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A SENSITIVITY ANALYSIS OF SIMULATED RIVER BASIN PLANNING FOR CAPITAL BUDGETING DECISIONS

by

Gary Ray Wells

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March 1974

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This report was submitted by Gary Ray Wells to the faculty of the University of Utah, Division of Business Administration, in partial fulfillment of the requirements for the Degree of Doctor of Philosophy.

This report is not to be construed as necessarily representing the views of the Federal Government or of the Corps of Engineers, U. S. Army.

PREFACE

The ideas expressed by the writer in this dissertation have evolved during the last five years. The writer's experience while working with the U.S. Army Corps of Engineers, the U.S. Bureau of Reclamation, and the Idaho Water Resource Board helped to generate the initial ideas. Many individuals in these organizations helped to mold the writer's thinking concerning river basin planning.

The writing of papers in the graduate finance seminars clarified the subject of the dissertation and led to the design of the study. In the writer's opinion, meaningful theory should be forged in the furnace of reality. This study offered the opportunity of refining the theory and applying the theory to reality.

Appreciation is extended to the U.S. Army Corps of Engineers and the University Research Committee for their financial support and to the members of my committee and Dr. Bruce F. Baird, Associate Dean, College of Business, for their advice and suggestions.

Special appreciation is extended to William E. Torget, Chief Economics Branch, North Pacific Division, Corps of Engineers, and to Dr. Ramon E. Johnson, Chairman of my committee, for their generous support.

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ABSTRACT

River basin planning for capital budgeting decisions requires a careful analysis of a combination of hydrologic, engineering, economic, and financial considerations. Simulation offers an analytical technique which allows each of these disciplines to be integrated into a model for the evaluation of multi-purpose projects for comprehensive geographic areas. Simulation also offers the opportunity to evaluate a large number of alternatives within less time than a segmented analysis.

The simulation model in this study is applied to the Grande Ronde River Basin which is located in northeastern Oregon. The exogenous variables in this study include: (1) hydrology data as based on 41 years of historical hydrology (uncontrollable exogenous variable); (2) capital sets as determined for three different sizes of two reservoirs or nine combinations (partially controllable exogenous variable); and (3) operating procedures as determined for three scales of irrigation development (partially controllable exogenous variable). The model has been refined to allow for stochastic variation in both the cost data (original outlay, replacement, and annual operation and maintenance) and the benefit data (as related to hydrologic phenomena). The functional relationships for benefits entail relationships between hydrologic phenomena and benefits for seven uses of water. These seven uses include:

(1) irrigation; (2) municipal and industrial water supply; (3) recreation; (4) salmon reared in reservoir; (5) resident trout in reservoir; (6) flood control; and (7) anadromous fish. The endogenous variables resulting from running the model include net present benefits and benefit-cost ratios for nine reservoir combinations and three operating procedures (a decision set of 27).

Analysis of variance is applied to the results from the simulation runs to determine significant differences among capital sets, operating procedures, and combinations of the two.

The results from the runs indicate that some decision sets are clearly superior to others. Operating procedures two (74,000 irrigated acres) and three (92,000 irrigated acres) are superior to one (55,000 irrigated acres) in terms of both net present benefits and benefit-cost ratios. In terms of an optimal set within the model, no one set is obviously optimal. Using analysis of variance at the .05 level of significance, there are no significant differences among the three sets with the highest net present benefits. This analysis, therefore, reduces the choice set from 27 to three.

If the data gathering by various governmental agencies were oriented to the simulation approach, this analytical framework could be applied to a variety of governmental decisions. In the future, water resource development may be expected to carry a significant role in the development of strong analytical techniques for governmental decision making.

I INTRODUCTION

Each year benefit-cost analysis plays a more important role in the governmental decision process at the federal level in the United States. Presently expenditures for just goods and services alone at the federal level account for about 100 billion dollars.[1] In the 1970 calendar year, the Federal Government purchases of goods and services were close to 10 percent of the gross national product. Although water resource projects include only a small portion of this total, the analytical techniques used in their evaluation are beginning to prevail on other areas of the budget.

Statement of the Problem

The application of benefit-cost analysis is rapidly increasing. In the fall of 1965, President Johnson announced to cabinet members and other heads of agencies that a new budgeting system was to be introduced. This system is called the "Planning-Programming-Budgeting System or PPBS." This system incorporates much of the work generated in benefit-cost analysis for water resource development into other areas of governmental decisions. Benefit-cost analysis has been used most extensively for the analysis of water development

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[1] U.S. President, et. al., Economic Report of the President Together with the Annual Report of the Council of Economic Advisers, (Washington, D.C.: Government Printing Office, 1971), p. 197.

projects. Yet, the validity of this tool has been severely criticized in that area where it has been used most extensively.[2] The limitations inherent in benefit-cost[3] analysis as it is applied to water resource development are likely to carry into the applications to other governmental decisions. Arthur Maass points out this consideration.

> The problem is to combine the advanced state of the art of efficiency benefit-cost analysis, as found in water resources planning, with an equally sophisticated technique for relating efficiency benefits and costs to those stemming from other objectives.[4]

During the period 1950-1960, the trend with respect to application of benefit-cost analysis has been toward strict appli-

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[2]Robert H. Haveman, Water Resource Investment and the Public Interest: An Analysis of Federal Expenditures in Ten Southern States (Nashville, Tenn.: Vanderbilt University Press, 1965), p. 117. Haveman points out that, according to his analysis, 63 of 147 projects built in the south from 1946-1962 representing $1,169,000 of committed federal funds (44 percent of the total projects of the Corps of Engineers for the period) should not have been undertaken.

[3]The benefit-cost ratio as it is applied to water resource development is of the following form:

$$R = \frac{\sum \frac{B}{(1+i)^t}}{K + \sum \frac{o}{(1+i)^t}}$$

where R - benefit-cost ratio
B - expected annual benefit
i - rate interest
t - life of project
k - fixed investment cost
o - annual operation, maintenance, and repair cost

[4]Arthur Maass, "Benefit-Cost Analysis: Its Relevance to Public Investment Decisions," Planning, Programming, Budgeting: A Systems Approach to Management ed. William F. Trent and Ernest G. Miller (Chicago: Markham Publishing Co., 1968), p. 223.

cation of economic efficiency on limited projects. More recent emphasis has been toward a more liberal interpretation of benefit-cost applications for multiple purposes and broader areas such as river basins.

Recent emphasis on the need for comprehensive river basin planning for multiple purposes and the limitations of present techniques have resulted in an attempt to formulate various new techniques for analyzing decisions at a more comprehensive level.

Simulation models of river basin systems incorporate the comprehensive viewpoint. The first problem in this study is concerned with the application of the technique of simulation to a given river basin system. The second problem in this study is concerned with the further development of the model to incorporate stochastic processes for capital budgeting decisions into the simulation models.

Objectives

The main objective of this study is to apply the technique of simulation for capital budgeting to a specific geographical location. A second objective is to examine the potential for improvements in the analytical technique. To accomplish these broad objectives, four specific research objectives are identified: (1) to develop a simulation model for the Grande Ronde River Basin; (2) to use the model to analyze the sensitivity of designs and operating procedures for alternative projects in the river basin on resulting benefit-cost relationships; (3) to test hypotheses concerning the results of the simulation runs using analysis of variance; and (4) to refine the model to account

for stochastic variation in the constructs.

Scope of the Research

In geographical scope, the research covers the Grande Ronde River Basin. This Basin is located in the northeastern portion of Oregon. The actual Basin has been determined in cooperation with the U.S. Army Corps of Engineers. This Basin has been selected for several reasons as follows: (1) the Basin is under investigation by the Corps of Engineers for project development; (2) data are available for analytical purposes; (3) the proposed projects in the Basin are multiple purpose projects; and (4) the Corps of Engineers is willing to provide data and financial support for the study. The delineation of the boundary has been determined by the direction of flow of water. Figure I-1 shows the location of the Grande Ronde River Basin.

Scope of the research includes analysis of the entire river basin including hydrology, costs, and benefits for multiple purposes. This analysis covers an in depth examination of relationships and alternatives for capital budgeting decisions and accompanying benefit-cost data through the utilization of a simulation model.

The scope of the project does not include an evaluation of the procedures for generating specific benefits. Musgrave[5] points out some of the limitations and advantages associated with benefit-cost analysis and the associated difficulties inherent in the measurement of benefits.

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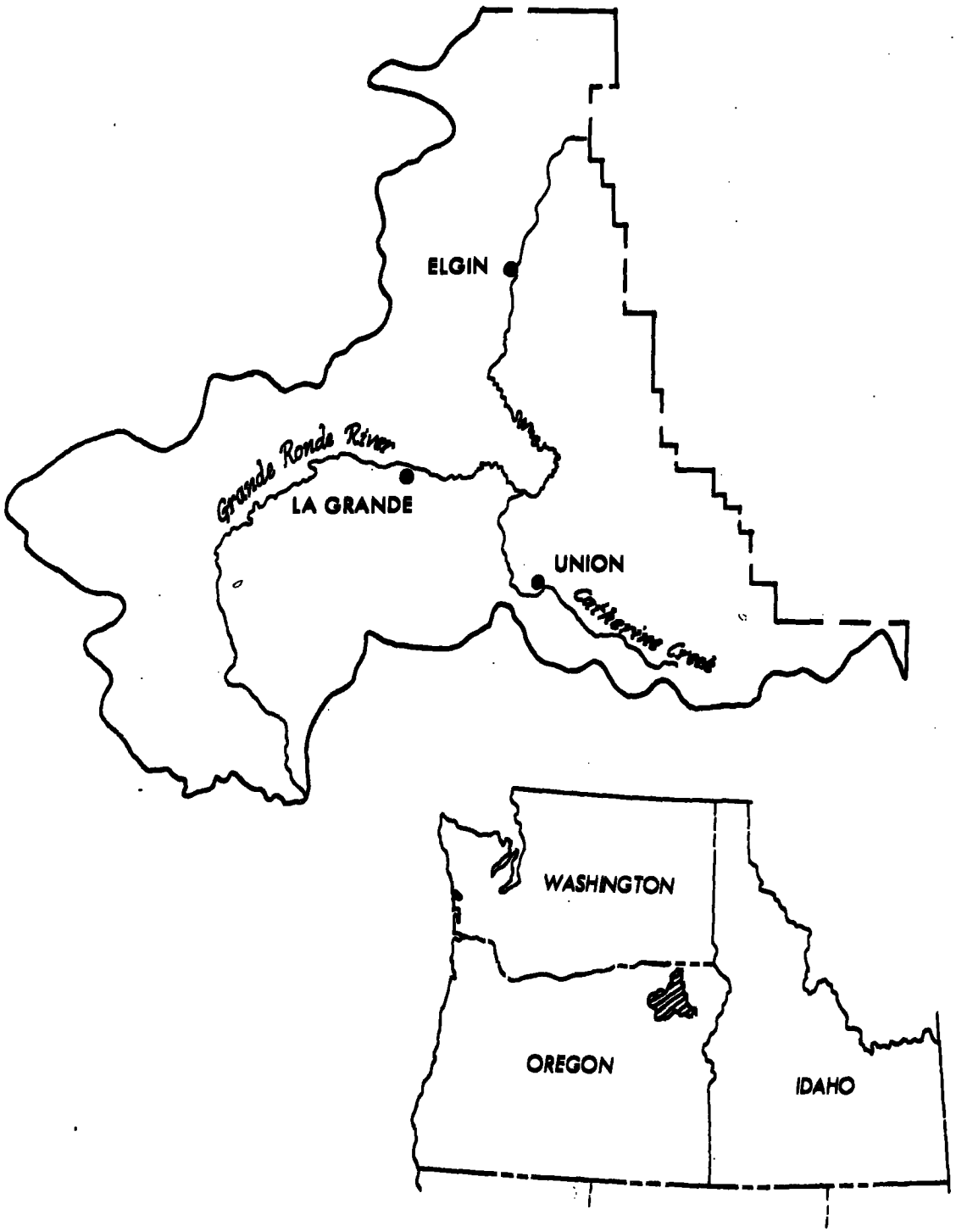
[5] Richard A. Musgrave, "Cost-Benefit Analysis and the Theory of Public Finance," Journal of Economic Literature, VII (September, 1969) pp. 797-806.

FIGURE I - 1

LOCATION OF THE GRANDE RONDE BASIN
IN THE PACIFIC NORTHWEST



The writer is aware of these difficulties and the problems associated with the measurement of benefits. Both the benefits and costs incorporated into this study represent the best estimates of well-informed individuals who are working directly in the area of project evaluations. The scope of the study also excludes the interest rate argument (determination of the correct social time preference or public development discount rate) and argument of project life. The study attempts to relate benefits (as generated by the Corps of Engineers) to the hydrologic phenomena of a given river basin.

General Method of Approach

The major task of the study is to analyze the relationships among capital sets, operating procedures, and benefit-cost derivations for the Grande Ronde River Basin. The capital sets include three sizes for each of two dam sites. The operating procedures comprise the control of the hydrology in the river basin system for three levels of irrigation development.

The simulation model is used to examine the sensitivity of changes in controlled exogenous and selected status variables on the endogenous variables and resulting benefits and costs.

Organization of the Study

The study is organized into six chapters. Chapter II examines the theoretical contributions which provide a framework for both the decisions and objectives. It also analyzes the criteria or objectives set forth by Congress for both water resource development and related economic objectives. Chapter II also presents recent models which have

been used for both water planning and capital budgeting, and this chapter also expresses some results of these models.

Chapter III includes the experimental design, the hypotheses, experimental model, and the method of testing the hypotheses.

Chapter IV contains a description of the simulation model and a flow chart for runs analyzing the river basin system. The form of hydrologic data is set forth in detail, the form of the benefit functions is set forth in detail, and the method of determining the stochastic functions is given.

Chapter V shows the results of the model which are generated with alternative capital designs and alternative operating procedures. Chapter V also shows an analysis of the data which are derived from the computer runs. Statistical tests are applied to the results of the simulation runs.

Chapter VI summarizes the results of the study and examines the implications of the study for river basin planning.

II BODY OF CURRENT THEORY

The Federal Government first entered the water development field during the period 1826-1839.[1] Since that date, the evolution of water resource objectives and the body of theoretical knowledge has been intertwined. As Prest and Turvey point out, the utilization of benefit-cost analysis requires "...drawing on a variety of traditional sections of economic study--welfare economics, public finance, resource economics--and trying to weld these components into a coherent whole."[2]

Early Developments

In the Post Civil War period, recognition of the need to attach benefits with costs became explicit.[3] Flood control and power developments evolved into the sphere of the Federal Government. Comprehensive basin development and multiple purpose planning as concepts for analysis were set forth.

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[1] U.S. Congress, House, Science Policy Research Division, Technical Information for Congress, Report to the Subcommittee on Science Research and Development of the Committee on Science and Aeronautics, 91st Cong., 1st Sess., 1969, p. 430. Chapter 16 of this publication entitled "Congressional Decisions on Water Projects" presents a comprehensive review of water resource development.

[2] A. R. Prest and R. Turvey, "Cost-Benefit Analysis: A Survey," Economic Journal, LXXV (December, 1965), p. 1.

[3] Op. cit., p. 430.

Five sets of benefits were mentioned as follows: "(1) Flood Control; (2) Power; (3) Silt-reduction downstream; (4) Stabilization of low flow (for eventual downstream irrigation and municipal use); and (5) Recreation".[4] Boulder Dam was built under these benefit criteria. The program under the Tennessee Valley Authority serves as an example of comprehensive basin development. During World War II, no new starts were made for water resource projects. Following World War II, the management responsibilities with respect to water resource development became segmented. State, Regional, and Federal jurisdictional divisions became apparent. Agency jurisdictions also became apparent, and in spite of prior emphasis on total basin planning, geographical jurisdictions (different levels of government) and agency jurisdictions (different agencies of government) appeared to negate this objective.

The economic objectives of the nation are set forth in the Full Employment act of 1946. This act specifies that the Federal Government is responsible "to promote maximum employment, production, and purchasing power." Inherent in this responsibility are the three objectives of budget policy as set forth in a simplified framework by Musgrave.[5] These objectives include: (1) allocation of resources (the allocation of resources between the public and private sectors of the economy); (2) distribution of income and wealth (the changes in distribution or redistribution among individuals); and (3) economic stabili-

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[4] Ibid., p. 431.

[5] Richard A. Musgrave, The Theory of Public Finance: A Study in Public Economy (New York: McGraw-Hill Book Company, Inc., 1959), p. 5.

zation (the maintenance of full employment with price stability and growth). This framework provides perspective for viewing the developments concerning objectives and criteria for benefit-cost analysis for water development projects.

The allocation of goods between the public and private sectors might be compared with the strict economic efficiency assumptions inherent in water resource planning. The redistribution of wealth might be compared with the redistributional aspects of congressional activities or equity considerations (either measured by transfers among income brackets or transfers among geographical locations). The economic stabilization might be compared with two phases of benefit-cost analysis as follows: (1) the utilization of expenditures to maintain a full employment level in the economy if the economy is operating at less than full employment (the Keynesian model) and (2) the added benefits provided without the associated costs when there is substantial unemployment. In such a case, the strict economic efficiency assumption does not hold.

Historically, the United States Congress has generated volumes of hearings and evaluations concerning benefit-cost analysis. In examining these writings, one observes conflicting trends as follows: (1) conflicts between public and private development; (2) conflicts between national and regional interest; (3) conflicts among federal agencies; and (4) conflicts between resource development and conservation.

During the period 1950-60, the trend was toward strict application of economic efficiency on limited projects as contrasted with a more liberal interpretation (including indirect benefits) of benefit-cost applications for multiple purposes and broader areas such as river basins. The "Green Book"[6] which was issued in 1950 was composed primarily of quantitative techniques for project evaluation with the emphasis on economic efficiency. However, it did mention that some effects could not be quantified, and these effects should not be overlooked. The interpretation of the "Green Book" became largely one of economic efficiency with rather strict interpretation.

The Bureau of the Budget issued circular No. A-47 on December 31, 1952. The Bureau declared that all reports submitted after July 1, 1953 were to conform to the circular. This circular placed further emphasis on tightening the precision of quantitative benefit-cost analysis.[7]

Circular No. A-47 had a definite "dampening effect" on new starts, and the circular received much criticism because of this effect. Criticisms included:

(a) The inclusion of tax losses incurred by the construction of a project as a cost;

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[6] Subcommittee on Benefits and Costs: Federal Inter-Agency River Basin Committee, Proposed Practices For Economic Analysis of River Basin Projects, (Washington, D.C., n.p., 1950). This is referred to as the "Green Book".

[7] Technical Information for Congress, p. 443.

(b) The arbitrary imposition of a 50-year amortization ceiling on projects presumed to have a longer life;

(c) The emphasis on tangible benefits;

(d) The criterion that projects not incorporate power generation features unless power could be produced from them more cheaply than by any alternative federally financed source;

(e) The shift from the incremental method to the separable costs-remaining benefits method of figuring costs and benefits of hydroelectric plants.[8]

Benefit-cost analysis became central to many of the conflicting issues. In 1959, the Select Committee on National Water Resources was established. The efforts of this committee were directed largely toward the supply and demand for water. Their report stressed the need for Federal, Basin, and State planning for comprehensive water resource development.

Water Planning Objectives

As early as 1955, Jewell J. Rasmussen[9] pointed out the need for comprehensive basin planning for multipurpose projects.

On May 29, 1962, a new set of policies and procedures for the development of water resources was set forth in Senate Document No. 97. This document set forth the objectives of planning as follows:

---

[8] Ibid., pp. 444-445.

[9] Jewell J. Rasmussen, "Criteria for Determining the Economic Justification of Water Development Projects" (paper presented to the American Society of Civil Engineers Irrigation and Drainage Subdivision, Denver, Colorado, Sept., 8, 1955).

A: Development

National economic development, and development of each region within the country, is essential to the maintenance of national strength and the achivement of satisfactory levels of living.

B: Preservation

Proper stewardship in the long-term interest of the nation's natural bounty...

C: Well-being of people[10]

Senate Document No. 97 differs substantially from Circular A-47. The emphasis shifts toward relaxing the assumptions of strict economic efficiency and shifts toward the inclusion of intangible benefits. Emphasis also shifted to inclusion of multipurpose planning, and the permissible period of analysis was extended from 50 years to 100 years. The emphasis became that of "stewardship" toward natural resources and development based on needs.

Senate Document No. 97 stresses the importance of comprehensive basin planning with multipurpose projects for water resource development.

Recent River Basin Planning

Recent emphasis on the need for comprehensive river basin planning for multiple purposes and the limitations of present techniques have resulted in an attempt to formulate various new techniques for analyzing decisions at a more comprehensive level.

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[10] U.S. Congress, Senate, Policies, Standards and Procedures in the Formulation, and Review of Plans for Use and Development of Water and Related Land Resources, S. Doc. 97, 87th Cong., 2nd Sess., 1962.

The Harvard Water Program[11] utilized simulation techniques as applied to a simplified river basin system. This project utilized a hypothetical river basin system with hydrology based on the Clearwater River in northern Idaho. This study illustrates the merits of utilizing such a technique for project design. The authors point out that

> ...We must acknowledge that at this stage of development the models are embryonic and that substantial simplification is required in their use.
>
> The science of production economics is not sufficiently advanced to deal fully with complex stochastic functions such as those created by the variable nature of streamflow. Hence the task of uniting engineering and economics in system design is a formidable one. We have made certain contributions to this area of knowledge, we believe, but we hasten to point to the need for considerably more research.[12]

In a later study which was completed in 1966 under the Harvard Water Program, the technique of simulation was applied to the Lehigh River system and the Delaware Basin.[13] This study utilizes simulation to attempt to evaluate the changes in hydrology on benefit-cost relationships. The authors conclude that simulation would probably be useful in the detailed planning stage.[14] The required inputs for simulation are more likely to be available at the detailed planning stage. The technique also appears to be useful to test alternative project and

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[11] Arthur Maass, et.al., Design of Water Resource Systems (Cambridge, Mass.: Harvard University Press, 1962).

[12] Ibid., p. 8.

[13] Maynard M. Hufschmidt and Myron B. Fiering, Simulation Techniques for Design of Water Resource Systems (Cambridge, Mass.: Harvard University Press, 1966).

[14] Ibid., p. 198.

system designs. The authors point out that "One possibility that remains to be explored is the development of simulation programs to serve as tools both for design and for system operation."[15]

Another simulation model was completed for the Calapooia River Basin. This model was less comprehensive than the Harvard study. The Calapooia study utilized the DYNAMO model to evaluate a combined dam and channel capacity. The model provides valuable insight concerning the potential for simulation for river basin planning.

The authors of the Calapooia study conclude:

> (1) Simulation as an approach to river basin planning appears to be promising. It appears to be the only way comprehensive planning can occur, if in fact comprehensive planning can be done. Simulation provides a visible integration of the hydrology and the technology with economics of a planning problem and illustrates how all three aspects affect the operation of a system and vice versa.
>
> (2) Simulation is a practical approach to the piecemeal planning philosophy wherein trial and error leads to improvement in the systems operation.
>
> (3) Simulation appears to be a method of encouraging the assembling of all relevant information and data that may impinge upon the development of a comprehensive plan.
>
> (4) Simulation encourages the planner to be explicit about his assumptions.[16]

Capital Budgeting

During the first part of the decade of the 1950's, Frederich and

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[15] Ibid., p. 200.

[16] A. N. Halter and S. F. Miller, River Basin Planning: A Simulation Approach (Corvallis, Ore.: Agricultural Experiment Station and Oregon State University, 1966), p. 84.

Vera Lutz[17] summarized and expanded the body of theory dealing with capital budgeting. During this same period, Joel Dean[18] completed his work in the area of capital budgeting. These two works provided much of the thrust for the implementation of strong analytical techniques in the area of capital budgeting during the 1950's and 1960's.

An analytical technique for dealing with risk and uncertainty[19] is still one of the controversial areas in finance. The concept of risk and uncertainty was explored by Lutz and Lutz in their classical work[20] which indicates a need for using a probabilistic approach for capital budgeting decisions. The Lutz and Lutz book points out, however, that in practice because of the lengthy computations based on a

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[17] F. Lutz and V. Lutz, Theory of Investment of the Firm (Princeton, N.J.: Princeton University Press, 1951).

[18] Joel Dean, Capital Budgeting: Top-Management Policy on Plant, Equipment, and Product Development (New York: Columbia University Press, 1951).

[19] The literature in the area of finance contains some confusion concerning definitions of "risk" and "uncertainty". Under "certainty", there is only one outcome to a particular course of action, and this outcome is known. Under "risk", some authors specify that there are two or more outcomes, and the probability of each is known, but under "uncertainty", the probabilities are not known. Other authors use the words "uncertainty" and "risk" as substitutes for one another since decision makers have some feeling about the probability of future events and are neither completely ignorant nor do they know the probabilities of future events. For an example of the latter use, see C. Jackson Grayson, Jr., "The Use of Statistical Techniques in Capital Budgeting", Financial Research and Management Decisions, ed. by Alexander A. Robichek (New York: John Wiley and Sons, 1967), pp. 90-91. Grayson uses the terms "uncertainty" and "risk" interchangeably. This study will adhere to the latter definition and use "risk" and "uncertainty" interchangeably.

[20] Lutz and Lutz, Theory of Investment of the Firm, pp. 179-192.

large number of probability distributions, "...the mere burden of the work of making such accurate calculations constrains him (the decision maker) to use much cruder methods."[21]

Through the use of computer simulation, the burden of the work of making such calculations can be removed.

Recent Capital Budgeting Models

During the first half of the decade of the 1960's, the analytical techniques for the inclusion of risk in the capital budgeting area were critically evaluated and expanded. Frederick Hillier pointed out that procedures generally in use "...suffer the disadvantage of suppressing the information regarding the risk of the proposed investment."[22] Hillier indicated that for capital budgeting purposes "...in addition to an estimate of the expected value of a prospective cash flow, the inexactitude of the estimate (should) be described by an estimate of the standard deviation."[23]

John F. Magee[24,25] illustrated a method of examining capital budgeting relationships for alternative investments over time. Magee

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[21] Ibid., p. 192.

[22] Frederick S. Hillier, The Derivation of Probabilistic Information for Evaluation of Risky Investments," Management Science, IX No. 3 (April, 1963), p. 444.

[23] Ibid., p. 456.

[24] John F. Magee, "Decision Trees for Decision Making," Harvard Business Review, XLII (July-August, 1964), pp. 126-138.

[25] John F. Magee, "How to Use Decision Trees in Capital Investment," Harvard Business Review, XLII (September-October, 1964) pp. 79-96.

used an expected value approach with decision trees to evaluate capital investment over time. A main advantage of this approach to capital budgeting is its ability to recognize explicitly each of the outcomes and to provide an expected present value cash flow figure for each outcome. A limitation of the decision tree approach is that it does not provide information concerning the risk associated with the outcomes.

The data utilized for the evaluation of capital budgeting decisions are usually accompanied by uncertainty. David B. Hertz pointed out that "Each assumption involves its own degree--often a high degree--of uncertainty; and taken together, these combined uncertainties can multiply into a total uncertainty of critical proportions."[26] The user of the single value estimate may be only vaguely aware of the relative risks associated with a given alternative or among a set of alternatives.

Hertz proposed the development of a frequency distribution or probability curve for the possible ranges of values of each of the input factors in the analysis of a capital budgeting decision.[27] The results include sets of subjective probability distributions. During computer simulations runs, each value in the range can be weighted by its chance of occurence.

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[26] David B. Hertz, "Risk Analysis in Capital Investment," Harvard Business Review, XLII (January - February, 1964), p. 95.

[27] Ibid., See page 102 for a pictoral display of a simulation for investment planning.

In a later work, Hespos and Strassman[28] combine the analytical frameworks of the decision tree and risk analysis. The Hespos and Strassmann model (stochastic decision trees) captures the advantages of both decision trees and risk analysis. The stochastic decision tree offers features as follows:

1. All quantities, including chance events, can be represented by continuous, empirical probability distributions.
2. The information about the results from any or all possible combinations of decisions made at sequential points in time can be obtained in a probabilistic form.[29]

The analytical framework of the stochastic decision tree offers the analyst the capability of evaluating the results from all possible combinations of decisions.

Although both the partially developed analytical framework and the physical capability (high speed computers) are available, simulation for the use of sensitivity analysis for governmental decision making in water resource development is limited. To the writer's knowledge, sensitivity analysis is not being used in that area of governmental decision making where much of the structure of benefit-cost analysis originated.

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[28] Richard F. Hespos and Paul A. Strassmann, "Stochastic Decision Trees for the Analysis of Investment Decisions, "Management Science, XI (August, 1965), pp. 244-259.

[29] Ibid., p. 253.

III EXPERIMENTAL DESIGN

The question to be answered by the model is as follows: What are the effects of changes in sets of capital and operating procedures on the resulting benefits and costs for the development of a given river basin system? An important aspect of the model includes an attempt to assess the relative risks associated with a given project and with changes in sets of capital and operating procedures.

Experimental Model

One method of answering the above question is the use of a simulation model. The model serves as an abstraction of the important relationships which exist in the actual system. The elements of a model can be separated into components, variables, and functional relationships.[1] Components of a model can include major sectors of the system or the entire system. Variables can be further separated into exogenous variables, status variables, and endogenous variables. Exogenous variables arise outside the component. Status variables describe the component at a given point in time. Endogenous variables are generated by the component. The functional relationships express the way in which the variables are related to one another.

Component for the Study

The component for this study is a river basin system (The Grande

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[1] Guy H. Orcutt, "Simulation of Economic Systems," The American Economic Review, L (December, 1960), pp. 893-907.

Ronde River Basin).

The exogenous variables for this study are amounts of capital, operating procedures, and hydrologic data. The amounts of capital including associated probability distributions are examined for original outlay costs, periodic replacement costs, and operation and maintenance costs.

Functional Relationships

The functional relationships for this study include the relationships among amounts of capital, operating procedures, and resulting benefits for seven major uses. These uses include the following: (1) irrigation, (2) anadromous fish, (3) recreation, (4) resident trout in reservoir, (5) salmon reared in reservoir, (6) municipal and industrial water supply, and (7) flood control.

Functional relationships describe the interactions among the variables of the component. These relationships apply to the analysis of the river basin system as follows: (1) size of investment and associated probability distribution (exogenous--partially controllable); (2) hydrologic flows (exogenous uncontrollable); (3) diversion requirements (status--partially controllable); and (4) benefit-cost relationships (endogenous--resulting from the simulations).

General Hypotheses

The hypotheses of this study are concerned with the effects of changes in the controllable exogenous variables (capital sets and operating procedures) on the endogenous variables.

In general, the null hypotheses are set forth as no significant differences in mean net present benefits and benefit-cost ratios for alternative reservoir combinations and operating procedures. The alternate hypotheses are expressed in the form of significant differences in mean net present benefits and benefit-cost ratios associated with alternative reservoir combinations and operating procedures. The individual hypotheses are stated explicitly in Chapter V.

Purpose and Methodology of Simulation

The methodology of the study is probabilistic utilizing historical hydrologic data for simulation of water flows and probability distributions for amounts of capital investment and annual operation and maintenance costs.

The purpose of the study is to assess the effects of changes in the controllable exogenous variables on the endogenous variables. The results will be tested for significant differences at the .05 level of significance using analysis of variance in Chapter V.

The value of simulation lies in its ability to aid in the understanding of the relationships among the variables of complex systems and to provide more meaningful analysis of alternatives concerning the design or use of such systems. The utility of simulation has been improved substantially through the use of the computer. In fact, simulation of complex systems can be accomplished only through the use of the computer.

River Basin Simulation Model

As mentioned, the hypotheses to be tested by the model include two major relationships. One relationship is concerned with capital sets. Another relationship is concerned with operating procedures. The capital sets for the model include three different scales for two different reservoirs. The capital sets include a combination of three reservoir sizes taken two at a time, or nine capital sets. Three different levels of operating procedures are examined within the system. These three operating procedures are concerned with three alternative levels of agricultural development within the basin and their required diversions for development. The resulting set entails 27 different combinations of reservoir sizes and operating procedures. These 27 combinations require 27 different computer runs to determine the resulting benefits. A matrix of these 27 combinations is shown in Table III-1.

Capital Budgeting Simulation Model

The benefits resulting from the river basin simulation are used as input for the capital budgeting simulation model. A set of costs is associated with each reservoir combination. These costs and benefits serve as the input for a sensitivity analysis of each of the 27 combinations. A discounted cash flow model using the probability distributions of benefits, initial outlay costs, replacement costs, and annual operation and maintenance costs serves as the framework for the analysis.

TABLE III-1

MATRIX SHOWING THE COMBINATIONS OF OPERATING PROCEDURES AND RESERVOIR SIZES FOR COMPUTER RUNS

Operating Procedures	Reservoir Size Combinations[a]								
	1,4	1,5	1,6	2,4	2,5	2,6	3,4	3,5	3,6
1	141	151	161	241	251	261	341	351	361
2	142	152	162	242	252	262	342	352	362
3	143	153	163	243	253	263	343	353	363

[a]Size designations for the first reservoir (Catherine Creek) are designated as 1, 2, and 3. Size designations for the second reservoir (Grande Ronde) are designated as 4, 5, and 6. An example of a given combination is as follows:

Catherine Creek - size 1
Grande Ronde - size 4
Operating Procedure - number 1
1 4 1

The results from the capital budgeting runs include a probability distribution of the net present benefits for each of the 27 combinations.

Tests of Hypotheses

The results of the 27 computer runs are tested for significant differences at the .05 level using analysis of variance. The results from the runs also offer a picture of the risk associated with the individual combinations and the project as a whole. The probability of any combination's being successful, (having a positive net present benefit) can be examined carefully for each of the combinations.

Summary

This chapter describes the experimental design for the models and the hypotheses for the models. Chapter IV gives a complete description of variables and functional relationships included in the models. These variables and functional relationships provide the input for both the river basin simulation model and the capital budgeting model. Chapter IV also provides a flow chart for the computer runs.

IV DESCRIPTION OF THE MODEL

The analytical framework for the study is a probabilistic decision model. The dynamics of the model are generated by moving the system through time with computer simulation.

Capital Sets

Early in the investigation of a river basin, attempts are made to evaluate all of the potential sites for development. Each of the potential dam sites is evaluated somewhat crudely. Those sites with extremely inferior cost-benefit-relationships are eliminated at this stage.

The remaining sites are subjected to a more rigorous analysis in an attempt to determine the design with the highest benefit-cost relationship. At the present stage of investigation of the Grande Ronde Basin, three different designs for each of two reservoir sites appear to merit consideration. These three designs for each reservoir site comprise the nine combinations of design sets for the simulation model. The reservoir sizes for the Grande Ronde Reservoir are listed in Table IV-1, and the reservoir sizes for Catherine Creek are listed in Table IV-2.

TABLE IV-1

PROPOSED DAM SIZES FOR CATHERINE CREEK RESERVOIR[a]

Identification Number	Reservoir Size (acre feet)
#1	42,000
#2	65,000
#3	87,000

[a]U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, Washington.

TABLE IV-2

PROPOSED DAM SIZES FOR GRANDE RONDE RESERVOIR[a]

Identification Number	Reservoir Size (acre feet)
#4	160,000
#5	190,000
#6	220,000

[a]U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, Washington.

Original Outlay, Replacement, and Annual Operation and Maintenance Costs

The costs associated with each design set (reservoir size) are estimated by the design engineers. The accuracy of each component of costs has been estimated for the purposes of this study. These costs and associated accuracies have been obtained from a civil engineer in the project planning section at Walla Walla, Washington's District Corps of Engineer's office. The costs and associated accuracies of different size reservoirs for Catherine Creek Dam and Grande Ronde Dam are listed in Table IV-3, IV-4, IV-5, and IV-6. Once a design set is selected, these associated costs and accuracies serve as uncontrollable endogenous variables for the system for the one hundred year life of the project. The discount rate for evaluation of the relationships includes the 3¼ percent established by Congress for the project.

Environmental Inputs-Hydrology

The hydrology data are uncontrollable exogenous variables for the model. The hydrology data (defined as surface water flows in this study) are available by month for six stations for 41 years for the Grande Ronde Basin. A period for the hydrologic analysis in the study is a specific month. The flow diagram for the hydrology appears in Chart IV-1. This flow diagram is the flow diagram used for controlling the computer simulation of water flows through the Grande Ronde River Basin. The flow diagram contains two reservoirs, six inflow points, twelve diversions, and twelve control points. The reservoir

TABLE IV-3

COST ESTIMATES FOR ANNUAL OPERATING EXPENSE AND ORIGINAL OUTLAY COSTS FOR ALTERNATIVE SIZES FOR CATHERINE CREEK RESERVOIR[a]

Reservoir Size (acre feet)	Annual Operation and Maintenance Expense		Original Outlay	
	Accuracy[b] (percent)	(dollars)	Accuracy of Component[b] (percent)	Cost of Component (dollars)
42,000	±20	138,500	±50	50,000[c]
			±40	120,000[d]
			±35	307,200[e]
			±33	91,500[f]
			±30	732,000[g]
			±25	1,810,700[h]
			±20	3,195,400[i]
			±15	1,155,300[j]
			±10	1,580,400[k]
				9,042,700
65,000	±20	138,500	±50	50,000[c]
			±40	130,800[d]
			±35	346,800[e]
			±33	99,800[f]
			±30	762,600[g]
			±25	1,696,500[h]
			±20	3,990,000[i]
			±15	1,406,700[j]
			±10	1,699,500[k]
				10,182,700

TABLE IV-3--Continued

Reservoir Size (acre feet)	Annual Operation and Maintenance Expense: Accuracy[b] (percent)	Annual Operation and Maintenance Expense: (dollars)	Original Outlay: Accuracy of Component[b] (percent)	Original Outlay: Cost of Component (dollars)
87,000	±20	138,500	±50	50,000[c]
			±40	142,800[d]
			±35	376,800[e]
			±33	109,350[f]
			±30	805,600[g]
			±25	1,682,300[h]
			±20	4,733,300[i]
			±15	1,574,800[j]
			±10	1,867,200[k]
				11,342,150

[a]Calculated from: Engineer's Estimate, Catherine Creek Dam and Reservoir - Scoping Study, June 24, 1970.

[b]Accuracy of estimates was determined by Walter Styner, Civil Engineer, Project Planning Section, Planning Branch, Walla Walla District, Corps of Engineers, Walla Walla, Washington, December 17, 1970. The accuracy of each cost estimate is based on the assumption that the distribution of the estimate is normal. The percent deviation (e.g. ± 50%) is the expected deviation within a 90 percent confidence level. Engineering, supervisory, and administrative costs are estimated as 20 percent of original outlay costs. Estimated construction time is 3½ years.

[c]This component includes dewatering of core trench.

[d]Items in this component include: foundation curtain, drilling, and grouting.

[e]This component includes rock excavation for tunnel.

TABLE IV-3--Continued

[f]Items in this component include: land and improvements under lands and damages; and land for fish and wildlife under lands and damages.

[g]Items in this component include: excavation of rock under relocations; reservoir boundary survey; stripping and excavation for dam; core excavation of rock; gates, hoists, and electrical system; electrical installation, hatches and airvents; range management fencing and non game fish control; entrance gate, operating equipment and piping; grading and landscaping; miscellaneous permanent operating equipment; plug for bypass; and temporary fish transportation.

[h]Items in this component include: excavation of rock for spillway; bridge over spillway; bulkhead gate, slide gates, gate guides, selector gates and trash rocks; valve installation; concrete for structures and pier for bridge and tower; slide gates for fish and fish transportation facilities; concrete for fish passage; hoist guides and transfer pipe; recreation facilities and bridge; water supply and distribution; hydrologic reporting network; stripping for cofferdam; and bulkhead gate for diversion tunnel.

[i]Items in this component include: relocations including common excavation, embankment, base course, culverts, bridge, and road relocation; reservoir clearing: dam including gravel, rockfill, and core excavation; mass concrete for spillway, drains, weepholes, excavation, levee fill, and riprap; outlet works including concrete conversions and trash rocks, excavation, steel spray shield, access road to tower, recreation access road, circulatory road, site roads, power lines, telephone lines, cofferdam filter zone and impervious, concrete lining for diversion tunnel; and rock bolts.

[j]Items in this component include: impervious core, floors and walls, and foundation preparation for dam; fence; concrete slab for bridge tower and fish trappings; concrete floors and walk for fish passage; service buildings and operator's house; bypass for diversion tunnel; and excavation for diversion channel.

[k]Items in this component include: administrative acquisition costs for lands and damages; leveling course and surface for relocations; guardrail, clearing and grubbing for dam; sand filter and gravel filter for dam; slurry grout and foundation preparation, crushed rock, mass concrete for chute and pier, and reinforced steel, and cement for dams, bridge tower, and fish passage.

TABLE IV-4

COST ESTIMATES FOR REPLACEMENT COSTS FOR COMPONENTS FOR CATHERINE CREEK RESERVOIR[a]

Accuracy of Component[b] (percent)	Life of Component (years)	Cost of Component (dollars)
±30%	40	60,000[c]
±30%	25	30,000[d]
±25%	40	443,000[e]
±25%	25	82,600[f]
±25%	10	18,000[g]
±20%	40	118,000[h]
±15%	50	67,000[i]

[a]Calculated from: Engineer's Estimate, Catherine Creek Dam and Reservoir - Scoping Study, June 24, 1970.

[b]Accuracy of estimates was determined by Walter Styner, Civil Engineer, Project Planning Section, Planning Branch, Walla Walla District, Corps of Engineers, Walla Walla, Washington, December 17, 1970. The accuracy of each cost estimate is based on the assumption that the distribution of the estimate is normal. The percent deviation (e.g. ± 30%) is the expected deviation within a 90 percent confidence level.

[c]Items included in this component are hatches and airvents.

[d]This component includes miscellaneous operating equipment.

[e]Items included in this component are valve installation, machinery in well, water pumps, and fingerling transfer pipe.

[f]Items included in this component are bucket transfer trolley, transfer frame, diffusion grating, filling pump controls and pipe, and hydrologic reporting network.

TABLE IV-4--Continued

[g]This component is a tank truck.

[h]This component is a steel spray shield.

[i]Items in this component include: garage, service building, and operator's house.

TABLE IV-5

COST ESTIMATES FOR ANNUAL OPERATING EXPENSE AND ORIGINAL OUTLAY COSTS FOR ALTERNATIVE SIZES FOR GRANDE RONDE RESERVOIR[a]

	Annual Operation and Maintenance Expense		Original Outlay	
Reservoir Size (acre feet)	Accuracy[b] (percent)	(dollars)	Accuracy of Component[b] (percent)	Cost of Component (dollars)
160,000	±20	233,000	±50	50,000[c]
			±40	456,000[d]
			±30	382,200[e]
			±25	2,414,000[f]
			±20	7,842,800[g]
			±15	1,522,400[h]
			±10	1,379,800[i]
				14,047,200
190,000	±20	233,000	±50	50,000[c]
			±40	488,000[d]
			±30	391,200[e]
			±25	2,500,300[f]
			±20	8,967,500[g]
			±15	1,620,600[h]
			±10	1,528,100[i]
				15,545,700

TABLE IV-5--Continued

Reservoir Size (acre feet)	Annual Operation and Maintenance Expense: Accuracy[b] (percent)	Annual Operation and Maintenance Expense: (dollars)	Original Outlay: Accuracy of Component[b] (percent)	Original Outlay: Cost of Component (dollars)
220,000	±20	233,000	±50	50,000[c]
			±40	520,000[d]
			±30	407,700[e]
			±25	2,479,000[f]
			±20	10,539,200[g]
			±15	1,753,200[h]
			±10	1,705,200[i]
				17,454,300

[a]Calculated from: Engineer's Estimate, Lower Grande Ronde Dam and Reservoir - Scoping Study, June 29, 1970.

[b]Accuracy of estimates was determined by Walter Styner, Civil Engineer, Project Planning Section, Planning Branch, Walla Walla District, Corps of Engineers, Walla Walla, Washington, December 17, 1970. The accuracy of each cost estimate is based on the assumption that the distribution of the estimate is normal. The percent deviation (e.g. ± 50%) is the expected deviation within a 90 percent confidence level. Engineering, supervisory, and administrative costs are estimated as 20 percent of original outlay costs. Estimated construction time is 3½ years.

[c]This component includes dewatering core trench.

[d]Items in this component include drilling and grouting.

TABLE IV-5--Continued

[e]Items in this component include: reservoir boundary survey, stripping for dam, electrical installation, elevator stairways, doors and hatches; valve installation; fencing for fish and wildlife; non game fish control, grading and landscaping of buildings and grounds; miscellaneous operating equipment; and fish transportation facilities.

[f]Items in this component include: access road, land, excavation of rock, gates, and guides; concrete for base, wall and pier; fish bucket, tank for bucket, frame steelwork, pump controls, machinery in well, water pumps, and fingerling transfer pumps; recreational facilities; water supply distribution; hydrologic reporting network; and stripping for cofferdam.

[g]Items in this component include: relocation of highways and utilities, reservoir clearing, excavation for dam; mass concrete for dams, anchor bars, concrete trash racks, and drains; steel spray shield, riprap, and concrete structure for fish trapping; circulatory roads, site roads, access roads, power line; telephone line; and filter zone.

[h]Items in this component include impervious fill, clearing and grubbing, backfill, foundation preparation, concrete for floors and walls, deck and surfacing, concrete slab for fish trapping; and garage, service building, and operator's house.

[i]Items in this component include administrative acquisition costs for lands and damages; and structural concrete, reinforced steel, and cement for dam.

TABLE IV-6

COST ESTIMATES FOR REPLACEMENT COSTS FOR COMPONENTS FOR GRANDE RONDE RESERVOIR[a]

Accuracy of Component[b] (percent)	Life of Component (years)	Cost of Component (dollars)
±30%	40	105,000[c]
±30%	25	30,000[d]
±25%	40	420,000[e]
±25%	25	110,400[f]
±25%	10	18,000[g]
±20%	40	223,600[h]
±15%	50	67,000[i]

[a]Calculated from: Engineer's Estimate, Lower Grande Ronde Dam and Reservoir - Scoping Study, June 29, 1970.

[b]Accuracy of estimates was determined by Walter Styner, Civil Engineer, Project Planning Section, Planning Branch, Walla Walla District, Corps of Engineers, Walla Walla, Washington, December 17, 1970. The accuracy of each cost estimate is based on the assumption that the distribution of the estimate is normal. The percent deviation (e.g. ± 30%) is the expected deviation within a 90 percent confidence level.

[c]Items in this component include elevator stairways, doors, hatches, and valve installation.

[d]Items in this component include miscellaneous permanent operating equipment.

[e]Items in this component include machinery in well, water pumps, and fingerling pipe.

TABLE IV-6--Continued

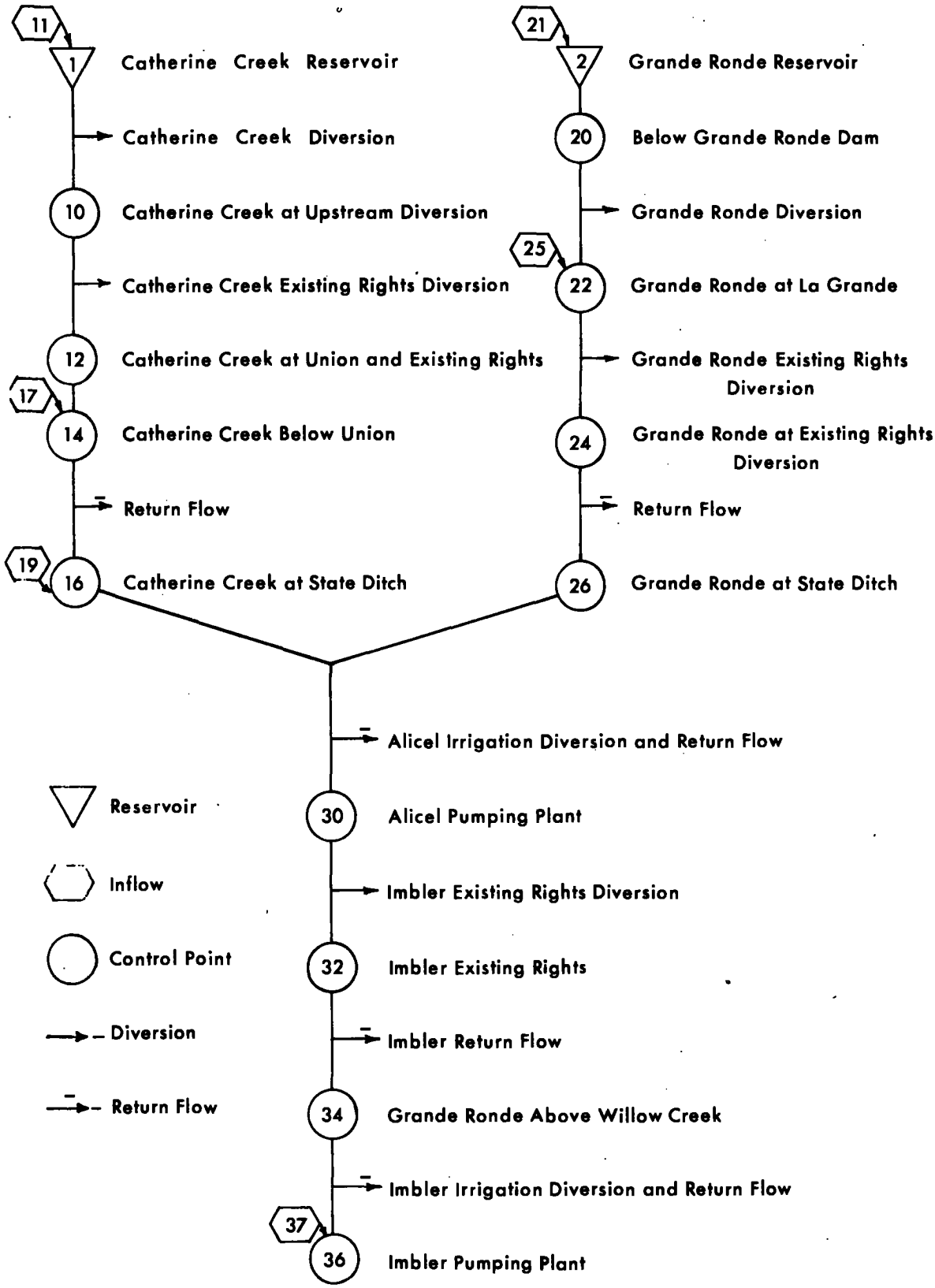
[f]Items in this component include bucket trolley, frame steelwork, diffusion grating, pump controls, and hydrologic reporting network.

[g]This component includes a tank truck.

[h]Items in this component include garage, service building, and operator's house.

CHART IV - 1

FLOW CHART OF HYDROLOGY FOR GRANDE RONDE RIVER BASIN



sites are represented by single digit numbers (1 - Catherine Creek Reservoir and 2 - Grande Ronde Reservoir). The inflows are represented by two digit odd numbers, and the control points are represented by two digit even numbers. The two digit numbers for the Catherine Creek drainage have a first digit of 1 (the number of Catherine Creek Reservoir). The two digit numbers for the Grande Ronde drainage have a first digit of 2 (the number of Grande Ronde Reservoir). The two digit numbers for the confluence have a first digit of 3. This coding allows the researcher to look at any control number in a computer-print-out and identify the location of the control number. Each control number represents an actual point in the Grande Ronde River Basin.

The hydrology data are available for 41 years. These 41 years of data are listed in Appendix A by inflow point, by number, and by month.

Reservoir Levels

In a river basin system, decisions are made periodically concerning the quantities of water which should be held in the reservoir. These decisions are important during certain seasons of the year. Prior to the potential flood periods and drouthy periods, the reservoir levels are critical. The control of the reservoir system includes making a decision concerning stream flows and reservoir levels for each month. These reservoir levels are an integral part of the control of a given reservoir system. The reservoir levels can be changed each month for a given size of reservoir, and the reservoir levels can be changed with a new capital set (different reservoir capacity).

Space within a reservoir can be allocated to various uses. The model for this study uses four levels. Level one in the study is minimum pool size. Level two allows the two reservoirs to be evacuated evenly. Level three is the bottom of the exclusive flood control space. Level four is the maximum pool size. Chart IV-2 shows an example of the various relationships among the levels, minimum pool space, joint use space, and flood control space.

Benefit Functions

Benefits for the Grande Ronde water development project are related primarily to three types of hydrologic phenomena. These three include: (1) diversions of water from the system for a specific use (irrigation and municipal and industrial water supply); (2) use of reservoir space in the reservoir (recreation, salmon reared in reservoir, resident trout in reservoir, and flood control); and (3) stream flows through system with and without the project (anadromous fish).

Irrigation benefits are a function of the diversions at a specific point in the system. A given level of development of agriculture (number of acres) requires a given amount of water for full benefits. The functional relationships between benefits and diversions by month are shown for three different levels of agricultural development in Table IV-7, Table IV-8, and Table IV-9.

Municipal and industrial water benefits are a function of diversions at a specific point. The municipal and industrial water diversions for the Grande Ronde Basin are for supplemental water during the late summer months of July, August, and September. This

CHART IV - 2

RESERVOIR LEVELS FOR CONTROL OF THE WATER FLOW THROUGH THE RESERVOIR SYSTEM

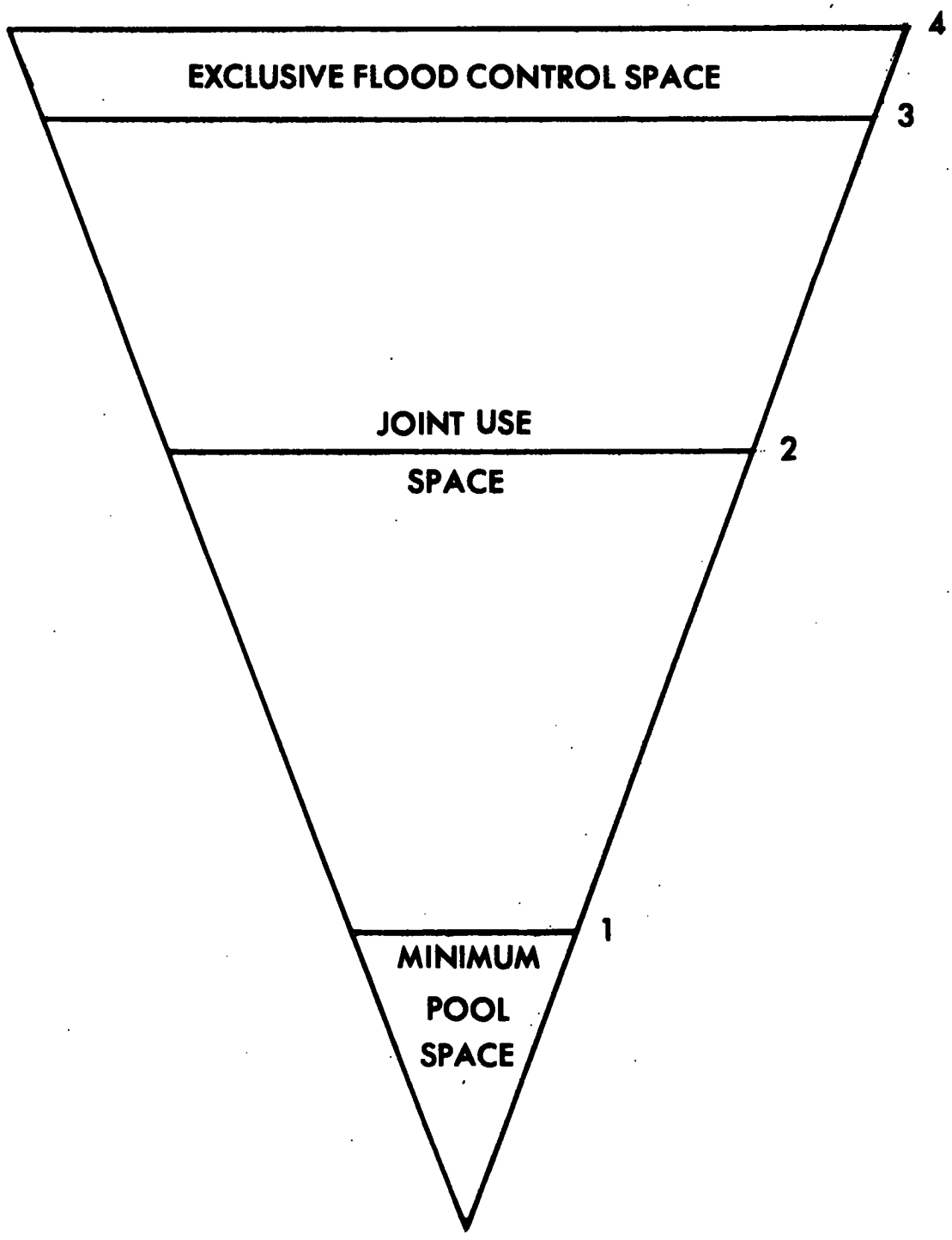


TABLE IV-7

FUNCTIONAL RELATIONSHIP BETWEEN AGRICULTURAL BENEFITS AND DIVERSIONS BY MONTH FOR AN AGRICULTURAL DEVELOPMENT OF 55,000 ACRES IN THE GRANDE RONDE BASIN[a]

Control Point Number	Month	Diversion (cubic feet per second)	Benefit (thousands of dollars)
10	May	0	0
10	May	81	14
10	May	999	14
10	June	0	0
10	June	111	18
10	June	999	18
10	July	24	0
10	July	122	20
10	July	999	20
10	August	22	0
10	August	112	18
10	August	999	18
10	September	0	0
10	September	79	14
10	September	999	14
22	May	0	0
22	May	161	16
22	May	999	16
22	June	0	0
22	June	205	20
22	June	999	20
22	July	46	0
22	July	227	22
22	July	999	22
22	August	42	0
22	August	208	20
22	August	999	20
22	September	0	0
22	September	156	15
22	September	999	15

[a]Calculated from: Data provided by Glenn H. Masters, Economist-Supervisor, U.S. Bureau of Reclamation, Boise, Idaho, February 5, 1971.

TABLE IV-8

FUNCTIONAL RELATIONSHIPS BETWEEN BENEFITS AND DIVERSIONS BY MONTH FOR AN AGRICULTURAL DEVELOPMENT OF 74,000 ACRES IN THE GRANDE RONDE BASIN[a]

Control Point Number	Month	Diversion (cubic feet per second)	Benefit (thousands of dollars)
10	May	0	0
10	May	116	19
10	May	999	19
10	June	0	0
10	June	148	24
10	June	999	24
10	July	33	0
10	July	163	27
10	July	999	27
10	August	30	0
10	August	150	25
10	August	999	25
10	September	0	0
10	September	113	18
10	September	999	18
22	May	0	0
22	May	215	21
22	May	999	21
22	June	0	0
22	June	273	26
22	June	999	26
22	July	61	0
22	July	303	30
22	July	999	30
22	August	56	0
22	August	277	27
22	August	999	27
22	September	0	0
22	September	208	20
22	September	999	20

[a]Calculated from: Data provided by Glenn H. Masters, Economist-Supervisor, U.S. Bureau of Reclamation, Boise, Idaho, February 5, 1971.

TABLE IV-9

FUNCTIONAL RELATIONSHIPS BETWEEN BENEFITS AND DIVERSIONS BY MONTH FOR AN AGRICULTURAL DEVELOPMENT OF 92,000 ACRES IN THE GRANDE RONDE BASIN[a]

Control Point Number	Month	Diversion (cubic feet per second)	Benefit (thousands of dollars)
10	May	0	0
10	May	145	24
10	May	999	24
10	June	0	0
10	June	185	29
10	June	999	29
10	July	41	0
10	July	204	33
10	July	999	33
10	August	38	0
10	August	188	31
10	August	999	31
10	September	0	0
10	September	141	22
10	September	999	22
22	May	0	0
22	May	268	26
22	May	999	26
22	June	0	0
22	June	341	33
22	June	999	33
22	July	76	0
22	July	379	37
22	July	999	37
22	August	69	0
22	August	346	34
22	August	999	34
22	September	0	0
22	September	261	25
22	September	999	25

[a]Calculated from: Data provided by Glenn H. Masters, Economist-Supervisor, U.S. Bureau of Reclamation, Boise, Idaho, February 5, 1971.

water is diverted at Union and LaGrande. The benefit functions for municipal and industrial water are shown in Table IV-10.

Recreational benefits are a function of the water level in a specific reservoir during a specific month. The recreational benefits for the Catherine Creek Reservoir and the Grande Ronde Reservoir are shown in Table IV-11.

Benefits for salmon reared in reservoir are a function of reservoir level in a specific reservoir. Of the two reservoirs (Catherine Creek and Grande Ronde), only Catherine Creek is amenable for rearing salmon. The benefit functions for salmon reared in Catherine Creek Reservoir are shown in Table IV-12.

Benefits for resident trout in reservoir are a function of reservoir level in a specific reservoir. Two factors have been considered which influence the relationship between benefits for resident trout and reservoir level. As the reservoir area increases, access is more convenient. As the surface area of the reservoir increases, however, a given fish population is more dispersed, and the fish catch (which influences fisherman days) decreases. These two offsetting influences are apparent in the benefit functions for resident trout in reservoir which are shown in Table IV-13.

Flood control benefits can be related to the size of flood that a specific reservoir is capable of controlling and to the allocation of the available space in the reservoir to exclusive flood control and joint uses. The flood control benefits become a function of reservoir size, exclusive flood control space, and joint use space. The

TABLE IV-10

RELATIONSHIP BETWEEN DIVERSIONS AND BENEFITS FOR MUNICIPAL AND INDUSTRIAL WATER USE IN THE GRANDE RONDE RIVER BASIN[a]

Control Point Number	Month	Diversion (cubic feet per second)	Benefit (thousands of dollars)
14	July	0	0
14	July	5	4
14	July	999	4
14	August	0	0
14	August	5	4
14	August	999	4
14	September	0	0
14	September	6	4
14	September	999	4
20	July	0	0
20	July	17	7
20	July	999	7
20	August	0	0
20	August	18	8
20	August	999	8
20	September	0	0
20	September	19	9
20	September	999	9

[a]Calculated from: Data provided by Ronald Barrett, Project Engineer, Project Planning Section, Planning Branch, Walla Walla District, Corps of Engineers, Walla Walla, Washington, February 23, 1971.

TABLE IV-11

RELATIONSHIP BETWEEN RESERVOIR LEVELS AND BENEFITS FOR RECREATIONAL WATER USE IN THE GRANDE RONDE RIVER BASIN[a]

Catherine Creek Reservoir

Control Point Number	Month	Reservoir Level (acre feet)	Benefit (thousands of dollars)
1	March	0	0
1	March	9,000	3
1	March	87,000	6
1	April	0	0
1	April	9,000	3
1	April	87,000	6
1	May	0	0
1	May	9,000	6
1	May	87,000	26
1	June	0	0
1	June	9,000	13
1	June	87,000	26
1	July	0	0
1	July	9,000	19
1	July	87,000	38
1	August	0	0
1	August	9,000	19
1	August	87,000	38
1	September	0	0
1	September	9,000	10
1	September	87,000	19
1	October	0	0
1	October	9,000	3
1	October	87,000	6

TABLE IV-11--Continued

Grande Ronde Reservoir			
Control Point Number	Month	Reservoir Level (acre feet)	Benefit (thousands of dollars)
2	March	0	0
2	March	27,000	4
2	March	220,000	9
2	April	0	0
2	April	27,000	4
2	April	220,000	9
2	May	0	0
2	May	27,000	9
2	May	220,000	18
2	June	0	0
2	June	27,000	18
2	June	220,000	35
2	July	0	0
2	July	27,000	26
2	July	220,000	53
2	August	0	0
2	August	27,000	26
2	August	220,000	53
2	September	0	0
2	September	27,000	13
2	September	220,000	26
2	October	0	0
2	October	27,000	4
2	October	220,000	9

[a]Calculated from: Catherine Creek Dam - Economic Analysis, November 10, 1970; Grande Ronde Dam - Economic Analysis, February 5, 1971; and data provided by B.C. Christensen, Chief, Land Use Planning Section, Planning Branch, Walla Walla District, Corps of Engineers, Portland, Oregon, February 22, 1971.

TABLE IV-12

RELATIONSHIP BETWEEN RESERVOIR LEVELS AND BENEFITS FOR SALMON REARED IN RESERVOIR FOR THE CATHERINE CREEK RESERVOIR[a]

Control Point Number	Months	Reservoir Level (acre feet)	Benefit (thousands of dollars)
1	April-January	0	0
1	April-January	9,000	13
1	April-January	40,000	16
1	April-January	50,000	16
1	April-January	60,000	17
1	April-January	87,000	19

[a]Calculated from: Catherine Creek Dam - Economic Analysis, November 10, 1970; and data provided by Edward Maines, Fisheries Research Biologist, North Pacific Division, Corps of Engineers, Portland, Oregon, February 22, 1971.

TABLE IV-13

RELATIONSHIP BETWEEN RESERVOIR LEVELS AND BENEFITS FOR RESIDENT TROUT IN RESERVOIRS FOR CATHERINE CREEK AND GRANDE RONDE RESERVOIRS[a]

Catherine Creek Reservoir

Control Point Number	Month	Reservoir Level (acre feet)	Benefit (thousands of dollars)
1	April	0	0
1	April	9,000	7
1	April	30,000	11
1	April	40,000	10
1	April	50,000	10
1	April	60,000	10
1	April	87,000	9
1	May	0	0
1	May	9,000	11
1	May	30,000	17
1	May	40,000	17
1	May	50,000	17
1	May	60,000	16
1	May	87,000	15
1	June	0	0
1	June	9,000	11
1	June	30,000	17
1	June	40,000	17
1	June	50,000	17
1	June	60,000	16
1	June	87,000	15
1	July	0	0
1	July	9,000	9
1	July	30,000	14
1	July	40,000	14
1	July	50,000	14
1	July	60,000	13
1	July	87,000	12
1	August	0	0
1	August	9,000	9
1	August	30,000	14

TABLE IV-13--Continued

Control Point Number	Month	Reservoir Level (acre feet)	Benefit (thousands of dollars)
1	August	40,000	14
1	August	50,000	14
1	August	60,000	13
1	August	87,000	12
1	September	0	0
1	September	9,000	5
1	September	30,000	7
1	September	40,000	7
1	September	50,000	7
1	September	60,000	7
1	September	87,000	6
1	October	0	0
1	October	9,000	2
1	October	30,000	4
1	October	40,000	3
1	October	50,000	3
1	October	60,000	3
1	October	87,000	3
	Grande Ronde Reservoir		
2	April	0	0
2	April	27,000	6
2	April	100,000	39
2	April	130,000	39
2	April	160,000	38
2	April	180,000	36
2	April	220,000	34
2	May	0	0
2	May	27,000	43
2	May	100,000	65
2	May	130,000	65
2	May	160,000	62
2	May	180,000	60
2	May	220,000	56
2	June	0	0
2	June	27,000	43

TABLE IV-13--Continued

Control Point Number	Month	Reservoir Level (acre feet)	Benefit (thousands of dollars)
2	June	100,000	65
2	June	130,000	65
2	June	160,000	62
2	June	180,000	60
2	June	220,000	56
2	July	0	0
2	July	27,000	35
2	July	100,000	52
2	July	130,000	52
2	July	160,000	50
2	July	180,000	48
2	July	220,000	45
2	August	0	0
2	August	27,000	35
2	August	100,000	52
2	August	130,000	52
2	August	160,000	50
2	August	180,000	48
2	August	220,000	45
2	September	0	0
2	September	27,000	17
2	September	100,000	26
2	September	130,000	26
2	September	160,000	25
2	September	180,000	24
2	September	220,000	22
2	October	0	0
2	October	27,000	9
2	October	100,000	13
2	October	130,000	13
2	October	160,000	12
2	October	180,000	12
2	October	220,000	11

[a]Calculated from: Catherine Creek Dam - Economic Analysis, November 10, 1970; Grande Ronde Dam - Economic Analysis, February 5, 1971; and data provided by Edward Maines, Fisheries Research Biologist, North Pacific Division, Corps of Engineers, Portland, Oregon, February 22, 1971.

relationship among reservoir size, exclusive flood control space, joint use space, and benefits for flood control for Catherine Creek and Grande Ronde Reservoir are shown in Tables IV-14 and IV-15 respectively.

Anadromous fish benefits are a function of the difference between the regulated river flow and the unregulated river flow. If the regulated river flow is less than the unregulated river flow during critical months, benefits can be lost during these periods. The relationships between regulated and unregulated flows and anadromous fish benefits are shown in Table IV-16.

Operating Procedures

The control of the hydrologic flows through the system comprises a given operating procedure. Three specific operating procedures are specified in this model. The major controlling factor in each operating procedure is the specification of diversions for agricultural development in the basin. The desired diversions for agricultural development for each of the three operating procedures is shown in Table IV-17.

The Simulation Models

The simulation flow charts for the analyses are shown in Chart IV-3. The simulations have been completed in two separate stages. The first stage has been completed for the derivation of the benefits. The second stage uses the output of the first stage (benefits in the form of punched cards) together with cost data to determine the benefit-

TABLE IV-14

RELATIONSHIPS AMONG EXCLUSIVE FLOOD CONTROL SPACE, JOINT USE SPACE, RESERVOIR SIZE, AND BENEFITS FOR FLOOD CONTROL FOR CATHERINE CREEK RESERVOIR[a]

Reservoir Size (000 of acre feet)	Reservoir Space	End of Month Space in Thousands of Acre Feet												Annual Benefit (000 of dollars)
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	
42	Flood Control	6	25	25	25	25	25	25	6	6	6	6	6	434
	Joint Use	27	8	8	8	8	8	8	27	27	27	27	27	
65	Flood Control	8	30	30	30	30	30	30	8	8	8	8	8	452
	Joint Use	48	26	26	26	26	26	26	48	48	48	48	48	
87	Flood Control	10	35	35	35	35	35	35	10	10	10	10	10	453
	Joint Use	68	43	43	43	43	43	43	68	68	68	68	68	

[a]Robert Rickel, Supervisory Hydraulic Engineer, Hydrology Section, Planning Branch, Walla Walla District, Walla Walla, Washington, February 10, 1971.

TABLE IV-15

RELATIONSHIPS AMONG EXCLUSIVE FLOOD CONTROL SPACE, JOINT USE SPACE, RESERVOIR SIZE, AND BENEFITS FOR FLOOD CONTROL FOR GRANDE RONDE RESERVOIR[a]

Reservoir Size (000 of acre feet)	Reservoir Space	End of Month Space in Thousands of Acre Feet												Annual Benefit (000 of dollars)
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	
160	Flood Control	9	70	70	70	70	70	70	9	9	9	9	9	664
	Joint Use	124	63	63	63	63	63	63	124	124	124	124	124	
190	Flood Control	12	80	80	80	80	80	80	12	12	12	12	12	666
	Joint Use	151	83	83	83	83	83	83	151	151	151	151	151	
220	Flood Control	15	90	90	90	90	90	90	15	15	15	15	15	667
	Joint Use	178	103	103	103	103	103	103	178	178	178	178	178	

[a]Robert Rickel, Supervisory Hydraulic Engineer, Hydrology Section, Planning Branch, Walla Walla District, Walla Walla, Washington, February 10, 1971.

TABLE IV-16

FUNCTIONAL RELATIONSHIPS BETWEEN BENEFITS FOR ANADROMOUS FISH AND REGULATED AND UNREGULATED FLOWS BY MONTH FOR THE GRANDE RONDE RIVER

Control Point Number	Month	Diversion (cubic feet per second)	Benefit (thousands of dollars)
22	May	0	0
22	May	20	2
22	May	40	5
22	May	60	10
22	May	100	17
22	May	130	21
22	May	999	21
22	June	0	0
22	June	70	7
22	June	120	14
22	June	160	25
22	June	200	37
22	June	275	45
22	June	999	45
22	July	0	0
22	July	100	5
22	July	170	15
22	July	220	27
22	July	280	43
22	July	410	67
22	July	999	64
22	August	0	0
22	August	80	5
22	August	140	15
22	August	200	28
22	August	270	42
22	August	390	64
22	August	999	64

TABLE IV-16--Continued

Control Point Number	Month	Diversion (cubic feet per second)	Benefit (thousands of dollars)
22	September	0	0
22	September	45	6
22	September	80	12
22	September	100	19
22	September	140	26
22	September	180	29
22	September	999	29

[a]Calculated from: Grande Ronde Dam - Economic Analysis, February 5, 1971; and data provided by Arthur Gerlach, Fisheries Biologist, North Pacific Division, Corps of Engineers, Portland Oregon, February 18, 1971.

TABLE IV-17

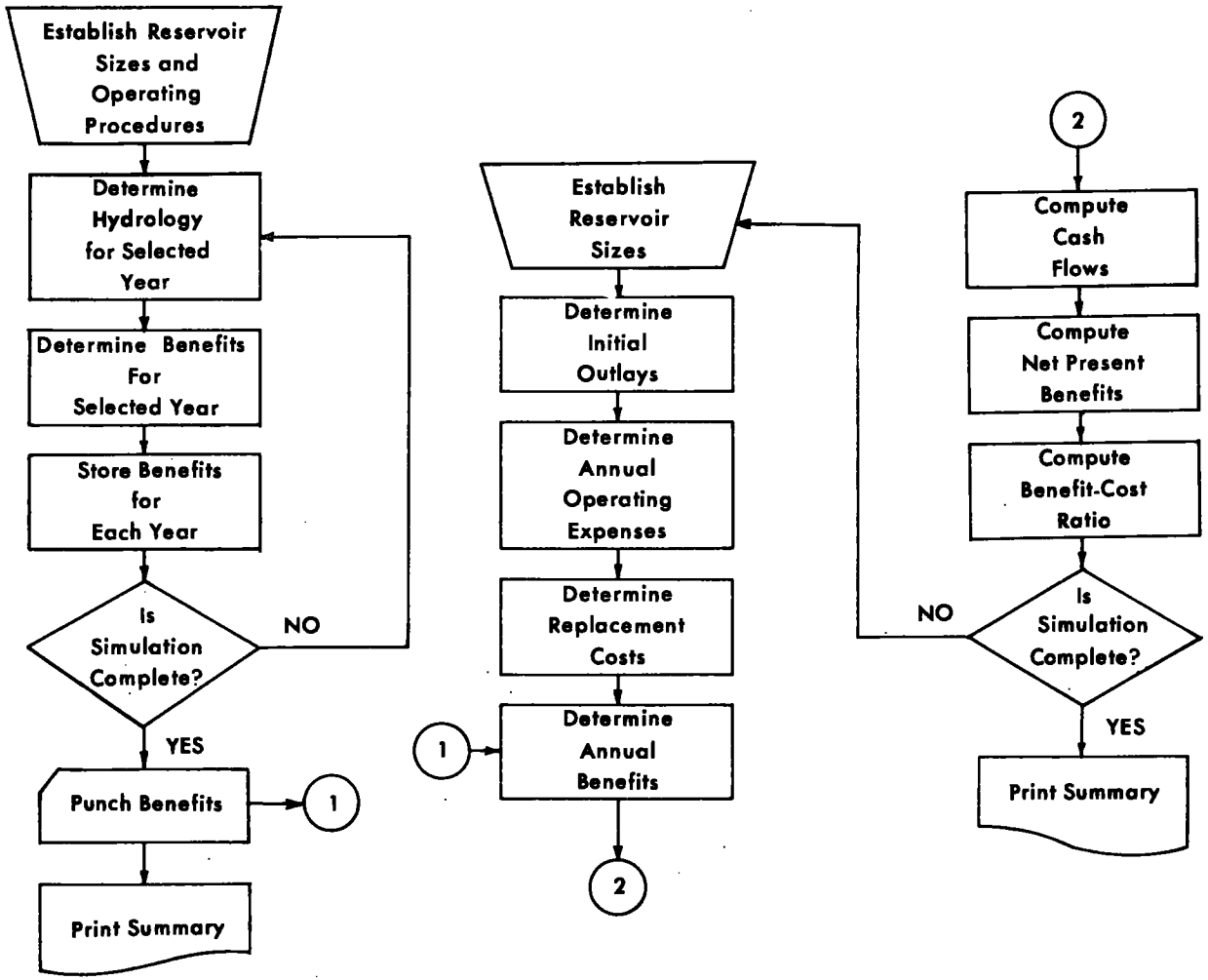
DESIRED DIVERSIONS FOR AGRICULTURAL DEVELOPMENT
IN THE GRANDE RONDE BASIN[a]

Size of Development (acres)	Control Point Number	Diversions in Acre Feet by Month				
		May	June	July	August	September
55,000	10	5,552	6,857	7,604	7,175	5,246
	22	9,848	12,163	13,816	12,730	9,305
74,000	10	7,402	9,143	10,138	9,567	6,994
	22	13,131	16,217	18,422	16,973	12,407
92,000	10	9,252	11,429	12,672	11,959	8,742
	22	16,414	20,271	23,028	21,216	15,509

[a]Calculated from: Data provided by Glenn H. Masters, Economist-Supervisor, U.S. Bureau of Reclamation, Boise, Idaho, February 5, 1971.

CHART IV - 3

FLOW CHART FOR SIMULATION OF RIVER BASIN SYSTEM



cost relationships. The flow chart for the capital budgeting model and the routine for selecting from the various distributions is shown in Chart IV-4. This chart expresses pictorially what the computer program accomplishes numerically. Each of the frequency distributions represents a specific distribution which serves as input into the computer model. The parameters for the cost distributions for original outlays and replacements are derived from Tables IV-3, IV-4, IV-5, and IV-6. These tables give the mean value and associated accuracy for a 90 percent confidence level. The standard deviation has been derived for each distribution. The mean and standard deviation serve as direct inputs into the computer model.

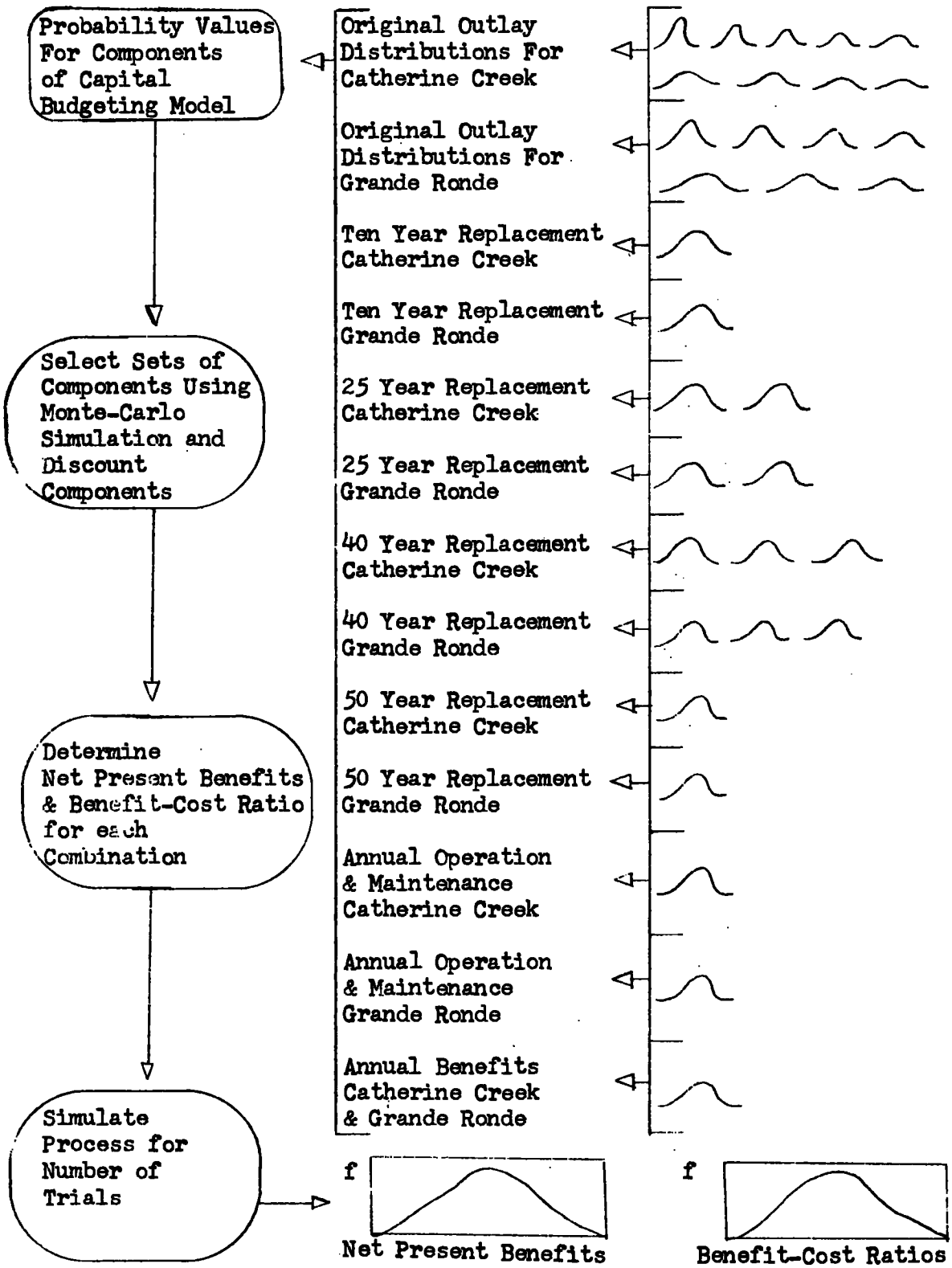
The frequency distribution of benefits is derived from the operation of the hydrology model. The model relates hydrological phenomena to benefits as expressed in Tables IV-7, IV-8, IV-9, IV-10, IV-11, IV-12, IV-13, IV-14, IV-15, and IV-16. The benefits associated with these tables are derived from the simulation of the water flows as expressed in Appendix A. The water flows are controlled by a specific operating procedure which diverts water for irrigation.

Summary

This chapter examines the variables and functional relationships for the simulation models. It also presents the flow chart of of the computer program used for the model. The model and computer program serve as means of generating data for testing the hypotheses.

CHART IV-4

FLOW CHART OF CAPITAL BUDGETING SIMULATION



The objective of the model is to analyze the results associated with the different designs (sets of capital) and operating procedures in order to determine the effects of changes in these variables on the resulting benefits and costs. This chapter examines the model. Chapter V examines the results of the model and determines the extent of the support for the hypotheses.

V DESCRIPTION AND ANALYSIS OF THE RESULTS

The last two chapters have given a description of the experimental design, a description of the model, and the techniques for operation of the model through computer simulation. This chapter covers a detailed account of the results from running the model and from making changes in the model according to the experimental design. The resultant effects of changes in the controllable exogenous variables (capital sets and operating procedures) on the resulting endogenous variables (net present benefits and benefit-cost ratios) is given. An analysis of the results is included. The implications for river basin planning are examined in the following chapter.

Results from the Runs

The results from the computer runs include 500 iterations for each cell in the design. The marginal computer costs for additional samples are minimal, and the size of the sample has been limited to the capability of analyzing the results from the rather extensive runs with an analysis of variance program. The results from the runs include a frequency distribution for net present benefits and a frequency distribution for the benefit-cost ratios. The results for the 27 runs are shown in Tables V-1 and V-2. Table V-1 gives frequency distributions of net present benefits. Table V-2 gives frequency distributions of benefit-cost ratios. These tables have been generated by the computer, and these frequency distributions provide a detailed description of outcomes from a sample of 500 for each of the 27 cells

TABLE V-1

FREQUENCY DISTRIBUTIONS OF NET PRESENT BENEFITS FOR ALTERNATIVE OPERATING PROCEDURES AND RESERVOIR COMBINATIONS FOR CATHERINE CREEK RESERVOIR AND GRANDE RONDE RESERVOIR[a]

141		151		161	
Dollars (Thousands)	Frequency	Dollars (Thousands)	Frequency	Dollars (Thousands)	Frequency
11,997 - 12,416	3	10,198 - 10,682	1	8,115 - 8,607	2
12,416 - 12,834	1	10,682 - 11,166	3	8,607 - 9,099	2
12,834 - 13,253	9	11,166 - 11,650	4	9,099 - 9,591	7
13,253 - 13,672	2	11,650 - 12,134	1	9,591 - 10,083	4
13,672 - 14,090	6	12,134 - 12,618	3	10,083 - 10,575	3
14,090 - 14,509	11	12,618 - 13,102	12	10,575 - 11,067	12
14,509 - 14,927	16	13,102 - 13,586	11	11,067 - 11,559	22
14,927 - 15,346	17	13,586 - 14,070	21	11,559 - 12,051	29
15,346 - 15,765	33	14,070 - 14,554	35	12,051 - 12,543	22
15,765 - 16,183	26	14,554 - 15,038	38	12,543 - 13,035	37
16,183 - 16,602	34	15,038 - 15,522	49	13,035 - 13,527	34
16,602 - 17,020	47	15,522 - 16,006	59	13,527 - 14,019	43
17,020 - 17,439	43	16,006 - 16,490	50	14,019 - 14,511	56
17,439 - 17,858	52	16,490 - 16,974	56	14,511 - 15,003	50
17,858 - 18,276	45	16,974 - 17,458	39	15,003 - 15,495	50
18,276 - 18,695	45	17,458 - 17,942	42	15,495 - 15,988	44
18,695 - 19,113	28	17,942 - 18,426	27	15,988 - 16,480	27
19,113 - 19,532	35	18,426 - 18,910	20	16,480 - 16,972	17
19,532 - 19,951	19	18,910 - 19,394	15	16,972 - 17,464	11
19,951 - 20,369	10	19,394 - 19,878	4	17,464 - 17,956	12
20,369 - 20,788	8	19,878 - 20,362	4	17,956 - 18,448	6
20,788 - 21,206	6	20,362 - 20,846	2	18,448 - 18,940	5
21,206 - 21,625	1	20,846 - 21,330	2	18,940 - 19,432	1
21,625 - 22,044	0	21,330 - 21,814	1	19,432 - 19,924	2
22,044 - 22,462	3	21,814 - 22,298	1	19,924 - 20,416	2

TABLE V-1--Continued

241		251		261	
Dollars (Thousands)	Frequency	Dollars (Thousands)	Frequency	Dollars (Thousands)	Frequency
12,308 - 12,728	4	10,604 - 11,098	4	8,129 - 8,629	2
12,728 - 13,149	2	11,098 - 11,592	6	8,629 - 9,130	1
13,149 - 13,570	1	11,592 - 12,085	3	9,130 - 9,630	5
13,570 - 13,990	4	12,085 - 12,579	7	9,630 - 10,131	5
13,990 - 14,411	10	12,579 - 13,073	4	10,131 - 10,631	9
14,411 - 14,832	8	13,073 - 13,567	11	10,631 - 11,132	17
14,832 - 15,252	14	13,567 - 14,061	27	11,132 - 11,632	22
15,252 - 15,673	27	14,061 - 14,555	29	11,632 - 12,133	29
15,673 - 16,094	29	14,555 - 15,049	46	12,133 - 12,633	31
16,094 - 16,514	25	15,049 - 15,542	30	12,633 - 13,134	39
16,514 - 16,935	37	15,542 - 16,036	48	13,134 - 13,634	54
16,935 - 17,356	46	16,036 - 16,530	43	13,634 - 14,135	47
17,356 - 17,776	48	16,530 - 17,024	62	14,135 - 14,635	41
17,776 - 18,197	43	17,024 - 17,518	50	14,635 - 15,136	44
18,197 - 18,618	42	17,518 - 18,012	39	15,136 - 15,637	38
18,618 - 19,038	47	18,012 - 18,506	30	15,637 - 16,137	29
19,038 - 19,459	25	18,506 - 19,000	22	16,137 - 16,638	26
19,459 - 19,880	31	19,000 - 19,493	15	16,638 - 17,138	18
19,880 - 20,300	27	19,493 - 19,987	11	17,138 - 17,639	18
20,300 - 20,721	7	19,987 - 20,481	9	17,639 - 18,139	14
20,721 - 21,142	5	20,481 - 20,975	2	18,139 - 18,640	4
21,142 - 21,562	12	20,975 - 21,469	1	18,640 - 19,140	4
21,562 - 21,983	4	21,469 - 21,963	0	19,140 - 19,641	2
21,983 - 22,404	0	21,963 - 22,457	0	19,641 - 20,141	0
22,404 - 22,824	2	22,457 - 22,951	1	20,141 - 20,641	1

TABLE V-1--Continued

341		351		361	
Dollars (Thousands)	Frequency	Dollars (Thousands)	Frequency	Dollars (Thousands)	Frequency
11,304 - 11,715	3	10,128 - 10,666	5	7,079 - 7,566	3
11,715 - 12,126	2	10,666 - 11,205	4	7,566 - 8,053	3
12,126 - 12,537	1	11,205 - 11,744	6	8,053 - 8,540	2
12,537 - 12,948	2	11,744 - 12,282	14	8,540 - 9,027	9
12,948 - 13,360	8	12,282 - 12,821	17	9,027 - 9,514	11
13,360 - 13,771	12	12,821 - 13,360	23	9,514 - 10,001	11
13,771 - 14,182	20	13,360 - 13,898	48	10,001 - 10,488	19
14,182 - 14,593	13	13,898 - 14,437	34	10,488 - 10,974	15
14,593 - 15,004	26	14,437 - 14,976	51	10,974 - 11,461	22
15,004 - 15,415	22	14,976 - 15,514	59	11,461 - 11,948	38
15,415 - 15,826	38	15,514 - 16,053	45	11,948 - 12,435	41
15,826 - 16,237	29	16,053 - 16,592	53	12,435 - 12,922	45
16,237 - 16,648	37	16,592 - 17,130	44	12,922 - 13,409	43
16,648 - 17,059	57	17,130 - 17,669	34	13,409 - 13,896	44
17,059 - 17,470	38	17,669 - 18,208	24	13,896 - 14,383	35
17,470 - 17,882	50	18,208 - 18,746	17	14,383 - 14,870	37
17,882 - 18,293	41	18,746 - 19,285	9	14,870 - 15,357	37
18,293 - 18,704	33	19,285 - 19,824	7	15,357 - 15,843	29
18,704 - 19,115	25	19,824 - 20,362	3	15,843 - 16,330	22
19,115 - 19,526	10	20,362 - 20,901	0	16,330 - 16,817	10
19,526 - 19,937	12	20,901 - 21,440	1	16,817 - 17,304	14
19,937 - 20,348	12	21,440 - 21,978	1	17,304 - 17,791	4
20,348 - 20,759	2	21,978 - 22,517	0	17,791 - 18,278	2
20,759 - 21,170	3	22,517 - 23,056	0	18,278 - 18,765	3
21,170 - 21,582	4	23,056 - 23,596	1	18,765 - 19,251	1

TABLE V-1--Continued

142		152		162	
Dollars (Thousands)	Frequency	Dollars (Thousands)	Frequency	Dollars (Thousands)	Frequency
13,183 - 13,569	1	10,610 - 11,077	3	7,547 - 8,071	1
13,569 - 13,955	4	11,077 - 11,544	0	8,071 - 8,594	0
13,955 - 14,341	4	11,544 - 12,011	2	8,594 - 9,118	2
14,341 - 14,727	11	12,011 - 12,479	4	9,118 - 9,641	1
14,727 - 15,113	12	12,479 - 12,946	9	9,641 - 10,165	1
15,113 - 15,498	14	12,946 - 13,413	9	10,165 - 10,688	5
15,498 - 15,884	17	13,413 - 13,880	14	10,688 - 11,212	13
15,884 - 16,270	19	13,880 - 14,347	24	11,212 - 11,736	15
16,270 - 16,656	30	14,347 - 14,814	28	11,736 - 12,259	19
16,656 - 17,042	29	14,814 - 15,282	26	12,259 - 12,782	21
17,042 - 17,428	44	15,282 - 15,749	26	12,782 - 13,306	23
17,428 - 17,814	37	15,749 - 16,216	43	13,306 - 13,830	43
17,814 - 18,200	40	16,216 - 16,683	44	13,830 - 14,353	52
18,200 - 18,586	41	16,683 - 17,150	51	14,353 - 14,877	51
18,586 - 18,971	44	17,150 - 17,617	44	14,877 - 15,400	61
18,971 - 19,357	31	17,617 - 18,085	42	15,400 - 15,924	55
19,357 - 19,743	26	18,085 - 18,552	36	15,924 - 16,447	32
19,743 - 20,129	23	18,552 - 19,019	38	16,447 - 16,971	22
20,129 - 20,515	25	19,019 - 19,486	20	16,971 - 17,494	28
20,515 - 20,901	20	19,486 - 19,953	17	17,494 - 18,018	21
20,901 - 21,287	7	19,953 - 20,420	7	18,018 - 18,541	15
21,287 - 21,673	12	20,420 - 20,888	9	18,541 - 19,065	12
21,673 - 22,059	4	20,888 - 21,355	3	19,065 - 19,588	1
22,059 - 22,444	3	21,355 - 21,822	0	19,588 - 20,112	4
22,444 - 22,830	2	21,822 - 22,290	1	20,112 - 20,636	2

TABLE V-1--Continued

242		252		262	
Dollars (Thousands)	Frequency	Dollars (Thousands)	Frequency	Dollars (Thousands)	Frequency
12,982 - 13,392	4	11,185 - 11,656	1	8,851 - 9,342	4
13,392 - 13,803	2	11,656 - 12,128	2	9,342 - 9,832	4
13,803 - 14,214	1	12,128 - 12,599	5	9,832 - 10,323	2
14,214 - 14,624	5	12,599 - 13,070	7	10,323 - 10,814	6
14,624 - 15,035	7	13,070 - 13,542	8	10,814 - 11,304	4
15,035 - 15,446	11	13,542 - 14,013	12	11,304 - 11,795	11
15,446 - 15,857	16	14,013 - 14,485	17	11,795 - 12,286	20
15,857 - 16,267	14	14,485 - 14,956	21	12,286 - 12,776	22
16,267 - 16,678	36	14,956 - 15,428	33	12,776 - 13,267	30
16,678 - 17,089	27	15,428 - 15,899	29	13,267 - 13,758	41
17,089 - 17,500	44	15,899 - 16,370	47	13,758 - 14,248	39
17,500 - 17,910	38	16,370 - 16,842	51	14,248 - 14,739	53
17,910 - 18,321	45	16,842 - 17,313	51	14,739 - 15,230	44
18,321 - 18,732	48	17,313 - 17,785	45	15,230 - 15,721	46
18,732 - 19,143	49	17,785 - 18,256	45	15,721 - 16,211	46
19,143 - 19,553	42	18,256 - 18,728	38	16,211 - 16,702	28
19,553 - 19,964	28	18,728 - 19,199	32	16,702 - 17,193	33
19,964 - 20,375	23	19,199 - 19,670	29	17,193 - 17,683	18
20,375 - 20,785	20	19,670 - 20,142	8	17,683 - 18,174	14
20,785 - 21,196	14	20,142 - 20,613	6	18,174 - 18,665	18
21,196 - 21,607	10	20,613 - 21,085	6	18,665 - 19,155	7
21,607 - 22,018	7	21,085 - 21,556	4	19,155 - 19,646	1
22,018 - 22,428	5	21,556 - 22,028	1	19,646 - 20,137	3
22,428 - 22,839	0	22,028 - 22,499	1	20,137 - 20,627	2
22,839 - 23,249	4	22,499 - 22,971	1	20,627 - 21,119	4

TABLE V-1--Continued

342		352		362	
Dollars (Thousands)	Frequency	Dollars (Thousands)	Frequency	Dollars (Thousands)	Frequency
11,707 - 12,164	2	9,325 - 9,843	1	7,438 - 8,008	3
12,164 - 12,620	3	9,843 - 10,362	1	8,008 - 8,579	2
12,620 - 13,076	1	10,362 - 10,880	1	8,579 - 9,149	3
13,076 - 13,532	3	10,880 - 11,398	3	9,149 - 9,720	3
13,532 - 13,989	5	11,398 - 11,917	3	9,720 - 10,290	5
13,989 - 14,445	8	11,917 - 12,435	8	10,290 - 10,861	16
14,445 - 14,901	16	12,435 - 12,953	9	10,861 - 11,431	22
14,901 - 15,358	28	12,953 - 13,472	16	11,431 - 12,001	30
15,358 - 15,814	31	13,472 - 13,990	22	12,001 - 12,572	38
15,814 - 16,270	39	13,990 - 14,508	27	12,572 - 13,142	53
16,270 - 16,727	32	14,508 - 15,027	41	13,142 - 13,713	43
16,727 - 17,183	35	15,027 - 15,545	41	13,713 - 14,283	49
17,183 - 17,639	54	15,545 - 16,063	48	14,283 - 14,854	55
17,639 - 18,096	46	16,063 - 16,582	58	14,854 - 15,424	49
18,096 - 18,552	47	16,582 - 17,100	61	15,424 - 15,995	32
18,552 - 19,008	37	17,100 - 17,618	46	15,995 - 16,565	27
19,008 - 19,464	34	17,618 - 18,137	42	16,565 - 17,136	24
19,464 - 19,921	22	18,137 - 18,655	23	17,136 - 17,706	12
19,921 - 20,377	25	18,655 - 19,173	17	17,706 - 18,277	18
20,377 - 20,833	11	19,173 - 19,692	17	18,277 - 18,847	6
20,833 - 21,290	7	19,692 - 20,210	10	18,847 - 19,417	4
21,290 - 21,746	7	20,210 - 20,728	3	19,417 - 19,988	3
21,746 - 22,202	4	20,728 - 21,247	1	19,988 - 20,558	2
22,202 - 22,659	0	21,247 - 21,765	0	20,558 - 21,129	0
22,659 - 23,115	3	21,765 - 22,283	1	21,129 - 21,699	1

TABLE V-1--Continued

143		153		163	
Dollars (Thousands)	Frequency	Dollars (Thousands)	Frequency	Dollars (Thousands)	Frequency
11,832 - 12,286	3	9,840 - 10,359	2	7,592 - 8,097	1
12,286 - 12,740	1	10,359 - 10,877	2	8,097 - 8,602	1
12,740 - 13,194	1	10,877 - 11,396	1	8,602 - 9,107	1
13,194 - 13,648	4	11,396 - 11,915	2	9,107 - 9,611	5
13,648 - 14,102	3	11,915 - 12,433	4	9,611 - 10,116	4
14,102 - 14,555	8	12,433 - 12,952	6	10,116 - 10,621	4
14,555 - 15,009	6	12,952 - 13,470	13	10,621 - 11,126	8
15,009 - 15,463	20	13,470 - 13,989	11	11,126 - 11,631	14
15,463 - 15,917	30	13,989 - 14,508	22	11,631 - 12,136	21
15,917 - 16,371	45	14,508 - 15,026	20	12,136 - 12,640	25
16,371 - 16,824	38	15,026 - 15,545	39	12,640 - 13,145	29
16,824 - 17,278	46	15,545 - 16,064	43	13,145 - 13,650	50
17,278 - 17,732	42	16,064 - 16,582	51	13,650 - 14,155	44
17,732 - 18,186	53	16,582 - 17,101	62	14,155 - 14,660	34
18,186 - 18,640	38	17,101 - 17,620	53	14,660 - 15,165	52
18,640 - 19,094	45	17,620 - 18,138	48	15,165 - 15,670	47
19,094 - 19,547	35	18,138 - 18,657	37	15,670 - 16,174	35
19,547 - 20,001	24	18,657 - 19,176	32	16,174 - 16,679	40
20,001 - 20,455	18	19,176 - 19,694	25	16,679 - 17,184	25
20,455 - 20,909	13	19,694 - 20,213	12	17,184 - 17,689	21
20,909 - 21,363	17	20,213 - 20,731	8	17,689 - 18,194	11
21,363 - 21,817	7	20,731 - 21,250	3	18,194 - 18,699	11
21,817 - 22,270	2	21,250 - 21,769	2	18,699 - 19,203	10
22,270 - 22,724	0	21,769 - 22,287	1	19,203 - 19,708	4
22,724 - 23,178	1	22,287 - 22,807	1	19,708 - 20,214	3

TABLE V-1--Continued

243		253		263	
Dollars (Thousands)	Frequency	Dollars (Thousands)	Frequency	Dollars (Thousands)	Frequency
12,237 - 12,685	1	10,349 - 10,815	1	6,677 - 7,201	1
12,685 - 13,134	1	10,815 - 11,282	0	7,201 - 7,725	1
13,134 - 13,583	0	11,282 - 11,749	4	7,725 - 8,250	0
13,583 - 14,031	1	11,749 - 12,216	3	8,250 - 8,774	0
14,031 - 14,480	3	12,216 - 12,683	4	8,774 - 9,298	3
14,480 - 14,928	10	12,683 - 13,149	4	9,298 - 9,823	1
14,928 - 15,377	13	13,149 - 13,616	6	9,823 - 10,347	3
15,377 - 15,825	27	13,616 - 14,083	15	10,347 - 10,871	7
15,825 - 16,274	24	14,083 - 14,550	15	10,871 - 11,396	8
16,274 - 16,723	29	14,550 - 15,017	17	11,396 - 11,920	11
16,723 - 17,171	36	15,017 - 15,483	21	11,920 - 12,444	25
17,171 - 17,620	54	15,483 - 15,950	36	12,444 - 12,968	27
17,620 - 18,068	42	15,950 - 16,417	46	12,968 - 13,493	29
18,068 - 18,517	51	16,417 - 16,884	48	13,493 - 14,017	46
18,517 - 18,965	41	16,884 - 17,351	53	14,017 - 14,541	47
18,965 - 19,414	45	17,351 - 17,817	50	14,541 - 15,066	38
19,414 - 19,862	32	17,817 - 18,284	41	15,066 - 15,590	63
19,862 - 20,311	30	18,284 - 18,751	33	15,590 - 16,114	51
20,311 - 20,760	21	18,751 - 19,218	31	16,114 - 16,639	40
20,760 - 21,208	17	19,218 - 19,685	22	16,639 - 17,163	27
21,208 - 21,657	11	19,685 - 20,151	25	17,163 - 17,687	26
21,657 - 22,105	2	20,151 - 20,618	10	17,687 - 18,211	16
22,105 - 22,554	5	20,618 - 21,085	3	18,211 - 18,736	13
22,554 - 23,002	2	21,085 - 21,552	11	18,736 - 19,260	11
23,002 - 23,452	2	21,552 - 22,018	1	19,260 - 19,784	6

TABLE V-1--Continued

343		353		363	
Dollars (Thousands)	Frequency	Dollars (Thousands)	Frequency	Dollars (Thousands)	Frequency
11,899 - 12,303	1	9,678 - 10,138	1	7,279 - 7,782	1
12,303 - 12,707	2	10,138 - 10,597	2	7,782 - 8,285	1
12,707 - 13,111	3	10,597 - 11,057	1	8,285 - 8,788	2
13,111 - 13,515	5	11,057 - 11,517	0	8,788 - 9,291	3
13,515 - 13,919	7	11,517 - 11,976	2	9,291 - 9,794	1
13,919 - 14,323	9	11,976 - 12,436	4	9,794 - 10,297	10
14,323 - 14,727	22	12,436 - 12,896	10	10,297 - 10,800	8
14,727 - 15,131	13	12,896 - 13,356	11	10,800 - 11,303	12
15,131 - 15,535	26	13,356 - 13,815	16	11,303 - 11,806	28
15,535 - 15,939	27	13,815 - 14,275	21	11,806 - 12,309	24
15,939 - 16,343	24	14,275 - 14,735	31	12,309 - 12,813	37
16,343 - 16,747	41	14,735 - 15,194	27	12,813 - 13,316	54
16,747 - 17,151	46	15,194 - 15,654	46	13,316 - 13,819	45
17,151 - 17,555	37	15,654 - 16,114	36	13,819 - 14,322	44
17,555 - 17,959	43	16,114 - 16,573	58	14,322 - 14,825	43
17,959 - 18,363	44	16,573 - 17,033	48	14,825 - 15,328	47
18,363 - 18,767	32	17,033 - 17,493	43	15,328 - 15,831	39
18,767 - 19,171	36	17,493 - 17,953	42	15,831 - 16,334	28
19,171 - 19,575	23	17,953 - 18,412	26	16,334 - 16,837	25
19,575 - 19,979	20	18,412 - 18,872	31	16,837 - 17,340	19
19,979 - 20,383	10	18,872 - 19,332	16	17,340 - 17,843	12
20,383 - 20,787	16	19.332 - 19,791	17	17,843 - 18,346	6
20,787 - 21,191	7	19,791 - 20,251	7	18,346 - 18,849	6
21,191 - 21,595	4	20,251 - 20,711	2	18,849 - 19,352	4
21,595 - 21,999	2	20,711 - 21,171	2	19,352 - 19,856	1

TABLE V-1--Continued

[a]The reservoir size and operating procedure codes are as follows: The first digit is Catherine Creek Reservoir with size 1 = 42,000 acre feet, 2 = 65,000 acre feet, and 3 = 87,000 acre feet. The second digit is Grande Ronde Reservoir with size 3 = 160,000 acre feet, 4 = 190,000 acre feet, and 5 = 220,000 acre feet. The third digit is operating procedure with 1 = 55,000 acres, 2 = 74,000 acres, and 3 = 92,000 acres. An example of a given combination is as follows:

Catherine Creek - size 3
Grande Ronde - size 6
Operating Procedure - number 1

3 6 1

TABLE V-2

FREQUENCY DISTRIBUTIONS OF BENEFIT-COST RATIOS FOR ALTERNATIVE OPERATING PROCEDURES AND RESERVOIR COMBINATIONS FOR CATHERINE CREEK RESERVOIR AND GRANDE RONDE RESERVOIR[a]

141		151		161	
Benefit-Cost Ratios	Frequency	Benefit-Cost Ratios	Frequency	Benefit-Cost Ratios	Frequency
1.2558 - 1.2701	3	1.2087 - 1.2245	2	1.1577 - 1.1722	3
1.2701 - 1.2845	3	1.2245 - 1.2403	5	1.1722 - 1.1867	4
1.2845 - 1.2989	8	1.2403 - 1.2561	1	1.1867 - 1.2012	7
1.2989 - 1.3132	7	1.2561 - 1.2719	4	1.2012 - 1.2157	5
1.3132 - 1.3276	11	1.2719 - 1.2877	14	1.2157 - 1.2302	15
1.3276 - 1.3420	17	1.2877 - 1.3035	18	1.2302 - 1.2447	24
1.3420 - 1.3563	19	1.3035 - 1.3192	34	1.2447 - 1.2592	32
1.3563 - 1.3707	34	1.3192 - 1.3350	35	1.2592 - 1.2737	35
1.3707 - 1.3851	32	1.3350 - 1.3508	48	1.2737 - 1.2882	36
1.3851 - 1.3994	39	1.3508 - 1.3666	65	1.2882 - 1.3027	39
1.3994 - 1.4138	47	1.3666 - 1.3824	53	1.3027 - 1.3172	55
1.4138 - 1.4281	43	1.3824 - 1.3982	58	1.3172 - 1.3317	50
1.4281 - 1.4425	53	1.3982 - 1.4140	36	1.3317 - 1.3462	55
1.4425 - 1.4569	42	1.4140 - 1.4298	42	1.3462 - 1.3607	46
1.4569 - 1.4712	35	1.4298 - 1.4456	28	1.3607 - 1.3752	29
1.4712 - 1.4856	30	1.4456 - 1.4614	23	1.3752 - 1.3897	20
1.4856 - 1.5000	30	1.4614 - 1.4772	13	1.3897 - 1.4042	12
1.5000 - 1.5143	18	1.4772 - 1.4930	10	1.4042 - 1.4187	9
1.5143 - 1.5287	10	1.4930 - 1.5088	2	1.4187 - 1.4332	8
1.5287 - 1.5431	8	1.5088 - 1.5246	3	1.4332 - 1.4477	6
1.5431 - 1.5574	5	1.5246 - 1.5404	2	1.4477 - 1.4622	4
1.5574 - 1.5718	2	1.5404 - 1.5562	2	1.4622 - 1.4767	2
1.5718 - 1.5862	1	1.5562 - 1.5720	0	1.4767 - 1.4912	2
1.5862 - 1.6005	0	1.5720 - 1.5878	1	1.4912 - 1.5057	0
1.6005 - 1.6149	3	1.5878 - 1.6036	1	1.5057 - 1.5203	2

TABLE V-2--Continued

241		251		261	
Benefit-Cost Ratios	Frequency	Benefit-Cost Ratios	Frequency	Benefit-Cost Ratios	Frequency
1.2566 - 1.2708	5	1.2116 - 1.2273	5	1.1533 - 1.1675	3
1.2708 - 1.2850	2	1.2273 - 1.2430	6	1.1675 - 1.1817	2
1.2850 - 1.2992	3	1.2430 - 1.2588	8	1.1817 - 1.1959	6
1.2992 - 1.3134	11	1.2588 - 1.2745	6	1.1959 - 1.2101	9
1.3134 - 1.3276	9	1.2745 - 1.2902	16	1.2101 - 1.2243	21
1.3276 - 1.3418	22	1.2902 - 1.3059	29	1.2243 - 1.2385	28
1.3418 - 1.3561	28	1.3059 - 1.3217	44	1.2385 - 1.2527	27
1.3561 - 1.3703	27	1.3217 - 1.3374	42	1.2527 - 1.2669	44
1.3703 - 1.3845	33	1.3374 - 1.3531	48	1.2669 - 1.2811	57
1.3845 - 1.3987	46	1.3531 - 1.3688	39	1.2811 - 1.2953	50
1.3987 - 1.4129	50	1.3688 - 1.3846	65	1.2953 - 1.3095	43
1.4129 - 1.4271	51	1.3846 - 1.4003	52	1.3095 - 1.3238	31
1.4271 - 1.4414	32	1.4003 - 1.4160	41	1.3238 - 1.3380	50
1.4414 - 1.4556	46	1.4160 - 1.4318	29	1.3380 - 1.3522	29
1.4556 - 1.4698	34	1.4318 - 1.4475	25	1.3522 - 1.3664	27
1.4698 - 1.4840	30	1.4475 - 1.4632	18	1.3664 - 1.3806	21
1.4840 - 1.4982	26	1.4632 - 1.4789	8	1.3806 - 1.3948	21
1.4982 - 1.5124	18	1.4789 - 1.4947	9	1.3948 - 1.4090	12
1.5124 - 1.5266	7	1.4947 - 1.5104	6	1.4090 - 1.4232	9
1.5266 - 1.5409	3	1.5104 - 1.5261	2	1.4232 - 1.4374	3
1.5409 - 1.5551	11	1.5261 - 1.5418	1	1.4374 - 1.4516	4
1.5551 - 1.5693	3	1.5418 - 1.5576	0	1.4516 - 1.4658	1
1.5693 - 1.5835	1	1.5576 - 1.5733	0	1.4658 - 1.4800	1
1.5835 - 1.5977	1	1.5733 - 1.5890	0	1.4800 - 1.4942	0
1.5977 - 1.6119	1	1.5890 - 1.6048	1	1.4942 - 1.5084	1

TABLE V-2--Continued

341		351		361	
Benefit-Cost Ratios	Frequency	Benefit-Cost Ratios	Frequency	Benefit-Cost Ratios	Frequency
1.2283 - 1.2410	4	1.1967 - 1.2137	7	1.1291 - 1.1420	3
1.2410 - 1.2537	1	1.2137 - 1.2307	4	1.1420 - 1.1549	4
1.2537 - 1.2664	2	1.2307 - 1.2477	18	1.1549 - 1.1678	6
1.2664 - 1.2791	8	1.2477 - 1.2648	20	1.1678 - 1.1807	14
1.2971 - 1.2919	12	1.2648 - 1.2818	30	1.1807 - 1.1936	13
1.2919 - 1.3046	22	1.2818 - 1.2988	56	1.1936 - 1.2065	21
1.3046 - 1.3173	18	1.2988 - 1.3158	46	1.2065 - 1.2194	19
1.3173 - 1.3300	26	1.3158 - 1.3328	63	1.2194 - 1.2323	31
1.3300 - 1.3427	23	1.3328 - 1.3498	48	1.2323 - 1.2453	42
1.3427 - 1.3555	42	1.3498 - 1.3669	64	1.2453 - 1.2582	43
1.3555 - 1.3682	31	1.3669 - 1.3839	47	1.2582 - 1.2711	48
1.3682 - 1.3809	48	1.3839 - 1.4009	27	1.2711 - 1.2840	45
1.3809 - 1.3936	47	1.4009 - 1.4179	29	1.2840 - 1.2969	42
1.3936 - 1.4063	39	1.4179 - 1.4349	19	1.2969 - 1.3098	34
1.4063 - 1.4190	49	1.4349 - 1.4519	7	1.3098 - 1.3227	29
1.4190 - 1.4318	36	1.4519 - 1.4690	7	1.3227 - 1.3356	30
1.4318 - 1.4445	29	1.4690 - 1.4860	4	1.3356 - 1.3485	31
1.4445 - 1.4572	20	1.4860 - 1.5030	1	1.3485 - 1.3614	13
1.4572 - 1.4699	9	1.5030 - 1.5200	0	1.3614 - 1.3743	9
1.4699 - 1.4826	13	1.5200 - 1.5370	2	1.3743 - 1.3872	13
1.4826 - 1.4954	7	1.5370 - 1.5540	0	1.3872 - 1.4001	3
1.4954 - 1.5081	5	1.5540 - 1.5711	0	1.4001 - 1.4131	2
1.5081 - 1.5208	4	1.5711 - 1.5881	0	1.4131 - 1.4260	3
1.5208 - 1.5335	1	1.5881 - 1.6051	0	1.4260 - 1.4389	1
1.5335 - 1.5463	4	1.6051 - 1.6221	1	1.4389 - 1.4517	1

TABLE V-2--Continued

142		152		162	
Benefit-Cost Ratios	Frequency	Benefit-Cost Ratios	Frequency	Benefit-Cost Ratios	Frequency
1.2856 - 1.2993	2	1.2153 - 1.2301	3	1.1431 - 1.1582	1
1.2993 - 1.3130	3	1.2301 - 1.2448	0	1.1582 - 1.1733	1
1.3130 - 1.3268	11	1.2448 - 1.2596	5	1.1733 - 1.1884	2
1.3268 - 1.3405	14	1.2596 - 1.2743	8	1.1884 - 1.2035	1
1.3405 - 1.3542	15	1.2743 - 1.2891	11	1.2035 - 1.2186	5
1.3542 - 1.3680	20	1.2891 - 1.3038	18	1.2186 - 1.2337	20
1.3680 - 1.3817	23	1.3038 - 1.3186	28	1.2337 - 1.2488	15
1.3817 - 1.3954	27	1.3186 - 1.3333	34	1.2488 - 1.2639	22
1.3954 - 1.4091	49	1.3333 - 1.3481	24	1.2639 - 1.2790	25
1.4091 - 1.4229	38	1.3481 - 1.3628	28	1.2790 - 1.2941	43
1.4229 - 1.4366	40	1.3628 - 1.3776	43	1.2941 - 1.3092	51
1.4366 - 1.4503	40	1.3776 - 1.3923	57	1.3092 - 1.3242	48
1.4503 - 1.4640	38	1.3923 - 1.4071	39	1.3242 - 1.3393	57
1.4640 - 1.4778	42	1.4071 - 1.4218	48	1.3393 - 1.3544	57
1.4778 - 1.4915	25	1.4218 - 1.4366	33	1.3544 - 1.3695	36
1.4915 - 1.5052	24	1.4366 - 1.4514	34	1.3695 - 1.3846	26
1.5052 - 1.5190	27	1.4514 - 1.4661	34	1.3846 - 1.3997	26
1.5190 - 1.5327	18	1.4661 - 1.4809	14	1.3997 - 1.4148	15
1.5327 - 1.5464	18	1.4809 - 1.4956	15	1.4148 - 1.4299	18
1.5464 - 1.5601	5	1.4956 - 1.5104	9	1.4299 - 1.4450	13
1.5601 - 1.5739	9	1.5104 - 1.5251	7	1.4450 - 1.4601	10
1.5739 - 1.5876	5	1.5251 - 1.5399	4	1.4601 - 1.4752	2
1.5876 - 1.6013	5	1.5399 - 1.5546	3	1.4752 - 1.4903	3
1.6013 - 1.6150	1	1.5546 - 1.5694	0	1.4903 - 1.5054	2
1.6150 - 1.6288	1	1.5694 - 1.5842	1	1.5054 - 1.5204	1

TABLE V-2--Continued

242		252		262	
Benefit-Cost Ratios	Frequency	Benefit-Cost Ratios	Frequency	Benefit-Cost Ratios	Frequency
1.2701 - 1.2837	5	1.2206 - 1.2356	1	1.1667 - 1.1807	7
1.2837 - 1.2974	1	1.2356 - 1.2507	4	1.1807 - 1.1946	1
1.2974 - 1.3110	2	1.2507 - 1.2657	6	1.1946 - 1.2086	8
1.3110 - 1.3246	10	1.2657 - 1.2808	12	1.2086 - 1.2225	4
1.3246 - 1.3383	11	1.2808 - 1.2958	13	1.2225 - 1.2364	14
1.3383 - 1.3519	16	1.2958 - 1.3109	21	1.2364 - 1.2504	25
1.3519 - 1.3655	22	1.3109 - 1.3259	26	1.2504 - 1.2643	27
1.3655 - 1.3792	37	1.3259 - 1.3410	38	1.2643 - 1.2783	37
1.3792 - 1.3928	29	1.3410 - 1.3560	39	1.2783 - 1.2922	45
1.3928 - 1.4064	45	1.3560 - 1.3711	53	1.2922 - 1.3061	32
1.4064 - 1.4201	39	1.3711 - 1.3861	51	1.3061 - 1.3201	60
1.4201 - 1.4337	45	1.3861 - 1.4012	50	1.3201 - 1.3340	45
1.4337 - 1.4474	47	1.4012 - 1.4162	48	1.3340 - 1.3479	52
1.4474 - 1.4610	49	1.4162 - 1.4312	37	1.3479 - 1.3619	29
1.4610 - 1.4746	35	1.4312 - 1.4463	29	1.3619 - 1.3758	30
1.4746 - 1.4883	25	1.4463 - 1.4613	34	1.3758 - 1.3898	28
1.4883 - 1.5019	24	1.4613 - 1.4764	13	1.3898 - 1.4037	15
1.5019 - 1.5155	15	1.4764 - 1.4914	10	1.4037 - 1.4176	9
1.5155 - 1.5292	17	1.4914 - 1.5065	2	1.4176 - 1.4316	15
1.5292 - 1.5428	5	1.5065 - 1.5215	6	1.4316 - 1.4455	7
1.5428 - 1.5564	10	1.5215 - 1.5366	4	1.4455 - 1.4595	1
1.5564 - 1.5701	4	1.5366 - 1.5516	1	1.4595 - 1.4734	2
1.5701 - 1.5837	3	1.5516 - 1.5667	1	1.4734 - 1.4873	2
1.5837 - 1.5973	1	1.5667 - 1.5817	0	1.4873 - 1.5013	1
1.5973 - 1.6111	3	1.5817 - 1.5967	1	1.5013 - 1.5151	4

TABLE V-2--Continued

342		352		362	
Benefit-Cost Ratios	Frequency	Benefit-Cost Ratios	Frequency	Benefit-Cost Ratios	Frequency
1.2349 - 1.2494	2	1.1759 - 1.1911	2	1.1351 - 1.1509	3
1.2494 - 1.2638	4	1.1911 - 1.2063	0	1.1509 - 1.1667	5
1.2638 - 1.2783	3	1.2063 - 1.2215	3	1.1667 - 1.1824	3
1.2783 - 1.2927	5	1.2215 - 1.2367	4	1.1824 - 1.1982	7
1.2927 - 1.3072	9	1.2367 - 1.2520	10	1.1982 - 1.2140	24
1.3072 - 1.3216	19	1.2520 - 1.2672	12	1.2140 - 1.2298	26
1.3216 - 1.3361	29	1.2672 - 1.2824	21	1.2298 - 1.2455	36
1.3361 - 1.3506	42	1.2824 - 1.2976	27	1.2455 - 1.2613	59
1.3506 - 1.3650	40	1.2976 - 1.3128	34	1.2613 - 1.2771	48
1.3650 - 1.3795	32	1.3128 - 1.3280	46	1.2771 - 1.2929	50
1.3795 - 1.3939	50	1.3280 - 1.3433	49	1.2929 - 1.3086	52
1.3939 - 1.4084	49	1.3433 - 1.3585	54	1.3086 - 1.3244	51
1.4084 - 1.4228	39	1.3585 - 1.3737	59	1.3244 - 1.3402	37
1.4228 - 1.4373	40	1.3737 - 1.3889	51	1.3402 - 1.3560	25
1.4373 - 1.4517	37	1.3889 - 1.4041	41	1.3560 - 1.3717	24
1.4517 - 1.4662	27	1.4041 - 1.4193	29	1.3717 - 1.3875	10
1.4662 - 1.4806	22	1.4193 - 1.4346	16	1.3875 - 1.4033	13
1.4806 - 1.4951	20	1.4346 - 1.4498	16	1.4033 - 1.4191	14
1.4951 - 1.5095	10	1.4498 - 1.4650	14	1.4191 - 1.4349	5
1.5095 - 1.5240	7	1.4650 - 1.4802	7	1.4349 - 1.4506	4
1.5240 - 1.5384	3	1.4802 - 1.4954	3	1.4506 - 1.4664	2
1.5384 - 1.5529	5	1.4954 - 1.5106	0	1.4664 - 1.4822	1
1.5529 - 1.5673	3	1.5106 - 1.5259	1	1.4822 - 1.4980	0
1.5673 - 1.5818	2	1.5259 - 1.5411	0	1.4980 - 1.5137	0
1.5818 - 1.5962	1	1.5411 - 1.5563	1	1.5137 - 1.5295	1

TABLE V-2--Continued

143		153		163	
Benefit-Cost Ratios	Frequency	Benefit-Cost Ratios	Frequency	Benefit-Cost Ratios	Frequency
1.2541 - 1.2698	3	1.1967 - 1.2135	2	1.1444 - 1.1589	1
1.2698 - 1.2855	2	1.2135 - 1.2303	3	1.1589 - 1.1733	2
1.2855 - 1.3012	4	1.2303 - 1.2471	1	1.1733 - 1.1878	4
1.3012 - 1.3169	4	1.2471 - 1.2639	5	1.1878 - 1.2023	5
1.3169 - 1.3326	10	1.2639 - 1.2807	8	1.2023 - 1.2168	7
1.3326 - 1.3483	10	1.2807 - 1.2976	15	1.2168 - 1.2313	9
1.3483 - 1.3640	26	1.2976 - 1.3144	17	1.2313 - 1.2458	21
1.3640 - 1.3797	47	1.3144 - 1.3312	25	1.2458 - 1.2602	28
1.3797 - 1.3954	44	1.3122 - 1.3480	37	1.2602 - 1.2747	28
1.3954 - 1.4111	44	1.3480 - 1.3648	47	1.2747 - 1.2892	45
1.4111 - 1.4268	44	1.3648 - 1.3816	46	1.2892 - 1.3037	45
1.4268 - 1.4425	57	1.3816 - 1.3984	63	1.3037 - 1.3182	38
1.4425 - 1.4582	34	1.3984 - 1.4152	59	1.3182 - 1.3327	48
1.4582 - 1.4739	45	1.4152 - 1.4320	45	1.3327 - 1.3472	46
1.4739 - 1.4896	34	1.4320 - 1.4488	36	1.3472 - 1.3616	38
1.4896 - 1.5053	27	1.4488 - 1.4657	28	1.3616 - 1.3761	37
1.5053 - 1.5210	18	1.4657 - 1.4825	27	1.3761 - 1.3906	34
1.5210 - 1.5367	13	1.4825 - 1.4993	19	1.3906 - 1.4051	14
1.5367 - 1.5524	10	1.4993 - 1.5161	5	1.4051 - 1.4196	13
1.5524 - 1.5681	15	1.5161 - 1.5329	6	1.4196 - 1.4341	10
1.5681 - 1.5838	6	1.5329 - 1.5497	1	1.4341 - 1.4486	10
1.5838 - 1.5995	2	1.5497 - 1.5665	3	1.4486 - 1.4630	7
1.5995 - 1.6152	0	1.5665 - 1.5833	1	1.4630 - 1.4775	4
1.6152 - 1.6309	0	1.5833 - 1.6001	0	1.4775 - 1.4920	4
1.6309 - 1.6465	1	1.6001 - 1.6169	1	1.4920 - 1.5066	2

TABLE V-2--Continued

243		253		263	
Benefit-Cost Ratios	Frequency	Benefit-Cost Ratios	Frequency	Benefit-Cost Ratios	Frequency
1.2535 - 1.2684	1	1.2002 - 1.2144	1	1.1211 - 1.1351	2
1.2684 - 1.2833	1	1.2144 - 1.2286	0	1.1351 - 1.1490	0
1.2833 - 1.2981	0	1.2286 - 1.2428	5	1.1490 - 1.1630	0
1.2981 - 1.3130	5	1.2428 - 1.2569	4	1.1630 - 1.1770	3
1.3130 - 1.3279	13	1.2569 - 1.2711	4	1.1770 - 1.1910	1
1.3279 - 1.3428	12	1.2711 - 1.2853	9	1.1910 - 1.2049	6
1.3428 - 1.3577	32	1.2853 - 1.2995	17	1.2049 - 1.2189	10
1.3577 - 1.3725	28	1.2995 - 1.3137	18	1.2189 - 1.2329	10
1.3725 - 1.3874	37	1.3137 - 1.3279	18	1.2329 - 1.2468	23
1.3874 - 1.4023	48	1.3279 - 1.3421	21	1.2468 - 1.2608	20
1.4023 - 1.4172	51	1.3421 - 1.3563	51	1.2608 - 1.2748	36
1.4172 - 1.4321	39	1.3563 - 1.3705	45	1.2748 - 1.2887	38
1.4321 - 1.4469	49	1.3705 - 1.3846	57	1.2887 - 1.3027	46
1.4469 - 1.4618	46	1.3846 - 1.3988	46	1.3027 - 1.3167	42
1.4618 - 1.4767	34	1.3988 - 1.4130	38	1.3167 - 1.3306	55
1.4767 - 1.4916	28	1.4130 - 1.4272	41	1.3306 - 1.3446	51
1.4916 - 1.5064	25	1.4272 - 1.4414	32	1.3446 - 1.3586	40
1.5064 - 1.5213	20	1.4414 - 1.4556	24	1.3586 - 1.3725	29
1.5213 - 1.5362	15	1.4556 - 1.4698	20	1.3725 - 1.3865	22
1.5362 - 1.5511	5	1.4698 - 1.4840	20	1.3865 - 1.4005	22
1.5511 - 1.5660	1	1.4840 - 1.4982	11	1.4005 - 1.4145	13
1.5660 - 1.5808	5	1.4982 - 1.5123	4	1.4145 - 1.4284	9
1.5808 - 1.5957	1	1.5123 - 1.5265	11	1.4284 - 1.4424	12
1.5957 - 1.6106	2	1.5265 - 1.5407	2	1.4424 - 1.4564	5
1.6106 - 1.6254	2	1.5407 - 1.5549	1	1.4564 - 1.4702	5

TABLE V-2--Continued

343		353		363	
Benefit-Cost Ratios	Frequency	Benefit-Cost Ratios	Frequency	Benefit-Cost Ratios	Frequency
1.2417 - 1.2540	2	1.1834 - 1.1965	1	1.1318 - 1.1451	1
1.2540 - 1.2664	4	1.1965 - 1.2096	2	1.1451 - 1.1584	3
1.2664 - 1.2788	4	1.2096 - 1.2226	1	1.1584 - 1.1716	2
1.2788 - 1.2911	8	1.2226 - 1.2357	1	1.1716 - 1.1849	2
1.2911 - 1.3035	10	1.2357 - 1.2488	5	1.1849 - 1.1981	11
1.3035 - 1.3158	22	1.2488 - 1.2618	10	1.1981 - 1.2114	10
1.3158 - 1.3282	17	1.2618 - 1.2749	12	1.2114 - 1.2246	16
1.3282 - 1.3406	31	1.2749 - 1.2880	17	1.2246 - 1.2379	33
1.3406 - 1.3529	26	1.2880 - 1.3010	24	1.2379 - 1.2511	30
1.3529 - 1.3653	25	1.3010 - 1.3141	32	1.2511 - 1.2644	46
1.3653 - 1.3777	50	1.3141 - 1.3272	35	1.2644 - 1.2776	61
1.3777 - 1.3900	43	1.3272 - 1.3402	45	1.2776 - 1.2909	35
1.3900 - 1.4024	44	1.3402 - 1.3533	39	1.2909 - 1.3041	45
1.4024 - 1.4147	37	1.3533 - 1.3664	55	1.3041 - 1.3174	44
1.4147 - 1.4271	36	1.3664 - 1.3794	45	1.3174 - 1.3306	43
1.4271 - 1.4395	35	1.3794 - 1.3925	44	1.3306 - 1.3439	27
1.4395 - 1.4518	28	1.3925 - 1.4056	31	1.3439 - 1.3571	29
1.4518 - 1.4642	20	1.4056 - 1.4186	27	1.3571 - 1.3704	19
1.4642 - 1.4766	17	1.4186 - 1.4317	26	1.3704 - 1.3836	15
1.4766 - 1.4889	9	1.4317 - 1.4447	14	1.3836 - 1.3969	12
1.4889 - 1.5013	14	1.4447 - 1.4578	17	1.3969 - 1.4102	4
1.5013 - 1.5136	8	1.4578 - 1.4709	10	1.4102 - 1.4234	6
1.5136 - 1.5260	4	1.4709 - 1.4839	3	1.4234 - 1.4367	2
1.5260 - 1.5384	3	1.4839 - 1.4970	2	1.4367 - 1.4499	3
1.5384 - 1.5506	3	1.4970 - 1.5100	2	1.4499 - 1.4631	1

TABLE V-2--Continued

[a]The reservoir size and operating procedure codes are as follows: The first digit is Catherine Creek Reservoir with size 1 = 42,000 acre feet, 2 = 65,000 acre feet, and 3 = 87,000 acre feet. The second digit is Grande Ronde Reservoir with size 3 = 160,000 acre feet, 4 = 190,000 acre feet, and 5 = 220,000 acre feet. The third digit is operating procedure with 1 = 55,000 acres, 2 = 74,000 acres, and 3 = 92,000 acres. An example of a given combination is as follows:

Catherine Creek - size 3
Grande Ronde - size 6
Operating Procedure - number 1
3 6 1

in the experimental design. The writer is aware that the measurement of the input data may not justify the four place accuracy in the results expressed in Table V-2. The data are expressed in this form to indicate the scope of the frequency distributions within the sample.

Mean Net Present Benefits

The means for net present benefits for each of the cells for the experimental design are plotted in Chart V-1. The means are charted for each reservoir combination for a given operating procedure.

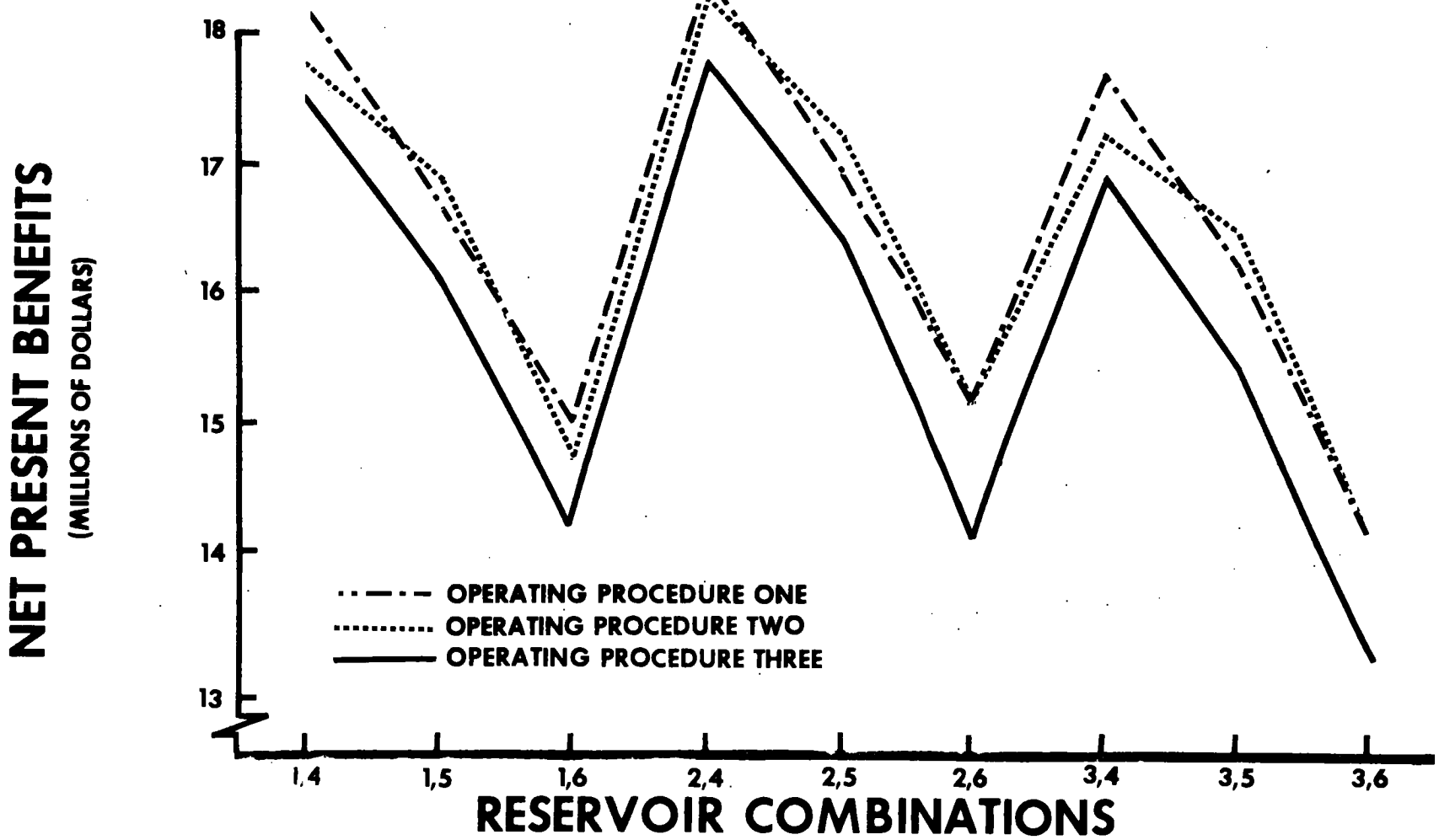
The reservoir combinations shown in Chart V-1 are charted from the smallest combination (1 for Catherine Creek Dam with 42,000 acre feet and 4 for Grande Ronde Dam with 160,000 acre feet) to the largest combination (3 for Catherine Creek Dam with 87,000 acre feet and 6 for Grande Ronde Dam with 220,000 acre feet). The mean values for net present benefits indicate that operating procedures two and three give a consistently higher net present benefit than operating procedure one. A cursory examination indicates that operating procedures two and three are not significantly different from one another. Operating procedure two results in a higher mean net present benefit than operating procedure three with those combinations of reservoirs which are of most interest (combinations with the highest net present benefits).

Reservoir combinations (1,4), (2,4), and (3,4) show higher mean net present benefits than the other reservoir combinations for each of the three operating procedures.

On the basis of the maximum net present benefit criteria and mean figures, reservoir combination (2,4) and operating procedure two

CHART V—1

MEAN VALUES OF NET PRESENT BENEFITS FOR ALTERNATIVE RESERVOIR COMBINATIONS AND OPERATING PROCEDURES IN THE GRANDE RONDE BASIN



result in the optimal selection from the 27 cells included in the experimental design.

Mean Benefit-Cost Ratios

The means for benefit-cost ratios for each of the cells for the experimental design are shown in Chart V-2. The means are charted in a fashion similar to Chart V-1. The results from the charting of benefit-cost ratios are similar to those from the charting of net present benefits. One interesting divergence, however, includes a different optimal reservoir combination as based on the highest mean benefit-cost ratio. Reservoir combination (1,4) gives the highest mean benefit-cost ratio.

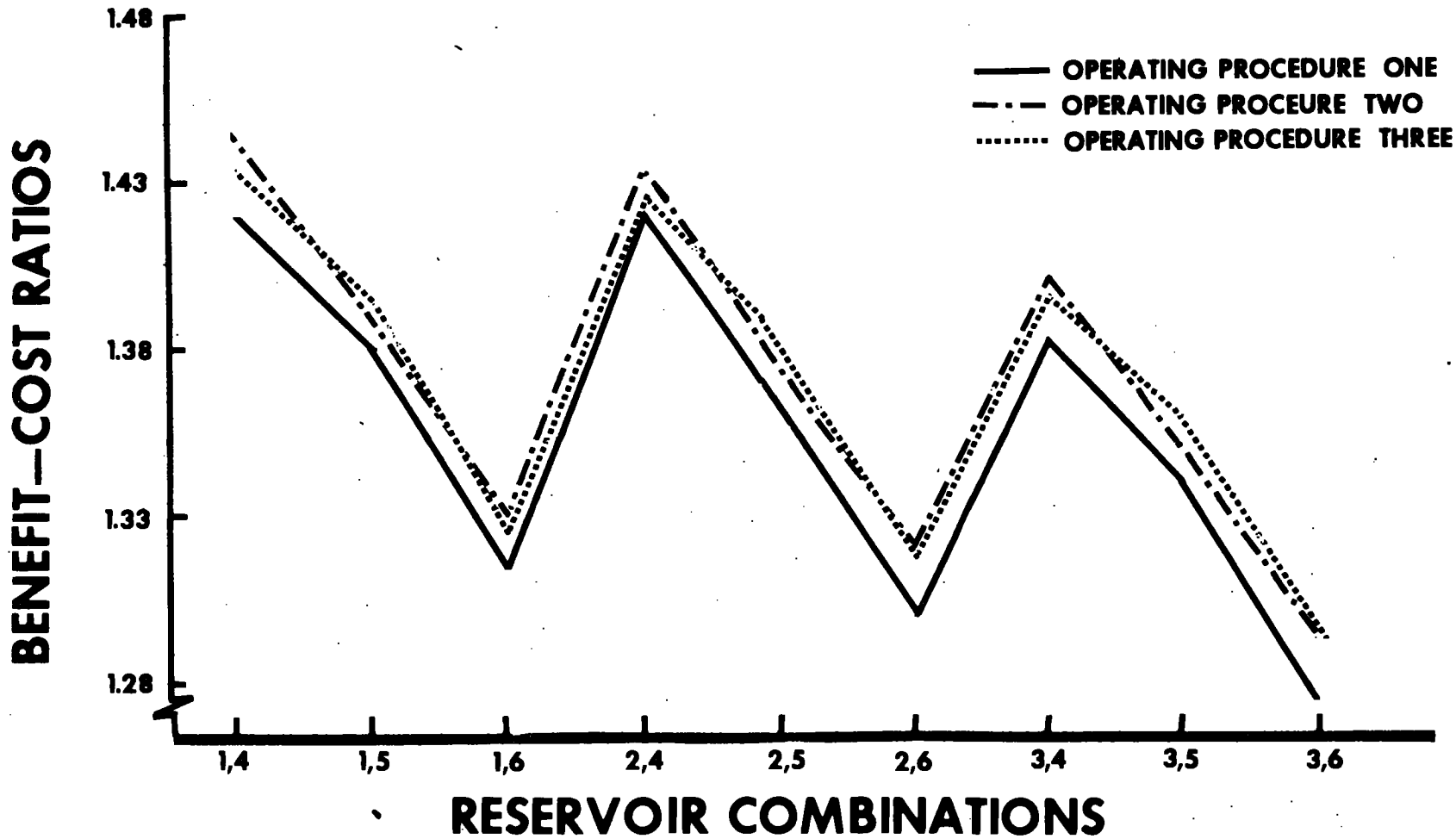
The two combinations of (1,4) and (2,4) are very close, and significant differences are not readily apparent from Chart V-2.

The Analysis of Variance of Net Present Benefits

The means for the cells in the experimental design provide insight into the patterns of each of the reservoir combinations and operating procedures. In order to test the hypotheses as set forth in the design, however, statistical tests are necessary to determine which changes in the experiemental design caused results to differ significantly from one another. Analysis of variance and multiple range tests are the statistical techniques which are used to analyze the results of the experiment and to determine the importance of selected changes.

CHART V —2

MEAN VALUES OF BENEFIT—COST RATIOS FOR ALTERNATIVE RESERVOIR COMBINATIONS AND OPERATING PROCEDURES IN THE GRANDE RONDE BASIN



The assumptions for this analysis and the use of analysis of variance include: normality of the population distribution; homogeneity of variance; and continuity and equal intervals of measures. Kerlinger points out that "The evidence to date is that the importance of normality and homogenity is overrated..."[1]

Cochran's test for homogeneity of variances and Bartlett's tests for homogeneity of variances serve as tests for homogeneity. Cochran's test has been used in this study because "...the use of the Bartlett test, which is 'nonrobust,' has been likened to going to sea in a rowboat to see if an ocean liner would be safe."[2] The results from Cochran's tests are shown in Table V-3. Since data for a sample of 500 are not available, no attempt is made to interpolate between 145 and infinity. If the maximum variance for the set divided by the summation of the variances for the set is less than the F distribution, the assumption of homogeneity is accepted.

There are nine reservoir combinations, three operating procedures, and a sample of 500 for each cell. The experiment for one variable, therefore, includes the analysis of 13,500 sample entries. This analysis covers two variables (net present benefits and benefit-cost ratios), and therefore the total number of individual samples is 27,000.

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[1] Fred N. Kerlinger, Foundations of Behavioral Research (New York: Holt, Rinehart, and Winston, 1964), p. 258.

[2] Ibid.

TABLE V-3

COCHRAN'S TEST FOR HOMOGENEITY OF VARIANCES
FOR NET PRESENT BENEFITS[a]

Sample Size(n)	Number of Variances(k)	Cochran's Test for Homogeneity: Max. $Si^2 / \sum_{i=1}^{k} Si^2$	F Distribution[b] n = 145	F Distribution[b] n = ∞
500	27	.04843	.0512	.0375
500	18	.07192	.0820	.0568

[a]Tests are for the .05 level of significance.

[b]William H. Beyer, ed., Handbook of Tables for Probability and Statistics (Cleveland, Ohio: The Chemical Rubber Co., 1968), p. 327. Figures are interpolated for number of variances included in the test.

Because of the size of the analytical task, the computer is used to perform the computations for the researcher to analyze.

One null hypothesis for the analysis of variance for net present benefits is as follows:[3]

H_1: $\mu_{14} = \mu_{15} = \mu_{16} = \mu_{24} = \mu_{25} = \mu_{26} = \mu_{34} = \mu_{35} = \mu_{36}$

The alternate hypothesis is:

H_2: $\mu_{14} \neq \mu_{15} \neq \mu_{16} \neq \mu_{24} \neq \mu_{25} \neq \mu_{25} \neq \mu_{26} \neq \mu_{34} \neq \mu_{35} \neq \mu_{36}$

This null hypothesis implies that means for the population for different reservoir combinations (columns) are not significantly different from one another. If the means for columns are equal to one another, the sub-populations can be assumed to be one large population.

Using analysis of variance on columns (reservoir combinations), the degrees of freedom are eight and the F ratio is 871. The differences among columns (reservoir combinations) are significant at the .001 level.

An important consideration in the analysis, however, is whether or not any one mean net present benefit is significantly different from the other means. A multiple range test can be used to compare each individual mean to each of the other means in the set. The mean net present benefits for each reservoir set are shown in rank order from lowest to highest in the first part of Table V-4.

Table V-4 also gives the results of the multiple range test. As an example, the mean for reservoir set 36 is significantly different

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[3]The subscripts for this null hypothesis represent various reservoir combinations (see footnote b of Table V-4).

TABLE V-4

RESERVOIR COMBINATIONS OF CATHERINE CREEK RESERVOIR AND GRANDE RONDE RESERVOIR WITH NET PRESENT BENEFITS FOR MEANS MULTIPLE RANGE TEST FOR SIGNIFICANT[a] DIFFERENCES

Reservoir Set[b]	Mean Net Present Benefits (dollars)
36	13,822,911
16	14,577,097
26	14,647,537
35	16,003,542
15	16,546,099
25	16,785,893
34	17,242,858
14	17,718,741
24	18,042,262

Res. Set 36 is not equal to:	Res. Set 16	Res. Set 26	Res. Set 35
	Res. Set 15	Res. Set 25	Res. Set 34
	Res. Set 14	Res. Set 24	
Res. Set 16 is not equal to:	Res. Set 35	Res. Set 15	Res. Set 25
	Res. Set 34	Res. Set 14	Res. Set 24
Res. Set 26 is not equal to:	Res. Set 35	Res. Set 15	Res. Set 25
	Res. Set 34	Res. Set 14	Res. Set 24
Res. Set 35 is not equal to:	Res. Set 15	Res. Set 25	Res. Set 34
	Res. Set 14	Res. Set 24	
Res. Set 15 is not equal to:	Res. Set 25	Res. Set 34	Res. Set 14
	Res. Set 24		
Res. Set 25 is not equal to:	Res. Set 34	Res. Set 14	Res. Set 24

TABLE V-4--Continued

Reservoir Set[b]		
Res. Set 34 is not equal to:	Res. Set 14	Res. Set 24
Res. Set 14 is not equal to:	Res. Set 24	

[a]Differences are tested at the .05 significance level.

[b]Reservoir combinations are as follows: 1 = Catherine Creek with 42,000 acre feet; 2 = Catherine Creek with 65,000 acre feet; 3 = Catherine Creek with 87,000 acre feet; 4 = Grande Ronde with 160,000 acre feet; 5 = Grande Ronde with 190,000 acre feet; and 6 = Grande Ronde with 220,000 acre feet.

from the means for reservoir sets 16, 26, 35, 15, 25, 34, 14 and 24 with a .05 probability of a type 1 error. Those reservoir sets which are not listed in the right side groupings of Table V-4 are not significantly different than the tested reservoir set. In a comparison of reservoir set 16 to the other reservoirs, reservoir set 26 does not appear in the list of reservoir sets to the right; this means that there is no significant difference between mean net present benefits for reservoir sets 16 and 26.

Reservoir set 24 is of most interest because it has the highest net present benefits. It also differs significantly from each of the other sets at the .05 level. Reservoir set 24 can be observed in each of the sets in the right side groupings of Table V-4.

A second null hypothesis[4] for net present benefits is as follows:

H_1: $\mu_1 = \mu_2 = \mu_3$

The alternate hypothesis is:

H_2: $\mu_1 \neq \mu_2 \neq \mu_3$

This null hypothesis implies that means for the population for different operating procedures (rows) are not significantly different from one another. If the means for net present benefits for rows are equal to one another, the sub-population can be assumed to be one large population.

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[4] The subscripts for this null hypothesis represent various operating procedures as follows: 1=55,000 irrigated acres; 2=74,000 irrigated acres; and 3=93,000 irrigated acres.

Using analysis of variance on rows (operating procedures), the degrees of freedom are two and the F ratio is 182. The differences among rows (operating procedures) are significant at the .001 level.

A multiple range test at a .05 level of significance on row means for net present benefits gives results as follows: The mean net present benefit for operating procedure one is not equal to those of operating procedure two or operating procedure three.

With respect to differences between operating procedures two and three, the two do not differ significantly at the .05 level.

Since operating procedures two and three show no significant differences, these sets were subjected to further analyses. A treatment means multiple range test at the .05 significance level gives results as shown in Table V-5.

Treatment 143 for net present benefits differs significantly from treatments 142, 243, and 242 at the .05 level. Treatments 142, 243, and 242 show no significant differences from one another at the .05 level.

The Analysis of Variance of Benefit-Cost Ratios

The results of Cochran's test for homogeneity of variances is shown in Table V-6. The explanation of this test is included in the previous section.

The null hypothesis[5] for the analysis of variance for benefit-

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[5]The subscripts for this null hypothesis represent various reservoir combinations (see footnote b of Table V-4).

TABLE V-5

RESERVOIR COMBINATIONS AND OPERATING PROCEDURES FOR CATHERINE CREEK RESERVOIR AND GRANDE RONDE RESERVOIR WITH NET PRESENT BENEFITS FOR TREATMENT MEANS MULTIPLE RANGE TEST FOR SIGNIFICANT[a] DIFFERENCES

Reservoir Set and Operating Procedure[b]	Mean Net Present Benefits (dollars)
362	14,108,341
363	14,120,982
163	14,670,728
162	14,865,709
263	14,920,519
262	14,921,638
352	16,206,881
353	16,363,093
152	16,718,989
153	16,772,359
252	16,948,037
253	17,115,525
343	17,354,211
342	17,559,294
143	17,740,168
142	18,065,689
243	18,161,410
242	18,263,123

362 is not equal to:	163	162	263	262	352	353
	152	153	252	253	343	342
	143	142	243	242		
363 is not equal to:	163	162	263	262	352	353
	152	153	252	253	343	342
	143	142	243	242		
163 is not equal to:	352	353	152	153	252	253
	343	342	143	142	243	242
162 is not equal to:	352	353	152	153	252	253
	343	342	143	142	243	242
263 is not equal to:	352	353	152	153	252	253
	343	342	143	142	243	242

TABLE V-5--Continued

Reservoir Set and Operating Procedure[b]						
262 is not equal to:	352 343	353 342	152 143	153 142	252 243	253 242
352 is not equal to:	152 143	153 142	252 243	253 242	343	342
152 is not equal to:	253 242	343	342	143	142	243
153 is not equal to:	253 242	343	342	143	142	243
252 is not equal to:	343	342	143	142	243	242
253 is not equal to:	342	143	142	243	242	
343 is not equal to:	143	142	243	242		
342 is not equal to:	142	243	242			
143 is not equal to:	142	243	242			

[a]Differences are tested at the .05 significance level.

[b]Reservoir Combinations and operating procedures are as follows: The first digit represents the size of Catherine Creek Reservoir with 1 = 42,000 acre feet, 2 = 65,000 acre feet, and 3 = 87,000 acre feet; The second digit represents Grande Ronde Reservoir with 4 = 160,000 acre feet, 5 = 190,000 acre feet, and 6 = 220,000 acre feet; The third digit represents operating procedures and their accompanying required irrigation diversions for acres with 1 = 55,000 acres, 2 = 74,000 acres, and 3 = 92,000 acres. An example is as follows:

Catherine Creek Reservoir - 42,000 acre feet
Grande Ronde Reservoir - 160,000 acre feet
Operating Procedure - 92,000 irrigated acres

1 4 3

TABLE V-6

COCHRAN'S TEST FOR HOMOGENEITY OF VARIANCES
FOR BENEFIT-COST RATIOS[a]

Sample Size(n)	Number of Variances(k)	Cochran's Test for Homogeneity		
		Max. $Si^2 / \sum_{i=1}^{k} Si^2$	F Distribution[b]	
			n = 145	n = ∞
500	27	.04255	.0512	.0375
500	18	.06287	.0820	.0568

[a]Tests are for the .05 level of significance.

[b]William H. Beyer, ed., Handbook of Tables for Probability and Statistics (Cleveland, Ohio: The Chemical Rubber Co., 1968), p. 327. Figures are interpolated for number of variances included in the test.

cost ratios is as follows:

H_1: $\mu_{14} = \mu_{15} = \mu_{16} = \mu_{24} = \mu_{25} = \mu_{26} = \mu_{34} = \mu_{35} = \mu_{36}$

The alternate hypothesis is:

H_2: $\mu_{14} \neq \mu_{15} \neq \mu_{16} \neq \mu_{24} \neq \mu_{25} \neq \mu_{26} \neq \mu_{34} \neq \mu_{35} \neq \mu_{36}$

The null hypothesis implies that means for the populations for different reservoir combinations (columns) for benefit-cost ratios are not significantly different from one another.

Using analysis of variance on columns (reservoir combinations), the degrees of freedom are eight and the F ratio is 1070. The differences among columns (reservoir combinations) are significant at the .001 level.

Using a multiple range test and a level of significance of .05, the differences among column means can be examined. The results from the column means multiple range test for benefit-cost ratios are shown in Table V-7. Reservoir combination 14, which results in the highest mean benefit-cost ratio, differs significantly from the other reservoir combinations at the .05 level.

A second null hypothesis[6] for benefit-cost ratios is as follows:

H_1: $\mu_1 = \mu_2 = \mu_3$

The alternate hypothesis is:

H_2: $\mu_1 \neq \mu_2 \neq \mu_3$

---

[6]The subscripts for this null hypothesis represent various operating procedures with acres for irrigation diversions as follows: 1=55,000 irrigated acres; 2=74,000 irrigated acres; and 3=92,000 irrigated acres.

TABLE V-7

RESERVOIR COMBINATIONS OF CATHERINE CREEK RESERVOIR AND GRANDE RONDE RESERVOIR WITH BENEFIT-COST RATIOS FOR MEANS MULTIPLE RANGE TEST FOR SIGNIFICANT[a] DIFFERENCES

Reservoir Set[b]	Mean Benefit-Cost Ratio
36	1.2868
26	1.3136
16	1.3231
35	1.3500
25	1.3793
15	1.3866
34	1.3925
24	1.4254
14	1.4323

Res. Set 36 is not equal to:	Res. Set 26 Res. Set 25 Res. Set 24	Res. Set 16 Res. Set 15 Res. Set 14	Res. Set 35 Res. Set 34
Res. Set 26 is not equal to:	Res. Set 16 Res. Set 15 Res. Set 14	Res. Set 35 Res. Set 34	Res. Set 25 Res. Set 24
Res. Set 35 is not equal to:	Res. Set 25 Res. Set 24	Res. Set 15 Res. Set 14	Res. Set 34
Res. Set 25 is not equal to:	Res. Set 15 Res. Set 14	Res. Set 34	Res. Set 24
Res. Set 15 is not equal to:	Res. Set 34	Res. Set 24	Res. Set 14

TABLE V-7--Continued

Reservoir Set[b]		
Res. Set 34 is not equal to:	Res. Set 24	Res. Set 14
Res. Set 24 is not equal to:	Res. Set 14	

[a]Differences are tested at the .05 significance level.

[b]Reservoir combinations are as follows: 1 = Catherine Creek with 42,000 acre feet; 2 = Catherine Creek with 65,000 acre feet; 3 = Catherine Creek with 87,000 acre feet; 4 = Grande Ronde with 160,000 acre feet; 5 = Grande Ronde with 190,000 acre feet; and 6 = Grande Ronde with 220,000 acre feet.

This null hypothesis implies that means for benefit-cost ratios for the population for different operating procedures (rows) are not significantly different from one another.

Using analysis of variance on the rows (operating procedures), the degrees of freedom are two and the F ratio is 99.2. The differences are significant at the .001 level.

A multiple range test at a .05 level of significance on row means for benefit-cost ratios gives results as follows: The mean benefit-cost ratio for operating procedure one is not equal to those of operating procedure two or operating procedure three.

With respect to differences between operating procedures two and three for mean benefit-cost ratios for operating procedures the two do not differ significantly at the .05 level.

The operating procedures for two and three were subjected to further analyses by completing a treatment means multiple range test at the .05 level. The results for the treatment means multiple range test are shown in Table V-8.

The reservoir set and operating procedure of most interest (the one with the highest benefit-cost ratio) is 142. Its benefit-cost ratio differs significantly from the other reservoir sets and operating procedures at the .05 level. Based on the criteria of benefit-cost ratios and the mean benefit-cost ratio, 142 is the optimal selection with a .05 level of significance.

TABLE V-8

RESERVOIR COMBINATIONS AND OPERATING PROCEDURES FOR CATHERINE CREEK AND GRANDE RONDE RESERVOIR WITH BENEFIT-COST RATIOS FOR TREATMENT MEANS MULTIPLE RANGE TEST FOR SIGNIFICANT[a] DIFFERENCES

Reservoir Set and Operating Procedure[b]	Mean Benefit-Cost Ratio
363	1.2929
362	1.2932
263	1.3193
262	1.3196
163	1.3243
162	1.3299
352	1.3541
353	1.3585
252	1.3821
253	1.3875
152	1.3903
153	1.3926
343	1.3936
342	1.4007
243	1.4276
242	1.4303
143	1.4330
142	1.4417

363 is not equal to:	263	262	163	162	352	353
	252	253	152	153	343	342
	243	242	143	142		
362 is not equal to:	263	262	163	162	352	353
	252	253	152	153	343	342
	243	242	143	142		
263 is not equal to:	162	352	353	252	253	152
	153	343	342	243	242	143
	142					
163 is not equal to:	352	353	252	253	152	153
	343	342	243	242	143	142

TABLE V-8--Continued

Reservoir Set and Operating Procedure[b]						
162 is not equal to:	352 343	353 342	252 243	253 242	152 143	153 142
352 is not equal to:	252 243	253 242	152 143	153 142	343	342
353 is not equal to:	252 243	253 242	152 143	153 142	343	342
252 is not equal to:	153 142	343	342	243	242	143
253 is not equal to:	342	243	242	143	142	
152 is not equal to:	342	243	242	143	142	
153 is not equal to:	243	242	143	142		
343 is not equal to:	243	242	143	142		
342 is not equal to:	243	242	143	142		
243 is not equal to:	142					
242 is not equal to:	142					
143 is not equal to:	142					

[a]Differences are tested at the .05 significance level.

[b]Reservoir Combinations and operating procedures are as follows: The first digit represents the size of Catherine Creek Reservoir with 1 = 42,000 acre feet, 2 = 65,000 acre feet, and 3 = 87,000 acre feet; The second digit represents Grande Ronde Reservoir with 4 = 160,000 acre feet, 5 = 190,000 acre feet, and 6 = 220,000 acre feet; The third digit represents operating procedures and their accompanying required irrigation diversions for acres with 1 = 55,000 acres, 2 = 74,000 acres, and 3 = 92,000 acres. An example is as follows:

Catherine Creek Reservoir - 42,000 acre feet
Grande Ronde Reservoir - 160,000 acre feet
Operating Procedure - 92,000 irrigated acres

1 4 3

VI SUMMARY AND CONCLUSIONS

Chapter V gives the results of the simulation model and an analysis of the results. Chapter VI summarizes the results of the study and points out some of the implications involved.

Summary of the Results

The simulation model provides a framework for the analysis of decision variables for river basin planning. The results from the runs indicate that some decision sets are clearly superior to others. Operating procedures two and three are superior to one in terms of both net present benefits and benefit-cost ratios. Reservoir combinations 14 and 24 are superior to the other combinations in terms of both net present benefits and benefit-cost ratios.

In terms of an optimal set within the model, no one set is obviously optimal. Based on the criterion of net present benefits, there are no significant differences among sets 142, 243, and 242. This analysis reduces the choice set from 27 to three. If there is some form of capital rationing, the criterion of benefit-cost ratios may be used. Using this criterion, 142 differs significantly from each of the other sets and may be considered optimal among the choice sets.

This analysis includes only those reservoir combinations which are under investigation by the Corps of Engineers. If data were available, the choice sets could be extended to include a reservoir of smaller scale for the Grande Ronde Reservoir. A smaller scale reser-

voir for the Grande Ronde could possibly lead to a higher net present benefit for the river basin system. Since data for a smaller scale of the Grande Ronde Reservoir are not available, such a choice set is beyond the scope of this study.

General Applicability of the Model

The model for this study is applicable to the Grande Ronde Basin. The analytical framework, however, could be used for the analysis of any river basin. River basin planning should consider the variability of stream flows and cost estimates. The analytical approach of this study allows such variability to be taken into consideration within the context of the planning framework.

The results from the runs in this study are approximately normally distributed. If different assumptions concerning input variables (for example highly skewed distributions) are included in the analysis, the results could be very meaningful, but they may not be subject to analysis of variance since the required assumptions may be violated.

Implications for River Basin Planning

River basin planning requires a careful analysis of a combination of hydrologic, engineering, economic, and financial considerations. Simulation allows each of these disciplines to be combined into a model. This model encompasses two decision variables (net present benefits and benefit-cost ratios).

A model for river basin planning appears to be valuable in terms of two aspects. First, the model can give a better decision (increases the probability that the solution is optimal). Second, the model can allow the evaluation of many alternatives in less time than a segmented analysis. The researcher has strived to incorporate both of these advantages into this model.

In an ideal application of the model, the extreme sizes of reservoir combinations (both very large and very small reservoirs) should be included.

Areas of Future Research

The researcher visualizes a heuristic model that includes a feedback mechanism to change the decision variables internally. After a run has been completed for a given number of trials, the decision variable could be changed internally, and as long as the result was more favorable, the decision variable would continue to be changed by increments. This approach would allow the program to approach an optimal set internally.

This study could serve as a first step for such a model. Such a model would also require extensive changes in the formulation of input data. Input data would have to be specified in the form of functional relationships over meaningful ranges.

If the data gathering by various governmental agencies were oriented to the simulation approach, this analytical framework could be applied to a variety of governmental decisions. In the future, water

resource development may be expected to carry a significant role in the development of strong analytical techniques for governmental decision making.

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APPENDIX A

MONTHLY HYDROLOGY DATA FOR GRANDE RONDE RIVER BASIN
WITH WATER FLOWS IN HUNDREDS OF ACRE FEET FROM 1928-1968

CONTROL POINT NUMBER	YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JLY	AUG	SEP
21	1928	77	329	224	281	76	556	635	518	84	33	12	15
25	1928	12	88	96	151	45	299	305	182	22	7	1	2
11	1928	63	53	65	59	42	120	148	459	119	40	18	17
17	1928	9	14	10	9	6	25	31	95	12	4	3	3
19	1928	13	19	14	14	9	61	37	57	12	6	3	2
37	1928	13	27	24	29	20	56	96	44	8	8	9	10
21	1929	19	16	11	10	12	258	438	537	238	33	12	11
25	1929	3	4	5	5	7	139	211	189	63	7	1	1
11	1929	20	22	16	16	15	62	90	295	228	70	24	14
17	1929	3	3	2	2	2	10	19	62	36	7	4	2
19	1929	5	5	4	4	4	45	33	29	28	9	4	3
37	1929	13	13	13	13	13	29	64	46	10	8	9	10
21	1930	13	11	20	8	168	284	257	142	131	23	14	12
25	1930	2	3	8	5	101	153	123	50	35	5	1	1
11	1930	15	12	12	7	19	38	129	121	84	21	7	9
17	1930	2	2	2	1	3	8	27	25	8	2	1	1
19	1930	4	3	3	3	5	28	20	15	9	5	2	2
37	1930	13	13	13	13	27	37	45	17	9	8	9	10
21	1931	26	17	14	14	27	322	510	192	37	12	4	5
25	1931	4	5	6	8	16	174	246	67	10	2	1	1
11	1931	19	8	8	12	14	4	116	210	78	24	13	13
17	1931	3	1	1	2	2	8	24	45	8	2	2	2
19	1931	5	3	3	3	3	26	25	26	9	5	3	2
37	1931	13	13	13	13	15	33	69	20	6	8	9	10
21	1932	11	13	15	31	61	670	850	665	133	22	10	8
25	1932	2	4	7	16	36	360	410	234	35	5	1	1
11	1932	18	15	17	15	16	69	190	375	195	58	19	14
17	1932	3	2	3	2	2	11	39	78	31	6	3	2
19	1932	3	3	4	4	4	49	53	47	20	7	5	2
37	1932	13	13	13	15	18	53	106	50	9	8	9	10
21	1933	10	26	17	28	23	209	543	662	336	38	14	13
25	1933	2	7	7	15	13	113	262	232	89	8	1	1
11	1933	14	25	22	27	12	31	144	258	354	71	23	18
17	1933	2	4	3	4	2	5	30	54	55	7	3	3
19	1933	3	5	5	6	3	45	45	32	35	8	5	3
37	1933	13	13	13	15	15	26	83	49	11	8	9	10
21	1934	14	21	128	161	101	209	158	53	68	20	4	6
25	1934	2	5	55	86	60	113	76	19	18	4	1	1
11	1934	17	21	28	40	36	21	139	84	39	19	11	11
17	1934	3	3	3	6	5	19	29	17	4	2	2	2
19	1934	4	5	6	8	8	36	20	10	6	4	2	2
37	1934	13	13	22	24	22	35	33	11	8	8	9	10

SOURCE: U.S. ARMY CORPS OF ENGINEERS, WALLA WALLA DISTRICT, WALLA WALLA, WASHINGTON

APPENDIX A -- Continued

MONTHLY HYDROLOGY DATA FOR GRANDE RONDE RIVER BASIN
WITH WATER FLOWS IN HUNDREDS OF ACRE FEET FROM 1928-1968

CONTROL POINT NUMBER	YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JLY	AUG	SEP
21	1935	15	21	49	44	63	131	431	295	77	20	6	4
25	1935	2	5	21	23	38	70	207	104	20	4	1	1
11	1935	16	24	23	21	23	32	149	256	126	33	16	11
17	1935	2	4	3	3	3	7	31	51	13	3	2	2
19	1935	4	5	5	5	5	28	37	32	14	5	4	1
37	1935	13	13	13	15	18	23	69	20	8	8	9	10
21	1936	10	13	13	30	29	251	706	389	84	22	6	8
25	1936	2	4	6	21	18	135	340	137	22	5	1	1
11	1936	13	13	14	14	14	32	216	249	76	22	11	11
17	1936	2	2	2	2	2	7	45	53	8	2	2	2
19	1936	2	3	3	3	3	22	53	32	9	5	3	1
37	1936	13	13	13	15	15	29	97	22	8	8	9	10
21	1937	9	12	8	5	9	200	474	539	130	34	10	8
25	1937	1	3	4	2	5	107	228	189	34	7	1	1
11	1937	11	11	12	12	13	35	80	235	118	33	17	13
17	1937	2	2	2	2	2	5	16	50	18	3	3	2
19	1937	2	3	3	3	3	25	26	29	12	5	3	1
37	1937	13	13	13	13	13	26	65	39	9	8	9	10
21	1938	15	25	69	55	64	249	477	434	140	34	11	9
25	1938	2	7	30	32	40	134	204	49	18	4	0	2
11	1938	16	22	48	25	31	80	212	335	206	52	21	14
17	1938	2	3	7	4	5	12	44	70	43	5	3	2
19	1938	4	5	11	5	6	51	55	40	22	7	5	2
37	1938	13	13	13	17	18	29	72	28	9	8	9	10
21	1939	17	27	37	26	25	517	536	222	59	15	5	8
25	1939	1	9	16	12	10	241	162	65	6	3	0	1
11	1939	16	23	32	24	20	92	202	239	82	32	15	12
17	1939	2	3	5	4	3	19	42	49	9	3	2	2
19	1939	4	5	7	5	5	37	48	30	10	5	3	1
37	1939	13	13	13	15	15	42	74	19	8	8	9	10
21	1940	17	19	22	28	156	335	268	141	29	8	4	13
25	1940	0	2	4	8	79	152	131	55	6	4	0	2
11	1940	14	13	17	24	31	85	170	204	78	24	13	16
17	1940	2	2	3	4	5	18	35	43	8	2	2	2
19	1940	2	3	4	5	6	46	30	26	9	5	2	2
37	1940	13	13	13	15	26	33	47	17	6	8	9	10
21	1941	25	63	108	41	51	215	231	340	447	151	31	42
25	1941	3	37	49	23	36	69	41	37	132	44	2	2
11	1941	23	28	34	28	27	82	138	206	149	57	28	34
17	1941	3	4	5	4	4	22	28	43	23	6	4	5
19	1941	5	6	7	6	6	43	35	28	18	8	5	3
37	1941	13	13	18	15	18	26	56	34	21	8	9	10

ARMY CORPS OF ENGINEERS, WALLA WALLA DISTRICT, WALLA WALLA, WASHINGTON

APPENDIX A -- Continued

MONTHLY HYDROLOGY DATA FOR GRANDE RONDE RIVER BASIN
WITH WATER FLOWS IN HUNDREDS OF ACRE FEET FROM 1928-1968

CONTROL POINT NUMBER	YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JLY	AUG	SEP
21	1942	78	192	273	100	91	244	778	704	284	117	24	16
25	1942	4	33	77	32	50	133	254	171	95	23	0	1
11	1942	33	36	77	37	44	51	244	227	170	71	27	18
17	1942	5	5	12	6	7	8	50	48	27	7	4	3
19	1942	7	8	17	9	10	37	61	25	20	11	5	3
37	1942	13	20	26	18	20	29	105	54	11	8	9	10
21	1943	11	30	122	134	213	351	762	478	382	119	27	17
25	1943	7	14	76	115	155	245	398	162	56	15	1	1
11	1943	16	23	24	28	42	50	196	209	193	105	29	19
17	1943	2	3	4	4	6	8	40	44	31	11	4	3
19	1943	4	5	5	6	8	44	50	25	20	11	5	3
37	1943	13	13	20	24	33	37	115	42	11	8	9	10
21	1944	18	26	24	16	29	152	311	197	108	33	10	10
25	1944	3	1	3	3	9	80	149	79	27	5	2	2
11	1944	20	21	16	15	19	32	113	176	118	42	19	15
17	1944	3	3	2	2	3	5	23	37	18	4	3	2
19	1944	5	5	4	4	5	24	30	21	12	6	3	2
37	1944	13	13	13	13	15	24	52	22	8	8	9	10
21	1945	12	15	11	42	67	153	375	545	243	33	11	12
25	1945	4	5	5	31	47	109	200	194	60	4	3	4
11	1945	13	15	12	25	25	38	96	288	202	60	23	18
17	1945	2	2	2	4	4	6	20	60	32	6	3	3
19	1945	2	4	3	5	5	28	38	35	21	7	5	3
37	1945	13	13	13	15	18	24	63	44	10	8	9	10
21	1946	14	27	85	76	61	371	562	389	143	49	13	19
25	1946	5	8	30	35	26	180	333	216	56	11	3	2
11	1946	17	21	22	22	19	56	200	318	140	54	23	18
17	1946	3	3	3	3	3	22	41	67	22	5	3	3
19	1946	4	5	5	5	5	40	48	39	15	7	5	2
37	1946	13	13	13	17	18	35	92	35	9	8	9	10
21	1947	27	51	207	73	205	271	384	274	159	33	12	13
25	1947	5	14	162	55	156	165	186	81	37	7	1	1
11	1947	18	22	52	42	57	67	139	268	120	40	20	18
17	1947	3	3	8	6	9	14	29	56	12	4	3	3
19	1947	5	5	11	9	13	42	29	33	12	6	4	2
37	1947	13	13	26	24	33	37	61	26	9	8	9	10
21	1948	22	103	140	185	132	173	697	1182	652	104	34	18
25	1948	4	47	76	100	110	113	350	463	138	19	3	2
11	1948	25	34	41	49	25	33	146	456	366	74	31	21
17	1948	4	5	6	7	4	5	30	94	76	8	5	3
19	1948	5	7	9	11	5	54	49	56	36	9	5	3
37	1948	13	13	20	24	26	29	105	96	16	8	9	10

SOURCE: U.S. ARMY CORPS OF ENGINEERS, WALLA WALLA DISTRICT, WALLA WALLA, WASHINGTON

APPENDIX A -- Continued

MONTHLY HYDROLOGY DATA FOR GRANDE RONDE RIVER BASIN
WITH WATER FLOWS IN HUNDREDS OF ACRE-FEET FROM 1928-1968

CONTROL POINT NUMBER	YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JLY	AUG	SEP
21	1949	24	29	31	25	90	443	655	557	119	25	12	12
25	1949	3	7	3	3	26	245	320	186	22	5	0	1
11	1949	20	20	19	15	21	62	178	347	129	36	19	16
17	1949	3	3	3	2	3	13	37	72	20	4	3	2
19	1949	5	5	5	4	5	37	45	43	13	6	5	2
37	1949	13	13	13	15	18	40	99	34	8	8	9	10
21	1950	19	28	29	42	164	355	597	531	424	92	25	14
25	1950	2	6	9	6	79	192	290	250	113	17	4	2
11	1950	18	22	23	17	25	44	106	216	216	85	28	17
17	1950	3	3	3	3	4	7	22	45	34	9	4	3
19	1950	5	5	5	4	5	43	27	27	22	10	3	3
37	1950	13	13	13	15	26	40	90	49	13	8	9	10
21	1951	27	62	119	117	274	305	621	400	112	29	12	11
25	1951	3	1	38	54	134	151	281	144	37	4	0	0
11	1951	21	23	27	22	36	41	173	257	114	42	20	15
17	1951	3	3	4	3	5	8	36	54	12	4	3	2
19	1951	5	5	6	5	9	29	43	32	12	6	3	2
37	1951	13	13	13	18	33	31	92	37	8	8	9	10
21	1952	23	22	30	29	36	199	485	553	156	55	15	11
25	1952	3	7	15	5	8	118	316	192	33	11	3	3
11	1952	26	23	29	28	22	43	257	360	174	63	26	19
17	1952	4	3	4	4	3	9	53	75	28	6	4	3
19	1952	6	5	6	6	5	41	65	44	18	7	5	3
37	1952	13	13	13	15	15	26	83	37	9	8	9	10
21	1953	11	12	16	137	198	282	521	498	514	76	25	15
25	1953	3	1	5	89	162	189	287	236	155	18	3	1
11	1953	16	17	18	37	42	56	142	282	340	132	38	22
17	1953	2	3	3	6	6	12	29	59	53	14	6	3
19	1953	4	4	5	9	9	55	49	34	34	14	6	3
37	1953	13	13	13	21	31	46	83	46	16	8	9	10
21	1954	18	25	71	53	152	171	359	249	222	55	19	15
25	1954	2	4	32	25	86	83	182	65	47	9	2	0
11	1954	22	22	24	23	31	41	102	192	118	50	25	17
17	1954	3	3	4	3	5	8	21	40	18	5	4	3
19	1954	5	5	5	5	6	29	25	24	12	7	4	2
37	1954	13	13	17	18	26	24	60	24	10	8	9	10
21	1955	14	17	13	16	16	44	359	524	248	60	14	11
25	1955	3	5	2	1	2	7	193	290	95	15	2	2
11	1955	15	15	16	15	13	16	48	181	201	51	21	17
17	1955	2	2	2	2	2	3	10	38	38	5	3	3
19	1955	3	4	4	4	3	27	20	21	21	7	4	1
37	1955	13	13	13	13	15	17	61	46	10	8	9	10

APPENDIX A -- Continued

MONTHLY HYDROLOGY DATA FOR GRANDE RONDE RIVER BASIN
WITH WATER FLOWS IN HUNDREDS OF ACRE FEET FROM 1928-1968

CONTROL POINT NUMBER	YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JLY	AUG	SEP
21	1956	18	49	287	185	103	486	946	989	305	57	25	16
25	1956	2	15	98	89	57	282	470	365	116	14	3	3
11	1956	19	25	39	44	25	66	210	354	182	59	25	18
17	1956	3	4	6	7	4	14	43	74	29	6	4	3
19	1956	5	5	9	10	5	48	52	44	19	7	5	2
37	1956	13	13	13	24	22	242	139	80	11	8	9	10
21	1957	22	25	87	34	113	346	590	772	159	37	14	12
25	1957	3	7	37	18	67	187	284	271	42	7	2	1
11	1957	19	17	34	22	27	77	154	336	178	43	20	15
17	1957	3	3	5	3	4	16	32	70	28	4	3	2
19	1957	5	4	7	5	6	47	40	41	19	6	3	2
37	1957	13	13	13	15	22	35	90	52	9	8	9	10
21	1958	29	25	105	74	479	204	759	724	228	62	15	13
25	1958	4	7	45	42	287	110	365	254	60	13	2	1
11	1958	21	18	26	23	70	55	126	422	204	51	25	19
17	1958	3	3	4	3	10	11	26	84	32	5	4	3
19	1958	5	5	6	5	16	41	42	52	21	7	5	2
37	1958	13	13	13	17	45	35	112	49	10	8	9	10
21	1959	13	52	225	244	126	214	392	363	149	28	14	23
25	1959	2	14	96	131	76	115	188	128	40	6	1	3
11	1959	19	42	73	62	41	49	157	225	206	52	29	34
17	1959	3	6	11	10	6	10	32	48	33	5	4	5
19	1959	5	8	16	13	9	40	40	28	21	7	5	5
37	1959	13	13	24	27	26	29	67	34	9	8	9	10
21	1960	64	81	38	18	29	413	470	584	214	31	18	14
25	1960	10	22	17	9	17	223	227	205	57	6	2	1
11	1960	95	60	44	28	30	102	175	198	171	43	24	18
17	1960	13	9	7	4	4	21	36	42	27	4	4	3
19	1960	19	14	10	6	6	43	45	25	18	6	5	2
37	1960	13	13	14	15	15	38	76	50	10	8	9	10
21	1961	20	47	29	23	243	300	265	339	141	22	10	14
25	1961	23	12	12	23	145	162	127	119	37	4	1	1
11	1961	17	22	16	18	31	42	98	216	183	35	17	17
17	1961	3	3	2	3	5	9	18	45	29	4	3	3
19	1961	4	5	4	5	6	29	28	27	19	6	3	1
37	1961	13	13	14	15	35	31	52	31	9	8	9	10
21	1962	16	14	15	99	87	171	485	371	159	27	14	11
25	1962	2	4	6	53	52	92	233	130	42	5	1	1
11	1962	18	17	15	30	30	30	166	186	158	49	20	16
17	1962	3	3	2	4	5	5	34	39	25	5	3	2
19	1962	5	4	4	6	6	28	42	22	17	7	4	2
37	1962	13	13	15	18	20	24	76	27	9	8	9	10

SOURCE: U.S. ARMY CORPS OF ENGINEERS, WALLA WALLA DISTRICT, WALLA WALLA, WASHINGTON

APPENDIX A -- Continued

MONTHLY HYDROLOGY DATA FOR GRANDE RONDE RIVER BASIN
WITH WATER FLOWS IN HUNDREDS OF ACRE FEET FROM 1928-1968

CONTROL POINT NUMBER	YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
21	1963	26	38	85	37	212	164	281	426	107	[illegible]	15	15
25	1963	4	10	36	20	127	88	135	149	[illegible]	[illegible]	2	2
11	1963	25	30	33	21	41	41	65	164	[illegible]	[illegible]	16	15
17	1963	4	4	5	3	6	8	13	34	[illegible]	[illegible]	2	2
19	1963	5	6	7	5	8	23	18	20	17	5	3	1
37	1963	13	13	14	15	31	24	52	38	8	8	9	10
21	1964	14	24	24	21	26	99	420	371	258	52	20	17
25	1964	2	6	10	12	16	54	202	130	69	11	2	2
11	1964	12	16	16	16	15	18	70	173	223	58	24	17
17	1964	2	2	2	2	2	3	14	36	40	6	4	3
19	1964	2	3	4	4	4	29	26	21	22	7	4	3
37	1964	13	13	14	15	15	20	67	32	10	8	9	10
21	1965	15	19	248	517	370	233	689	499	252	61	37	23
25	1965	2	5	106	279	222	125	332	175	67	13	4	3
11	1965	13	15	29	54	60	46	161	279	228	63	29	20
17	1965	2	2	4	8	9	7	33	56	23	6	4	3
19	1965	2	3	6	11	42	12	42	49	39	13	6	5
37	1965	13	27	24	29	20	56	96	44	8	8	9	10
21	1966	17	21	12	16	12	143	246	136	54	23	8	11
25	1966	3	6	5	9	7	77	127	48	15	5	1	1
11	1966	18	19	17	15	13	34	81	121	51	22	12	10
17	1966	3	3	2	2	2	5	17	24	5	2	2	1
19	1966	3	5	4	4	3	25	20	21	9	5	3	2
37	1966	13	13	13	13	15	20	40	15	8	8	8	8
21	1967	16	32	95	162	132	226	255	669	245	43	12	10
25	1967	4	8	37	67	60	102	110	177	35	3	0	1
11	1967	13	18	22	27	28	39	54	258	256	74	22	15
17	1967	2	3	3	4	4	6	11	52	26	7	3	2
19	1967	2	3	5	6	6	28	15	45	45	16	5	3
37	1967	13	13	26	24	33	37	61	26	9	8	9	10
21	1968	17	18	71	72	263	148	108	157	75	17	16	15
25	1968	2	6	34	25	145	62	33	27	7	2	3	1
11	1968	18	16	19	25	62	69	68	183	150	38	24	21
17	1968	3	2	3	4	9	11	14	37	15	4	4	3
19	1968	3	3	5	6	13	16	49	45	27	9	5	5
37	1968	13	13	13	13	15	24	52	22	8	8	9	10

SOURCE: U.S. ARMY CORPS OF ENGINEERS, WALLA WALLA DISTRICT, WALLA WALLA, WASHINGTON

VITA

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College	Idaho State College Pocatello, Idaho 1956-1960
Universities	Brigham Young University Provo, Utah 1960-1961 University of Utah Salt Lake City, Utah 1961-1963 1969-1971
Degrees	B.S., Business, Idaho State College M.S., Economics, Brigham Young University Ph.D., Finance, University of Utah
Awards	Teaching Assistantship Brigham Young University Provo, Utah 1960-1961 Teaching Assistantship University of Utah Salt Lake City, Utah 1961-1963 N.D.E.A. Doctoral Fellowship University of Utah Salt Lake City, Utah 1969-1971
Organizations	American Finance Association Operations Research Society of America American Economic Association

Positions	Research Associate Bureau of Economic & Business Research University of Utah Salt Lake City, Utah 1963-1965
	Assistant Professor & Assistant Director Bureau of Business Research Idaho State University Pocatello, Idaho 1965-1967
	Assistant Professor & Project Director Idaho Economic Base Study for Water Requirements Idaho State University Pocatello, Idaho 1967-1969
	Assistant Professor School of Business and Economics University of Puget Sound Tacoma, Washington 1971
Publications	"Utah Food Canning Industry" (with K.L. Lueck and O.L. Harline). Utah Economic and Business Review, Volume XXIV, Number 11, November, 1963.
	"1963 Business in Utah Counties." Utah Economic and Business Review, Volume XXIV, Number 4, April, 1964.
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