III, that flows below 12,000 cfs drastically decreased the substrate available in the stream for food production. It was further concluded that flows varying from 12,000 to 15,000 cfs, at different times of the year, were the minimum acceptable flows for supporting salmonid fishes. Consideration was given to the flow requirements for migrating, spawning, and feeding. Higher flows (e.g. 12,000 cfs, compared to 5000 cfs) also generally improve the water quality in the stream, particularly with regard to temperature and dissolved oxygen content (Bayha and Koski 1974, pp. 179, 182). One advantage to fish in years when the streamflow in the Snake is reduced would be that there would be less water spilled in the late spring period at the Lower Snake and Lower Columbia River dams. Reduction of the spill would in turn reduce the nitrogen supersaturation in the water at a time when the anadromous fish are moving both upstream and downstream. (Corps 1972, p. 12).

One use of the river not discussed in the chapter should be mentioned for completeness. A fairly large industry in Southern Idaho is aquaculture, raising fish in artificial ponds, primarily for sale as food for human consumption. There are several of these "fish farms" located in the vicinity of Thousand Springs, Idaho, which utilize the water discharging from the Snake River Plain at that point to supply their fish tanks. The springs have a nearly constant discharge of about 6000 cfs and a fairly uniform temperature year-round, which makes the site an excellent location for growing fish. The incoming water, from the springs, is not noticeably affected by "upstream" users, and the effluent released downstream is essentially the same as the inflow, less some evaporation. Hence, the aquaculture industry cannot truly be considered a competing use of the river at the present time.

V. IDAHO POWER COMPANY SYSTEM

A. Resource and Load Characteristics

Before the Jim Bridger steam electric plant was brought on line in the fall of 1974, the Idaho Power Company was possibly the last sizable electric utility in the United States to be almost entirely based on hydro-electric power (Little 1976, p. 1). Prior to 1974, hydro plants within the system supplied base loads, intermediate loads, and peak loads. The only real exception was during the summer season when the annual system peak occurred, caused by large irrigation loads.[1] This demand could not be met by company-owned units alone, so in recent years, Idaho Power has met the load by importing energy from neighboring utilities. Conveniently for the power company, their load pattern differs substantially from the Pacific Northwest Coordinated System's wherein the peak load occurs in the winter period due to high heating demands in the larger cities to the west of Idaho. Thus, there are large transfers of energy from east to west in

---

[1]The fluctuation in the company's system demand for a one-week period in the summer is shown in Figure 3, data for which were obtained from Idaho Power Company (1970, App. V, p. 4).

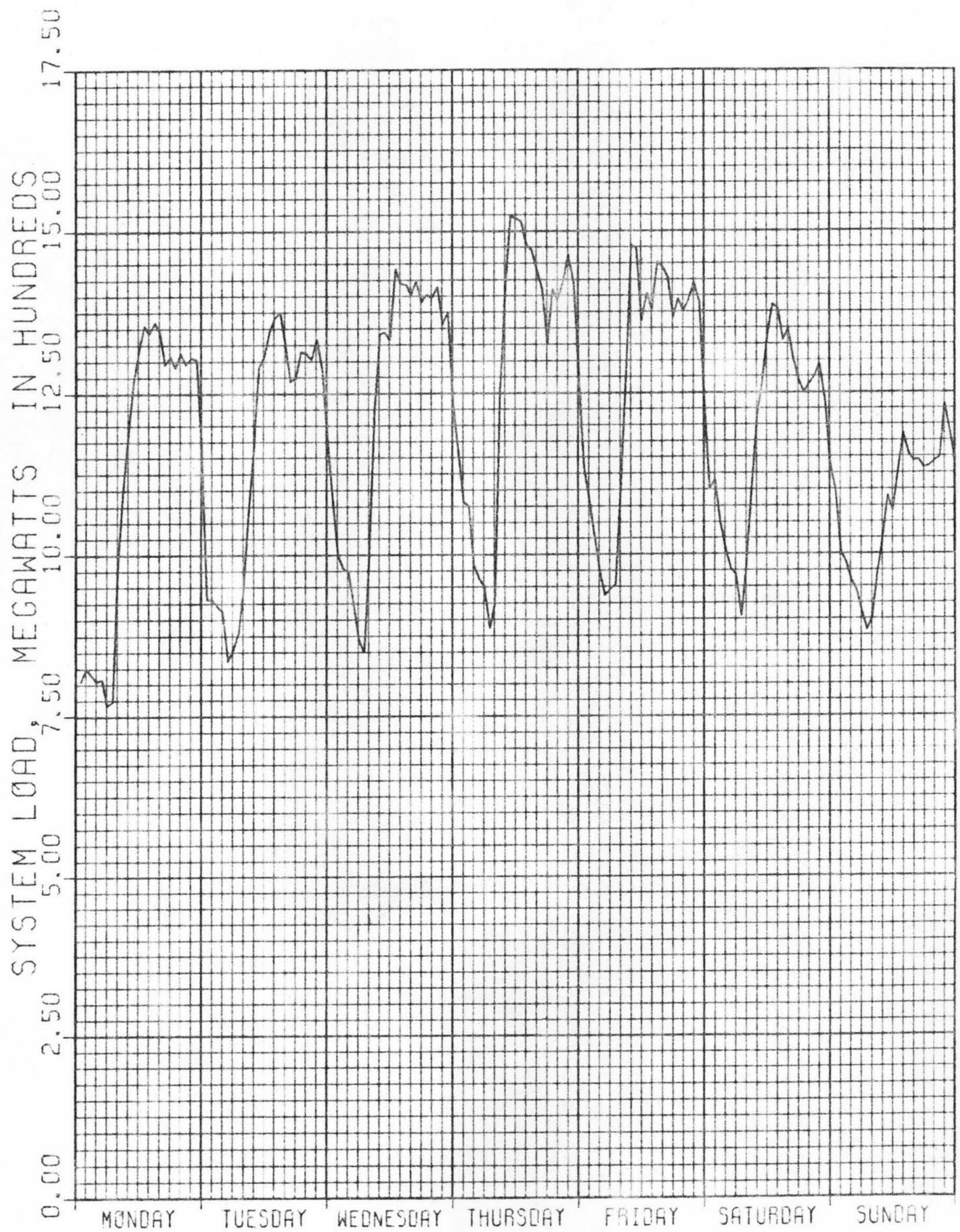

Figure 3. Typical summer weekly power demand--Idaho Power Company system. (curve shown for July 7-13, 1969)

the winter, in exchange for similar transfers from west to east during the summer (Little 1976, p. 88).

The Pacific Northwest Power Pool, of which Idaho Power Company is a member, was organized in 1940 to assist the interconnected private and public utilities. For quite some time, pool participants supported each other to meet regional energy needs, with the federal system providing major backbone services in power supply and transmission. The federal government had been the supplier of about 75 percent of the region's power until the late 1950s. Eisenhower's intended "partnership policy" had actually weakened quite a bit the position of the federal government and had divided the responsibility for major water resource development on a highly integrated basis (Bessey 1964, p. 14). The federal government had also been kept out of a large share of Idaho until 1963, when the Secretary of the Interior extended the marketing area of Bonneville Power Administration (BPA) to include the Snake Basin. Idaho Power currently contracts with BPA to wheel power to BPA customers in Idaho Power's service area. This service was formerly done for an exchange of energy from BPA, but in July 1975, BPA notified Idaho Power that they would pay in cash in the future, eliminating another of Idaho Power's external summer resources (Little 1976, p. 90). Other power-related entities in the region with which Idaho Power has been associated are another power and energy coordinating group called the Intercompany Pool (also called INTERPOOL or ICP), Washington Water Power Company (WWP), Utah Power and Light Company (UP&L), and Pacific Power and Light Company (PP&L). Idaho Power has contracted for exchanges with both WWP and UP&L; and PP&L, who owns a two-thirds share of Jim Bridger coal-fired plant in Wyoming (Idaho Power owns the other third), has agreed to sell any power from Bridger in excess of its own requirements (Little 1976, p. 89).

The Idaho Power system has a continuous power generation capability of somewhat over 1800 megwatts, including a small combustion plant at Wood River used primarily for peaking and also including existing capacity at the Jim Bridger coal plant (Little 1976, p. 85). This figure is for nameplate power rating; peak generation for the system is about 15 percent higher. Since the hydroelectric plants, which account for about half of the current system capacity, are primarily run-of-river units, their actual available generation fluctuates with seasonal water conditions. Maximum generation occurs in February, and the low point is in July when there is a heavy diversion of water for irrigation purposes and the streamflow remaining for power production is low (Little 1976, p. 75). Thus, the need is seen for effective coordination with other systems, particularly when Idaho experiences low water years. Unfortunately, however, much of the neighboring systems' generation is also hydroelectric and Idaho's low water years are usually their low water years as well.

Idaho Power Company sees disadvantages in relying too much on other utilities, aside from the fact that the others may not have the resources to spare. Commenting on a proposal several years ago to require the company to increase its minimum reservoir release, the company maintained (1970, p. 17),

> The increase in loads in the next few years, when coupled with the decrease in water flows due to additional irrigation and other uses, will require an increase in imports to the Idaho area. At the present time any increased imports to the Idaho system would increase existing loads on the Northwest Power Pool with a tendency to decrease reliability of all power systems in the Northwest due to critically loaded circuits. From a reliability and stability standpoint, any increase of generation in the Idaho area for heavy load conditions occurring in July and August is extremely beneficial.

Since 1970, when the above comments were made, the Pacific Northwest situation has further tightened, and Idaho Power's has tightened at least as much, due to growth in usage and lesser growth in generation. Arthur D. Little, Inc., in its study done for the Idaho Public Utilities Commission, projected a 4-5 percent annual growth rate in Idaho Power's energy requirements through 1980, decreasing slightly from 1980 to 1985. They further noted that Idaho Power Company's traditional hydroelectric generating resources have little scope for expansion. External resources would be a possible means of energy supply, but the region's utilities were taking the position that power would be in short supply in the 1980's (Little 1976, pp. 3-5).

The dams on the Middle Snake comprise over half of the company's total generating resources, if they can be operated at maximum capacity. As will be seen in the following sections, however, the manner in which the company would prefer to operate its projects does not always coincide with how various segments of the public feel they should be operated. This conflict, and any of the "solutions" yet devised, have failed to satisfy all interests, if such an end is indeed possible.

B. Middle Snake Projects

1. Description

The Federal Power Commission granted Idaho Power Company its license for Project No. 1971 in August 1955. It specified that Brownlee Dam construction was to start within one year and be completed within three years, that Oxbow was to start within four years of the license issuance and end within two years thereafter, and that Hells Canyon Dam was to be started within six years and completed within three years. After minor adjustments had been made in the scheduling, Brownlee generation was added to the system in 1959, Oxbow's was added in 1961, and Hells Canyon came on line in 1968. Addition of the power from the three dams increased the company's existing nameplate rating by over 200 percent. Thus, before the Jim Bridger plant was installed, the Middle Snake dams possessed about two-thirds of Idaho Power's electric capacity, almost all of which was hydroelectric.

Brownlee Reservoir is the largest of the three, holding a usable storage capacity of about one million acre-feet. Oxbow Reservoir is immediately downstream, and Hells Canyon is the furthest downstream (Figure 2 shows the relative location of the projects). According to Idaho Power (1970, p. 9), the Oxbow and Hells Canyon dams downstream from the Brownlee dam were constructed to utilize the outflow from Brownlee reservoir to the fullest extent in the production of power consistent with the navigation release requirements provided by the license." The Oxbow portion of the project has a usable storage capacity of about 5500 acre-feet; the main use of this storage is to reregulate the releases from Brownlee (Corps 1961, p. 13). Hells Canyon has a usable storage of about 11,000 acre-feet. It was originally intended to be used as a peaking plant, since another company had been planning to build a dam downstream which could have reregulated the widely variant Hells Canyon peaking releases (see Chapter II). Since the intended dam was not built nor is likely to be built, Idaho Power must operate Hells Canyon within fairly strict operating criteria. These restrictions are described in Section 2, dealing with the FPC license.

The FPC had granted a license to Pacific Northwest Power Company (PNPC) in 1964 for its planned High Mountain Sheep Project. This dam would have benefited IPC's operation as well, and the latter company significantly modified its design in accordance with the PNPC plan. The FPC authorized IPC to increase its initial capacity at Hells Canyon from 270 total megawatts to 370 total megawatts and raise its reservoir's height five feet to provide additional peaking operation. "In addition to the increase in installed capacity, the Company was required to make provisions in its Hells Canyon Project for encroachment upon the Hells Canyon Dam of a reservoir formed by construction of a dam downstream with a pool elevation of 1510 feet. This elevation would extend up approximately 40 feet on the Hells Canyon Dam and would lower the power capability of the project during the storage period. . . . The Company in its final planning for the construction of the Hells Canyon unit contemplated that a project would be built downstream, since such a project had been licensed by the Federal Power Commission (FPC License No. 2243). Acting in reliance upon this licensing by the Federal Power Commission the Company, in order to obtain maximum peaking capacity, installed the additional generating capacity and likewise made provision for the higher tailwater elevation of the downstream project" (IPC 1970, p. 10). The High Mountain Sheep Project License was subsequently reviewed by the Supreme Court, which instructed the FPC to reconsider it and to take into account the alternative of preserving Hells Canyon from all dam construction. The FPC Examiner later recommended a new license for a slightly modified project. The Commission did not act on it, however, and passage of the Hells Canyon National Recreation Area Act in 1975 (see Chapter II) prohibited all further construction in the vicinity.

As noted above, Oxbow and Hells Canyon power plants are operated in close conjunction with the Brownlee power plant, since they have little storage of their own. Operation of Brownlee varies with the season of the year. High flows are usually stored during the spring snowmelt runoff season. Natural flow is used for power during the summer when the reservoir is full (hopefully). Storage is released for flood control during the fall, winter, and early spring, augmenting the natural flows during these months. The reservoir is then refilled in the spring.

All three of the Middle Snake plants have a larger "ultimate" capacity than initial capacity, as provided in the FPC license. This means each has room for expansion, in fact, two additional units at each plant (Little 1976, pp. 76-78). The company plans a fifth generating unit for Brownlee in 1979, but it has no plans at present for increasing Oxbow or Hells Canyon. Additional generating units at Hells Canyon would probably not be fully utilized, due to the release restrictions on the plant.

2. Federal Power Commission License

Over 20,000 pages of testimony were collected by the FPC in its hearing process prior to licensing Idaho Power's Middle Snake Project in 1955. Input was collected from numerous federal, state, and local agencies, private groups, and private individuals as the Commission tried to decide whether the private or the federal project offered the better alternative. Then, after concluding in favor of the private one, it was up to them to also decide how the project should best be operated in the public interest, primarily with respect to its effects on navigation in the Snake River and on downstream flooding, mainly along the Lower Columbia River. The primary input for these considerations was obtained from the Army Corps of Engineers, and the Commission included the Corps' recommendations almost verbatim as part of the license.[1]

The license requirements, in summary, are that the project must regulate its releases to the downstream channel (i.e. below Hells Canyon Dam) such that:

(1) the flow is never less than 5000 cfs,

(2) a flow of at least 13,000 cfs is maintained at Lime Point (a point downstream of where the Salmon River joins the Snake River) at least 95 percent of the

---

[1]Compare Articles 42 and 43 of license (14 FPC 55) with letter from C.H. Chorpening to FPC Chairman, dated 1 July 1953, contained as Appendix III of IPC 1970).

time during the months of July, August, and September, and

(3) the river level at Johnson Bar (15 miles downstream of Hells Canyon Dam) should not fluctuate more than one foot per hour.

These provisions are to make the operation amenable with navigation. In addition, Brownlee Reservoir should be operated such that:

(1) at least 500,000 acre-feet of flood control storage are provided by 1 March of each year, and of each year, and

(2) any additional storage, up to the full capacity of 1,000,000 acre-feet, as recommended by the Corps of Engineers, will be provided by 1 April.

These regulations are not ideal and are not universally applauded, particularly the ones pertinent to navigation. The power company feels they are too strict, and the people who use the river downstream feel they should be made more strict. In fact, in 1968 a serious attempt was made to try to persuade the FPC to require a higher minimum release from the Idaho Power project. As mentioned earlier, in Chapter III, two committees from Lewiston, Idaho, and Clarkston, Washington, Chambers of Commerce sent the FPC a petition requesting the minimum required release be raised from 5000 to 10,000 cfs. An alternative proposal they suggested was "10,000 cfs or the inflow to Brownlee." Their interest was pleasure boating, commercial boating, and preservation of fish and wildlife on the Snake River. The FPC asked for recommendations from the Corps of Engineers on the proposal. The Corps requested a year's time to conduct a boating survey on the river, after which it made an initial recommendation in favor of the change. Idaho Power Company, vehemently opposed to the idea, responded in 1970 with a report "prepared in order to portray to the Corps of Engineers and other interested parties the detrimental and perhaps disastrous effect that can occur if the proposed changes are made in existing Article 43 of Federal Power Commission License No. 1971" (IPC 1970, p. 4). Their analysis was apparently convincing, as the Corps' final review report (Corps 1972) recommended no change in the license until further study could be done. The proposed changes in the license have not been made to date.

The navigation provisions in the existing license were based partly on historical conditions and partly on navigation requirements in the river. Gen. C.H. Chorpening, Assistant Chief of Engineers for Civil Works, advised the FPC chairman in 1953 that 5000 cfs was necessary for navigation in the channel reach from Johnson Bar to the Salmon River (IPC 1970, Appendix III). Johnson Bar is generally considered the uppermost point for safe navigation. It was also noted that 13,000 cfs was necessary for navigation in the river reach below the Salmon River. However, since this 13,000 cfs minimum had occurred historically only 91 percent of the time, with all the "misses" occurring in July, August, and September, it was felt that the power company should not be required to do so a full 100 percent of the time. Thus, they are required to keep the discharge at Lime Point at or above 13,000 cfs "95 percent of the time" during the summer months. This phrase is rather ambiguous and is open to different interpretations. Idaho Power (1970, p. 13) holds that determination should be made on the mean monthly flow, while the Corps (1972, p. 21) favors using hourly flows, saying that the Lime Point flow may be less than 13,000 cfs for 110 hours during the summer months. The Corps observed (1972, p.45):

> there are still considerable differences of opinion regarding interpretation of the existing license provision stipulating that flows of 13,000 cfs be maintained at Lime Point 95 percent of the time. It is impossible to evaluate whether the Licensee is meeting this imprecise provision until it is more clearly defined.

The effects the license requirements have on the operation of the power plants will be examined in the following two sections.

3. Operation for Navigation

When the Middle Snake Project license was issued in 1955, commercial navigation was the primary concern on the Snake River below Hells Canyon Dam. Subsequently, especially since the mid-1960s or so, recreation-oriented boating has increased to the point where it is also a major consideration. Recreational boating pursuits include boaters travelling strictly for pleasure, people travelling on the river to a hiking, camping, or picnicking destination, and people floating downriver in rafts, canoes, and kayaks.

The license requirement for 13,000 cfs below the Salmon River was based on creating a flow with a three-foot depth over all shoals and rapids, determined to be sufficiently safe for that reach of the river. To obtain a comparable channel above the Salmon River actually requires about 8500 cfs, more than the license minimum required (Corps 1961, p. 30). The 5000 cfs minimum was selected "in recognition of both the historic minimum flow in the river as measured at Weiser, Idaho, and that needed for protection of the anadromous and resident fishery in the river above the mouth of the Salmon" (Corps 1972, p. 9). The Corps did propose in 1961, however, a change in the license to require Idaho Power to release 8500 cfs on specified days of the week, but withdrew the proposal half a year later, citing changed conditions, including probable licensing of High Mountain Sheep Dam (Corps 1972, Exhibits 6 and 7).

Operation at present, then, consists of always maintaining a release of at least 5000 cfs from Hells Canyon, and 13,000 cfs at Lime Point almost all the time. These conditions are fairly easily met in most years, when the inflow to Brownlee exceeds the required outflow. The problem comes during the summer season of low water years. "Construction of reservoirs in the headwaters has improved the streamflow pattern somewhat, but this improvement has been offset by increased irrigation depletions" (Corps 1972, p. 12). In dry years, the situation is magnified as more water is required for irrigation to be supplied by the already-too-low river. However, the significant fact is that summer low-flow conditions, making navigation conditions difficult, have always existed on this reach of the river (Corps 1972, p. 12). Idaho Power emphasizes that its project is not to blame for low water in the Snake River, citing historical accounts of past water shortages in the canyon (IPC 1970, p. 28).

Idaho Power Company also maintains (1970, p. 31) that it has attempted to get along with the boating public:

> Over the years the Company has assiduously attempted to cooperate in order to please the public in the Lewiston-Clarkston area. This cooperation has included many meetings with interested parties, notices of water changes given to the news media, telephoning the marina operators and news media of proposed changes, posting of information on scheduled water releases and timing of water releases so that the mail boat would have ample water. The Company has also provided a free telephone service from the Lewiston-Clarkston area to Boise in order to obtain latest water release information to any boater desiring such information. All of these and many other activities, including installation of stage markers on the river, have been undertaken by the Company in order to cooperate to the best of its ability. The Company intends to and will in the future continue such activity and cooperation.

Nonetheless, conditions for boating, especially in the summer months, are not always ideal. Since power demand varies quite a bit during each day, the power plants' output must vary to stay with the load. The result is fluctuating hydroelectric discharges and consequent fluctuating water levels, which are most noticeable during low-flow periods. Further effects are well described by the Corps of Engineers (1972 p. 13):

> The extent to which an individual plant must fluctuate its output depends on the characteristics of the system power load at any given time, the ability of the other power plants in the system to help carry the load at that time, and concurrent streamflows. Presently, no reregulating structure exists below Hells Canyon Dam to reregulate the discharges associated with the daily peaking operations. The Licensee, recognizing the navigation problems, has attempted to minimize recreation season fluctuations on this reach of the river to the extent possible within the capabilities of the rest of its system. However, there are times when the load-resource situation requires the Hells Canyon powerplant carry a larger share of the peaking burden. When these situations coincide with unusually low prevailing flows, unfavorable navigation conditions result. The situation that occurred in the summer of 1968 resulted from such a combination of occurrences.

The Corps of Engineers has the power, granted in Article 18 of Idaho Power's license (FPC 1955), to "use water in such amount to be determined by the Secretary of the Army, as may be necessary for the purposes of navigation on the navigable waterway affected. . . ." The Corps sees the power company's position, though, and obviously makes every attempt that it can to cooperate. It has so far not formally required the company to operate under terms more stringent than the license specifies.

A condition which is probably more of a nuisance to boaters than the low flows themselves is the water level fluctuations caused by peaking operations. The Corps notes that boating conditions could be significantly improved if peaking were eliminated when average flows were less than 9500 cfs or when the peaking resulted in flows dropping below 9500 cfs for a few hours a day. The Corps recognizes, however (1972, p. 38), that "it would be impossible to eliminate these conditions entirely without reducing Hells Canyon peaking capability." (U.S. Army 1972, p. 38). Thus, the navigation conditions controversy still remains, and it is very unlikely to be easily resolved to the mutual satisfaction of all parties concerned.

4. Operation for Flood Control

The other portion of the FPC license which restricts the project's operation is that related to flood control. Article 42, requiring Idaho Power to lower its pool level each winter and spring to help retain snowmelt flood flows, has been much less controversial than Article 43, the navigation provisions.

The license flood control requirements were again adopted upon recommendation by Gen. Chorpening of the Corps of Engineers (IPC 1970, Appendix III). His suggestions were that Idaho Power construct its project so as to have one million acre-feet of usable storage and then operate it so that half the storage would be available by 1 March each year and any additional amount up to the full usable storage would be made available by 1 April. Said Chorpening of the 1,000,000 acre-feet, "This amount of storage would be adequate to control the Snake River runoff for the second greatest flood of record, that of 1948. Additional storage of 1,300,000 acre-feet would be required for control of greater floods, such as the record flood of 1894" (IPC 1970, Appendix III). The Corps had originally proposed, in its 1948 "308" Review Report for the Columbia Basin, to have 2.3 million acre-feet of storage in high Hells Canyon Dam, and in addition, it had "planned" at that time for several basin storage projects totaling almost 21 million acre-feet, including Hungry Horse, Glacier View, Libby, Grand Coulee, Priest Rapids, Palisades, Boise River Projects, Payette River Projects, Hells Canyon, and John Day (Corps 1961, p. 26). The Corps' 1948 Main Control Plan had proposed all this upstream storage with the main intention of decreasing flood damage on the Lower Columbia River. They hoped to limit flows at The Dalles to 800,000 cfs should a flood of 1894's magnitude occur again. Despite the fact that Brownlee Reservoir's 1,000,000 acre-feet of storage was not the 2.3 million sought by the Corps, the FPC noted (1955, 14 FPC 62) that the Department of the Army had no objections and had, in fact, recommended "license conditions which would require Brownlee to be operated under the Army's direction for flood control purposes." According to the Corps (1961, App. C, p. 1), "flood control regulation at Brownlee is provided mainly on the basis of reduction of flows at The Dalles, Oregon, for protection of the Lower Columbia-Portland-Vancouver area, and on the Snake River as necessary. The FPC saw fit to license Project No. 1971 with the aforementioned restrictions.

The requirement for half of Brownlee's usable storage each year is straightforward--it must be provided. The rest of the space is made available if forecasts indicate the need. Because of the changing influence of irrigation in the basin, the Corps feels, at least in 1961 (1961, p. 37), that "seasonal runoff at Brownlee is probably the most complex combination of variables encountered anywhere in the Columbia River Basin where seasonal forecasting is required." An increased use of groundwater for irrigation, an increase in irrigation storage reservoirs, and uncertainty about irrigation return flows make matching up of past years' runoff records with future years having similar precipitation records very difficult at best. Nonetheless, with nothing better to utilize, forecasts are made, generally using regression relationships for snow course and precipitation measurements. The Corps and Idaho Power each make their own forecasts (Corps 1961, App. B) and compare them to try to arrive at a mutually acceptable forecast. If agreement cannot be reached, the

Corps' procedure is used to determine the flood control storage requirements (Corps 1961, p. 38).

The largest floods at The Dalles (i.e. 1894 and 1948) resulted from greater than normal accumulated snowpacks, cool temperatures which helped retard the runoff in the early part of the snowmelt season, heavy spring precipitaion, and prolonged high temperatures in late May and early June resulting in rapid melting of the snow pack. The 1956 flood, another large one, was caused by heavy fall precipitation making an early snowpack, followed by widespread heavy rains (Corps 1961, p. 18). In no case, however, has a major flood at The Dalles occurred before 1 May. Thus, the Corps objective with respect to annual flood control planning, has been to obtain by 1 May the storage required to control the flood forecast for that year. As for the length of time that storage should be kept available, they concluded (1961, p. 22) "that flood control regulation at the Brownlee Project should be available during the period 1 May through 30 June for the Lower Columbia, and 15 April through 20 June for the Lower Snake, the amount depending on the estimated runoff of the Snake River above Brownlee."

Provision of the space to help contain flood flows in Brownlee clearly has a benefit to those areas downstream normally subject to flooding, and it also has a cost to the power company. Ideally, if they did not have to concern themselves with operation for flood control, Idaho Power would quite likely try to keep Brownlee as full as possible. Operating in this manner would permit holding water over to times of short supply, as well as more "efficient" use of the water for power by generating at a higher head. If the full amount of storage is required, however, its timing is very important, i.e. what part of the year it comes in. During the discussion about increasing Idaho Power's minimum flow requirement, the Corps of Engineers offered in "exchange" a provision that would permit IPC to delay evacuation of Brownlee's first 500,000 acre-feet of storage until 1 April. Said Idaho Power in response (1970, p. 23), "While it is true this could provide a higher head for the longer period of time and thus theoretically provide more energy and capacity, from a practical standpoint, this may not be beneficial because the storage may be more useful in carrying load at an earlier time. In any event, the additional energy and capacity would represent much less benefit than the loss that would be incurred by the change in Article 43." The company also noted that, since Snake River flood flows usually pass early in April and May, there would be a greater probability of not refilling Brownlee with the subsequent streamflows, and power outputs for the entire following year would be adversely affected. Thus, Idaho Power clearly did not welcome a change in its reservoir-lowering schedule in return for a change in its release requirements.

VI. IDAHO'S FUTURE POWER NEEDS

Arthur D. Little, Inc.'s study in 1975-76 (see Chapter III) attempted to assess for the Idaho Public Utilities Commission the need for Idaho Power Company to develop new sources of generating capacity. The study looked at existing resources owned by the company, existing external resources used by the company, the company's expected growth in demand with respect to both power and energy, and the company-owned or potentially available generation resources to meet the demand. With respect to electricity distribution within the state of Idaho, there are several private companies or other agencies besides Idaho Power who generate or market power or do both. However, since the present study is concerned only with the generating plants in the Hells Canyon reach of the Snake River and factors directly affecting their operation, and since these projects all belong to Idaho Power Company, Idaho Power will be the primary subject of this discussion.

The annual plant factor is expected to remain at about 60 percent. Arthur D. Little projected (1976, p. 3) a growth rate for Idaho Power's annual energy demand of "between 5.5 percent and 4.0 percent annually through 1980, between 5.3 percent and 3.5 percent annually during 1980-85, and between

4.4 percent and 3.0 percent annually during 1985-90." The peak July demand (i.e. annual peak) is expected to grow at approximately the same rate. The study by Arthur D. Little explained that the growth in electrical demand has been caused by two primary factors. First is just the growth in the population and the economy of Idaho Power's service territory. Second is the change in electricity usage, such as energy usage per household and increases in the energy intensity of agriculture. The report noted that its projections were lower than ones made by the power company itself, primarily because Little had considered effects of price-induced energy conservation while the company projected a continuation of the historical trend. Also, the power load of the heavy chemicals industry, which is not expected to increase very much, should dampen the overall system growth somewhat.

Throughout the Pacific Northwest, there are several sites for large-size hydroelectric energy development. However, environmental and social acceptability restraints make possible development unlikely. Because of this, new sources of generation are expected to be thermal--either nuclear or coal-fired power plants. Five years before Arthur D. Little's study, the Pacific Northwest River Basins Commission, an intergovernmental state and federal coordinating group in the region, expressed (PNWRBC 1971) a strong need for development of additional generating capacity throughout the Northwest.

They commented that load resource studies showed "a precarious power balance in the region," even if power transfers to California were withdrawn and the federal government made no new commitments for industrial power supply. "The growth of Pacific Northwest energy needs requires development of large thermal resources to be supplemented with additional low-cost hydro capacity to meet regional power needs effectively." Then the existing hydro plants will probably shift their major emphasis from their current base-load duty towards more peaking operation. To increase the peaking capability somewhat, a few additional units can still be added at the existing plants as Idaho Power plans at Brownlee, and development of some pumped storage generation is also possible (Little 1976, p. 88).

Idaho Power Company is currently able to meet its summer load peaks by importing power from neighboring utilities. Arthur D. Little, in its report, indicated, "The PNUCC[1] companies have been unwilling to furnish firm energy to Idaho Power on long or short term bases. However, since critical water periods do not occur every year, the possibility of short-term (6-12 month) contracts for firm power does exist

----

[1]Pacific Northwest Utilities Conference Committee, a group of utility representatives which makes studies of load forecasts and does regional power planning, of which Idaho Power Company is not a member (Little 1976, p. 86).

during periods when streamflows produce energy in quantities greater than requirements. Due to uncertainty of precipitation from year to year, however, long-term commitments are difficult to make." They also noted that it would be quite advantageous if Idaho Power could establish a long-term seasonal trading arrangement with the other utilities, but that such a contract is not immediately foreseeable.

Arthur D. Little concluded, then, that Idaho Power Company would need approximately 500 megawatts of additional generating capacity by 1981 to meet requirements. If, however, the load growth is slower than anticipated, if Idaho Power can arrange seasonal trades of power, and if water years are not critical, the need for the extra 500 megawatts may be deferred until at least 1985. Recommendations for the type of generating units are for base-load thermal (i.e. nuclear or coal-fired) if the company figured it could sell the excess capacity in the winter, or peaking units (e.g. gas turbine) if it felt it could not. The study by Little had been done as a means of the Idaho PUC's gathering information for the hearings on Idaho Power Company's proposed Pioneer coal-fired plant near Boise. The final recommendation by Little was to try to arrange power trading with one or more utilities in order to delay the need for Pioneer II until 1985. Pioneer II was another coal plant tentatively planned by IPC as part of the Pioneer project. Pioneer lacked public support and the certification application was subsequently denied by the PUC in September 1976, forcing Idaho Power Company to continue its search for a solution to its expected power generation deficit in the near future (Lewiston Morning Tribune 1976, p. 6A)

VII. FUTURE AVAILABILITY OF SNAKE RIVER WATER

The friction between the competing river users is most acute during years when the water supply is low. When it is high, there is usually enough water to satisfy most requirements if not desires. In dry years, however, there may not be enough water to meet _anybody's_ demand, let alone everybody's demand. Then the tension develops, with each interest attempting to force the others to give up their water. In Idaho, the irrigation interests are very powerful and, for all practical purposes, have priority on the water. The Snake River is, in fact, all but dried up between Milner Dam and Thousand Springs by irrigation diversions at Milner, even in normal water years. In addition, a provision of Idaho Power Company's Middle Snake Project license from the FPC (1955, Article 41) states that no flow requirements in Hells Canyon can be used to limit development or diversions for irrigation in Southern Idaho. A similar provision is also included as part of the Hells Canyon National Recreation Area Act. The conclusion is apparent that low-precipitation years are troublesome at present, but that years in the future with the same water "supply" will undoubtedly be worse, due to expected increases in irrigated agriculture.

The Idaho Water Resource Board has projected, in the State Water Plan (IWRB 1976, p. 117), that irrigated acreage could expand by 850,000 acres in the Snake River system in Idaho from 1974 to 2020. There had been in the draft of the plan several projections of future development levels, each possible under different circumstances and dependent on future state and national policy and on the desires of the people. The projections ranged from a low of 640,000 acres for an alternative emphasizing maintenance of instream flows to a high of 2.5 million acres for the alternative based on the historical growth rate (IWRB 1976, p. 78).

In the Middle Snake Project Operation Manual by the Corps of Engineers in 1961, it was noted that this further water resource development of the Snake River Basin above Brownlee would have effects on existing and future power and flood control projects downstream, both on the Snake and Columbia Rivers. "The water supply at the downstream projects will be reduced," the Corps said (1961, p. 17), "due to consumptive use from the greater application of water for irrigation and evaporation losses from water surface areas on new storage reservoirs." Summer low flows have been fairly common historically, as Idaho Power mentioned in its analysis report (1970, p. 28). but projections for the future reveal expectations of flows to be as low as or lower than in the past.

As a prelude to the State Water Plan, the Idaho Water Resource Board's study on water availability (IWRB 1974) made projections of the flow levels that could have been expected in the Snake River over 40 years of record had the existing irrigation and storage (ie. Present Conditions) or the 2020 irrigation and storage (Future Conditions) been there for the whole period. Their findings, based on a computer simulation of the Snake River in Southern Idaho, were that the instream flows were expected to be diminished substantially by the new irrigation development. Even the current levels of development, when applied to the historical hydrologic data, caused significant depletions. Future levels can be expected to increase the depletions more. Factors suggested which could possibly mitigate the effects are pumping from groundwater and improving the water use efficiency of the irrigation.

VIII. REREGULATING DAM BELOW HELLS CANYON DAM

As noted earlier, the license restrictions on the operation of Idaho Power's Middle Snake Project reduce optimal operating conditions from the level possible under unrestricted operation, at least from the viewpoint of power generation. The power company had planned to have the Hells Canyon plant in its system as a peaking plant, but the requirements for minimum discharge and maximum allowable rate of change of discharge limit the peaking generation possible. Idaho Power had originally counted on having its restrictions effectively relaxed by construction of the Mountain Sheep Dam downstream by the Pacific Northwest Power Company. Had the project been built, the company would most likely have had a mandate to cooperate with the downstream project in its releases, but it would undoubtedly have been better able to use its turbines' peaking capacity.

The lack of use of the full power peaking capability is in a sense "lost" generation, and is a potential source of additional capacity for meeting the company's future demand (see Chapters IV and V). A dam downstream from Hells Canyon Dam to reregulate the releases would permit nearly unrestricted peaking operation of Hells Canyon and would tend to dampen the fluctuations in the river level downstream of Johnson Bar, in addition to permitting maintenance much more easily of the minimum streamflow of 5000 cfs. Such a reregulating dam could be either a large dam built for power production at a site quite a way downstream (such as Mountain Sheep), or it could be a dam constructed specifically for reregulation purposes at a site between Hells Canyon Dam and Johnson Bar.

The matter of PNPC's High Mountain Sheep Dam was discussed briefly in Chapters II and V. Essentially, the effect of that proposed project on Idaho Power Company's plans was to require some modification in its Hells Canyon Dam design. The Chief of the Army Corps of Engineers noted in 1960 that an application had been filed with the FPC for a project downstream, with a pool elevation of 1510 feet. Since the normal tailwater elevation for Hells Canyon was to be only 1470 feet, the new reservoir at full pool would extend up the dam about 40 feet, and the Corps recommended to the FPC that Idaho Power be required to provide appropriate protective measures for the water encroachment (IPC 1970, Appendix II). In addition, prior to actual construction of Hells Canyon, the company made some studies which indicated that more economical operation could be realized if the maximum reservoir level were raised five feet and if three 123.3 MW units (total of 370 MW) were installed instead of the originally-planned five 54-MW units (total of 270 MW). The FPC authorized this increase in 1964.

According to Idaho Power (1970, p. 11),

> Acting in reliance upon this licensing by the Federal Power Commission [of High Mountain Sheep Dam][, the Company, in order to obtain maximum peaking capacity, installed the additional generating capacity and likewise made provision for the higher tailwater elevation of the downstream project. These additional expenditures by the company were the direct result of the recommendation by the Corps of Engineers and the licensing by the Federal Power Commission.

Since the time when Hells Canyon Dam was constructed and High Mountain Sheep Dam was first barred by the Supreme Court, the possibility of installing a dam for the single purpose of reregulating Hells Canyon flows has been investigated. Idaho Power Company made a brief study in 1969 (IPC 1976), the Corps of Engineers investigated it prior to 1972 when they were evaluating the license modification proposal (Corps 1972, p. 30), and the author did a brief examination in 1975.

The power company study investigated two conditions: (1) the very minimal structure required to reregulate the maximum peaking condition for a minimum flow of 5000 cfs and a maximum rate of change of one foot per hour in the river level; and (2) a structure to give peaking flexibility, i.e. to reregulate the river to a constant flow equal to the inflow. They determined that 9500 acre-feet of storage would be needed to control peaking discharges that fluctuated daily from 0 to 30,000 cfs, flowing for up to 12 hours and that approximately 15,000 acre-feet would be required to keep the downstream flow equal to the system inflow. Figure 4 shows a plot of maximum

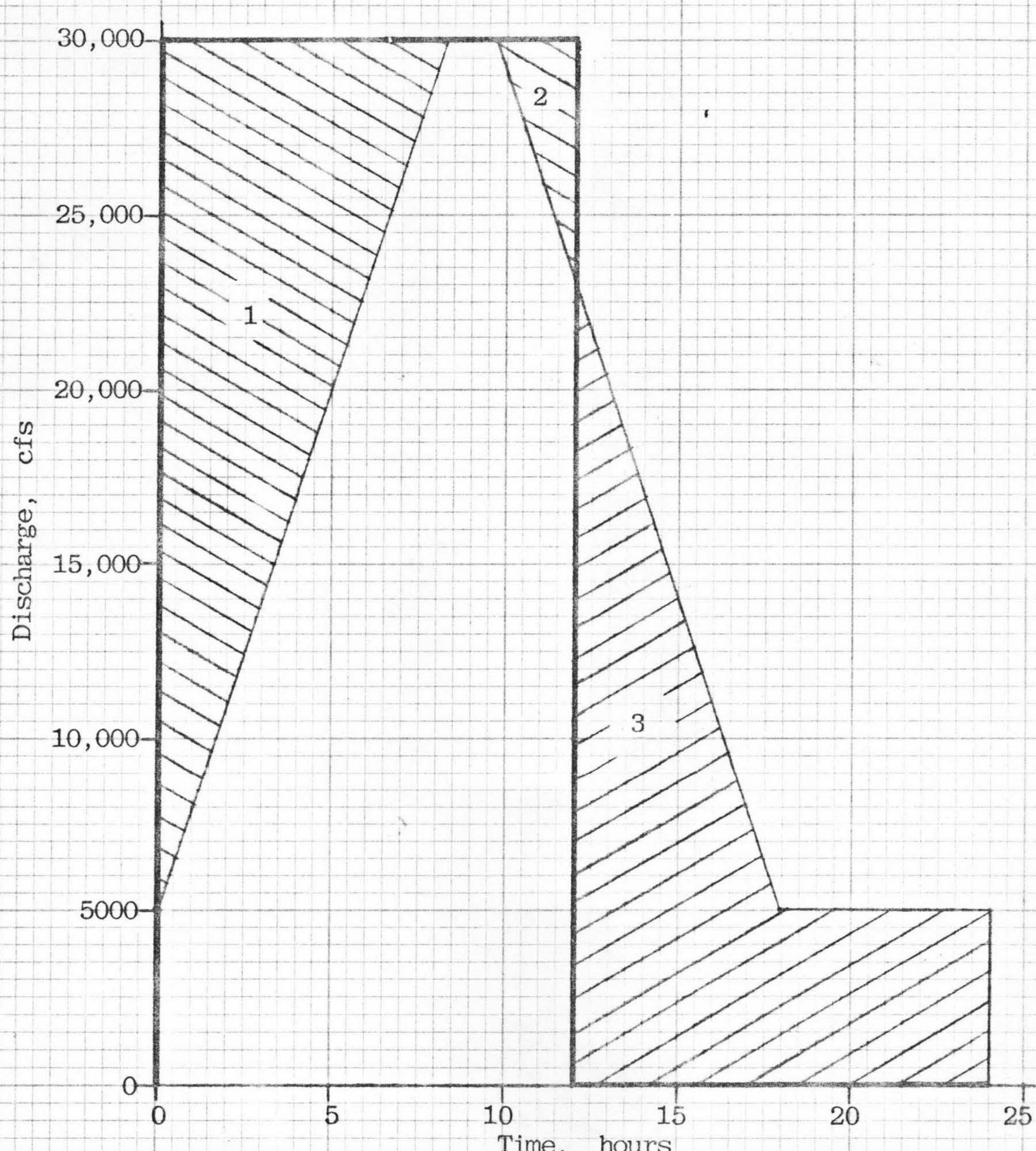

Figure 4. Reregulated 24-hour hydrograph--maximum condition.

condition operation. The heavy, dark line represents the discharge from Hells Canyon Dam, and the lighter, sloping line represents the releases from the reregulating dam. Areas 1 and 2 indicate the amount of water stored in the reregulating reservoir, when Hells Canyon's discharge exceeds the reregulator's. Area 3 indicates the water being released from storage in the reregulating reservoir, after the release from Hells Canyon Dam has dropped to zero. In this situation, Hells Canyon Dam is turned "on" for 12 hours, then shut "off" instantaneously. The reregulating dam releases always at least 5000 cfs, and its rate of change does not exceed 3000 cfs per hour (1 foot per hour at Johnson Bar). From the graph, it can be seen that the water stored (areas 1 and 2) is approximately equal to the water released from storage (area 3), both being just under 9500 acre-feet.

The company then selected two potential damsites and plotted the volume contained as a function of maximum pool elevation. This capacity-stage relationship is shown in Figure 5. Site #1 is located approximately at Snake River mile 240 and site #2 is at about river mile 239. For comparison, Hells Canyon Dam is at river mile 247.5, and Johnson Bar is at about river mile 230. From the graph, required water depths at the two sites would be about 73 feet for 9500 acre-feet and about 90 feet for 15,000 acre-feet of storage. A separate Idaho Power source (1970, p. 25) estimated that the reregulating dam

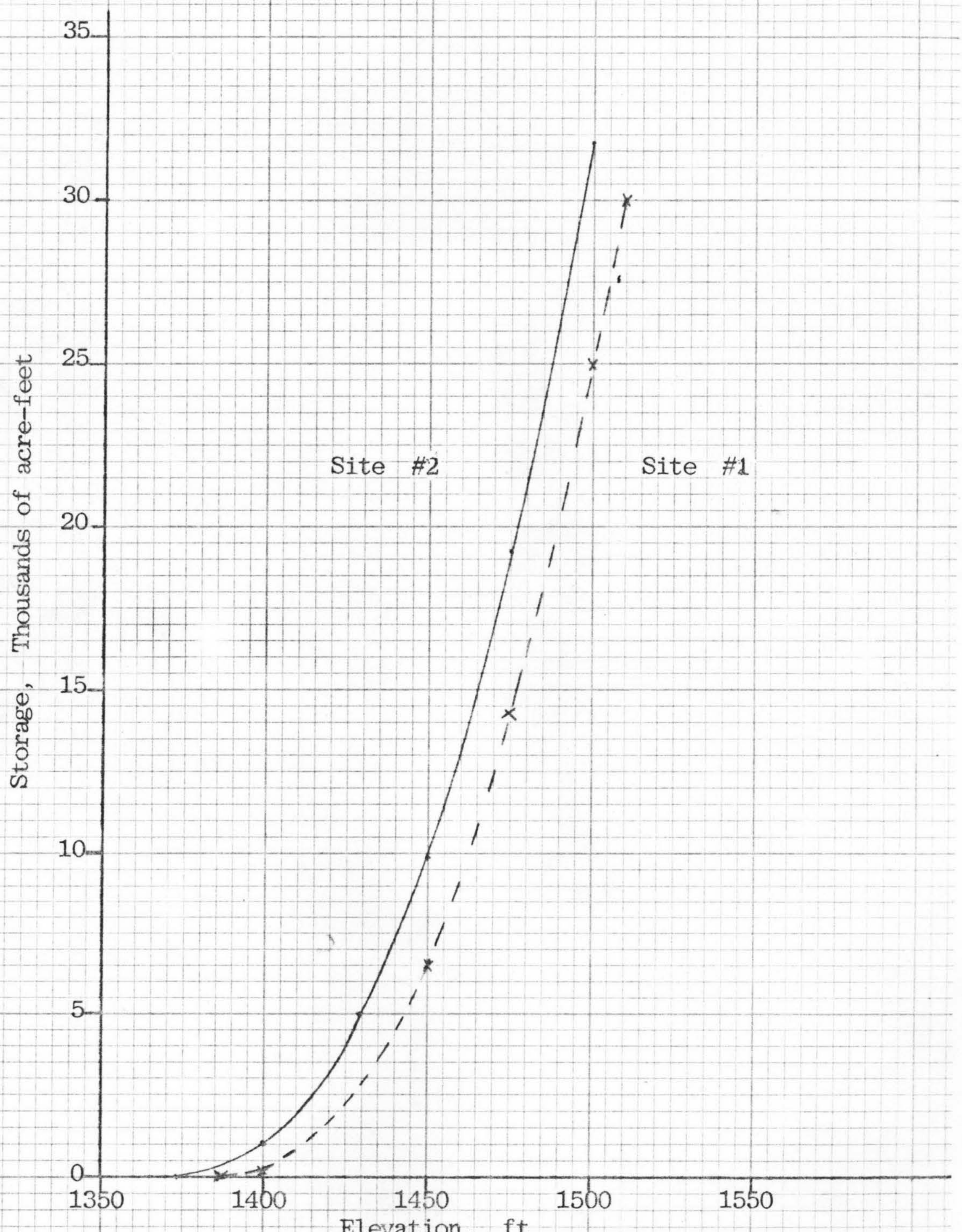

Figure 5. Gross storage as function of surface elevation--Idaho Power Company study.

might cost $30 million, with an annual cost of $3,700,000 per year, in 1970 figures.

The analysis by the Corps was done as a part of its review of the advantages and disadvantages related to modifying the flow requirements of Idaho Power's FPC license (Corps 1972). A reregulating dam downstream was initially considered as one solution to the boating problem, alternatives to the license modifications proposed. They estimated the amount of storage required to maintain a minimum outflow of 9500 to 10,000 cfs, with an average inflow of 11,500 cfs and variations in discharge from Hells Canyon Dam from near zero to 30,000 cfs daily. The conclusion was that a water depth of at least 80-85 feet would have to be developed by the dam to provide enough reregulation storage for full utilization of the upstream power plants. They estimated construction costs of at least $40 million for an 80-foot dam without power generation of its own, and they figured a reregulating dam with power generating facilities would have to be well over 100 feet high and more expensive if it were found feasible (Corps 1972, p. 30). The Corps ultimately concluded that, because of the time required for in-depth analysis, authorization, evaluation of current FPC license requests (Mountain Sheep Dam license proceedings were ongoing at that time), design, and construction (possibly 8 to 10 years in total), the reregulating dam was not considered a realistic alternative to solve the boating problem. They noted (1972, p. 33), "However, construction of a reregulating dam would be the only way to fully utilize the peaking potential of the Hells Canyon Project in the event open-river status (i.e. no downstream power dams) is legislated for the Middle Snake River below Johnson Bar."

The author's analysis was done in December 1975. The original intent of the study was to make an economic and engineering appraisal of the Snake River between Hells Canyon Dam and Johnson Bar for a site that could provide a feasible location for a reregulating dam. Reregulation was considered a viable long-term alternative solution to the conflict between the power company, not being able to fluctuate its power releases at rates and magnitudes that it would like to, and the downstream interests who felt (and still feel) that the river fluctuates too much already. Subsequent passage of the Hells Canyon National Recreation Area Act at the end of December 1975, before the analysis was fully developed, precluded further consideration of a reregulator as a realistic solution to the problem. Nonetheless, the results are presented herein to serve as an aid for any future work which may be related and could benefit from the methodology or the data.

Essentially, the procedure consisted of planimetering the areas of elevation contours between designated river stations and Hells Canyon Dam. Then volumes of the layers formed by two adjacent contour levels were estimated by taking the average of the upper and lower areas and multiplying it by the thickness of the layer. A typical shape formed by the sloping sides of the canyon, the horizontal contour areas, and the vertical limits upstream and downstream is shown in Figure 6A. The shape shown is representative of most of the volumes. In most cases the thickness of the layer is equal to the contour interval. In some cases, however, primarily the "bottom" layer in some of the sections, the area of the contour does not extend to the upstream limit, and the downstream "thickness" is less than the contour interval. Such a shape is represented in Figure 6B. For the planimetering, a contour map by the Walla Walla District of the Corps of Engineers dated May 9, 1951, and with a contour interval of 50 feet, was used. The measured and calculated results are shown in Table 1.

After the volume of each layer was estimated, the total volume that would be stored behind a dam at a particular station below a particular upper elevation was determined. For each of the study locations, river miles 241, 237, 233, and 229, calculations were made of the storage that would be contained below each of the contours if that contour were the top of the reservoir. The tabulated storage values are shown in Table 2, and Figure 7 shows the data plotted. From the graph, the required upper elevation can be found for a dam at

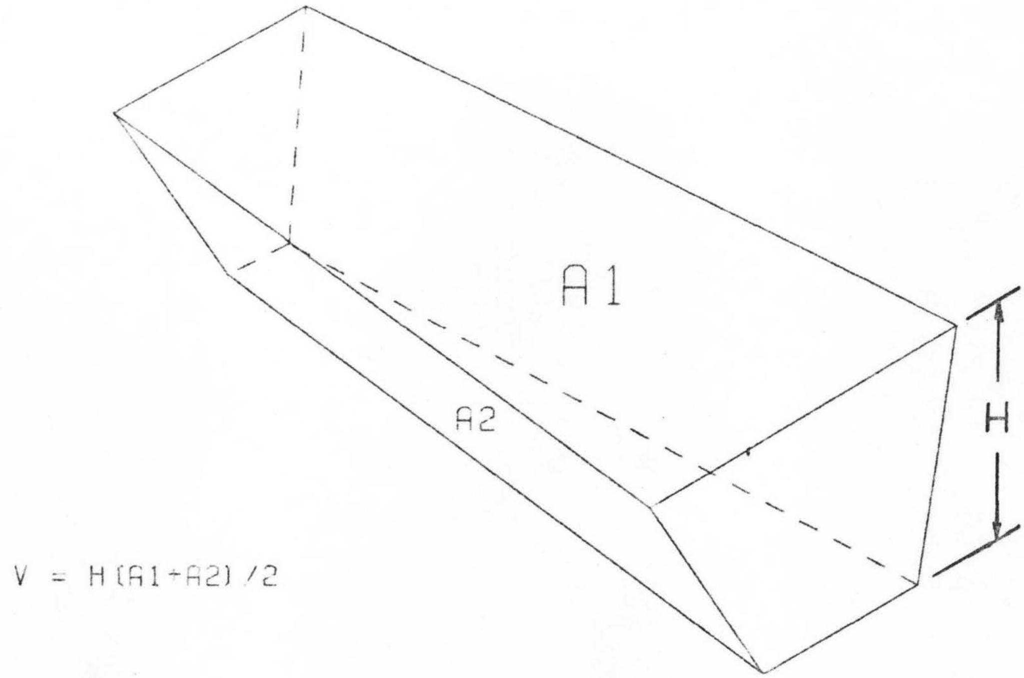

Figure 6A. Representative shape of layer between contour intervals.

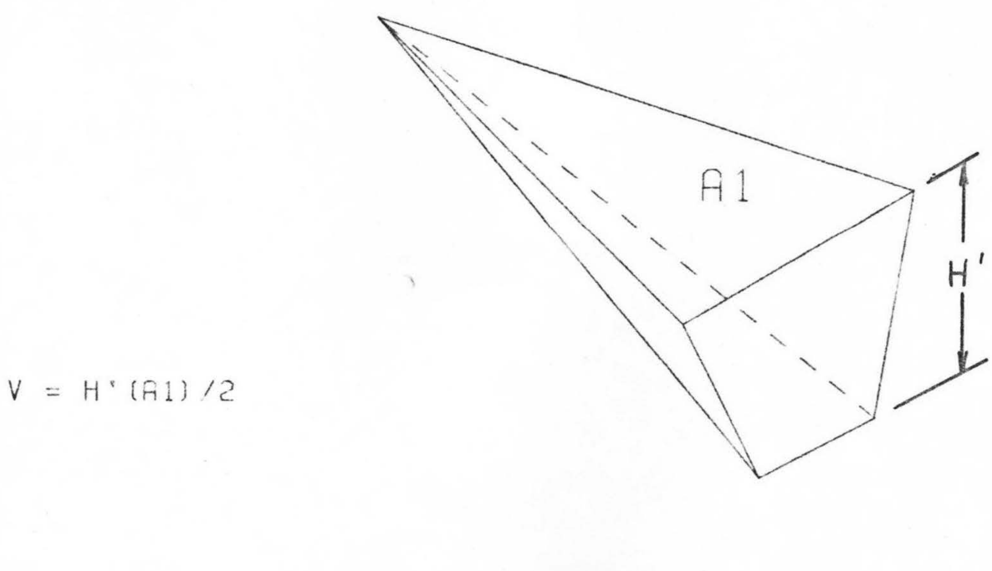

Figure 6B. Representative shape of layer below "bottom" contour.

TABLE 1

MEASURED AND CALCULATED FIGURES FOR HELLS CANYON REREGULATING DAM

(1) R.M.[1] at Start	(2) R.M. at End	(3) Upper Elev. (ft)	(4) Plan.[2] #1	(5) Plan. #2	(6) Plan. #3	(7) Plan. Avg.	(8) Map Area[3] (in²)	(9) True Area[4] (ft²)	(10) Hgt. of Layer[5] (ft)	(11) Vol. of Layer Below[6] (ft)	(12) Vol. of Layer Below (ac-ft)	(13) Storage Below 1550 ft (ac-ft)	(14) Storage Below 1500 ft (ac-ft)	(15) Storage Below 1450 ft (ac-ft)	(16) Storage Below 1400 ft (ac-ft)	(17) Storage Below 1350 ft (ac-ft)
247.5	245	1550	.208	.208	.206	.207	2.07	8.3×10^6	50	359×10^6	8,241					
		1500	.151	.152	.153	.152	1.52	6.1 "	50	192 "	4,408	12,649	4,408	--	--	--
245	241	1550	.382	.395	.377	.385	3.85	15.4 "	50	653 "	14,990					
		1500	.254	.257	.293	.268	2.68	10.7 "	50	474 "	10,881					
		1450	.200	.210	.207	.206	2.06	8.2 "	50	208 "	4,775					
		1400	.002	.002	.002	.002	.02	.08 "	1	.04 "	.92	30,647	15,657	4,776	1	--
241	237	1550	.440	.430	.446	.439	4.39	17.6 "	50	802 "	18,411					
		1500	.353	.364	.371	.363	3.63	14.5 "	50	646 "	14,830					
		1450	.295	.280	.277	.284	2.84	11.3 "	50	473 "	10,858					
		1400	.190	.188	.192	.190	1.90	7.6 "	49	190 "	4,375	48,474	30,063	15,233	4,375	--
237	233	1550	.573	.561	.559	.564	5.64	22.6 "	50	1034 "	23,737					
		1500	.463	.474	.473	.470	4.70	18.8 "	50	847 "	19,444					
		1450	.366	.385	.381	.377	3.77	15.1 "	50	665 "	15,266					
		1400	.289	.283	.291	.288	2.88	11.5 "	50	495 "	11,364					
		1350	.211	.205	.204	.207	2.07	8.3 "	50	232 "	5,326					
		1300	.024	.024	.026	.025	.25	1.0 "	10	5 "	115	75,252	51,515	32,071	16,805	5,441
233	229	1550	.964	.949	.975	.963	9.63	38.5 "	50	1801 "	41,345					
		1500	.836	.840	.837	.838	8.38	33.5 "	50	1537 "	35,285					
		1450	.694	.694	.708	.699	6.99	28.0 "	50	1258 "	28,880					
		1400	.563	.575	.538	.559	5.59	22.4 "	50	946 "	21,717					
		1350	.381	.394	.385	.387	3.87	15.5 "	50	619 "	14,210					
		1300	.236	.225	.234	.232	2.32	9.3 "	50	289 "	6,641					
		1250	.016	.017	.016	.016	.16	.64 "	4	1.28 "	29.3	148,107	106,762	71,477	42,597	20,880

Notes

[1] River Mile.
[2] Planimeter reading (total for given contour).
[3] Reading of .10 on planimeter indicated area of 1.0 in².
[4] Map scale = 1:24,000.
[5] Height at downstream end (if less than (50 ft).
[6] Average of area and area below, times height.

TABLE 2

REREGULATING DAM STORAGE AS FUNCTION OF

SURFACE ELEVATION AND RIVER MILE

Damsite (R.M.)	Storage Below 1550 ft (ac-ft)	Storage Below 1500 ft (ac-ft)	Storage Below 1450 ft (ac-ft)	Storage Below 1400 ft (ac-ft)	Storage Below 1350 ft (ac-ft)
241	43,296	20,065	4,776	--	--
237	91,770	50,128	20,009	4,375	--
233	167,022	101,643	52,080	21,180	5,441
229	315,129	208,405	123,557	63,777	26,321

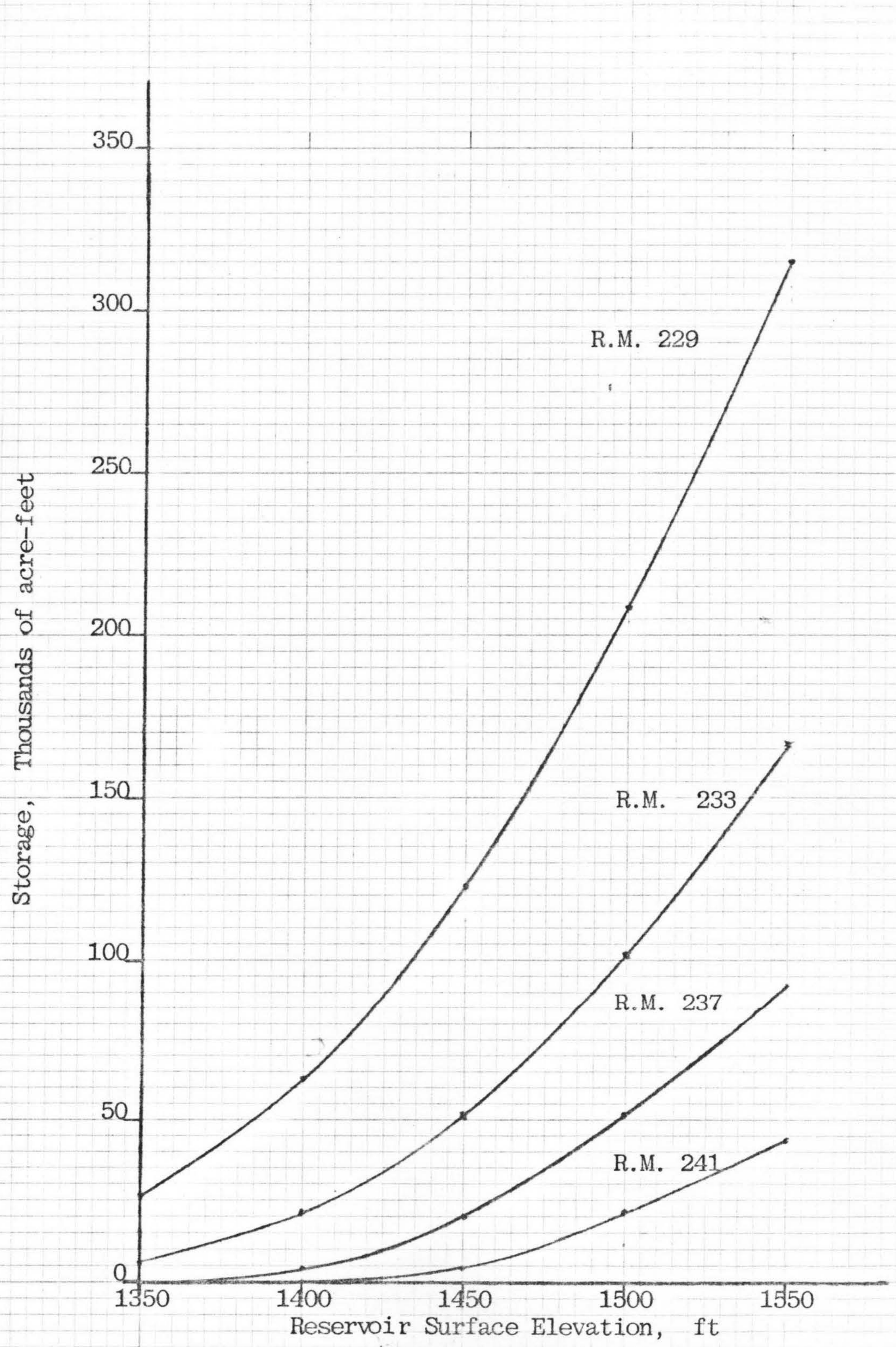

Figure 7. Gross storage as function of surface elevation and river mile.

a given location to provide a given amount of storage. Conversely, if the maximum upper reservoir elevation is specified, and a certain storage volume is desired, the approximate location of a dam providing those characteristics can be determined by interpolating between the curves.

The main effect to be realized from construction of a reregulating dam is a smoothing out of the river discharges. Widely varied flows are discharged into the reregulator pool, and more constant flows are released therefrom. The benefit to the power company of such a project is that greater capacity to generate power for peak loads is obtained. Output of electricity at a high power level can be done for a longer period of time than when the generating dam itself must reregulate its own releases, i.e. keep them from varying too much. In addition, there may be an increase in the minimum flow releases from the reregulator to the stream below. In the case of Hells Canyon, installation of a reregulating dam could possibly permit maintaining a streamflow above 5000 cfs at times when Hells Canyon Dam would normally release only the required 5000 cfs. Much depends on the streamflow coming into the project (i.e. into Brownlee in this case), and also on the load characteristics at the time.

As mentioned above, possibility of actual construction of a reregulating dam in Hells Canyon is very remote. Federal law in the body of the Hells Canyon National Recreation Area

Act prohibits any dam construction at all within the boundaries of the recreation area, which extends from Hells Canyon Dam approximately to the Washington-Oregon state line. In addition, inaccessibility to the canyon bottom would make construction difficult and expensive, as noted above. Possibilities for improving the benefits of a reregulator would be installing pump-turbines in Hells Canyon Dam and using the reregulating reservoir as the lower pool of a pumped storage scheme, or installing generating units in the reregulating dam to generate power as it made its releases. Should the public desire for power capacity in the future exceed that for environmental preservation enough to withdraw Hells Canyon dam-building restrictions, the details of the economics and engineering feasibility of a reregulating dam could be further examined.

IX. COMPUTER OPERATION STUDY OF BROWNLEE RESERVOIR RELEASES

A computer program has been developed to permit analysis of the effects on energy production, and on Hells Canyon streamflows to some extent, caused by different minimum releases required from the Middle Snake project and by various projected Snake River streamflows upstream (i.e. inflows to the project). The minimum flows were varied from the required 5000 cfs upward to 10,000 cfs. None were tried below 5000 cfs, as this was felt to be the lowest level practicable for downstream users. Five different schemes of input streamflow were used. First was historical records, the monthly average flows recorded at the USGS Weiser gage. In addition, four different conditions of flow, determined by variations in assumptions of future development of irrigation in the Upper Snake River Basin, were provided by the Idaho Department of Water Resources. These are described in more detail below. A final aspect of this study was an examination of the effects on energy production of relaxing the rule curve under which Idaho Power Company is required to operate Brownlee Reservoir for flood control. The new hypothetical rule curve was varied from 100 percent of the existing rule curve (full restriction) to 0 percent of the existing rule curve (no restriction;

reservoir permitted to be full year-round).

A. Description of the River System

1. Upper Snake River Basin

The Snake River originates in Yellowstone National Park in Wyoming. It runs generally east to west across southern Idaho, then heads north, forming the border between Idaho and Oregon and having flowed about 650 miles before reaching Brownlee Reservoir (see Figure 1). The river continues northward out of Hells Canyon and meets the Columbia River near Pasco, Washington. The upper basin, above Brownlee, consists of steep mountains and wide valleys. A very large portion of the drainage is made up by the Snake River Plain, which contributes no appreciable surface runoff but has a large underlying aquifer that provides a near-constant discharge into the Snake River at Thousand Springs. The normal annual precipitation varies from less than 6 inches over the plains to about 60 inches in Wyoming's Teton Mountains. The basin-wide average is about 16 inches.

The total area drained above Hells Canyon Dam is about 73,300 square miles, 72,590 of which are also above Brownlee Dam. Over 200 dams of many different sizes provide a total active storage capacity above Hells Canyon in excess of 10 million acre-feet, which includes Brownlee's one million acre-feet (Corps 1961, Table 2). About 3.8 million acres of land are irrigated in the Snake River Basin above Hells Canyon

(1975 figure), of which about 740,000 are irrigated by pumping from groundwater (1966 figure) (U.S. Geological Survey 1975, p. 260). It is groundwater pumping projects that account for the large power usage during Idaho Power's summer peak demand period, while the surface irrigation projects account for the summer depletion in the Snake River water supply. In addition, there are major irrigated areas that pump directly from the river, thus both using power and depleting the streamflow.

2. Middle Snake Projects

A development chronology and description of Idaho Power's three Middle Snake dams are contained in Chapters II and IV, respectively. Briefly, the project has three hydroelectric dams in series within about 40 miles of each other on the Snake River. Brownlee Dam and Reservoir, furthest upstream, contains the storage capacity, about 1 million acre-feet, while Oxbow and Hells Canyon are essentially run-of-river power plants. The releases from Hells Canyon are restricted by the FPC license to always be at least 5000 cfs, to be at least 13,000 cfs when combined with the Salmon River outflow at least 95 percent of the time, and to never fluctuate the river level more than one foot per hour at Johnson Bar (which translates to 3000 cfs per hour variation at the dam). In addition, the level of Brownlee Reservoir is restricted by the license to be low enough to provide 500,000 acre-feet of storage for flood control on 1 March every year and to provide additional flood control storage as requested by the Corps of Engineers.

According to the Corps of Engineers (1975, Chap. 7), a rule curve for a multi-purpose project when power is one of the purposes tries to provide balanced operation for generation of firm and secondary energy through high-, medium-, and low-flow periods, while maintaining optimum storage capacity for flood control. Thus, the pool level should at all times be only as high as necessary to assure availability of firm power and energy. The Corps states that all operation for power in a reservoir also used for flood control should center on the rule curve. When the pool level is at or below the rule curve height for that date, only scheduled firm power should be generated. When it is below, a drought is in progress, the severity of which will not be known until the water in storage attains the rule curve level again. If high inflows occur and the pool rises above the rule curve level, secondary energy should be generated to drop it back down to the rule curve level. Firm energy is described as the generation which would exactly draw the reservoir to the bottom of the power pool during the most severe drought of record (Corps 1975, p. 7.01). The rule curve is developed based on firm energy commitments and on the worst recorded drought. Thus, if the reservoir starts at or above the rule curve level, no potential drought should cause the pool to fall below the rated pool (i.e. the minimum power production level). This assumes, though, that only firm energy is generated, that the generation pattern generally agrees with that used in the development studies, and that the drought experienced is not more severe than the worst drought of record (Corps 1975, p. 7.01).

Essentially, a rule curve is constructed by studying the period of maximum drawdown (i.e. the critical period), as well as some periods of lesser severity to check whether combinations of power demand and hydrologic conditions at times other than during the critical period might affect the curve's location. For Brownlee, the period of analysis was July 1929 through June 1957, and the worst recorded drought was the 1936-37 water year (Corps 1961, p. 26). Brownlee's curve is such that generation of firm energy from the rule curve, based on these flows, would draw the reservoir down to elevation 1976, the lower limit of power storage. Brownlee's rule curve, obtained from Plate 17 of the Reservoir Regulation Manual for Brownlee, Oxbow, and Hells Canyon (Corps 1961), is shown in Figure 8, along with a graph of the actual reservoir contents for water year 1973.

The requirement that Idaho Power provide half a million acre-feet of storage by March first every year was made primarily in an effort to reduce flooding at The Dalles, Oregon, on the Lower Columbia. Consideration was given to flooding problems in Lewiston-Clarkston and on the Lower Snake, but the

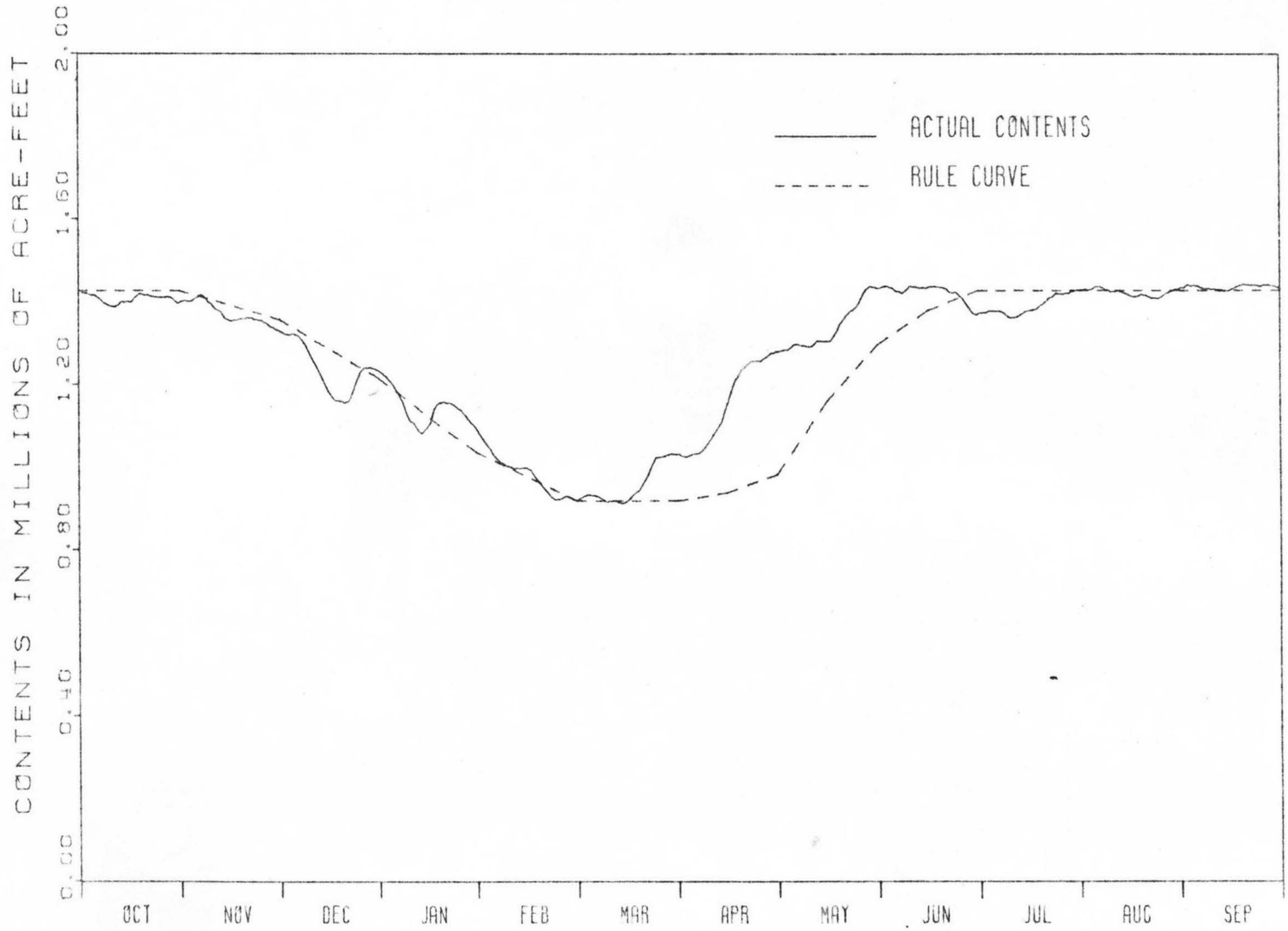

Figure 8. Brownlee Reservoir rule curve and 1973 contents.

main interest was controlling main-stem Columbia floods. The Dalles had a levee system adequate to protect the city from flows in the Columbia up to 800,000 cfs. The Corps of Engineers' primary flood control objective was to obtain upstream storage sufficient to reduce the peak discharge of the flood of record (1,240,000 cfs in 1894) to 800,000 cfs at The Dalles. The Corps determined that about 17 million acre-feet of effective flood control storage, including existing storage, would be required for such flood peak reduction (Krutilla 1967, p. 120). At the time of planning for the Middle Snake projects in the early 1950s, it was considered that Brownlee would offer a sizable contribution to Lower Columbia flood control. Subsequent to the construction of Brownlee and inclusion in Idaho Power's FPC license of the storage provision requirement, however, the United States negotiated a treaty with Canada under which the Canadians were to provide three storage reservoirs with a total capacity of 15.5 million acre-feet and the United States had an option to construct Libby Dam on the Kootenai River in Montana, with 5 million acre-feet of storage (Krutilla 1967, p. 88). The Kootenai is an Upper Columbia tributary which originates in Canada and flows into the United States before returning to Canada to empty into the Columbia River. It appears conceivable that the value of Brownlee storage for flood control at The Dalles has been reduced by construction of the upstream projects. As a preliminary examination, the author in his simulated operation of Brownlee power plant considered reducing the extent of the flood control restrictions, i.e. not requiring the reservoir to draw down the full half-million acre-feet each spring. If such an investigation indicated potential benefits, then possibly a more in-depth analysis would be warranted.

B. Description of Simulation Model

Since Brownlee Dam is the project with the storage, it was selected for use in the operation study. It was felt that a more direct relationship existed between draft of storage and generation at Brownlee than generation at either Oxbow or Hells Canyon. A simplified application could probably have been made to these two projects as well, but the results of Brownlee should be indicative of the project-wide (i.e. all three projects) performance to be expected under the same conditions. In the study, Brownlee was assumed to be held to the 5000 cfs release required from Hells Canyon Dam downstream. This would not strictly be a requirement on Brownlee in actual operation, since Oxbow and Hells Canyon serve to reregulate the Brownlee discharges, but the monthly average flow from Brownlee would most likely closely coincide with the monthly average flow from the lower dams. Also, the minimum required release was felt to be an important part of the system operation, so it was imposed on Brownlee's discharges. Monthly flows were used since they were the only data available for the future Idaho conditions, a vital part of the study. Historical records could be obtained on a daily basis, but projections of streamflows based on future conditions of irrigation development at various levels were made only for monthly average flows. The restriction to one foot per hour maximum water level change at Johnson Bar was not made part of the computer program, as such a consideration is not meaningful on the one-month time scale used.

A detailed description and a listing of the computer program used for the simulation are contained in Appendix I. A few of the important assumptions and parameters are reviewed here, and a general description of the program is offered. The program is written in FORTRAN and currently requires all inputs to be from punched cards, though this is easily modified if use of data contained on tape or disk is convenient. Required data are the required water release from the power plant (in cfs); the rule curve factor desired (explained later); parameters specific to the reservoir and obtained from elevation-area and elevation-capacity rating curves; evaporation coefficients for each month; and the reservoir-specific quantities--power plant efficiency, contents when full (total contents), contents when "empty" (dead storage); a suitable approximation for the tailwater elevation, assumed to be constant at all discharges; and the power-generating capacity of the plant.

The form of the output may be modified, depending on the use to be made of it. Full output of results may be obtained, as shown in Figure I-3 in Appendix I, in which computed quantities are printed for each month of each year of the study, or simply the summary information, displayed in Figure I-4, may be given. The full table is beneficial for documenting results, identifying errors in input quantities or program logic, and for pointing out problems in the chosen mode of operation. If only the final results are desired, however, as for comparison purposes, then the simplified version would be more desirable, as the required computer execution time is drastically reduced. Printing of the entire table may be omitted by deleting the appropriate WRITE statements, indicated in Figure I-1 in Appendix I.

The program places first priority on meeting the minimum flow requirement every month, using this release to generate electricity. It then checks the pool level and compares it with the rule curve level. If the pool is above the rule curve, extra energy is generated to bring the level down to the maximum level permitted. If the preliminarily-computed release exceeds the power plant capacity, the extra water is spilled. If making the required flow release had already brought the pool level to or below the rule curve, no further energy is generated for that month. No computations are made relative to system or plant power demand for each month, as such information was not readily available. The main operation of the power plant-reservoir centers on releasing the required flow, then keeping the reservoir as full as possible without exceeding the rule curve limit. No attempt has been made to maximize power production--the power plant is merely operated for power generation in accordance with the two primary criteria mentioned.

C. Input Data Used

All of the data for the dam, power plant, and reservoir characteristics were obtained from the Reservoir Regulation Manual written by the Walla Walla District of the Corps of Engineers for Idaho Power Company's three projects (Corps 1961). Evaporation coefficients to estimate monthly reservoir evaporation were provided by the Idaho Department of Water Resources. Streamflow data, the fundamental material for the study, were obtained from two sources. The historical records and monthly totals are contained on disk at the University of Idaho, accessed through the Hydrologic Information Storage and Retrieval System (Molnau 1975). The system was used to print out the monthly totals for the Snake River at Weiser, which were then punched onto data cards for use in the analysis.

Most of the streamflow data used, however, were figures furnished by the Idaho Department of Water Resources from their studies of future water availability in the Snake River in Idaho. Chapter III describes more fully their studies relative to expected flows under Present Conditions and under Future Conditions of irrigation development.

More recently, the Department of Water Resources investigated some irrigation growth alternatives which are in between Present Conditions and Future Conditions studies, both in amount of irrigation and in resulting streamflows. One assumes development of all the irrigation for which licenses or permits had been given for water rights as of May 1975. The second assumes development of all the water rights applied for as of May 1975, in addition to the licenses and permits issued. Again, both these studies determined what the streamflows would have been historically if the assumed levels of development had existed throughout the period of analysis. As with the historical records, data for these last four studies were received in computer printout form, from which data cards were punched for use with the program. All the data used for input to the program are presented in Appendix II.

D. Analysis Procedure

The initial stages of the study concentrated on looking generally at the power that could be produced and the water releases that would be made from the power plant with assumed required releases of 5000 cfs and 7000 cfs and under historical and future conditions. The primary intent was to determine whether a streamflow greater than 5000 cfs could be sustained on a reliable basis, and what consequential effect it would have on power production. Average power generated for each month was computed, but no consideration was given to losses due to evaporation, and a flaw in the program permitted release of the full 7000 cfs minimum even when the live storage in the reservoir had been depleted and the monthly inflow was far less than 7000 cfs.

Subsequently it was deemed desirable to undertake a more quantitative analysis, so the program was modified to account for monthly evaporation, the permissible releases under reservoir-empty conditions were made more reasonable, and power was computed using average head for the month instead of simply the end-of-month head. Also, to permit better quantitative comparisons, the total energy produced during each month, year, and the whole period of study were computed, rather than just the average monthly power produced. In addition, a count was made of the number of cases when the monthly discharge did not equal or exceed the required minimum flow due to emptying of the reservoir and the inflow being less than the minimum.

The computer model was then operated for Brownlee Dam and Reservoir, using the five streamflow conditions described previously and varying the minimum required releases between 5000 and 10,000 cfs. Then, for each of these combinations, the reservoir rule curve was varied, from 100% of the rule curve (as is now required) to 0% (no drawdown required at all). The results were then tabulated and each of the alternatives--minimum flow adjustment and rule curve modification--was compared under the different projected future water supply conditions. Because of the large amount of data generated, the user should be sure that only the figures of interest are printed out. In this study, the intermediate values were not needed, so only the final results were printed.

E. Results

Total energy generation studies were done for all five streamflow conditions, for rule curve fractions of 0%, 25%, 50%, 75%, and 100% and for minimum releases of 5000, 6000, 7000, and 10,000 cfs. The figures obtained are tabulated in Table 3. Graphs of the energy produced at different minimum releases are presented in Figures 9 through 13, at the various rule curve percentages. The results from the portion of the analysis investigating the number of months when the reservoir emptied and failed to meet the minimum release requirement are shown in Table 4.

Concentrating first just on the unmodified rule curve, the 100% study, it is quickly apparent that there is only a slight drop in total energy production for each particular condition of streamflow and a large drop in total energy production in going from the historical flows to the flows projected under the future conditions. This latter observation

TABLE 3

TOTAL ENERGY GENERATION, 1928-1968,

UNDER VARIOUS CONDITIONS (GWH)

	STUDY	Required Release, cfs 5000	6000	7000	10,000
100%*	Historical Records	101,158	101,156	101,119	99,905
	Present Conditions	97,781	97,768	97,727	96,278
	Licenses, Permits	92,396	92,324	92,059	88,452
	Licenses, Permits, Applications	89,170	88,923	88,379	83,974
	Future Conditions	77,369	76,788	75,876	69,261
75%	Historical Records	101,896	101,896	101,886	100,805
	Present Conditions	98,851	98,848	98,828	97,688
	Licenses, Permits	93,514	93,466	93,252	89,853
	Licenses, Permits, Applications	90,320	90,095	89,614	85,208
	Future Conditions	78,420	77,922	77,041	69,930
50%	Historical Records	102,386	102,386	102,382	101,474
	Present Conditions	99,635	99,635	99,632	98,756
	Licenses, Permits	94,310	94,278	94,096	90,837
	Licenses, Permits, Applications	91,148	90,955	90,502	86,083
	Future Conditions	79,242	78,830	77,975	70,371
25%	Historical Records	102,682	102,682	102,680	101,895
	Present Conditions	100,209	100,209	100,208	99,494
	Licenses, Permits	94,891	94,860	94,701	91,533
	Licenses, Permits, Applications	91,759	91,569	91,160	86,632
	Future Conditions	79,906	79,532	78,698	70,575
0%	Historical Records	102,780	102,780	102,778	101,993
	Present Conditions	100,611	100,610	100,610	99,993
	Licenses, Permits	95,249	95,218	95,059	91,907
	Licenses, Permits, Applications	92,142	91,952	91,548	86,921
	Future Conditions	80,486	80,143	79,340	70,772

*Percent of rule curve used for study.

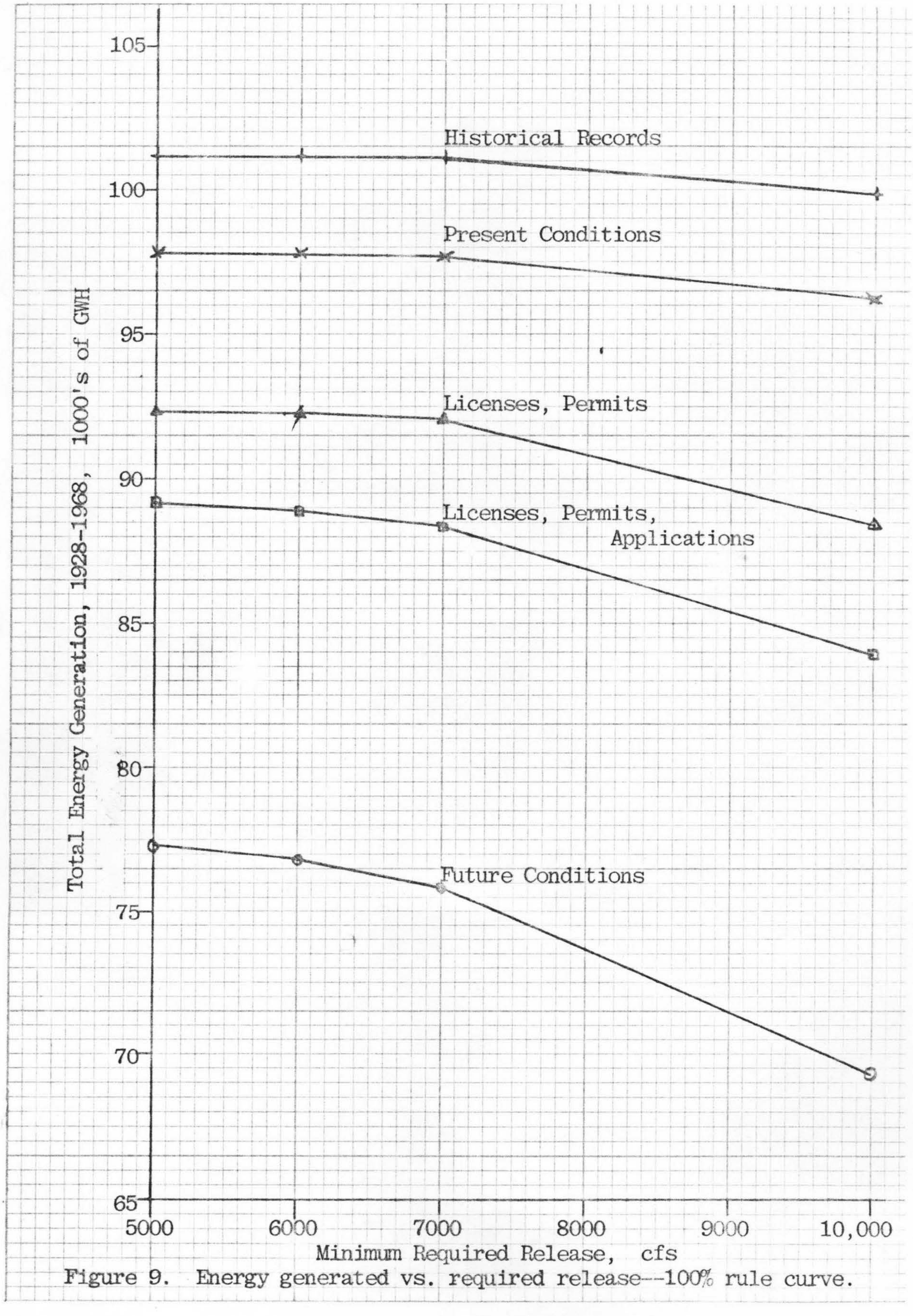

Figure 9. Energy generated vs. required release—100% rule curve.

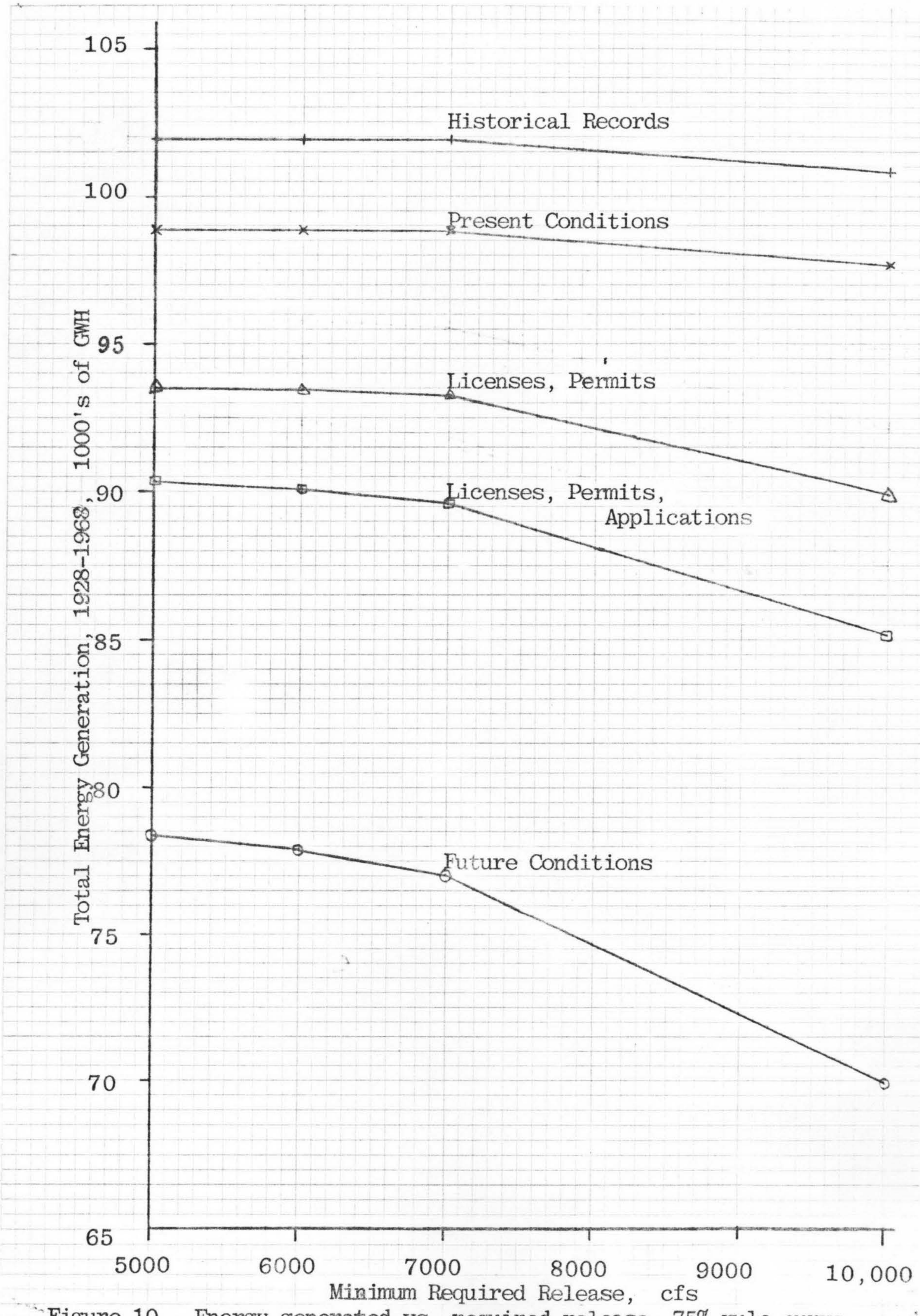

Figure 10. Energy generated vs. required release--75% rule curve.

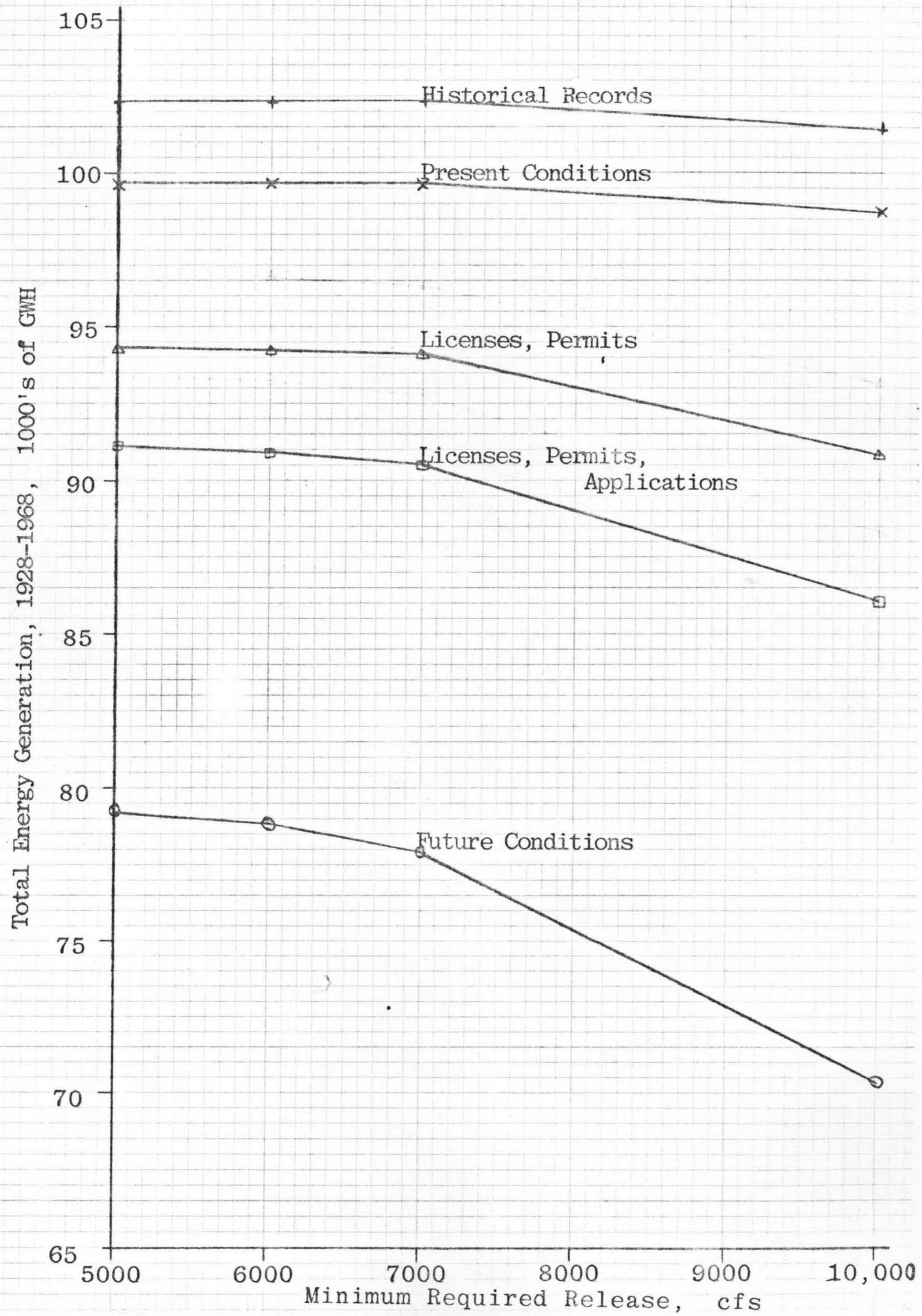

Figure 11. Energy generated vs. required release—50% rule curve.

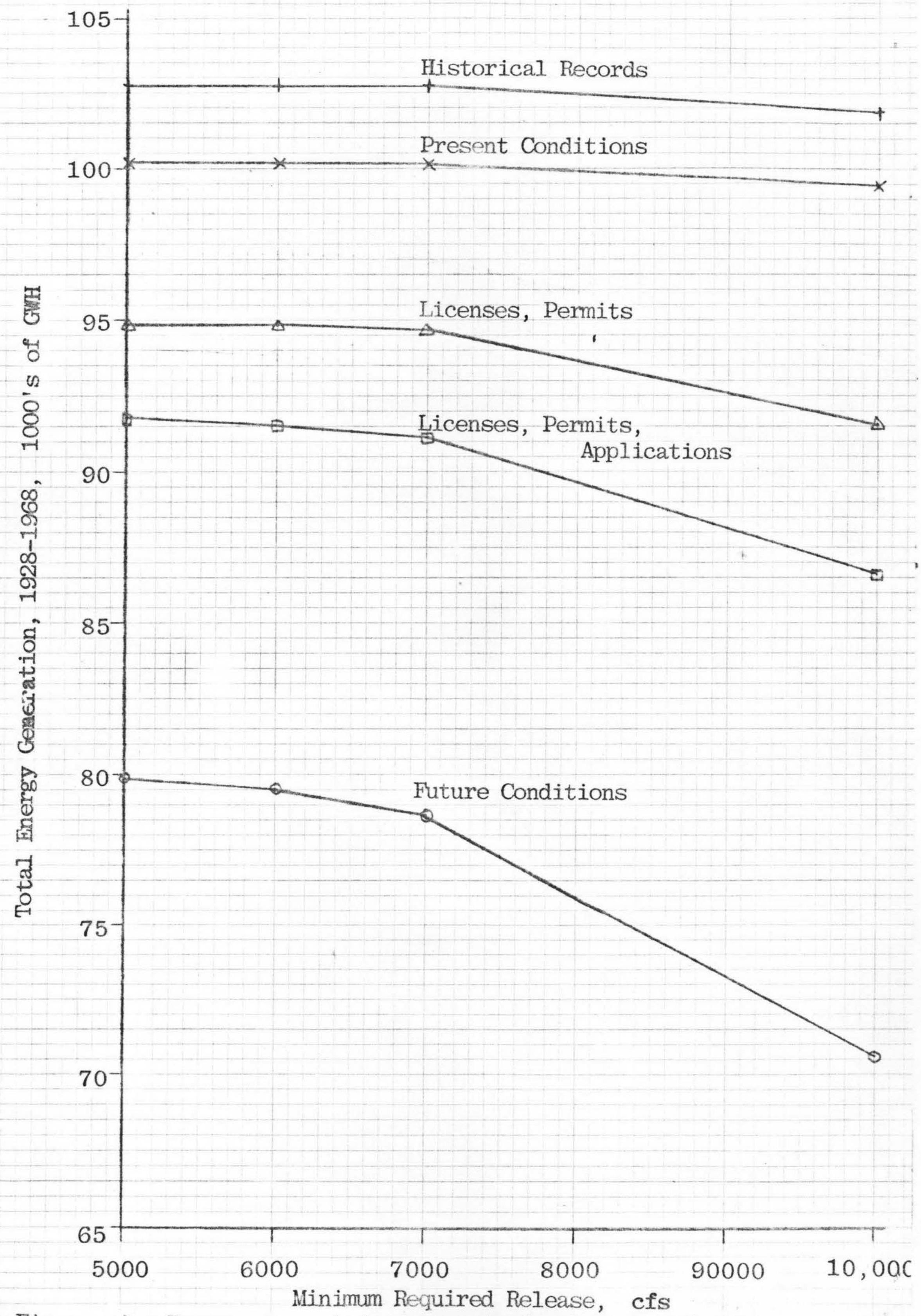

Figure 12. Energy generated vs. required release--25% rule curve

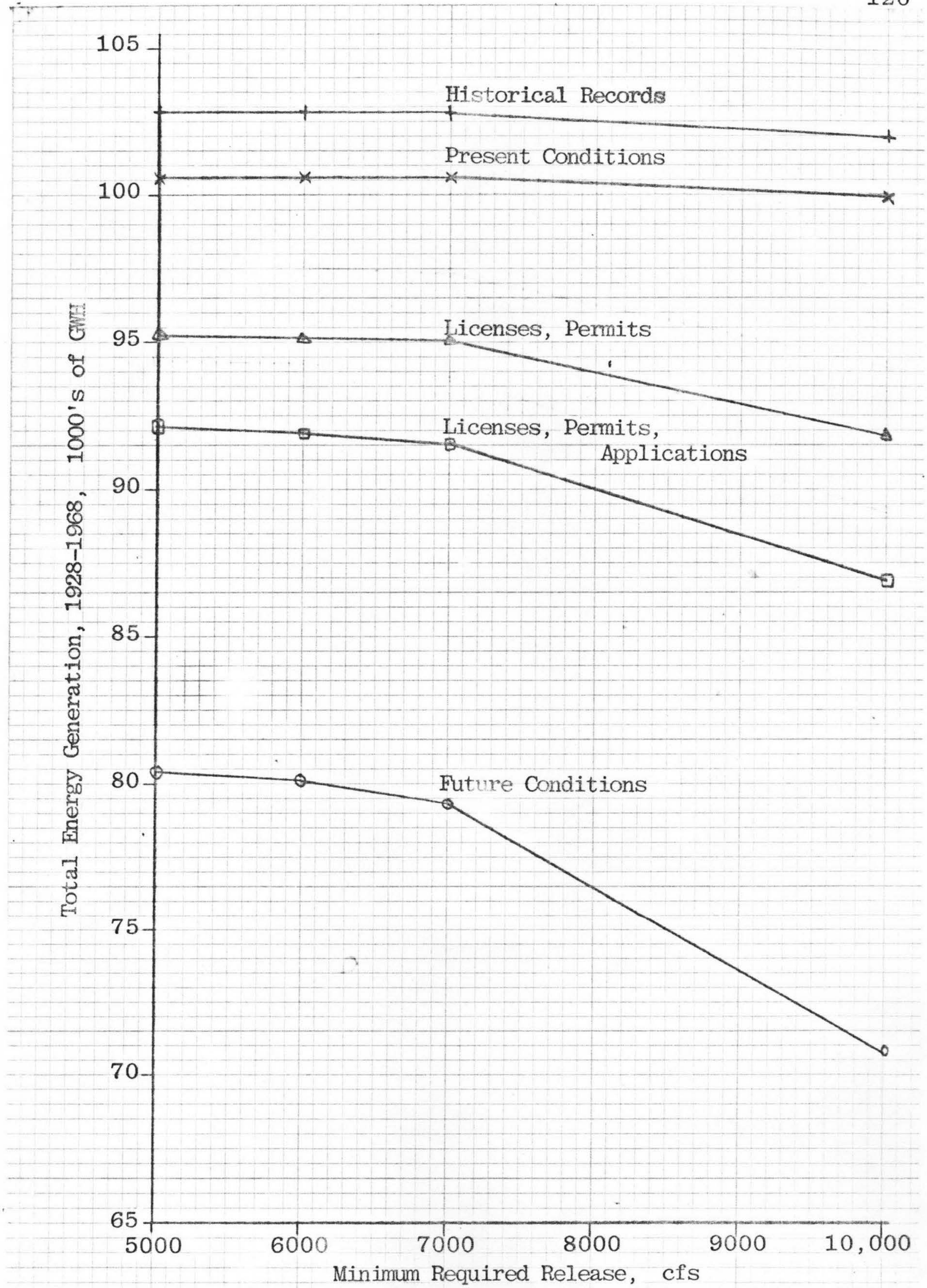

Figure 13. Energy generated vs. required release-- 0% rule curve.

TABLE 4

NUMBER OF MONTHS NOT MEETING MINIMUM

FLOW REQUIREMENT IN EACH STUDY

	STUDY	Required Release, cfs 5000	6000	7000	10,000
100%*	Historical Records	--	--	--	3
	Present Conditions	--	--	--	2
	Licenses, Permits	--	--	--	13
	Licenses, Permits, Applications	--	--	--	24
	Future Conditions	--	2	5	82
75%	Historical Records	--	--	--	--
	Present Conditions	--	--	--	--
	Licenses, Permits	--	--	--	7
	Licenses, Permits, Applications	--	--	--	17
	Future Conditions	--	--	4	79
50%	Historical Records	--	--	--	--
	Present Conditions	--	--	--	--
	Licenses, Permits	--	--	--	6
	Licenses, Permits, Applications	--	--	--	12
	Future Conditions	--	--	3	75
25%	Historical Records	--	--	--	--
	Present Conditions	--	--	--	--
	Licenses, Permits	--	--	--	5
	Licenses, Permits, Applications	--	--	--	11
	Future Conditions	--	--	1	72
0%	Historical Records	--	--	--	--
	Present Conditions	--	--	--	--
	Licenses, Permits	--	--	--	4
	Licenses, Permits, Applications	--	--	--	8
	Future Conditions	--	--	--	68

*Percent of rule curve used for study.

is reasonable in light of the fact that the inflows are substantially less under the future conditions. Hence, the amount of water passing through the plant is much lower and the energy generated is less as well. Actually, the decrease in energy output from a 5000 cfs minimum to 10,000 cfs for the future conditions was almost 11%, fairly sizable, but still small compared to the decreases in excess of 23% in going from historical to future conditions.

The indication is that, given certain streamflows in the river, the total electric energy production from these flows is not very dependent on the minimum flow release maintained downstream, at least in the case of Brownlee. This holds more consistently at the higher flow levels and less at the depleted levels, where the system seems to be more sensitive to the release restriction. An important further consideration, however, is not the energy generated in total over the long run, but the energy availability over shorter periods, particularly during drier years. Comparison of two sample computer runs for the same conditions, 5000 and 10,000 cfs with full development of licenses, permits, and applications, shows a wide variation in the annual energy produced for the two minimum releases. In one year, the energy generation with the 5000 cfs release was 4% less than that generated with 10,000 cfs, while in another year, the 5000 cfs run produced 26% more than the 10,000 cfs run. This latter year was an especially dry one, but no trend was apparent from inspection as to which were the more favorable years for energy production under a given required release, dry ones or wet ones.

A look at Table 3 shows a definite tendency for the higher releases to have more failures in meeting the minimums for constant streamflow conditions, as should be expected. With the future conditions, when the required release was supposed to be 10,000 cfs, the actual release was less than 10,000 cfs 82 times, an average of two months during each year of the 41-year study. At one time the downstream discharge dropped as low as 2353 cfs. The failures were mostly in August and September but occasionally in October and occasionally in July. When the minimum release required was 7000 cfs or below, it was met at all times, except in a few cases in the future conditions study.

Examining the variation in energy production with modification of the rule curve, it can be seen that there was little effect in the total period-of-record generation, even with complete relaxation of the rule curve requirement. Generally, there was a 1.5% to 2.5% increase in the energy produced by going from 100% rule curve restriction to 0%.

X. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The problems of the Hells Canyon dams and their operation have been examined. The existing problems have been scrutinized, and the problems expected in the future have also been probed to a certain extent. The computer program described herein could be improved for further application, and there are other possible investigations that could be done to try to obtain an operating plan that would be more favorable to all the parties concerned. The following paragraphs summarize the findings of the present research and point out the specific areas for the need for further study.

First, a look was taken at the controversies in Hells Canyon both before and after installation of the Idaho Power Company projects, followed by a brief survey of the plans for the Hells Canyon National Recreation Area. Next, examination was made of past studies which had been done for planning purposes or for assessing the water or power needs of the area. The parties interested in using the river were considered, along with the nature of their needs with respect to timing and/or quantity of water required. Next, it was noted that the three Middle Snake River dams, as a system, play a major role in the power company's system. Brownlee's storage is, in fact, the only significant storage the company has. The three power plants associated with Brownlee Reservoir must be operated to meet the load not otherwise met (i.e. by the thermal or other hydro plants), providing the only flexibility available in dry years. Thus, Idaho Power has little ability to change its operating procedure pertinent to the Middle Snake River projects.

The expected growth in population and in irrigation development were assessed, along with a consequent increase in the future demand for electricity in Idaho and a decrease in the future supply of water in the Snake River to the Middle Snake River projects. The strongest indication is that current trends in Snake River water use cannot continue without at least some of the parties concerned experiencing undesirable water shortages. If the irrigated agriculture does expand as projected, less water will be available in the coming decades for power production and the other uses. It is apparent that either the increase in irrigation depletions will have to be reduced to preserve the streamflows, or energy production facilities with greater "reliability," less dependence on river water supplies, will have to be developed.

Possibilities for constructing a reregulating dam below Hells Canyon Dam were also reviewed. Earlier studies of the idea were mentioned, and a short analysis was performed in addition. A graph (Figure 7) was presented showing storage available as a function of upper reservoir elevation and distance downstream from Hells Canyon Dam. The dam was determined to be a physically possible alternative, but it appears to have little support socially and politically, so it is ultimately infeasible.

Finally, a simplified model was developed to operate Brownlee storage reservoir and compute the electric energy that would be generated under various conditions of operation. It was determined that a drop of up to 23% in energy production was possible if streamflows dropped to the Future Conditions level and if the 5000 cfs minimum release were maintained. It was seen that raising the minimum flow requirement had only a slight effect on total energy production--decreasing it about 10% in the most severe case and about 6% in the next most severe case. One very serious consequence of increasing the minimum required flow, however, was that the number of times when the minimum was not satisfied increased markedly at the higher requirements, most notably at 10,000 cfs. In addition to the minimum flow not being satisfied, the power load at the time would not have been met either. For the last portion of the analysis, it had been considered a possibility that the Brownlee storage may not be as necessary for use as flood control storage as it had been at one time, and that perhaps the storage space could be put to better use for power and energy production. It was observed, though, that even complete removal of the flood control rule curve increased energy production a maximum of only 4%.

A few notes pertinent to the results from the computer operation study should be brought forward. The figures obtained and used in the analysis were totals of energy generation for the 41-year period of record. As such, they are long-term totals and can be useful for indicating general trends and making general comparisons, but they may not be representative of any given year's energy production. Probably the most serious limitation of the study is that it was unable to consider power peaking operations. First, detailed information on the power company's loads was not available, and second, the data available for the streamflows in the computer program were only on a monthly basis. While certain months of the year may offer annual high loads, true peaking operations of interest to the company are the instantaneous peaks each year, so the company will know its required output capacity. A good approximation of the instantaneous demand could probably be made on the basis of hourly or even daily demand. While hourly streamflows are not easily obtained on a reliable basis, daily flows are available (at least for the historical records).

A future study could consider the effect on total peaking production of varying the parameters considered here (minimum flow, inflow level, rule curve level). In addition, the power generation should coincide with the demand schedule, and possibly even coordination with the Pacific Northwest electric system could be included. Such an analysis should center on critical combinations of hydrologic conditions and demand characteristics (e.g. the worst likely case each year).

A possible innovation which could be applied to the computer program would be inclusion of a feature to accept hydrologic data for each year (e.g. snow pack information, precipitation), make a forecast of that year's spring runoff, and adjust the rule curve for Brownlee up or down as necessary. These modifications would make the simulation model quite a bit more realistic, but they would considerably complicate it, too, which may exceed the benefits gained.

Further analysis which would be vital before any serious decisions could be based on the results of the computer program study is an economic accounting of the benefits and costs that would be realized under the alternative operating schemes. The analysis should consider the benefits, as well as the costs, that would accompany raising the minimum release in low-flow summers. The economic effect of higher required releases on peaking capability should also be examined. Another facet for consideration is the benefits from energy and power production and the costs from increased flood damages of operating with a less stringent (i.e. higher) flood control rule curve. Finally, the consequences of the reservoir emptying and not meeting the minimum release should be determined in terms of losses in power and energy production, losses to people using the river downstream for navigation, losses of fish living and/or spawning in the river downstream, and losses to people interested in recreation pursuits, both on the open river downstream and in the drawn-down reservoir.

Another potential study method that could be quite useful would be an analysis to optimize the operation of the Brownlee-Oxbow-Hells Canyon system. This could be done to maximize the net economic benefits, or a scheme could be devised to try to optimize in some manner the releases from the projects. It appears the economic approach, if practicable, would be more easily quantified. An analytical technique, such as linear or dynamic programming, possibly combined with a simulation model of the hydroelectric system, would probably be the best way to determine optimization. Of the two analytical techniques, dynamic programming would likely be more appropriate since reservoir operations are sequential decision problems, best handled by a dynamic programming application.

In conclusion, the existence of a problem with respect to the flows of the Snake River in the vicinity of Hells Canyon has been shown. No firm solution has been determined, but some alternatives have been examined and possible avenues of future pursuit have been opened and discussed. The existence of the national recreation area below the existing power dams will inevitably have an effect on the option or options selected for solving the problem. If it has no other effect, the law creating the recreation area will at least exclude all new dams from construction within the area, thus excluding any type of reregulating dam below Hells Canyon Dam. The canyon will therefore be without any further development and will be left to be enjoyed solely as an environmental resource.

LIST OF REFERENCES

Citations

Arthur D. Little, Inc. 1976. Idaho Power Company's need for additional generating capacity. Report to Idaho Public Utilities Commission. Cambridge, Mass.

Bayha, Keith, and Koski, Charles, eds. 1974. Anatomy of a river: an evaluation of water requirements for the Hell's Canyon reach of the Middle Snake River. Vancouver, Washington: Pacific Northwest River Basins Commission.

Bessey, Roy F. 1956. The political issues of the Hells Canyon controversy. In: Western Political Quarterly. Vol. 9. pp. 676-690.

_________. 1964. The public issues of Middle Snake River development. Bulletin No. 9. Olympia, Washington: State of Washington, Division of Power Resources.

Hells Canyon National Recreation Area Act. 1975. Statutes at Large, vol. 60, p. 1117.

Hells Canyon Preservation Council, Inc. 1968-1975. Newsletter. Idaho Falls, Idaho.

Hull, C.H.J. 1967. River regulation. In: River Management, ed. by Peter C.G. Isaac. University, Alabama: University of Alabama Press.

Idaho Department of Water Resources. 1976. Summary report: conclusions and recommendations for the state water plan--part II, Snake River basins. Boise, Idaho.

Idaho Water Resource Board. 1974. Water availability for meeting alternate levels of in-stream flows--Snake River from Swan Falls to below Hells Canyon Dam. Boise, Idaho.

_________. 1976. The state water plan--part two. Boise, Idaho.

Idaho Power Company. 1970. Analysis of the detrimental effect of any change in Article 43 of Federal Power Commission License No. 1971. Boise, Idaho.

_________. 1976. Personal meeting with company engineer, 13 August, Boise, Idaho.

________. 1977. Public hearing, 31 March, Lewiston Idaho.

Krutilla, John V. 1967. _The Columbia River Treaty: the economics of an international river basin development_. Baltimore: Johns Hopkins Press.

Lewiston Morning _Tribune_. 23 September, 1976. Alternate sites eyed for coal-fired plant. Lewiston, Idaho.

Molnau, Myron. 1975. A guide to the use of HISARS, a hydrologic information storage and retrieval system. University of Idaho, College of Agriculture. Miscellaneous Series No. 32.

Moss, Sen. Frank E. 1967. _The water crisis_. New York: Frederick A. Praeger, Inc.

Pacific Northwest River Basins Commission. 1971. _Long-range schedules of priorities for the Pacific Northwest region_. Vancouver, Washington.

Udall v. FPC. 387 U.S. 428 (1967).

U.S. Army, Corps of Engineers, Hydrologic Engineering Center. 1975. _Hydrologic engineering methods for water resources development: volume 8--reservoir yield_. Davis, California.

U.S. Army, Corps of Engineers, North Pacific Division. 1972. _Review of provisions for navigation, FPC License, Project No. 1971_. Portland, Oregon.

U.S. Army, Corps of Engineers, Walla Walla District. 1961. _Reservoir regulation manual: Brownlee, Oxbow and Hells Canyon Projects, Federal Power Commission Project No. 1971, Idaho Power Company_. Walla Walla, Washington.

________. 1969. Report on review of effects on navigation and flood control of Idaho Power Company projects in Hells Canyon Reach of Snake River. Walla Walla, Washington.

U.S. Congress, House. 1926. Examination of streams for water-power development. H. Doc. 308. 69th Congress, 1st Session.

________. 1933. Report on improvement of Columbia River and minor tributaries. H. Doc. 103. 73rd Congress, 1st Session.

_________. 1948. Columbia River and tributaries northwestern United States. H. Doc. 531. 81st Congress, 2nd Session.

U.S. Congress, Senate, Committee on Interior and Insular Affairs Subcommittee on Parks and Recreation. 1971. Hearings on S. 717 and S. 488. 92nd Congress, 1st Session.

U.S. Department of Interior, Geological Survey. 1976. Water Resources data for Idaho, water year 1975. Springfield, Virginia: National Technical Information Service.

U.S. Federal Power Commission. 1955. Opinion and order issuing license, projects nos. 1971, 2132, 2133. 14 FPC 55.

_________. 1975. Draft environmental impact statement--Middle Snake River project no. 2243/2273. Washington, D.C.

Weatherby, James B. 1968. The Hells Canyon controversy: a study of the Hells Canyon associations and their view of comprehensive river basin development. M.A. thesis (political science). Moscow, Idaho: University of Idaho.

Additional References

Bary, Constantine W. 1963. Operational economics of electric utilities. New York: Columbia University Press.

Bugliarello, George, and Gunther, Fred. 1974. Computer systems and water resources. New york: Elsevier Scientific Pub. Company.

Buras, Nathan. 1972. Scientific allocation of water resources. New York: Elsevier Scientific Pub. Co.

Columbia Basin Inter-Agency Committee. 1955-1962. Annual report. Portland, Oregon.

Cunningham, Floyd F. 1967. 1001 questions answered about water resources. New York: Dodd, Mead & Company.

Dailey, Donald J. 1972. The Hells Canyon Dilemma: a case study involving the endeavors and opposition to damming the Middle Snake River. Research paper. Washington, D.C.: American University.

Ellis, Clyde T. 1966. A giant step. New York: Random House.

Gladwell, John S., and Warnick, Calvin C. 1976. Instream flow needs and competing uses for water. Summary report of Water resources Seminar, Fall 1975. Moscow, Idaho: Idaho Water Resources Research Institute.

Hickel, Walter J. 1971. Who owns America? Englewood Cliffs, N.J.: Prentice-Hall, Inc.

Hirshleifer, Jack, De Haven, James C., and Milliman, Jerome W. 1960. Water supply: economics, technology, and policy. Chicago: University of Chicago Press.

Idaho Department of Water Resources. 1976. Effects of full development of existing water rights permits and applications below Milner Dam on flows of Snake River. by R.J. Sutter. Boise, Idaho.

Idaho Water Resource Board. 1973. River operation studies for Idaho. Boise, Idaho.

Jordan, Grace. 1953. Home below Hells Canyon. New York: Thomas Y. Crowell Co.

Laycock, George. 1970. The diligent destroyers. Garden City, New York: Doubleday & Company.

Mother Earth News Staff. 1974. The Mother Earth News handbook of homemade power. New York: Bantam Books.

Olson, Charles E. 1970. Cost considerations for efficient electricity supply. East Lansing, Michigan: Institute of Public Studies, Michigan State University.

Oregon Water Resources Board. 1958. Snake River study--interim report no. 1. Salem, Oregon.

Pacific Northwest Regional Planning Commission. 1943. Pacific Northwest development in perspective. Portland, Oregon.

Price, Truman P. 1971. Hydroelectric power policy. Springfield, Virginia: National Technical Information Service.

Reische, Diana, ed. 1975. Energy: demand vs. supply. New York: The H.W. Wilson Co.

Scheufele, Roy. 1970. History of the Columbia Basin Inter-Agency Committee. Vancouver, Washington: Pacific Northwest River Basins Commission.

Skow, John. 1967. Farewell to Hells Canyon. Saturday Evening Post. Vol. 240, no. 13.

Stoner, Carol H., ed. 1974. Producing your own power: how to make nature's energy sources work for you. Emmaus, Penn.: Rodale Press, Inc.

Sutherland, R.A., and Tinney, E. Roy. 1964. Hydraulic model studies of the Hells Canyon hydroelectric project. Pullman, Washington: Washington State University.

Tininenko, Robert D. 1967. Middle Snake River development: the controversy over Hells Canyon, 1947-1955. M.A. thesis (history). Pullman, Washington: Washington State University.

U.S. Congress, House, Committee on Interior and Insular Affairs Subcommittee on Irrigation and Reclamation. 1952. Hearings on H.R. 5743. 82nd Congress, 2nd Session.

________. 1955. Hearings on H.R. 4719, H.R. 4730, H.R. 4739, H.R. 4740. 84th Congress, 1st Session.

U.S. Congress, Senate, Committee on Interior and Insular Affairs. 1957. Report on S. 555, construction, operation, and maintenance of the Hells Canyon Dam on the Snake River between Idaho and Oregon. 85th Congress, 1st Session.

U.S. Congress, Senate. 1975. Senator Church speaking in support of Hells Canyon National Recreation Area bill, S. 322. Congressional Record. vol. 112.

U.S. Department of Agriculture, Forest Service. 1976. Hells Canyon National Recreation Area study plan. Baker, Oregon: Wallowa-Whitman National Forest.

U.S. Department of Interior, Office of Water Resources Research, Water Resources Scientific Information Center. 1972. A selected annotated bibliography on the analysis of water resource systems. Washington, D.C.

U.S. Federal Power Commission. 1955-1975. License file on Idaho Power Company Project No. 1971.

APPENDIX I

DESCRIPTION OF COMPUTER PROGRAM

The FORTRAN program developed by the author and used for the analysis of Chapter IX operates a dam with storage reservoir for power production. In this case, it was used to simulate operation of Brownlee Reservoir, taking into account a minimum release requirement for the downstream channel, restrictions on maximum permissible level of the Brownlee pool at different times of the year, and estimated evaporation from the reservoir surface. The entire listing of the program, with comments included for clarification, is shown in Figure I-1. Figure I-2 shows a list of most of the data cards used for the present study.

A. General Operation

The program begins by assigning storage for the arrays used, assigning names and numbers of days to each month, and reading in values for the required release, the rule curve factor, the maximum permissible end-of-month contents in the reservoir (as shown on the rule curve), values for reservoir contents, elevation, and surface area at different levels, estimated evaporation

```
C                          RESERVOIR REGULATION PROGRAM
C
C
C
C   PURPOSE
C        THIS IS A FORTRAN PROGRAM TO COMPUTE STORAGE IN, DISCHARGES FROM, AND
C        ELECTRIC ENERGY PRODUCED AT A HYDROELECTRIC PROJECT.  IT CONSIDERS
C        MINIMUM REQUIRED RELEASES FROM THE POWER PLANT, POOL LEVEL RESTRICTIONS
C        IN THE RESERVOIR, EVAPORATION FROM THE RESERVOIR, AND MAXIMUM GENERA-
C        TING CAPACITY OF THE POWER PLANT.  THE RESERVOIR IS ASSUMED TO START
C        FULL FOR THE FIRST MONTH FOR WHICH STREAMFLOW DATA ARE GIVEN.  THE
C        FIRST YEAR OF ANALYSIS MAY BE STARTED IN ANY MONTH BY PLACING ZEROES
C        (OR BLANKS) BEFORE THE DESIRED STARTING MONTH ON THE DATA CARD FOR THE
C        FIRST YEAR OF STREAMFLOW.
C
C        THE PROGRAM IS SET UP NOW FOR BROWNLEE RESERVOIR ON THE SNAKE RIVER.
C        TO ADAPT IT TO ANOTHER RESERVOIR OR OTHER OPERATING CONDITIONS, SOME
C        OF THE CONSTANTS AND INPUT QUANTITIES MUST BE CHANGED, AS DESCRIBED
C        BELOW.
C
C
C   DESCRIPTIONS OF VARIABLES AND CONSTANTS
C
C        QUANTITIES CONSTANT IN PROGRAM
C             A          = A CONSTANT TO CONVERT FROM CFS TO ACRE-FT PER DAY.
C             DAYS(I)    = NUMBER OF DAYS IN EACH MONTH.
C             MONTH(I)   = NAME OF MONTH.  ASSUMES WATER YEAR, STARTING WITH OCT.
C
C        QUANTITIES TO BE INPUT FROM DATA CARDS
C             REQREL     = REQUIRED RELEASE FROM RESERVOIR, IN CFS.
C             RULFAC     = FACTOR INDICATING PROPORTION OF RULE CURVE DRAWDOWN
C                          DESIRED FOR ANALYSIS.  1.0 INDICATES FULL RULE CURVE
C                          DRAWDOWN, 0. INDICATES NONE.
C             P(I)       = MAXIMUM ALLOWABLE END-OF-MONTH CONTENTS IN RESERVOIR,
C                          IN ACRE-FT, DETERMINED FROM RULE CURVE FOR RESERVOIR.
C             CONTEN(I)  = CONTENTS OF RESERVOIR AT DIFFERENT POOL LEVELS, IN
C                          ACRE-FT.  RANGE SHOULD BE BROKEN INTO 12 (NOT NECES-
```

Figure I-1. Listing of reservoir regulation program.

```
C                         SARILY EQUAL) INTERVALS.  MINIMUM CONTENTS MUST BE
C                         LISTED FIRST AND MAXIMUM LISTED LAST.
C            ELEV(I)    = ELEVATION OF RESERVOIR AT DIFFERENT CAPACITIES, IN FT.
C                         RANGE SHOULD BE BROKEN INTO 12 INTERVALS, EACH COR-
C                         RESPONDING WITH THE CONTENTS GIVEN FOR CONTEN(I).
C            AREA(I)    = SURFACE AREA OF RESERVOIR AT DIFFERENT ELEVATIONS, IN
C                         ACRES.  EACH SHOULD CORRESPOND WITH CONTEN(I) AND
C                         ELEV(I).
C            EVAPCO(I)  = ESTIMATED EVAPORATION COEFFICIENT FOR THE RESERVOIR
C                         FOR EACH MONTH, IN ACRE-FT PER ACRE PER MONTH..
C            EFF        = EFFICIENCY OF POWER PLANT, EXPRESSED AS A DECIMAL.
C            TAILWA     = NORMAL TAILWATER ELEVATION, IN FEET ABOVE MEAN SEA
C                         LEVEL.
C            POWMAX     = MAXIMUM POWER GENERATING CAPACITY OF POWER PLANT, IN
C                         KILOWATTS.
C            NRUNS      = NUMBER OF SEPARATE COMPUTATION RUNS TO BE PERFORMED,
C                         CONSIDERING ONE RUN TO BE FOR A PARTICULAR MINIMUM
C                         RELEASE, RULE CURVE FACTOR, AND STREAMFLOW CONDITION.
C            STUTYP     = TYPE OF STUDY PARTICULAR RUN IS DONE FOR (E.G. PRESENT
C                         CONDITIONS, FUTURE CONDITIONS).
C            NOYR       = NUMBER OF YEARS FOR WHICH STREAMFLOW DATA ARE SUPPLIED
C            LUNIT      = CODE DESCRIBING THE UNITS FOR THE STREAMFLOW:
C                 LUNIT= 0 FOR ACRE-FEET (PER MONTH).
C                 LUNIT= 1 FOR CFS-DAYS (PER MONTH).
C                 LUNIT= 2 FOR CFS (AVG. FOR MONTH).
C            DISFAC     = FACTOR BY WHICH ACTUAL STREAMFLOWS HAVE BEEN DIVIDED T
C                         TO FACILITATE INPUT ON DATA CARDS (USUALLY A POWER
C                         OF 10).
C            NYEAR      = WATER YEAR CORRESPONDING TO STREAMFLOW DATA.
C            D(I)       = MONTHLY STREAM DISCHARGE, INFLOW TO RESERVOIR, IN CFS,
C                         CFS-DAYS, OR ACRE-FT (LUNIT MUST INDICATE WHICH UNIT
C                         IS USED).
C
C       QUANTITIES COMPUTED IN PROGRAM
C            PMULT      = MULTIPLIER USED IN POWER COMPUTATION (CONSTANT).
C            CONT       = TOTAL END-OF-MONTH CONTENTS IN RESERVOIR, IN ACRE-FEET
C            TOTGWH     = TOTAL ENERGY PRODUCED DURING PERIOD OF STUDY, IN
```

Figure I-1 (continued)

```
C                       GIGAWATT-HOURS (1 GWH=1 MILLION KWH).
C          ANNGWH     = ENERGY PRODUCED FOR THE YEAR, IN GWH.
C          OLDH       = PREVIOUS MONTH'S POWER HEAD, IN FEET.
C          OLDSUR     = RESERVOIR SURFACE AREA FOR PREVIOUS MONTH., IN ACRES.
C          FULCON     = RESERVOIR CONTENTS WHEN FULL, IN ACRE-FEET.
C          EMPCON     = RESERVOIR CONTENTS WHEN EMPTY, I.E. DEAD STORAGE, IN
C                       ACRE-FEET.
C          NL         = NUMBER OF LOOPS (YEARS).  PROGRAM REWRITES COLUMN
C                       HEADINGS ONCE EVERY 8 YEARS AND THEN RESETS NL TO 0.
C          NFAIL      = NUMBER OF TIMES MINIMUM REQUIRED RELEASE IS NOT MET.
C          MYEAR      = LAST 2 DIGITS OF WATER YEAR.
C          EVAP       = MONTHLY EVAPORATION, IN ACRE-FEET.
C          F          = MONTHLY INFLOW TO RESERVOIR, CONVERTED FROM INPUT
C                       UNITS TO ACRE-FEET.
C          T          = TOTAL MONTHLY RELEASE FROM RESERVOIR, IN ACRE-FEET.
C          R(I)       = REQUIRED MONTHLY RESERVOIR RELEASE, IN ACRE-FEET.
C          STOR       = TOTAL END-OF-MONTH LIVE STORAGE IN RESERVOIR, IN AC-FT
C          TF         = AVERAGE MONTHLY RELEASE, IN CFS.
C          EL         = END-OF-MONTH WATER SURFACE ELEVATION, IN FT ABOVE MSL.
C          SURF       = END-OF-MONTH RESERVOIR SURFACE AREA, IN ACRES.
C          FACTOR     = FACTOR USED TO INTERPOLATE BETWEEN GIVEN INTERVALS TO
C                       DETERMINE EXACT ELEVATION AND SURFACE AREA.
C          H          = POWER HEAD AT DAM AT END OF MONTH, IN FEET.
C          AVHEAD     = AVERAGE HEAD FOR MONTH, IN FEET.
C          POWER1     = AVERAGE MONTHLY POWER OUTPUT FROM PLANT, IN KILOWATTS.
C          POWREL     = AVERAGE MONTHLY POWER RELEASE, IN CFS.
C          SPILL      = MONTHLY AMOUNT OF WATER SPILLED, IN ACRE-FEET.
C          EXCESS     = MONTHLY AVERAGE POWER OUTPUT IN EXCESS OF PLANT CAPA-
C                       CITY, IN KILOWATTS.
C          EXTRA      = WATER RELEASE CORRESPONDING TO EXCESS POWER GENERATION
C                       IN CFS.
C          POWER      = MONTHLY AVERAGE POWER OUTPUT, IN MEGAWATTS.
C          ENERGY     = TOTAL MONTHLY ENERGY PRODUCTION, IN GWH.
C          AVANEN     = AVERAGE ANNUAL ENERGY PRODUCTION, FOR ENTIRE PERIOD
C                       OF STUDY, IN GWH.
C
C
```

Figure I-1 (continued)

```
C*****************************************************************************************
      DIMENSION D(12),R(12),P(12),DAYS(12),    MONTH(12),CONTEN(12),ELEV(
     C12),        AREA(12),EVAPCO(12),STUTYP(20)
C
C********ASSIGN NAMES OF MONTHS AND NUMBER OF DAYS IN EACH.
      DATA MONTH/'OCT.','NOV.','DEC.','JAN.','FEB.','MAR.','APR.','MAY '
     1,'JUN.','JUL.','AUG.','SEP.'/
      DATA DAYS/31.,30.,2*31.,28.,31.,30.,31.,30.,2*31.,30./
C
C********INPUT VALUES FROM DATA CARDS.
      READ(5,5) REQREL
    5 FORMAT(F8.0)
      READ(5,6) RULFAC
    6 FORMAT(F5.2)
      READ(5,8) (P(I),I=1,12)
    8 FORMAT(10F8.0)
      READ (5,30) (CONTEN(I),I=1,12)
   30 FORMAT (10X,6F8.0)
      READ (5,40) (ELEV(I),I=1,12)
   40 FORMAT (12X,12F5.0)
      READ (5,50) (AREA(I),I=1,12)
   50 FORMAT (6X,12F6.0)
      READ (5,20) (EVAPCO(I),I=1,12)
   20 FORMAT (8X,12F4.2)
      READ (5,300) EFF,TAILWA,POWMAX
  300 FORMAT(F5.3,F8.0,F10.0)
C
C********ADJUST RESERVOIR RULE CURVE BY DESIGNATED FACTOR.
      DO 70 I=1,12
   70 P(I)=CONTEN(12)-RULFAC*(CONTEN(12)-P(I))
C
C********READ NUMBER OF RUNS DESIRED AND DO ONE COMPUTATION LOOP FOR EACH.
      READ(5,75) NRUNS
   75 FORMAT(I2)
      DO 500 JK=1,NRUNS
C
C********READ TYPE OF STUDY FOR THIS RUN AND INFORMATION ON THE STREAMFLOW DATA.
```

Figure I-1 (continued)

```
      READ (5,76) STUTYP
   76 FORMAT (20A4)
      READ(5,85) NOYR,LUNIT,DISFAC
   85 FORMAT (I4,I3,F5.1)
C
C********WRITE COLUMN HEADINGS, CHECKING WHICH UNIT OF INFLOW IS APPROPRIATE.
      WRITE (6,240)
  240 FORMAT ('1')
      WRITE (6,250)
  250 FORMAT (T110,'SURF.  AVG.')
      WRITE (6,251)
  251 FORMAT (T2,'MONTH.',T28,'MIN.          TOTAL      POWER',
     1T64,'MAX. PERM.  ACTUAL        LIVE      SURF.',T110,'ELEV.  POWER AVG.'
     2/T2,'WATER   INFLOW  INFLOW   RELEASE   RELEASE  RELEASE    SPILL
     3  CONTENTS  CONTENTS  STORAGE  AREA      EVAP.   (FT,    HEAD POWER E
     4NERGY')
      IF (LUNIT.EQ.2) WRITE (6,255)
      IF (LUNIT.EQ.1) WRITE (6,256)
      IF (LUNIT.EQ.0) WRITE (6,257)
  255 FORMAT (T3,'YEAR     (CFS)   (AC-FT)   (AC-FT)     (AC-FT)    (CFS)    (A
     5C-FT)     (AC-FT)   (AC-FT)  (AC-FT) (ACRES) (AC-FT)    MSL)   (FT)
     6(MW)   (GWH)'//)
  256 FORMAT (T3,'YEAR (CFS-DAYS)(AC-FT)   (AC-FT)    (AC-FT)     (CFS)    (A
     5C-FT)     (AC-FT)   (AC-FT)  (AC-FT) (ACRES) (AC-FT)    MSL)   (FT)
     6(MW)   (GWH)'//)
  257 FORMAT (T3,'YEAR    (AC-FT) (AC-FT)  (AC-FT)     (AC-FT)    (CFS)    (A
     5C-FT)     (AC-FT)   (AC-FT)  (AC-FT) (ACRES) (AC-FT)    MSL)   (FT)
     6(MW)   (GWH)'//)
C
C********INITIALIZE VARIABLES, CONSTANTS, AND COUNTERS.
      A=1.98347
      PMULT=62.4*EFF*.7457/550.
      CONT=CONTEN(12)
      TOTGWH=0.
      ANNGWH=0.
      OLDH=ELEV(12)-TAILWA
      OLDSUR=AREA(12)
```

Figure I-1 (continued)

```
      FULCON=CONTEN(12)
      EMPCON=CONTEN(1)
      NL = 0
      NFAIL=0
C
C********DETERMINE MONTHLY REQUIRED RELEASE IN ACRE-FEET.
      DO 100 I=1,12
  100 R(I)=REQREL*A*DAYS(I)
C
C********DO COMPUTATION LOOP ONCE FOR EACH YEAR.
      DO 200 J=1,NOYR
      NL = NL + 1
C
C********INPUT THE YEAR AND THE MONTHLY VALUES FOR RESERVOIR INFLOW, ONE YEAR
C********        AT A TIME.
      READ(5,11) NYEAR,(D(N),N=1,12)
   11 FORMAT (I4,12F6.0)
C
C********RETAIN ONLY LAST 2 DIGITS OF YEAR TO SIMPLIFY OUTPUT.
      IF (JK.EQ.1) MYEAR=NYEAR-(NYEAR/100)*100
      IF (JK.NE.1) MYEAR = MYEAR+1
C
C********DO COMPUTATION LOOP ONCE FOR EACH MONTH.
      DO 150 K=1,12
C
C********ADJUST NUMBER OF DAYS IN MONTH FOR FEBRUARY OF EACH LEAP YEAR.
      IF (K.EQ.5) DAYS(K)=28.
      IF ((K.EQ.5).AND.(MYEAR.EQ.4*(MYEAR/4))) DAYS(K)=29.
      D(K)=DISFAC*D(K)
C
C********SKIP TO END OF LOOP (END OF MONTH) IF NO DISCHARGE (INFLOW) IS GIVEN
C********        FOR A MONTH DURING THE FIRST YEAR OF ANALYSIS.
      IF (D(K).EQ.0.AND.J.EQ.1) GO TO 150
C
C********COMPUTE MONTHLY EVAPORATION AND RESULTING RESERVOIR CONTENTS.
      EVAP=EVAPCO(K)*OLDSUR
      CONT=CONT-EVAP
```

Figure I-1 (continued)

```
      IF (LUNIT.EQ.0) GO TO 77
      IF (LUNIT.EQ.2) GO TO 4
C
C********CONVERT MONTHLY INFLOW FROM CFS-DAYS TO ACRE-FEET.
      F=A*D(K)
      GO TO 7
C
C********CONVERT MONTHLY INFLOW FROM CFS TO ACRE-FEET, BASED ON NUMBER OF DAYS
C********        IN MONTH.
    4 F=A*D(K)*DAYS(K)
      GO TO 7
   77 F=D(K)
C
C********COMPUTE TOTAL RESERVOIR RELEASE (T) IN ACRE-FEET, BY ADDING THIS
C********        MONTH'S INFLOW TO CONTENTS AT END OF LAST MONTH AND SUBTRACTING
C********        THE MAX. ALLOWABLE CONTENTS.
    7 T=CONT+F-P(K)
C
C********ADJUST MINIMUM RELEASE FOR FEBRUARY OF EACH LEAP YEAR.
      IF ((K.EQ.5).AND.(MYEAR.EQ.4*(MYEAR/4))) R(5)=R(5)*29./28.
C
C********SET RELEASE EQUAL TO MINIMUM REQUIREMENT IF IT IS LESS THAN THE
C********        REQUIREMENT.
      IF (T.LT.R(K)) T=R(K)
C
C********COMPUTE CONTENTS AT END OF THIS MONTH (CONT) IN ACRE-FEET BY ADDING
C********        LAST MONTH'S CONTENTS TO THIS MONTH'S INFLOW AND SUBTRACTING
C********        THIS MONTH'S TOTAL RELEASE.  IF THE RESERVOIR EMPTIES, ADJUST
C********        THE TOTAL RELEASE ACCORDINGLY.
   21 CONT=CONT+F-T
      IF (CONT.GE.EMPCON) GO TO 22
      T=T-(EMPCON-CONT)
      CONT=EMPCON
   22 STOR=CONT-EMPCON
C
C********COMPUTE AVG. RELEASE FOR MONTH (TF) IN CFS,SETTING IT EQUAL TO THE
C********        REQUIRED RELEASE IF IT IS LESS THAN 1 CFS BELOW THE REQUIREMENT.
```

Figure I-1 (continued)

Figure I-1 (continued)

```
      TF=T/DAYS(K)/A
      IF ((TF.LT.REQREL).AND.(TF+1..GT.REQREL)) TF=REQREL
C
C********COMPUTE RESERVOIR ELEVATION (EL), BASED ON ELEVATION-CAPACITY RATING
C********      CURVE AND THE SURFACE AREA (SURF), BASED ON AREA-CAPACITY RATING
C********      CURVE.  IF ACTUAL CONTENTS DO NOT EQUAL ONE OF THE INPUT VALUES
C********      (CONTEN), COMPUTE A FACTOR AND INTERPOLATE FOR THE EXACT FIGURE.
      DO 60 I=1,12
      IF (CONT.LE.CONTEN(I)) GO TO 80
   60 CONTINUE
   80 IF (CONT.NE.CONTEN(I)) GO TO 90
      EL=ELEV(I)
      SURF=AREA(I)
      GO TO 110
   90 FACTOR=(CONTEN(I)-CONT)/(CONTEN(I)-CONTEN(I-1))
      EL=ELEV(I)-FACTOR*(ELEV(I)-ELEV(I-1))
      SURF=AREA(I)-FACTOR*(AREA(I)-AREA(I-1))
C
C********COMPUTE GROSS HEAD AND AVERAGE HEAD ON POWER PLANT.
  110 H=EL-TAILWA
      AVHEAD=(H+OLDH)/2.
C
C********COMPUTE AVG. POWER OUTPUT FOR THE POWER PLANT FOR THE MONTH (POWER1)
C********      IN KW, BASED ON THE TOTAL MONTHLY RELEASE AND THE AVERAGE HEAD
C********      FOR THE MONTH.
  120 POWER1=TF*PMULT*AVHEAD
C
C********CHECK TO SEE IF POWER OUTPUT EXCEEDS PLANT CAPACITY.
      IF (POWER1.GT.POWMAX) GO TO 221
C
C********COMPUTE AVG. POWER RELEASE (POWREL) AND, IF NECESSARY, WATER TO BE
C********      SPILLED (SPILL).
      POWREL=TF
      SPILL = 0.
      GO TO 125
  221 EXCESS = POWER1 - POWMAX
      POWER1 = POWMAX
```

```
      EXTRA = EXCESS/(PMULT*AVHEAD)
  122 POWREL = TF - EXTRA
      SPILL=A*DAYS(K)*EXTRA
C
C********CONVERT POWER FROM KW TO MW, DETERMINE MONTHLY EVERGY PRODUCTION, AND
C********      INCREMENT ANNUAL SUM BY MONTHLY AMOUNT.
  125 POWER=POWER1/1000.
      ENERGY=POWER*DAYS(K)*24./1000.
      ANNGWH=ANNGWH+ENERGY
C
C********IF MONTHLY RELEASE DOESN'T MEET MINIMUM REQUIRED, INCREASE COUNT BY 1.
      IF (POWREL.LT.REQREL) NFAIL=NFAIL+1
C
C********WRITE OUT VALUES FOR THIS MONTH.
      WRITE (6,25) MONTH(K),MYEAR,D(K),F,R(K),T,POWREL,SPILL,P(K),
     9CONT,STOR,SURF,EVAP,EL,AVHEAD,POWER,ENERGY
   25 FORMAT (1X,A1,I3,F10.0,F9.0,F9.0,F10.0,F9.0,F10.0,F10.0,F10.0,
     AF9.0,F8.0,F8.0, F7.0,F6.1,F6.1,F7.1)
C
C********MAKE AN ASTERISK BY MONTHLY RELEASE IF IT FAILS TO MEET THE MINIMUM.
      IF (POWREL.GE.REQREL) GO TO 410
      WRITE (6,325)
  325 FORMAT ('+',T53,'*')
C
C********WRITE APPROPRIATE SYMBOLS NEXT TO ACTUAL CONTENTS TO INDICATE
C********      RESERVOIR BEING FULL TO RULE CURVE LEVEL AND/OR FULL TO CAPACITY.
  410 IF (P(K).NE.CONT) GO TO 330
      IF (CONT.NE.FULCON) GO TO 425
      WRITE (6,420)
  420 FORMAT ('+',T83,'F')
  425 WRITE (6,430)
  430 FORMAT ('+',T73,'*')
  330 OL DH=H
      OLDSUR=SURF
      IF ((K.EQ.5).AND.(MYEAR.EQ.4*(MYEAR/4))) R(5)=R(5)*28./29.
  150 CONTINUE
C
```

Figure I-1 (continued)

```
C********INCREMENT TOTAL ENERGY PRODUCTION BY ANNUAL AMOUNT AND WRITE OUT
C********      ANNUAL AMOUNT.
      TOTGWH=TOTGWH+ANNGWH
      WRITE (6,24) ANNGWH
   24 FORMAT (T86,'TOTAL ENERGY GENERATED THIS YEAR =  ',F8.1,' GWH')
      ANNGWH=0.
      WRITE (6,25)
C
C********REWRITE COLUMN HEADINGS ONCE EVERY 8 YEARS.
      IF (NL .NE.8) GO TO 200
      WRITE (6,26)
   26 FORMAT (1X,///)
      WRITE (6,250)
      WRITE (6,251)
      IF (LUNIT.EQ.2) WRITE (6,255)
      IF (LUNIT.EQ.1) WRITE (6,256)
      IF (LUNIT.EQ.0) WRITE (6,257)
      NL = 0
  200 CONTINUE
      MYEAR=0
C
C********COMPUTE AVERAGE ANNUAL ENERGY OUTPUT.
      AVANEN=TOTGWH/FLOAT(NOYR)
C
C********WRITE OUT FINAL COMPUTATION FIGURES FOR THIS RUN.
      WRITE (6,205) TOTGWH,NOYR,AVANEN
  205 FORMAT (/////5X,'TOTAL ENERGY GENERATED=  ',F10.0,' GWH FOR ',I4,
     7' YEARS OF GENERATION.'//5X,'THE AVERAGE ANNUAL GENERATION= ',
```

Figure I-1 (continued)

```
      8F10.1,' GWH.'///)
       WRITE (6,208) STUTYP
  208 FORMAT (/////5X,'STUDY BASED ON ',20A4///)
  270 WRITE (6,206) REQREL,RULFAC,NFAIL
  206 FORMAT (  ///5X,'DATA COMPILED USING REQUIRED RELEASE OF   ',F7.0,' CFS
     1 CFS AND RULE CURVE DRAWDOWN FACTOR OF ',F5.2//
     25X,'THE NUMBER OF MONTHS WHEN THE MINIMUM WAS NOT MET IS ',I4///)
  500 CONTINUE
       STOP
       END
```

Note: Darkened statements represent those cards which may be removed to produce summary results only, as shown in Figure I-4. Operating the program with the cards left in produces output of the form shown in Figure I-3.

Figure I-1 (continued)

SAMPLE DATA CARDS

```
10000.


  1.


1426700.1357450.1217200.1037400. 918900. 918900. 981970.1296370.1426700.1426700.
1426700.1426700.


CONTENTS     446450. 516400. 589100. 665150. 749800. 842650.
CONTENTS2    938200.1037400.1148700.1276250.1412750.1426700.


ELEVATIONS    1976.1986.1996.2006.2016.2026.2036.2046.2056.2066.2076.2077.


AREAS   6400. 7000. 7600. 8200. 8800. 9300. 9800.10700.11600.12900.14700.15000.


EVAPCO    .07                        .16 .27 .36 .59 .52 .31


   .90    1800.   360400.
```

Figure I-2. Sample data cards for use with computer program.

```
 1
FULL DEVELOPMENT OF ALL LICENSES, PERMITS, AND APPLICATIONS AS OF MAY 1975
  41  2  1.0
192813652.18384.18562.18560.18647.28265.38690.30698.18722. 6839. 5962. 9303.
```

Note: Numbers at tops of columns indicate appropriate columns on data cards.

Figure I-2 (continued)

coefficients for each month, and the power plant characteristics--efficiency, tailwater elevation, and maximum power generating capacity. The appropriate units for each of these quantities are given in the comment statements preceding the program listing. The values for reservoir contents, elevation, and surface area, which are used for interpolating the exact values in the program, should be determined from rating curves or tables for the particular reservoir by dividing the range of contents into 11 intervals and giving the contents, elevation, and area at each interval endpoint. The intervals need not be equal in size, but it is important that the first one be for the reservoir at the top of the dead storage and the 12th one be for the reservoir at full capacity. The values used for Brownlee Reservoir are given in Appendix II. The tailwater elevation should be in the middle range for the releases expected, or should agree with the most common situation, if external conditions affect it (such as water backed up from a pool downstream).

After input of the "background" data, the monthly maximum pool levels are modified by raising them closer to full contents by the fraction of drawdown specified by RULFAC (or lowering them if RULFAC is greater than 1). For example, if the rule curve is desired to be modified to be halfway between maximum drawdown under the existing rule curve and zero drawdown, RULFAC would be specified as .50 (50%). Then the number of runs desired is read in, as well as the type of study and information about the streamflow data to follow. The streamflow data header card should indicate the number of years for which data are given, the units the flows are given in (described by a code--see program listing), and the factor that the flows have all been divided by to make their data card input easier. For example, since it is desirable to have all 12 months' data on one card for each year, flows requiring more than six places should be divided by 10 or 100 to permit fitting them into 6 places; they are then remultiplied by the factors used (DISFAC) before application in the program.

Next, the headings are written out for each of the columns, and internal variables for the program are initialized. Since the reservoir is assumed to start with full contents, CONT (contents), OLDH (last month's power head), and OLDSUR (last month's surface area) are set to the maximum amounts, corresponding to the reservoir being full. Then the required minimum release is converted from cfs to acre-feet for each month, after which the water year and monthly streamflows for the year are read in.

To permit the analysis beginning with the reservoir full in any desired month of the first year (the present study assumed it to be full as of 1 July, the end of Brownlee's spring drawdown season), a check is made to see whether any of the first months should be skipped. If the streamflow for any month during the first year is zero, then the program skips to the end of the loop and looks at the next month.

The reservoir evaporation is then computed by a simplified procedure. Since the reservoir contents affect the surface area, and the surface area affects the evaporation, and the evaporation affects the end-of-month contents, a long iteration process would be required to determine exactly the evaporation from this month's surface area or from the average of last month's and this month's areas. Thus, an approximation is made by estimating the area as last month's surface area alone. In this case, the evaporation was always much less than 1% of the inflow volume, so the error is probably not very significant. After the evaporation is estimated, the tentative contents for this month are computed by subtracting the water lost to evaporation.

Then all the monthly inflows are converted from their input units to acre-feet and the tentative monthly release is determined by adding this month's inflow to the contents and subtracting the allowable contents for the end of this month. This represents the maximum release possible. Next, a check is made to see whether the monthly release computed is below the minimum required, and if so, the release is raised to the minimum level. The contents are then adjusted by the difference between the inflow and release volumes and a check is made to see whether the reservoir has been emptied. If the reservoir is below the dead storage level, the release is reduced to keep the end-of-month contents just equal to the dead storage.

The storage is then computed as the contents stored above the dead storage, and the monthly release is converted from acre-feet to cfs. A rounding-off error of some sort became apparent in the analysis when the total release was set equal to the required release in acre-feet, but it was not equal when converted back to cfs. The difference was very slight, much less than one unit, but it was enough to considerably throw off the count of the months not meeting the minimum. Thus, a statement was introduced to set the monthly release equal to the required release if this situation was indicated.

Once the end-of-month contents have been finally determined, the surface area and elevation of the reservoir are calculated. Then the power head is determined by taking the difference between the reservoir elevation and the tailwater elevation, and the average of last month's head and this month's head is computed. The average power output is then calculated, based on the average head. If the power indicated exceeds the plant generating capacity, it is reduced to the plant capacity and the extra water is spilled. The power generated is converted to megawatts, and the monthly energy output is determined.

A check is then made as to whether this month's release is at or above the required level, and the values for the quantities of interest are written out for this month. For ease of inspection, an asterisk is placed by the month's release if it has failed to meet the minimum requirement, and marks are placed by the contents level to indicate various conditions. If the reservoir is as full as the rule curve permits it to be, an asterisk is placed before the contents. If, in addition, the reservoir is full to capacity, an "F" is placed after the contents (see Figure I-3, a sample page of output giving results for each month).

To complete the loop for the month, OLDH and OLDSUR are set to this month's end-of-month head and surface area, respectively. Computations are then performed in the manner described above for all the other months of

MONTH, WATER YEAR	INFLOW (CFS)	INFLOW (AC-FT)	MIN. RELEASE (AC-FT)	TOTAL RELEASE (AC-FT)	POWER RELEASE (CFS)	SPILL (AC-FT)	MAX. PERM. CONTENTS (AC-FT)	ACTUAL CONTENTS (AC-FT)	LIVE STORAGE (AC-FT)	SURF. AREA (ACRES)	EVAP. (AC-FT)	SURF. ELEV. (FT, MSL)	AVG. POWER HEAD (FT)	AVG. POWER (MW)	ENERGY (GWH)
J 28	5027.	309098.	614876.	614876.	10000.	0.	1426700.	1112071.	665621.	11304.	8850.	2053.	264.9	201.7	150.0
A 28	6207.	381653.	614876.	614876.	10000.	0.	1426700.	872970.	426520.	9459.	5878.	2029.	240.9	183.5	136.5
S 28	7966.	474010.	595041.	595041.	10000.	0.	1426700.	749006.	302556.	8794.	2932.	2016.	222.5	169.4	122.0
TOTAL ENERGY GENERATED THIS YEAR = 408.5 GWH															
O 29	10172.	625452.	614876.	614876.	10000.	0.	1426700.	758965.	312515.	8849.	616.	2017.	216.4	164.8	122.6
N 29	13858.	824608.	595041.	595041.	10000.	0.	1357450.	988532.	542082.	10257.	0.	2041.	229.0	174.4	125.6
D 29	12010.	738466.	614876.	614876.	10000.	0.	1217200.	1112121.	665671.	11304.	0.	2053.	246.9	188.0	139.9
J 29	11610.	713871.	614876.	788591.	12825.	0.	1037400.*	1037400.	590950.	10700.	0.	2046.	249.4	243.5	181.2
F 29	8273.	459459.	555372.	577958.	10407.	0.	918900.*	918900.	472450.	9699.	0.	2034.	240.0	190.2	127.8
M 29	13268.	815817.	614876.	815816.	13268.	0.	918900.*	918900.	472450.	9699.	0.	2034.	234.0	236.4	175.9
A 29	13827.	822763.	595041.	758141.	12741.	0.	981970.*	981970.	535520.	10197.	1552.	2040.	237.2	230.1	165.7
M 29	9520.	585362.	614876.	614876.	10000.	0.	1296370.	949702.	503252.	9904.	2753.	2037.	238.8	181.8	135.3
J 29	9047.	538333.	595041.	595041.	10000.	0.	1426700.	889429.	442979.	9545.	3566.	2031.	234.0	178.2	128.3
J 29	3638.	223692.	614876.	614876.	10000.	0.	1426700.	492613.	46163.	6796.	5631.	1983.	206.7	157.4	117.1
A 29	4541.	279215.	614876.	321844.	5234.*	0.	1426700.	446450.	0.	6400.	3534.	1976.	179.3	71.5	53.2
S 29	6444.	383444.	595041.	381460.	6411.*	0.	1426700.	446450.	0.	6400.	1984.	1976.	176.0	85.9	61.9
TOTAL ENERGY GENERATED THIS YEAR = 1534.3 GWH															
O 30	8628.	530515.	614876.	530067.	8621.*	0.	1426700.	446450.	0.	6400.	448.	1976.	176.0	115.5	86.0
N 30	10873.	646988.	595041.	595041.	10000.	0.	1357450.	498396.	51946.	6846.	0.	1983.	179.7	136.8	98.5
D 30	12277.	754883.	614876.	614876.	10000.	0.	1217200.	638402.	191952.	7989.	0.	2002.	193.0	146.9	109.3
J 30	9055.	556770.	614876.	614876.	10000.	0.	1037400.	580296.	133846.	7527.	0.	1995.	198.6	151.2	112.5
F 30	13315.	739477.	555372.	555372.	10000.	0.	918900.	764401.	317951.	8879.	0.	2018.	206.2	157.0	105.5
M 30	12624.	776219.	614876.	621720.	10111.	0.	918900.*	918900.	472450.	9699.	0.	2034.	225.8	173.8	129.3
A 30	8340.	496264.	595041.	595041.	10000.	0.	981970.	818571.	372121.	9170.	1552.	2023.	228.7	174.1	125.4
M 30	8310.	510962.	614876.	614876.	10000.	0.	1296370.	712180.	265730.	8533.	2476.	2012.	217.5	165.6	123.2
J 30	6415.	381719.	595041.	595041.	10000.	0.	1426700.	495786.	49336.	6823.	3072.	1983.	197.3	150.2	108.2
J 30	3178.	195407.	614876.	240718.	3915.*	0.	1426700.	446450.	0.	6400.	4026.	1976.	179.5	53.5	39.8
A 30	4090.	251484.	614876.	248156.	4036.*	0.	1426700.	446450.	0.	6400.	3328.	1976.	176.0	54.1	40.2
S 30	6072.	361309.	595041.	359325.	6039.*	0.	1426700.	446450.	0.	6400.	1984.	1976.	176.0	80.9	58.3
TOTAL ENERGY GENERATED THIS YEAR = 1136.2 GWH															
O 31	8979.	552097.	614876.	551649.	8972.*	0.	1426700.	446450.	0.	6400.	448.	1976.	176.0	120.2	89.5
N 31	9728.	578856.	595041.	578856.	9728.*	0.	1357450.	446450.	0.	6400.	0.	1976.	176.0	130.4	93.9
D 31	9261.	569436.	614876.	569436.	9261.*	0.	1217200.	446450.	0.	6400.	0.	1976.	176.0	124.1	92.3
J 31	9663.	594154.	614876.	594154.	9663.*	0.	1037400.	446450.	0.	6400.	0.	1976.	176.0	129.5	96.3
F 31	9182.	509942.	555372.	509942.	9182.*	0.	918900.	446450.	0.	6400.	0.	1976.	176.0	123.0	82.7
M 31	10428.	641192.	614876.	614876.	10000.	0.	918900.	472766.	26316.	6626.	0.	1980.	177.9	135.4	100.8
A 31	7231.	430274.	595041.	455530.	7655.*	0.	981970.	446450.	0.	6400.	1060.	1976.	177.9	103.7	74.7
M 31	5340.	328344.	614876.	326616.	5312.*	0.	1296370.	446450.	0.	6400.	1728.	1976.	176.0	71.2	53.0
J 31	4566.	271696.	595041.	269392.	4527.*	0.	1426700.	446450.	0.	6400.	2304.	1976.	176.0	60.7	43.7
J 31	2414.	148431.	614876.	144655.	2353.*	0.	1426700.	446450.	0.	6400.	3776.	1976.	176.0	31.5	23.5
A 31	3214.	197621.	614876.	194293.	3160.*	0.	1426700.	446450.	0.	6400.	3328.	1976.	176.0	42.3	31.5
S 31	5417.	322334.	595041.	320350.	5384.*	0.	1426700.	446450.	0.	6400.	1984.	1976.	176.0	72.1	51.9
TOTAL ENERGY GENERATED THIS YEAR = 833.7 GWH															
O 32	8147.	500939.	614876.	500491.	8140.*	0.	1426700.	446450.	0.	6400.	448.	1976.	176.0	109.1	81.2
N 32	9831.	584985.	595041.	584985.	9831.*	0.	1357450.	446450.	0.	6400.	0.	1976.	176.0	131.7	94.9
D 32	9226.	567284.	614876.	567284.	9226.*	0.	1217200.	446450.	0.	6400.	0.	1976.	176.0	123.6	92.0
J 32	8831.	542997.	614876.	542977.	8831.*	0.	1037400.	446450.	0.	6400.	0.	1976.	176.0	118.3	88.0
F 32	7838.	450847.	575206.	450847.	7838.*	0.	918900.	446450.	0.	6400.	0.	1976.	176.0	105.0	73.1
M 32	15134.	930553.	614876.	614876.	10000.	0.	918900.	762126.	315676.	8866.	0.	2017.	196.7	149.7	111.4
A 32	15478.	921004.	595041.	699742.	11760.	0.	981970.*	981970.	535520.	10197.	1419.	2040.	228.9	204.9	147.6
M 32	16529.	1016328.	614876.	699174.	11371.	0.	1296370.*	1296370.	849920.	13165.	2753.	2067.	253.9	219.9	163.6
J 32	14506.	863166.	595041.	728096.	12236.	0.	1426700.*	1426700.F	980250.	15000.	4740.	2077.	272.2	253.6	182.6
J 32	4299.	264335.	614876.	614876.	10000.	0.	1426700.	1067308.	620858.	10942.	8850.	2049.	262.8	200.1	148.9

Figure I-3. Sample computer program output--monthly.

the year, after which the annual energy production is written out. Then, after all the years of streamflow data have been analyzed, the period-of-record energy production, the average annual energy output, the number of months not meeting the minimum streamflow requirement, and explanatory information relevant to the particular run are printed out. These latter data, shown in Figure I-4, may be written alone, rather than having each month's results printed for the whole period of analysis. Then, if desired (i.e. if NRUNS is greater than 1), another run is made.

B. Input of Data

As indicated, the program is set up now to read all the data from punched cards. If another mode of input is desired for any of the quantities, modifications of the input and/or FORMAT statements in the program will be required. Sample data cards to accompany the program are shown in Figure I-2. The formats to use with each card are described in Table I-1.

```
TOTAL ENERGY GENERATED=      69262. GWH FOR   41 YEARS OF GENERATION.
THE AVERAGE ANNUAL GENERATION=      1689.3 GWH.

STUDY BASED ON FUTURE CONDITIONS

DATA COMPILED USING REQUIRED RELEASE OF   10000. CFS AND RULE CURVE DRAWDOWN FACTOR
    OF  1.00

THE NUMBER OF MONTHS WHEN THE MINIMUM WAS NOT MET IS   82
```

Figure I-4. Computer program output--summary results.

TABLE I-1

FORMATS FOR DATA INPUT

Card No.	Variable	Format
1	REQREL	First 8 columns in card.
2	RULFAC	First 5 columns on card.
3,4	P(I)	First 10 values taking 8 columns each on first, last 2 on second card.
5,6	CONTEN(I)	Skipping first 10 columns on each card, place 6 values in 8 columns each.
7	ELEV(I)	Skipping first 12 columns, place all 12 values on first card in 5 columns each.
8	AREA(I)	Skipping first 6 columns, place all 12 values on first card in 6 columns each.
9	EVAPCO(I)	Skipping first 8 columns, place all 12 values on one card in 4 columns each.
10	EFF, TAILWA, POWMAX	Enter EFF in first 5 columns, TAILWA in next 8, and POWMAX in next 10.
11	NRUNS	First 2 columns on card.
12	STUTYP	May take up to 80 columns on card.
13	NOYR, LUNIT, DISFAC	Enter NOYR in first 4 columns, LUNIT in next 3, and DISFAC in next 5.
14	NYEAR, D(I)	Enter NYEAR in first 4 columns and all 12 values for D on same card, using 6 columns for each.

Note: In FORTRAN, if a decimal point is punched on the card (for the decimal quantities), the number of decimal places on the card need not agree precisely with the FORMAT statement specifications, but the number of columns used must agree.

APPENDIX II

DATA USED IN RESERVOIR REGULATION ANALYSIS

The streamflow data used are presented in Tables II-1 through II-5. Table II-1 gives the historical streamflows for the Snake River at Weiser (USGS gage no 13-2690-00) in cfs-days. Tables II-2 through II-5 give the data from the various flow studies for the Snake River at Weiser, provided by the Idaho Department of Water Resources. All the flows are in cfs. Table II-6 gives the values used for elevation and surface area for Brownlee Reservoir at different levels of storage (contents, actually). Finally the monthly values for EVAPCO at Brownlee, also provided by the state Department of Water Resources, and the values used for power plant efficiency, tailwater elevation and power plant capacity are shown in Table II-7.

HISTORICAL RECORDS--SNAKE RIVER AT WEISER (CFS-DAYS)

W-YR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
28	0	0	0	0	0	0	0	0	0	306560	249650	297880
29	495000	455300	425600	431400	340500	664300	779500	574700	507500	245570	228090	277280
30	342300	498100	491700	456500	485000	419900	427200	516700	384100	235890	254040	277540
31	361060	405000	449700	380500	318400	424400	385260	353510	233770	202410	219250	243050
32	292510	332490	342000	336900	337300	719000	745000	997200	762800	298310	250000	285100
33	343650	368200	379800	364100	325200	449600	522300	573800	813200	272540	259840	287880
34	343670	361200	385900	434600	349200	390300	424900	341610	249140	224500	229050	238550
35	284480	307040	319000	324650	285780	341000	491000	522000	478730	242530	242810	262930
36	292390	314800	307480	342920	354570	441700	1005800	1051900	775010	256480	265670	297720
37	326720	330500	333300	332070	298300	418500	617600	559100	388420	248170	258250	279200
38	334130	361400	466200	390800	382000	709500	1213100	1339200	1075300	596730	281310	304780
39	396800	390800	393400	395100	396600	751900	718600	552800	314670	271270	267630	301370
40	340030	338300	357000	374000	460000	670200	842700	667200	400830	259030	260370	333290
41	382100	396700	398800	399000	426500	542400	510700	588700	589100	286610	305800	336200
42	394600	417000	475000	412600	440400	479300	1003100	791600	746000	320690	286600	338400
43	403300	458400	531800	718900	714100	1051100	1813000	1102700	1395700	768300	339700	357300
44	528300	524800	476800	441000	367800	473700	601300	497700	694400	297580	299070	329980
45	376600	403200	367900	430500	497400	507200	582500	940700	935900	356120	309260	351800
46	424900	525700	604600	613600	500600	916200	1396600	1051600	722200	332820	309110	371300
47	484000	523800	612200	439600	519700	532000	573400	865000	904800	317150	313230	360300
48	453300	446600	489500	519800	447000	434000	653100	905200	1006600	366510	327400	369500
49	408400	388800	468900	497100	574900	867200	705300	749500	540100	313400	327200	364900
50	449300	424400	406200	441800	482500	681600	938500	829100	914900	615470	357100	399500
51	523600	516600	539200	607400	800800	903200	1083600	1185400	764600	412200	384500	385500
52	577900	539800	627600	636800	696600	986000	2057200	1602400	942200	506500	364900	418600
53	452000	376000	392680	585900	519500	616200	608700	652600	1241200	447200	349900	399300
54	445200	425100	447200	470000	470200	567100	699000	692600	605700	380770	349070	384800
55	481000	442900	427800	426400	337500	424300	549600	503100	450900	333250	318180	357500
56	424200	356100	603500	613600	598000	895700	1027000	1114900	1135300	359200	372600	403500
57	522300	471200	478500	442700	571700	960400	1000900	1483000	800400	347400	358600	414700
58	487100	413200	454400	455500	640200	690300	992400	1066700	726600	348400	376900	415400
59	459800	409900	405300	421000	386100	424600	426400	481300	463900	318280	363100	458400
60	485600	398200	404300	375300	416200	574500	557600	538700	476590	316640	364800	382700
61	421800	403100	386300	352100	395800	403600	353480	371000	323210	256760	279120	324470
62	368800	356600	358400	338100	427900	489900	580200	612500	459800	288950	332050	370900
63	492300	430400	453900	391800	533200	387700	476100	607600	995400	324610	330700	397600
64	416100	424200	417100	397700	385700	444500	685500	770800	1017300	340460	337700	398500
65	445700	480500	773400	824100	1167000	1098700	1126200	1206100	889100	471900	433200	435200
66	489500	487400	605900	630500	532500	543700	410500	365100	327740	295510	312690	357500
67	412700	389300	404900	418200	351700	370600	365100	517300	678500	366160	311680	371800
68	450800	465600	489900	473700	557500	441700	324920	336620	380760	280070	401480	373600

TABLE II-1

HISTORIC RECORDS STREAMFLOW DATA USED IN COMPUTER OPERATION STUDY

PRESENT CONDITIONS--SNAKE RIVER AT WEISER (CFS)

W-YR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
28	0	0	0	0	0	0	0	0	0	10263	9631	12038
29	12392	15422	14591	16085	11630	17245	16892	12882	12286	8592	8472	10113
30	11398	11883	13682	11477	16071	15800	12248	12081	10443	8479	8470	9565
31	11459	11365	10999	11249	11161	13405	11348	9052	8641	6858	7243	8756
32	9936	11453	10940	10637	10413	18044	17963	19423	16825	9114	8378	10741
33	12148	12645	12116	11922	12168	13405	14669	14251	17603	8675	8754	10648
34	11822	12512	12305	13290	12708	12740	12881	9409	9028	7843	8229	9364
35	10718	11667	10901	10887	11320	11808	14723	12712	11748	8322	8334	9402
36	11311	11494	10758	11027	11314	13967	23485	20890	14507	8979	8983	10862
37	12046	12564	11811	11707	11428	12732	13732	12916	10795	8427	7720	9770
38	11376	12798	14860	12831	14425	18408	29009	29427	23959	12360	9607	11515
39	13443	13317	14165	12500	13275	19044	19247	13638	10659	8635	8044	11186
40	12118	11967	11670	12577	15489	21471	21493	15421	11099	8522	8297	11398
41	12397	13047	13175	13857	15954	17944	14855	14461	14524	8807	9684	11267
42	12646	13218	14839	12972	14729	15535	21498	17620	18888	9604	9272	11760
43	13108	14482	15280	18976	28519	33791	54609	30788	30519	18464	10516	12237
44	13631	15789	17143	17915	15075	16129	17018	13104	13614	9220	9173	11427
45	12634	14229	13677	13003	16332	16580	17876	20333	18377	9932	9432	11732
46	12755	15214	19447	20003	16761	30787	42645	26354	19690	10116	9792	12493
47	13652	16418	19121	16494	17404	19051	21069	24917	19675	9747	9351	11807
48	13206	14487	15742	16809	15835	15700	18449	24063	27330	10279	9574	11989
49	13109	14701	14873	13446	16008	27886	22513	25801	15439	8844	8658	10796
50	12535	13858	15611	13831	17197	19314	40546	17852	21941	13182	10077	11986
51	15855	21808	20813	19051	28241	30628	39225	32724	19943	10605	10296	12210
52	14929	16452	21715	20368	23338	28413	67962	54423	26033	12403	10127	12632
53	13578	15068	15259	18341	17452	16558	21264	17984	34463	12566	9820	12329
54	13601	14140	15837	14819	15972	18655	29825	21944	19865	10316	9881	11896
55	13311	13478	14253	13646	13287	13730	17806	14964	13761	9091	8945	11156
56	13186	13388	19945	18562	29225	31199	35442	34930	26532	10680	10303	12594
57	14356	16437	17798	18057	20967	26291	37322	46534	25891	10098	9832	12570
58	13690	15338	16250	16536	22430	19186	34223	37617	23999	9829	10529	12641
59	13421	14145	14123	13952	14415	14220	14155	13846	15627	8904	9579	13243
60	14430	12863	12740	12527	14157	19180	21126	15259	16621	8973	9870	11759
61	13269	13391	12540	11896	14443	14191	11827	12118	10327	7790	7891	10399
62	11622	12305	13067	11260	16774	16591	20005	16156	14931	9060	9239	11251
63	14887	14223	14985	12345	19474	14555	17196	17397	29095	9677	9458	12316
64	13318	13982	14093	12517	12751	14985	22851	23519	30173	9740	9701	12278
65	13776	15931	25447	26066	39167	30286	44992	36576	32150	13882	12583	13380
66	15393	19768	19280	19127	16055	17655	14001	11926	10190	8946	9220	11422
67	12939	12750	12757	13493	13141	12542	11693	16298	25616	10492	9748	11858
68	13965	15900	15567	17105	17378	17222	11839	10845	11726	8892	11891	12242

TABLE II-2

PRESENT CONDITIONS STREAMFLOW DATA USED IN COMPUTER STUDY

LICENSES AND PERMITS—SNAKE RIVER AT WEISER (CFS)

W-YR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
28	0	0	0	0	0	0	0	0	0	8224	7417	10379
29	12551	15894	14692	16729	12271	17126	17796	12484	11554	6333	5925	8514
30	11263	12698	13514	11613	15589	14298	12145	12016	9363	6067	6128	7723
31	11345	11604	12200	11654	11420	13659	11769	8655	7789	4231	4596	6675
32	9532	11530	11104	11055	10509	18299	18072	19173	15706	6379	5714	8956
33	12003	13030	12547	12686	12191	13768	14646	14058	16592	5878	6221	8667
34	11842	12992	13217	14335	12950	13274	11939	8814	8166	5310	5200	6479
35	9827	11492	10929	11033	11005	11466	14793	11921	10548	5559	5535	7323
36	10966	11615	10918	11697	11767	14076	22789	19989	14355	6267	6518	9202
37	11802	12775	12154	12002	11211	12950	14629	12350	9799	5761	5316	7930
38	10890	12956	15262	13380	14187	18893	26933	28178	23714	9760	6681	8970
39	12819	14284	14505	13536	13061	19549	18218	12663	9548	6250	6318	9000
40	12199	12310	12304	12952	16239	21557	22135	14611	9851	5915	5708	9479
41	12226	13424	13723	14074	16416	17940	14581	13737	13175	6229	6984	9136
42	12342	13283	15055	13137	14638	15525	20755	17113	17772	6526	6282	9730
43	12549	14468	15225	19043	22094	32267	60687	30735	28380	15951	7513	10202
44	13131	15981	18364	17690	16933	16456	17593	12464	12708	6536	6570	9536
45	12271	14292	13813	13540	16218	16504	17283	19500	18106	7172	6717	9974
46	12180	15331	19138	19344	16882	31476	42492	24382	18857	7436	7003	10748
47	13339	16462	18447	16847	16882	19007	20881	24409	19192	7301	6866	10003
48	12373	13760	16169	15577	16825	15986	18607	22575	25164	7526	6591	9843
49	12466	14660	15074	12991	15613	27477	21850	25576	14408	6042	6105	8818
50	12425	14064	15373	14175	14847	21614	38586	18873	19709	10582	7551	10014
51	13130	22297	22462	18618	26398	29825	38319	31812	20065	7825	7767	10019
52	14348	16573	21552	19506	24585	28761	65228	52316	26934	9611	7211	10318
53	13058	14560	15552	18954	16840	18955	19774	19347	31925	9695	6943	10222
54	13212	14239	16115	15218	17319	19138	28219	21538	19050	7525	6983	10061
55	13040	14119	14492	13248	13077	13488	17396	14574	12435	6319	5901	8897
56	12545	13422	19954	19151	21479	31477	38397	34216	27188	7973	7808	10676
57	14208	16684	18180	17464	21083	26973	35725	45341	26173	7317	7105	10658
58	13137	15280	16289	15338	22238	21045	31359	36464	23405	6905	7695	10567
59	12907	14200	15071	14135	14019	14231	13424	13530	14276	6002	6838	11412
60	14248	13151	14284	13357	14139	20445	20510	15087	15458	6427	7341	9734
61	12460	13544	12883	12193	14413	14202	10971	11286	9008	4840	4861	8024
62	10749	12245	13244	11421	15518	15351	19959	17755	14087	6068	6183	9036
63	14101	13790	15228	12552	19296	14089	17631	16307	28090	6683	6377	10271
64	12369	14107	14463	12981	12901	14657	24385	21951	27167	6750	6782	10293
65	12671	14570	25894	26836	33455	31401	46673	37116	30951	11362	5980	11716
66	13135	19477	21390	18651	16099	18011	13941	11100	9067	5945	6112	8615
67	12177	12813	13047	13769	13016	12688	11512	15454	23651	7370	6442	9555
68	13020	15896	15775	14092	18420	17356	11237	9897	10411	5824	9098	9720

TABLE II-3

LICENSES AND PERMITS STREAMFLOW DATA USED IN COMPUTER OPERATION STUDY

LICENSES, PERMITS, AND APPLICATIONS--SNAKE RIVER AT WEISER (CFS)

W-YR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
28	0	0	0	0	0	0	0	0	0	6839	5962	9303
29	12217	15989	14618	16656	12189	17049	17677	12154	10971	4946	4468	7438
30	10929	12790	13440	11540	15507	14220	12026	11686	8780	4680	4672	6647
31	11011	11699	12127	11624	11403	13742	11605	8322	7203	2841	3137	5596
32	9195	11621	11193	10982	10608	18385	17953	18842	15123	4990	4256	7880
33	11669	13123	12601	12644	12293	13702	14527	13726	16009	4489	4763	7589
34	11508	13085	13307	14233	13051	12848	11818	8480	7581	3920	3740	5398
35	9492	11583	11016	11121	11103	11547	14669	11585	9960	4166	4072	6240
36	10629	11706	11005	11655	11818	14097	22669	19655	13770	4877	5059	8122
37	11469	12869	12137	11980	11313	12893	14150	12017	9214	4371	3857	6850
38	10555	13047	15290	13307	14289	18752	26813	27846	23129	8371	5223	7893
39	12484	14377	14431	13463	12979	19347	18099	12333	8965	4864	4862	7924
40	11866	12405	12395	12879	16160	21575	22014	14278	9266	4525	4249	8401
41	11891	13516	13720	14001	16354	17971	14460	13406	12590	4841	5526	8059
42	12007	13374	14924	13227	14739	15381	20525	16783	17189	5139	4826	8654
43	12215	14563	15152	18970	22149	31942	60558	30402	27795	14561	6053	9124
44	12796	16073	18290	17617	16854	16380	17474	12134	12125	5149	5114	8460
45	11937	14387	13738	13467	16136	16427	17165	19170	17523	5785	5259	8898
46	11847	15426	19066	19269	16800	31400	42373	24052	18274	6049	5547	9672
47	13005	16556	18373	16775	16800	18929	20762	24079	18609	5914	5410	8927
48	12539	13853	16096	15504	16746	15910	18488	22245	24581	6139	5135	8767
49	12132	14755	15000	12919	15531	27400	21731	25246	13824	4655	4649	7742
50	12092	14132	15301	14103	14767	21536	33467	18543	19126	9196	6093	8938
51	12797	22223	22391	18547	26318	29750	38203	31483	19485	6439	6313	8943
52	14014	16666	21478	19433	24506	28685	65109	51985	26351	8224	5755	9242
53	12725	14652	15480	18879	16758	18877	19655	19017	31342	8309	5487	9146
54	12879	14333	16042	15145	17237	19060	28100	21206	18467	6139	5527	8985
55	12706	14214	14418	13176	12996	13411	17277	14244	11852	4932	4445	7821
56	12211	13516	19881	19078	21400	31400	38278	33884	26605	6586	6350	9600
57	13875	16777	18108	17389	21006	26894	35606	45011	25589	5930	5649	9582
58	12803	15373	16216	15264	22158	20967	31242	36132	22822	5518	6239	9491
59	12574	14295	14996	14062	13988	14155	13305	13199	13693	4614	5380	10336
60	13914	13244	14211	13284	14060	20369	20391	14757	14875	5040	5885	8708
61	12126	13639	12866	12120	14515	14285	10850	10953	8423	3450	3402	6941
62	10414	12337	13168	11423	15454	15052	19784	17423	13504	4680	4726	7960
63	13768	13883	15156	12479	19214	14013	17512	15977	27507	5296	4921	9195
64	12036	14200	14390	12909	12822	14579	24268	21619	26584	5364	5326	9217
65	12338	14538	25823	26765	33377	31325	46556	36788	30370	9977	8524	10640
66	12801	19403	21320	18581	16020	17936	13825	10771	8487	4559	4657	7539
67	11843	12906	12974	13697	13010	12771	11390	15121	23063	5978	4980	8476
68	12683	15950	15701	14020	18343	17279	11118	9567	9828	4437	7641	8644

TABLE II-4

LICENSES, PERMITS, AND APPLICATIONS STREAMFLOW DATA USED IN COMPUTER OPERATION STUDY

FUTURE CONDITIONS--SNAKE RIVER AT WEISER (CFS)

W-YR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
28	0	0	0	0	0	0	0	0	0	5027	6207	7966
29	10172	13858	12010	11610	8273	13268	13827	9520	9047	3638	4541	6444
30	8628	10873	12277	9055	13315	12524	8340	8310	6415	3178	4090	6072
31	8979	9728	9261	9663	9182	10428	7231	5340	4566	2414	3214	5417
32	8147	9831	9226	8831	7838	15134	15478	16529	14506	4299	5126	6625
33	9359	10547	9801	9468	9252	11452	11398	10341	15881	3153	4625	6255
34	9141	10564	10394	11715	10422	10367	8430	5420	4648	2646	3572	5076
35	8161	9726	8969	9150	8926	8925	11578	9082	7733	3187	4191	5221
36	8567	9666	8835	9511	8888	11626	19717	17199	10837	3369	3833	6376
37	9336	10245	10118	9462	9509	10307	9099	9134	6876	3133	4036	5817
38	9315	10978	13139	10961	11988	16237	25176	24439	23344	7254	5382	6841
39	10943	11475	10676	10081	10101	14388	14060	9980	6061	3223	4341	7043
40	9273	10249	10179	10605	13901	18337	18475	12141	7699	3083	3694	6772
41	9631	11196	11262	11562	13741	14873	10690	10628	12534	3381	5099	6326
42	9390	11201	13290	10573	12356	11568	17661	13166	15907	3842	4847	6831
43	10385	12720	13830	17336	18659	31241	40537	28007	26835	13356	6188	7757
44	11479	12789	11764	10820	10969	11026	13072	9590	10080	3822	5016	7321
45	10143	11755	10757	11260	14423	13028	13460	17321	14869	4649	5659	7807
46	10150	13607	14910	15047	13109	23830	39930	26059	19111	4717	5880	8261
47	11647	14761	16998	13467	14582	14949	15909	22921	16474	3984	5282	7305
48	11335	13327	13178	13813	13069	12405	14690	16751	23986	4822	5931	7709
49	10455	12934	12099	11211	13077	22802	16615	25420	12160	3641	4381	6651
50	9940	13460	12440	11415	13632	16931	32143	14500	19991	8585	6106	7678
51	11728	18906	18473	16768	25249	27504	35555	27459	18690	5887	6903	8161
52	12849	15144	17074	17791	18866	25551	63531	50754	24476	7620	6570	8527
53	10674	13102	12433	15418	15084	13596	15983	15224	32674	7923	6202	8066
54	10553	13348	12894	12312	12951	14081	20845	20725	17059	5465	6146	7483
55	10563	11983	11428	10844	10297	9714	12939	12053	10806	4448	5473	7275
56	10287	12077	18209	15849	20499	27780	31637	31263	24612	5134	6513	8028
57	11542	14956	14745	11918	18710	21737	31947	40723	24715	4653	6383	8403
58	11375	13793	13996	12835	20559	16307	29260	36489	22425	4911	7070	8707
59	10501	12208	11901	12274	11779	11273	10900	10532	12776	3602	5292	8613
60	13334	11139	10595	10350	11710	15508	15671	11271	14621	3704	5663	7686
61	10291	11469	10357	9407	12440	10921	8201	8703	7468	3217	3644	5992
62	9411	10368	10045	9362	13676	11241	14604	12761	13363	4026	5607	7559
63	12496	12827	12724	10307	16903	9774	11432	12253	19753	4087	5747	7925
64	10517	12395	11041	10391	10002	11313	16897	17002	25841	4797	6242	8102
65	11015	13009	24706	24203	37372	27310	38547	32623	31117	9267	8668	9467
66	12296	15841	16162	16632	13248	13533	12096	8541	6878	4056	4930	7694
67	9798	11061	10780	11263	10277	10115	8266	12111	20274	5183	5322	6903
68	10932	14153	12705	11758	16667	14537	8213	7186	9892	3448	7772	7860

TABLE II-5

FUTURE CONDITIONS STREAMFLOW DATA USED IN COMPUTER OPERATION STUDY

TABLE II-6

RESERVOIR CHARACTERISTICS FOR BROWNLEE RESERVOIR

USED IN COMPUTER OPERATION STUDY

ELEV(1) =1976 ft	CONTEN(1) = 446,450 ac-ft	AREA(1) = 6,400 acres
ELEV(2) =1986 "	CONTEN(2) = 516,400 "	AREA(2) = 7,000 "
ELEV(3) =1996 "	CONTEN(3) = 589,100 "	AREA(3) = 7,600 "
ELEV(4) =2006 "	CONTEN(4) = 665,150 "	AREA(4) = 8,200 "
ELEV(5) =2016 "	CONTEN(5) = 749,800 "	AREA(5) = 8,800 "
ELEV(6) =2026 "	CONTEN(6) = 842,650 "	AREA(6) = 9,300 "
ELEV(7) =2036 "	CONTEN(7) = 938,200 "	AREA(7) = 9,800 "
ELEV(8) =2046 "	CONTEN(8) =1,037,400 "	AREA(8) =10,700 "
ELEV(9) =2056 "	CONTEN(9) =1,148,700 "	AREA(9) =11,600 "
ELEV(10)=2066 "	CONTEN(10)=1,276,250 "	AREA(10)=12,900 "
ELEV(11)=2076 "	CONTEN(11)=1,412,750 "	AREA(11)=14,700 "
ELEV(12)=2077 "	CONTEN(12)=1,426,700 "	AREA(12)=15,000 "

TABLE II-7

EVAPORATION COEFFICIENTS AND BROWNLEE POWER PLANT CHARACTERISTICS USED IN COMPUTER OPERATION STUDY

Evaporation Coefficients

EVAPCO(1) =	.07	acre-ft/acre	(Oct.)
EVAPCO(2) =	-	"	(Nov.)
EVAPCO(3) =	-	"	(Dec.)
EVAPCO(4) =	-	"	(Jan.)
EVAPCO(5) =	-	"	(Feb.)
EVAPCO(6) =	-	"	(Mar.)
EVAPCO(7) =	.16	"	(Apr.)
EVAPCO(8) =	.27	"	(May)
EVAPCO(9) =	.36	"	(June)
EVAPCO(10)=	.59	"	(July)
EVAPCO(11)=	.52	"	(Aug.)
EVAPCO(12)=	.31	"	(Sep.)

Power Plant Efficiency

EFF = .90 (may actually be at high end of range)

Tailwater Elevation

TAILWA = 1800 ft (accurate within 5 ft for flows 0-40,000 cfs)

Power-Generating Capacity

POWMAX = 360,400 kw