AN ABSTRACT OF THE THESIS OF

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Title: A SIMULATION ANALYSIS OF THE HOLLEY DAM AND RESERVOIR PROJECT WITH EMPHASIS ON ANADROMOUS FISH ENHANCEMENT

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Albert N. Halter

The objectives of this study are to revise and reformulate a previous simulation model of the Calapooia River and proposed Holley Dam project and to critically investigate the anadromous fish enhancement function of the project.

The Corps of Engineers proposes a 145,000 acre-foot reservoir for the Calapooia River at Holley, Oregon. Previously, a 97,000 acre-foot reservoir was proposed. The larger project's justification is based mainly on anadromous fish enhancement. Investigation revealed that there is a great deal of uncertainty and lack of information about: (1) temperature requirements of anadromous fish in the Calapooia River and whether they can be met, (2) the affects of high streamflow discharges on spawning, incubation, and rearing of anadromous fish in the Calapooia River,

(3) the affects of variability in food supply due to fluctuations in the level of the water in the reservoir, and (4) the survival rates of salmon eggs to fry, fry to smolts, and ocean survival.

A simulation model in DYNAMO computer language is formulated and includes the following components: (1) hydrology generator, (2) reservoir regulation and flood control procedures, (3) freshwater life cycle of Spring Chinook and Fall Chinook Salmon, (4) supply of recreation user days, (5) supply of resident fishing angler days, and (6) supply of irrigation water. The model calculates the daily, monthly, and yearly variability of various physical, economic, and intangible outcomes.

The simulation of floods and their regulation corresponds to historical data and regulation hypothesized by the Corps of Engineers. The dynamic nature of the Spring and Fall Chinook Salmon populations are modeled and computer results indicate that the likelihood of conservation and enhancement is not great enough to justify the 145, 000 acre-foot reservoir.

Due to the fluctuations in the reservoir level which accompany flood control regulation and reflect the variability in the hydrology, the recreational use and resident fishing angler use is highly variable and the average use is unlikely to reach the estimated supply potential. The reservoir, as simulated by the model, has sufficient capacity to supply water for the proposed irrigation project. However, it appears that uncertainty remains concerning the dollar benefits that are obtainable from irrigating soils along the Calapooia River.

Further study is necessary to determine whether the 97, 000 acre-foot reservoir is a feasible alternative to the proposed 145, 000 acre-foot reservoir. The computer model is general in formulation and can be utilized to provide information to decision makers in determining the feasibility of further dam and reservoir construction.

A Simulation Analysis of the Holley Dam and Reservoir Project with Emphasis on Anadromous Fish Enhancement

by

Renny Joel Avey

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I INTRODUCTION

With the advent of the high speed digital computer the modeling and simulation of complex physical, biological, economic, and social systems are economically feasible and potentially productive as a research method. In the design and planning of water resource use systems, and especially in the planning of dams and reservoirs, the impact of computer simulation has been mainly in the research area rather than at the operational level of policy and decision making. Following the monumental work of Maas, et al., (1962) a number of large scale simulations of river basins were carried out as research exercises. Hamilton, et al., (1964) prepared a computer simulation model of the Susquehanna River Basin in 1964 and published further results for the Susquehanna and Delaware River systems in 1969 under the general heading of regional analysis. Rivers as insignificant as the Calapooia in Oregon also receive research attention. The Halter and Miller (1966) study of the Calapooia River was followed by another by Kerri (1969) of Sacramento State College. The Calapooia is the basis of this study as well.

The U. S. Army, Corps of Engineers has been influenced by this intellectual stimulation and attempts have been made to operationalize certain aspects of computer simulation in their river basin planning efforts. Beard (1965) of the Corps of Engineers has developed a number of streamflow simulators. The Corps of Engineers in Portland, Oregon, have computer programs that simulate thermal conditions of reservoirs and of streamflows downstream from dams. Apparently the Corps of Engineers is beginning to see computer simulation as an economical alternative to the makeshift paper and pencil simulations they are performing in their river basin planning work.

River basin planning as conducted by the Corps of Engineers and other public agencies is much less influenced by the systems analysis approach. A broad definition of the term system is any entity with parts or components in interaction. The systems analysis approach provides a comprehensive view of river basin planning and promotes the isolation and formulation into a mathematical model of those components of a river basin system and their interactions which contribute to the attainment of multiple objectives. Building a computer simulation model of a river basin system forces the planner to bring together relevant information about the components of the system and their interactions. The model provides the means for identifying conflicting information and for resolving information inconsistencies that may arise in putting together the model. Because of lack of public interest or Congressional authorization, the public agencies concerned with river basin planning are not being moved to adopt the systems analysis approach. In the course of this study it was found that the following agencies are involved in providing information or planning of the Holley Dam project on the Calapooia River: (1) U. S. Department of the Interior, Bureau of Reclamation, (2) U. S. Department of the Interior, Bureau of Sport Fisheries and Wildlife, (3) Environmental Protection Agency (formerly U. S. Department of the Interior, Federal Water Pollution Control administration), (4) Oregon Game Commission, (5) Oregon Fish Commission, and (6) U. S. Army, Corps of Engineers. While the Corps of Engineers has the major responsibility of putting together the final plan of project development, they are not building comprehensive models of their plans which could be simulated and tested for inconsistencies. Thus, while there has been token recognition of computer simulation there has not been a change in planning philosophy in the direction of systems analysis. It is the intent of this study to give further intellectual incentive to the public agencies responsible for comprehensive systems planning to adopt a systems analysis approach.

Problem Definition

In 1950 Congress authorized construction of a reservoir on the Calapooia River and associated channel improvements downstream from the reservoir. The reservoir, which would be located in the Western Cascade foothills at Holley, Oregon, was to be 97, 000 acre-feet in capacity. The purposes of the reservoir were to control floods, conserve water to be used for irrigation, and to increase low-water flows for navigation on the Willamette River. The channel improvements while providing flood control and drainage benefits, would have provided the additional channel capacity necessary for postflood evacuation of water stored in Holley Reservoir. Detailed planning on both the reservoir and channel improvements was initiated in 1957. Planning was discontinued in 1958 because it was found that the legally required local cash contribution was not available for the channel improvements necessary for reservoir flood control operation. In 1959 the Senate Committee on Public Works adopted a resolution requesting a review study of Calapooia River by the Corps of Engineers. That study which includes consideration of both the channel problem and potential to serve additional project purposes was initiated in fiscal year 1962.

The preliminary findings by the Corps of Engineers' district office in Portland include an enlarged reservoir provision to

145, 000 acre-feet and the additional water use functions of recreation, municipal and industrial water supply, and fish enhancement. In addition to these new project functions the new project size would provide the originally attributed benefits from irrigation, flood control, drainage, some fish enhancement, water quality, and navigation. Before completion of the Corps of Engineers' restudy Halter and Miller (1966) employed the Calapooia River basin in their testing of the applicability of simulation in evaluating water resource development projects. Their tests included several management policies affected upon a computer simulation model of the basin. The model was designed with 67, 000 and 97, 000 acre-feet project sizes and various channel size combinations.

The proposed problem for this study arises out of the Corps of Engineers' restudy and preliminary conclusions for increased project size and limited channel improvement downstream from the dam. Some channel improvements are planned as an integral part of the reservoir development. However, planned improvements for the channel are much less extensive than those authorized in 1950.

In the initial stages of the research of this study, discussions with personnel from the various agencies mentioned above revealed a great deal of uncertainty about the interactions between the water use functions and about specifying critical parameters as they relate to the planning of the Calapooia River project.

As an aid in conceptualizing the problem and identifying components of the Calapooia River basin system which are more critical to model than others, the choice between the originally proposed 97, 000 acre-foot reservoir and the 145, 000 acre-foot reservoir is formalized as a decision-making problem under uncertainty (Halter and Dean, 1971). The two sizes of reservoirs are the possible actions and the states of nature are made up of various combinations of circumstances or conditions which might favor or inhibit the realization of the benefits from the four main functions of the reservoir. The four main functions are flood control, anadromous fish enhancement, supplying recreation, and supplying water for irrigation. Lesser benefits are expected from water supplied for municipal and industrial use, and for navigation on the Willamette River. Because these two functions do not interact to a great degree with the other components of the project they are not given further consideration in this thesis, nor are they considered in calculating the payoff table. The payoff table for the various combinations of states and the two actions are presented in Table 1. 1. The payoffs are net of total cost and are expressed as annual net benefits.

The payoff to state of nature θ_1 and the 97, 000 acre-foot reservoir, action a_1, is 509 thousand dollars. For the same

Table 1.1. Payoff table for eight states of nature and two actions, Holley Dam project.

State of nature	Definition	a_1 97,000 acre-foot reservoir (000)	a_2 145,000 acre-foot reservoir (000)
θ_1	Favorable to flood control, fish, recreation and irrigation	\$509	\$837
θ_2	Favorable to flood control, fish, irrigation, unfavorable to recreation	329	418
θ_3	Favorable to flood control, irrigation, recreation, unfavorable to fish	509	188
θ_4	Favorable to flood control, fish, recreation, unfavorable to irrigation	400	777
θ_5	Favorable to flood control, fish, unfavorable to irrigation and recreation	220	358
θ_6	Favorable to flood control, recreation, unfavorable to fish and irrigation	400	128
θ_7	Favorable to flood control, irrigation, unfavorable to fish and recreation	329	-231
θ_8	Favorable to flood control, unfavorable to fish, recreation, and irrigation	220	-291
Expected value		364.5	273.0

state, the payoff to the 145, 000 acre-foot reservoir, action a_2, is 837 thousand dollars.[1/] State of nature θ_1 is such that the environment created by the presence of the proposed structures is favorable to anadromous fish, recreation, irrigation and flood control. State of nature θ_2 is such that the environment created by the structures is favorable to fish, irrigation, and flood control, but is unfavorable to recreation. It is assumed sufficiently unfavorable to recreation that all the benefits to recreation are lost, but yet the costs of providing the recreational facilities were incurred. This unfavorable condition may be due to lack of demand or due to the environment created by the dam, e.g., the growth of unsightly algae or excessive turbidity.

State of nature θ_3 is such that conditions are favorable to flood control, recreation, and irrigation, but unfavorable to fish enhancement. This unfavorable condition could be due to the inability of getting the reservoir-reared fish through the dam in order for them to migrate to the ocean. Such a condition was the

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1/ The total annual gross benefits as calculated by the Corps of Engineers for (θ_1, a_1) is \$1, 895, 000. The amortized cost of the full project is \$1, 386, 000 per year. Thus, the net benefit is \$1, 895, 000 - \$1, 386, 000 = \$509, 000. For (θ_1, a_2) the total annual gross benefit is \$2, 734, 000 and the amortized cost is \$1, 897, 000 per year. The net benefit is \$2, 734, 000 - \$1, 897, 000 = \$837, 000.

case at Cougar Dam on the McKenzie River. Also, temperature conditions or other environmental conditions downstream from the dam may be unfavorable to migrating fish and inhibit spawning and incubation of eggs. Such conditions have occurred at Pelton Dam on the Deschutes River.

Conditions defined by state of nature θ_4 are unfavorable to irrigation but favorable to the other functions. As was the case of Fern Ridge Reservoir at Eugene, Oregon, the anticipated demand for irrigation did not materialize. States of nature θ_5 through θ_7 are unfavorable to two functions and favorable to two functions. State of nature θ_8 is favorable to flood control only. Since the main purpose of the dam is flood control, the assumption is made that there will always be rain along the Calapooia and hence conditions will always be favorable for flood control. Thus, no state of nature was conceptualized with unfavorable conditions for flood control. However, this does not imply that the regulation of the dam may cause larger floods than occur naturally.

If the decision maker(s), in this case perhaps the U. S. Congress, were faced with making the decision between the two sizes of reservoirs and not knowing that any one of the eight states had a greater probability of occurring than any other, he (they) might assign equal probabilities to each state and choose the action with the highest expected value. With equal probabilities attached to each state, the highest expected value is 364.5 thousand dollars for the 97,000 acre-foot reservoir. Since the Corps of Engineers is recommending the 145,000 acre-foot reservoir, their probability distribution over the eight states of nature must be different than the uniform distribution assumption.

Not knowing what the Corps of Engineers' probability distribution is, one might ask: What is the minimum probability that could be assigned to any state in order that a_2 is the preferred action? The technique of deriving these minimum probabilities is given by Halter and Dean (1971). Calculations are performed by a FORTRAN computer program (Avey, 1970). Firstly, notice that a_2 is the preferred action if one knew for certain that any one of the states of nature θ_1, θ_2, θ_4, or θ_5 would occur. Secondly, if one knew for certain that the states of nature θ_3, θ_6, θ_7 or θ_8 would occur, a_1 is the preferred action. The minimum probabilities for the four states of nature which would leave a_2 the preferred action are:

$$P(\theta_1) = .630631$$

$$P(\theta_2) = .862866$$

$$P(\theta_4) = .537803$$

$$P(\theta_5) = .802292.$$

The minimum probabilities for the four states that would leave a_1 the preferred action are:

$$P(\theta_3) = .537803$$

$$P(\theta_6) = .580894$$

$$P(\theta_7) = .402348$$

$$P(\theta_8) = .424550.$$

These minimum probabilities are interpreted as follows: If the probability of state of nature θ_1 is equal to or greater than .630631 with the remaining probability of 1.0-.630631 on any other state or combination of states then a_2 remains the preferred action. If the probability of θ_1 is less than .630631, then a_1 is the preferred action.

Two observations, which aid in identifying the problem investigated by this study, can be made from the minimum probabilities. Firstly, the set of minimum probabilities that leave a_2 the preferred action are greater in magnitude than those that leave a_1 the preferred action. The smallest probability is for θ_4 which is larger than the largest of the set of minimum probabilities that leave a_1 the preferred action. Secondly, the four states of nature associated with a_2 as the preferred action involve having favorable conditions for anadromous fish enhancement. The other four states, θ_3, θ_6, θ_7 and θ_8, involve conditions unfavorable to anadromous fish enhancement. The problem investigated by the study reported in this thesis is whether the probabilities of states θ_1, θ_2, θ_4 and θ_5 are less than approximately .6. The emphasis of the study is upon anadromous fish since the four states of nature associated with the preferred 145, 000 acre-foot reservoir must all be favorable to fish enhancement.

Objectives of Thesis

In order to bring together knowledge and information that contributes to the understanding of the problem as stated above, a systems analysis approach is taken in this study. The specific objectives of this thesis are:

1. To revise and reformulate the DYNAMO computer simulation model of the Calapooia River, and proposed Holley Dam, as originally formulated by Halter and Miller (1966) and Kerri (1969).

2. To critically investigate the anadromous fish enhancement function of the proposed Holley Dam project in conjunction and interaction with the other functions of the project.

The revisions of the computer simulation model involving the hydrology of the Calapooia River are presented in Chapter II. The reformulations of the computer simulation model with emphasis upon anadromous fish are discussed in Chapter III. The results from a number of computer runs are given in Chapter IV. The fifth chapter summarizes the study and presents the conclusions.

II. HISTORICAL AND SIMULATED HYDROLOGY OF THE CALAPOOIA RIVER

This chapter contains a description of the hydrology generator used in the simulation model along with the historical data upon which the parameters of the generator are based, and some of the results from preliminary computer runs of the generator. The hydrology generator is one of the main components of the simulation model and forms the basis for building the other components. Without an accurate generator of the hydrology of the Calapooia River, there would be little need to attempt to model the various water use functions connected with the Holley Dam project. Closely allied to the hydrology generator is the simulation of the reservoir and channel regulation. It is the regulation of the flows that give rise to the proposed benefits of the Holley Dam project. Since flood control is the main project benefit and because it is a direct function of the hydrology generator, a description of the reservoir and channel regulation procedure is also given in this chapter. A discussion of flood benefits and how they are calculated in the simulation model are presented at the end of the chapter. The other water use functions are discussed in the next chapter.

Historical Data

The historical data available for constructing and validating the hydrology generator are from measurements of daily stream flows taken at Holley (the dam site) and at Albany (the outlet of the river into the Willamette River). The periods of record used in this study are from 1936 to 1965 for Holley and from 1941 to 1965 for Albany. The historical data are described by monthly means, medians, standard deviations, and exceedence functions.

The mean annual runoff at Holley dam site for the period 1936-1965 is 450 c.f.s., or 325,700 acre-feet.[1/] Extremes were 13 c.f.s., which occurred in September 1940, and 12,600 c.f.s., which occurred in December 1964, and is the largest observed flood of record on the Calapooia River. That flood peak discharge is believed to have been exceeded by the unmeasured floods of 1861 and 1890. From limited hydrometeorological information the December 1861 flood was estimated to have a peak discharge of 15,000 c.f.s. at Holley. This magnitude of discharge is considered the Intermediate Regional flood.[2/] The mean annual

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1/ Cubic feet per second is abbreviated here by c.f.s.

2/ The Intermediate Regional flood is defined by the Corps of Engineers as having on the average a recurrence of 1 in 100 years.

runoff at Albany for the period 1941 to 1965 is 929 c. f. s., or 673, 272 acre-feet. Extremes were four c. f. s. which occurred in October 1953, and 32, 700 c. f. s., which occurred in December 1956. That flood peak discharge is believed to have been exceeded only by the unmeasured flood of 1861, which was estimated to have a peak discharge of 48, 000 c. f. s. at Albany. This is considered the Intermediate Regional flood at Albany. The natural peak discharges of floods and historical estimates are presented in Table 2. 1.

Table 2. 1. Maximum peak discharges of floods of record and historical estimates.

Station	Discharges for floods in cubic feet per second				
	1946	1956	1965	1890[a/]	1861[a/]
Holley dam site	12, 200	10, 700	12, 600	13, 800	15, 000
Shedd	13, 300	b/	b/	24, 300	28, 000
Albany	14, 500	32, 700	28, 400	b/	48, 000

a/ Estimated from meager records of rainfall and river stages by the Corps of Engineers.

b/ Not available.

Source: U. S. Army, Corps of Engineers, 1970.

The general frequency functions of the monthly mean-daily flows on the Calapooia are skewed. The median flow occurs to the left of the mean so that in any month most of the flows are less than the average for the month. The frequency of flows peak at the median and then gradually tail off to the right giving the characteristic skewness to the frequency function. The historical means, standard deviations, and medians as calculated by Halter and Miller in 1966 are shown in Table 2. 2 for Holley and Table 2. 3 for Albany. Also shown in Tables 2. 2 and 2. 3 are the most recent mean-daily flows as determined by the Corps of Engineers.

Exceedence Functions

An exceedence function is a probability function that shows the cumulative frequency of maximum or minimum annual discharges. The exceedence curves for the Calapooia River are developed from peak annual discharges of record and estimates of extreme events such as the 1890 and 1861 floods. When plotted on logarithmic probability graph paper the log normally distributed flows produce a straight line (Aitchison and Brown, 1957). Plotting the peak annual flows provides a quick means for testing for the log normality of the distribution and also gives the recurrence interval or probability of recurrence for a flow of given magnitude. The maximum discharge exceedence frequency curves for the Holley gage and Albany gage are presented in Figures 2. 1 and 2. 2, respectively. Years of recurrence are read along the horizontal axes and

Table 2.2. Historical mean daily streamflows, Calapooia River, Holley gage.

Month	Halter-Miller study [a]			Corps of Engineers [b]
	Mean	St. dev.	Median	Mean
	(c.f.s.)	(c.f.s.)	(c.f.s.)	(c.f.s.)
January	851	886	570	848
February	896	730	700	892
March	740	509	585	737
April	592	395	500	586
May	368	764	300	378
June	203	168	165	195
July	77	40	69	76.8
August	41	14	38	41.5
September	43	38	34	43.2
October	174	375	80	162
November	559	761	317	576
December	847	1054	600	887
Annual	450			450

[a] These data are for the historical period October 1936 to September 1960, Halter and Miller (1966).

[b] Data for period 1936 to 1965, U. S. Army, Corps of Engineers (1970).

discharges in c.f.s. are read along the vertical axes. The probability of recurrence can be determined for a given magnitude of discharge. For example, the one in one-hundred-years flood at the Holley gaging station, which has a probability of 1/100 or .01, has a peak discharge of at least 16,000 c.f.s. Similarly, the one in one-hundred-years flood at Albany on the Calapooia would have a magnitude of at least 45,000 c.f.s. Since the 1861 and 1890

Table 2.3. Historical mean daily streamflows, Calapooia River, Albany gage.

Month	Halter-Miller study a/			Corps of Engineers b/
	Mean	St. dev.	Median	Mean
	(c. f. s.)	(c. f. s.)	(c. f. s.)	(c. f. s.)
January	2230	1740	771	2214
February	2037	1220	708	2049
March	1473	822	426	1476
April	942	440	194	958
May	531	262	86	590
June	247	51	33	235
July	87	16	11	89
August	41	11	0	41.6
September	44	24	0	45.4
October	262	537	55	254.9
November	1114	1109	206	1166
December	1974	1578	575	2102
Annual	915			929

a/ These data are for period October 1940 to September 1960, Halter and Miller (1966).

b/ Data for period 1940 to 1965, U.S. Army, Corps of Engineers, 1970.

floods are based upon meager data there is a degree of extrapolation of the historical record to include these extreme flows into the development of the exceedence curves.

In a similar manner, minimum annual discharge exceedence frequency curves have been developed for this study based upon low flow data provided by the Corps of Engineers. The probability of recurrence of an annual minimum flow can be determined from

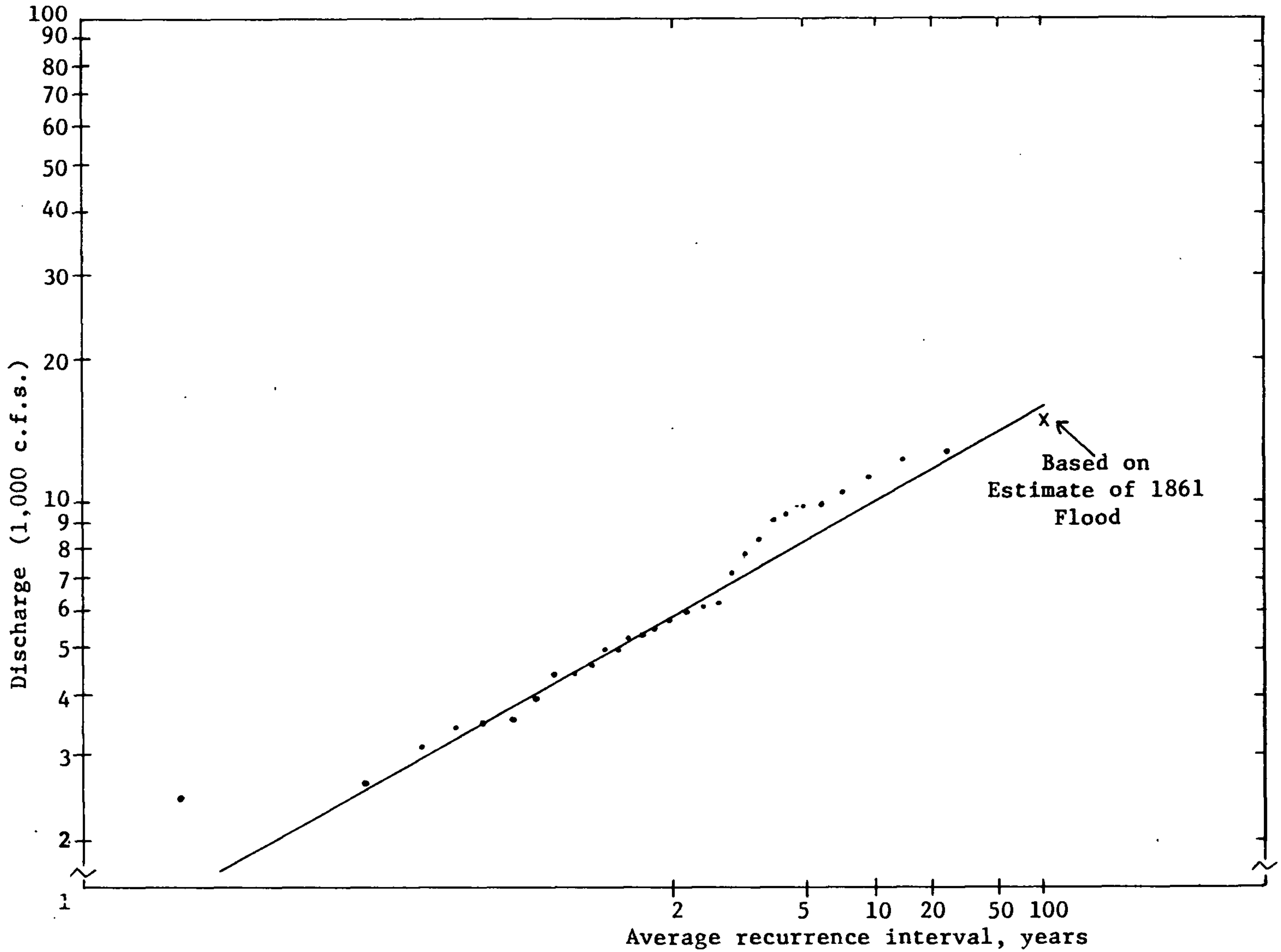

Figure 2.1. Maximum annual discharge exceedence, Calapooia River at Holley, Oregon.

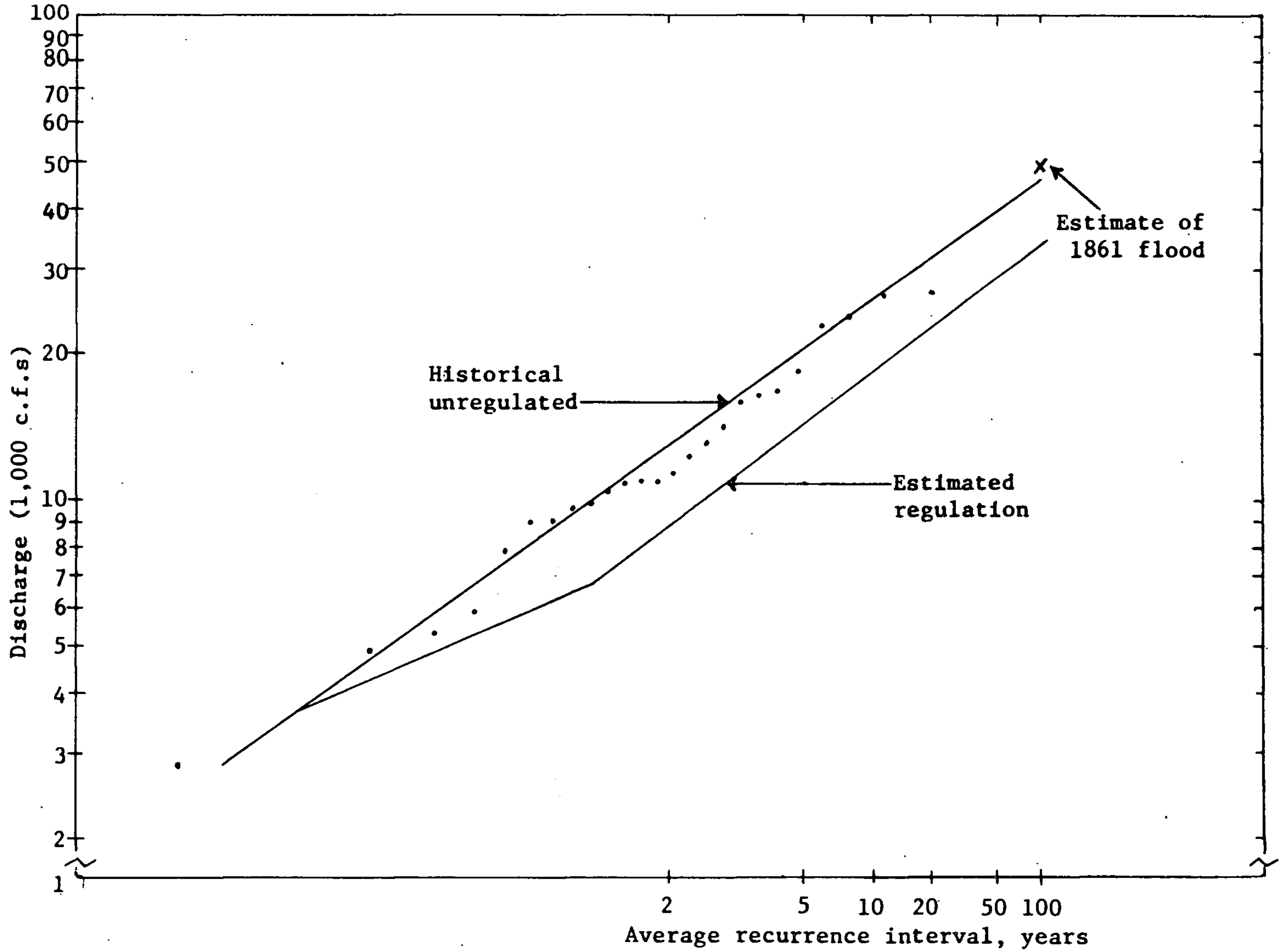

Figure 2. 2. Maximum annual discharge exceedence, Calapooia River at Albany, Oregon.

this type of curve. Annual minimum exceedence frequency curves for the Holley and Albany gages on the Calapooia River are presented in Figures 2.3 and 2.4. A minimum flow at Holley on the Calapooia of about 15 c.f.s. or less has a probability of occurrence of .01 or one in one-hundred-years. The one in one-hundred-year minimum flow at Albany on the Calapooia is 6 c.f.s. or less. These curves were determined by plotting the data of record at 3-1/3 year intervals for Holley and 4 year intervals for Albany. Because of the limited length of record these exceedence curves may be biased just as the maximum exceedence curves may be biased.

Hydrology Generator

In reviewing the Halter and Miller (1966) simulation model of the Calapooia River it was found that their hydrology generator did not simulate the straight line characteristic of the exceedence functions. Following the Halter and Miller study, Kerri (1969) developed a hydrology generator for the Calapooia River based upon methods developed by Beard (1965). Beard developed the general procedures and computer programs for daily streamflow synthesis using the mean, standard deviation, and skewness for each day from natural logarithms of the flows. Kerri converted Beard's procedures into the DYNAMO computer simulation

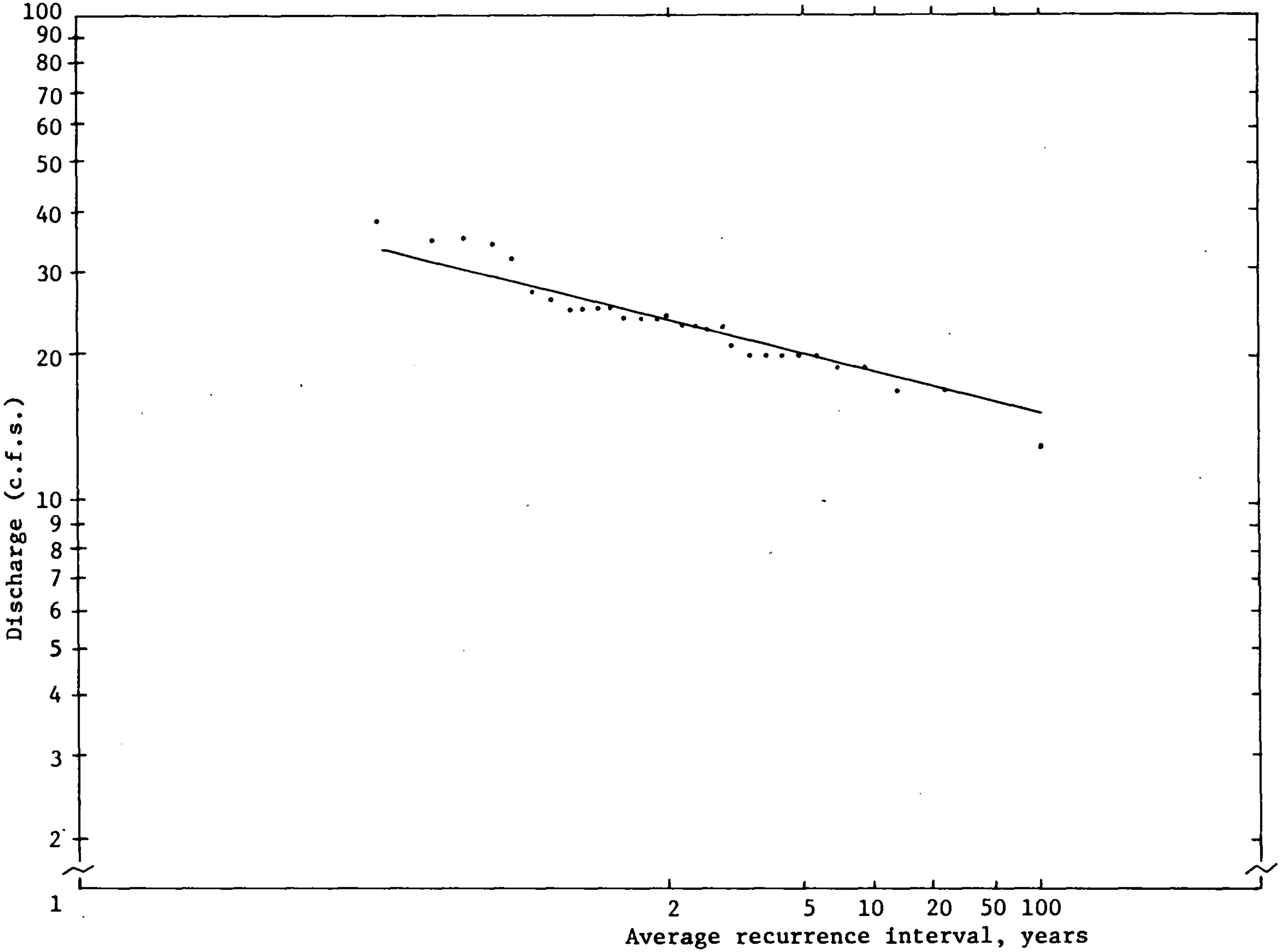

Figure 2.3. Minimum annual discharge exceedence, Calapooia River at Holley, Oregon.

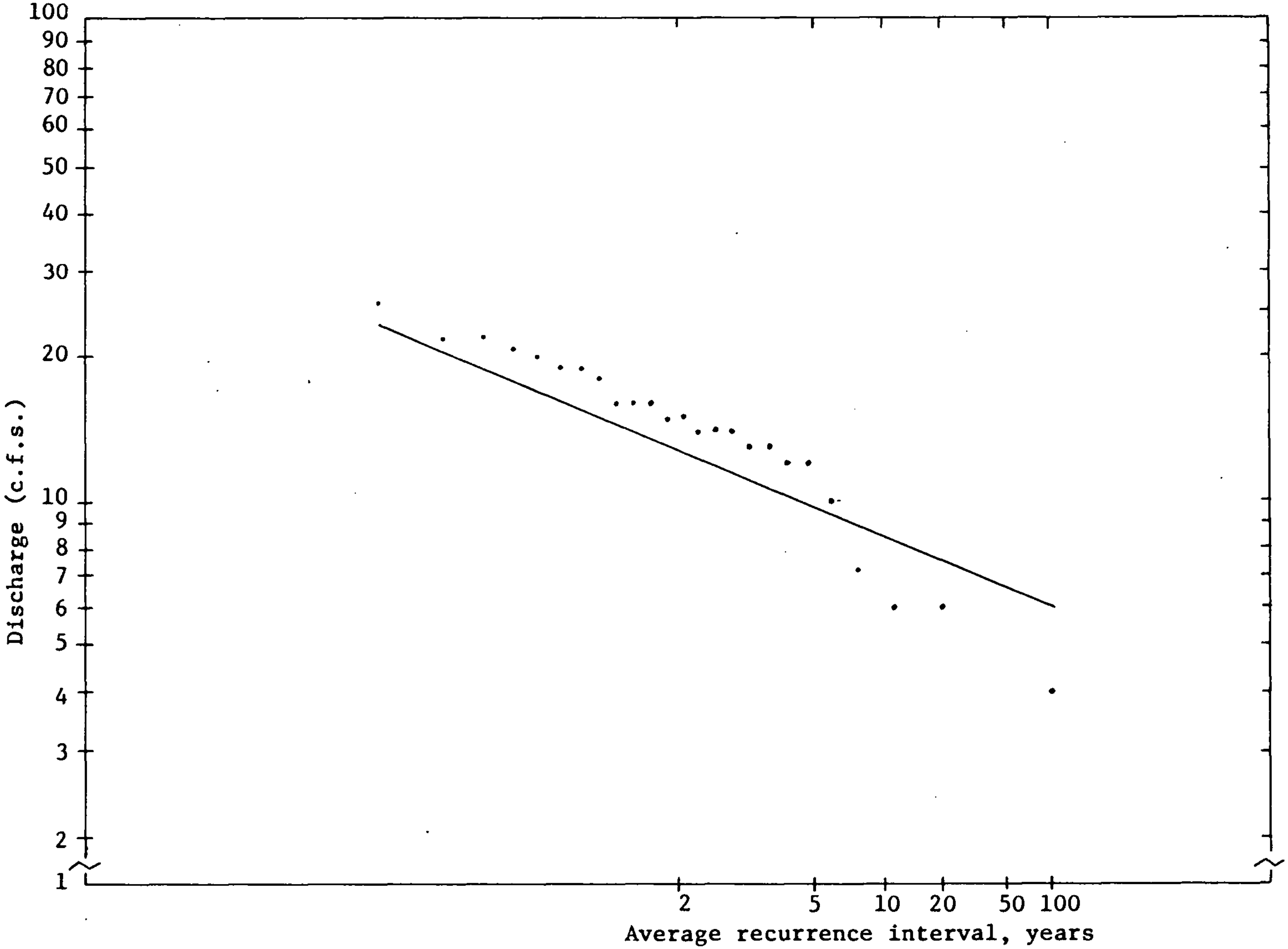

Figure 2.4. Minimum annual discharge exceedence, Calapooia River at Albany, Oregon.

language (Forrester, 1961; Pugh, 1963; Pugh, 1971).

The hydrology generator is based upon the log-Pearson Type III probability function (Beard, 1965). Simulated flows in cubic feet per second are calculated daily for Holley and Albany by the following formula:

$$\text{Ln } Q = M + \frac{KS}{C}$$

or:

$$Q = e^{M + (KS/C)},$$

where:

Q = value of streamflow in c. f. s.,

M = the mean of the logarithms of the daily flows,

S = the standard deviation of the logarithms of the daily flows,

K = the Pearson Type III deviate, and

C = a constant which characterizes the stream.

The Pearson Type III deviate (K) assumes a value depending upon daily skewness (g) and the logarithm of the daily streamflow transformed to a normal standard deviate. The normal standard deviate is calculated from a regression equation which relates flows of one station to those of another. The Holley gage daily normal standard deviate is regressed against the previous day's normal standard deviate at Holley. The Albany gage daily normal standard deviate is regressed against the previous day's normal standard deviate at Albany and with the current value of the normal standard deviate at Holley. The C value in the streamflow equation is a constant depending on the stream and can be adjusted to reduce variability in the extreme simulated flows. The values of the daily means, standard deviations, and skewness (g) are input data to the computer program and are shown in table functions in the DYNAMO computer program in Appendix A. The value of K, the Pearson Type III deviate, is calculated by the computer program.

Modifications to the Kerri Generator

The hydrology generator used by Kerri (1969) was modified slightly for use in this study. The first change involved reducing the 364 day year to 360 days to facilitate use of tabular data in the DYNAMO format in simulating the water use algorithms. A second change involved changing the C values and introducing a constant to bring about correspondence between the historical and simulated exceedence functions.

In initial computer runs the streamflows that were simulated were tested to determine whether the simulated distributions approximated the historical distributions. The criteria for these tests were monthly means, and annual maximum and minimum exceedence frequency curves plotted on log-probability graph paper.

The monthly means for Holley and Albany, Oregon, based on two computer runs of the hydrology generator are shown in Table 2.4. By comparing the simulated means with the historical means of Tables 2.2 and 2.3, it can be seen that there is a close correspondence. The annual average simulated mean flow for Run 1 and Run 2 exceeds the historical mean by 1.5 and 6 percent, respectively, for Holley. The annual average simulated mean flow for Run 1 and Run 2 exceeds the historical mean by 3.8 and 8 percent, respectively, for Albany.

Table 2.4. Simulated mean monthly streamflows for Holley and Albany, Oregon, on the Calapooia River.

Month	Holley		Albany	
	Run 1 a/	Run 2 b/	Run 1 a/	Run 2 b/
	(c.f.s.)	(c.f.s.)	(c.f.s.)	(c.f.s.)
January	822	860	2231	2341
February	911	906	2153	2113
March	743	739	1615	1589
April	590	571	1002	937
May	396	376	659	584
June	197	198	273	273
July	78	73	123	111
August	44	41	67	58
September	45	46	58	50
October	143	165	188	213
November	594	643	1131	1227
December	922	1111	2074	2556
Annual	457	477	965	1004

a/ Simulation for 100-year period.

b/ Simulation for 50-year period.

In an initial computer run for 100 years the annual minimum exceedence frequency curve for the Albany gage from the simulated flows was higher than the historical relationship as depicted in Figure 2.5. The simulated low flows are about 15 c.f.s. higher throughout the range of the exceedence curve. This is believed to be caused by an assumption built into Kerri's formulation concerning streamflow correlation between gages. It was assumed that if any day's simulated downstream flow was less than a previous day's simulated upstream flow then the downstream flow for that day was set equal to the upstream flow. This, however, is not realistic since it produced simulated low flows at Albany higher than those at Holley. The low flows typically occur in the drier summer months when surface losses from evaporation, ground seepage, and irrigation uses deplete the stream as it meanders down towards Albany. Therefore the Albany low flows, as depicted by the historical exceedence curves, are lower than at Holley. Some adjustment was made in the C coefficient associated with Albany low flows. However, subsequent runs with lower or higher C coefficients only changed the slope of the simulated exceedence curve. Finally, in order to lower the simulated Albany low flow exceedence curve a constant value of 15 c.f.s. was subtracted whenever a low flow was calculated in the computer program for the Albany gage. This constant was required to adjust the minimum

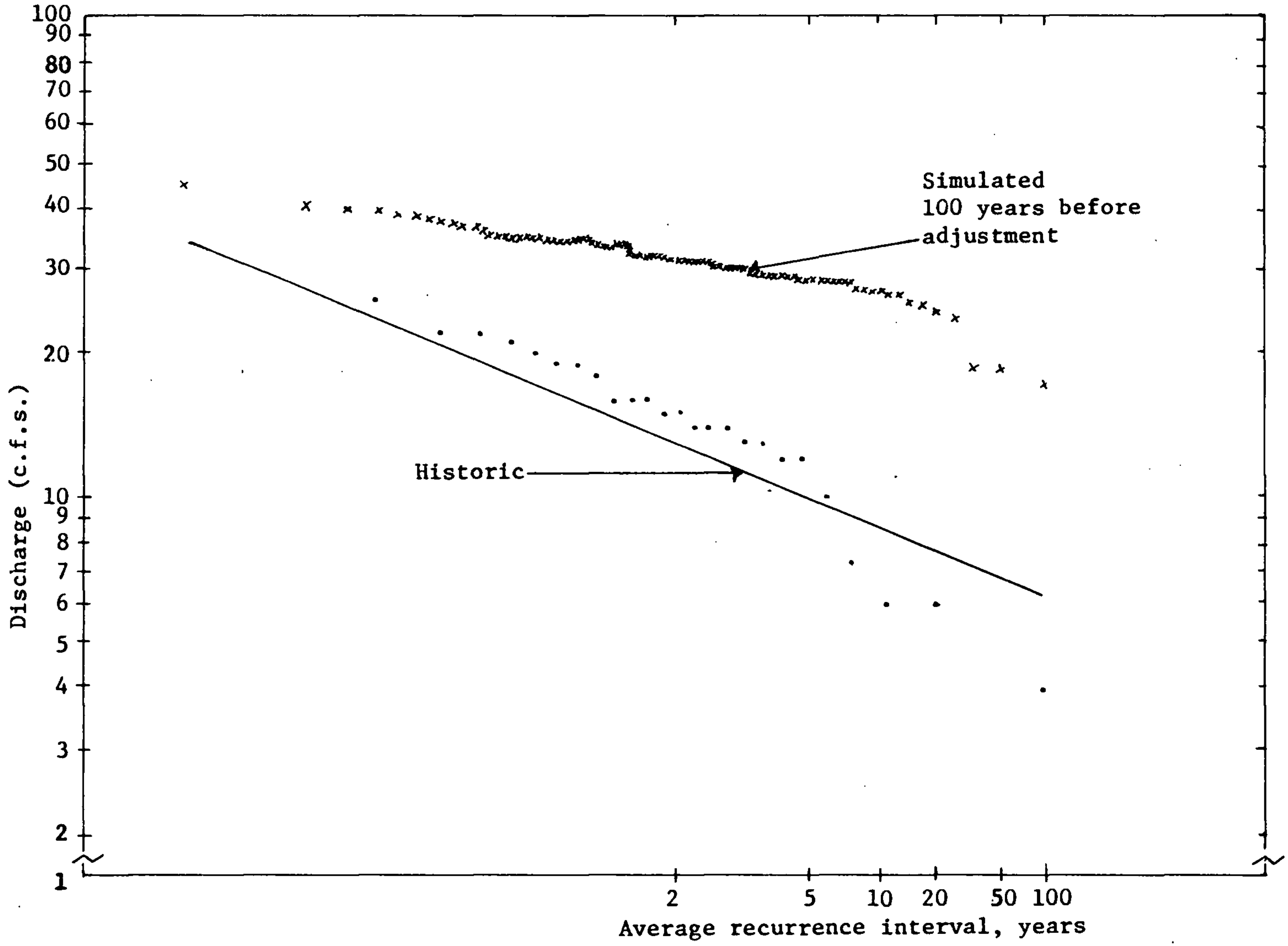

Figure 2.5. Simulated and historical minimum annual discharge exceedence, Calapooia River at Algany, Oregon.

exceedence curve at the Albany gage. The final simulated minimum annual discharge exceedence frequency curves for the Holley and Albany gages are presented in Figures 2.6 and 2.7, respectively. The historical exceedence curve and the scatter diagram of historical points are given in Figure 2.7 so that a better comparison can be made with the simulated scatter diagram. The simulated Albany minimum annual discharge exceedence frequency curve is based on 20 years of simulated values while the Holley minimum annual discharge exceedence frequency curve is based on 100 years of simulated values.

Some adjustment of the C coefficients determined by Kerri for maximum flows was also required to obtain simulated flows representative of the historical record. The final C coefficients are presented in Table 2.5.

Table 2.5. Coefficients for the stream used in the hydrology generator.

Pearson deviate (K)	Holley (upstream)	Albany (downstream)
Negative (low flows)	1.35	1.45
Positive (high flows)	1.17 (1.1) a/	1.22 (1.2) a/

a/ Coefficients determined for Calapooia River by Kerri (1969).

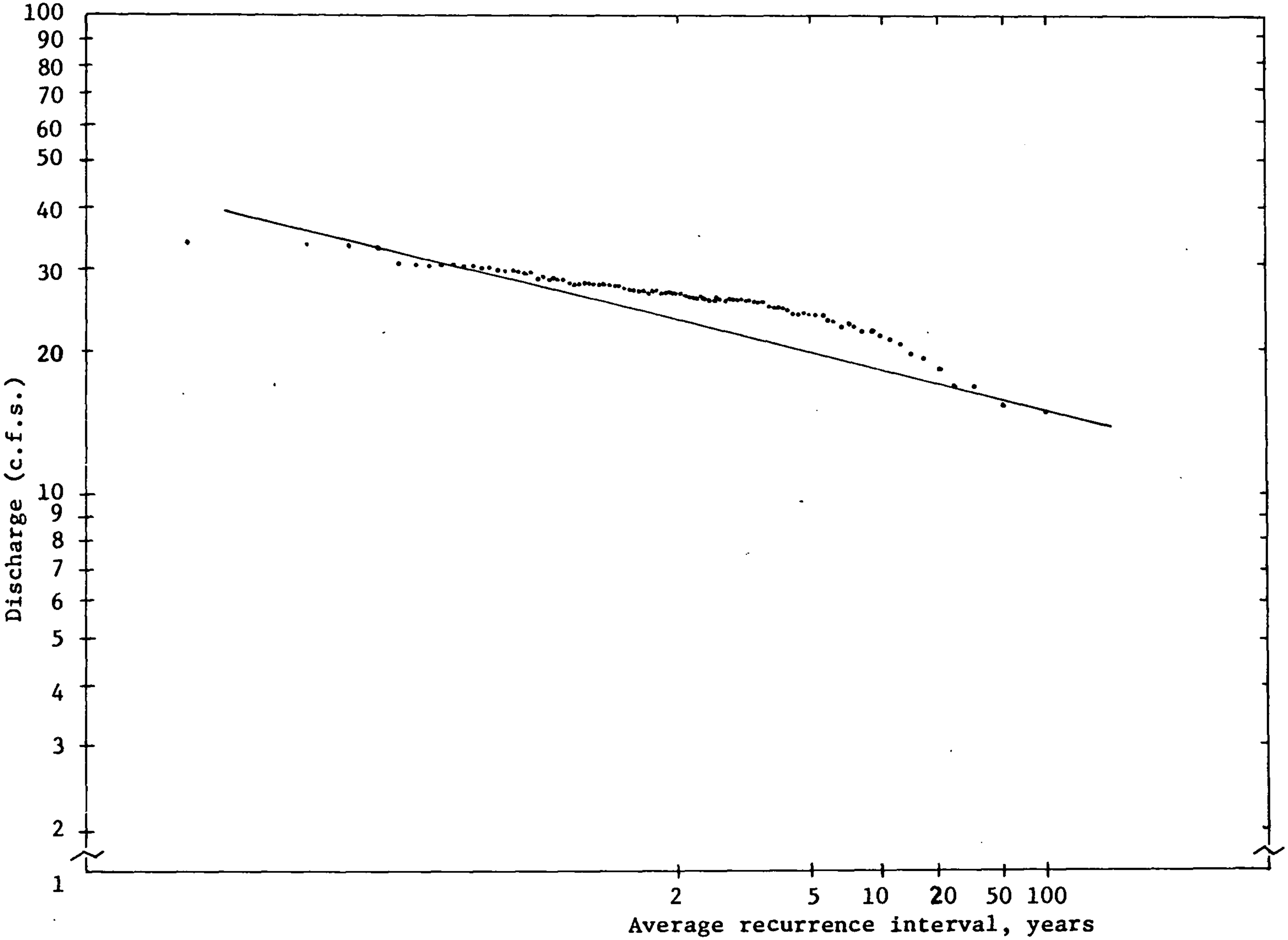

Figure 2.6. Simulated minimum annual discharge exceedence, Calapooia River at Holley, Oregon.

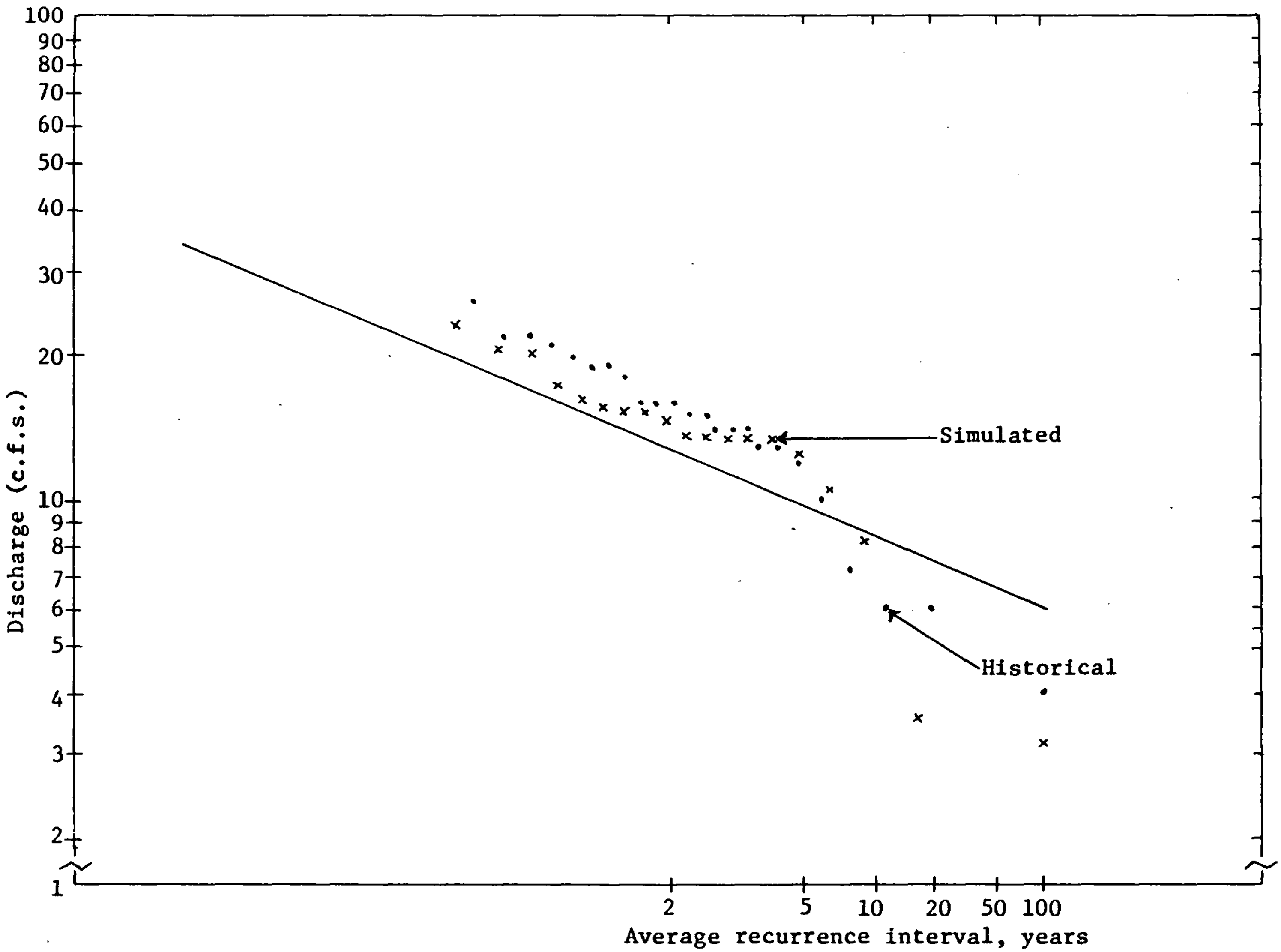

Figure 2.7. Simulated and historical minimum annual discharge exceedence, Calapooia River at Albany, Oregon.

The simulated maximum annual discharge exceedence frequency curves for the Holley and Albany gages are presented in Figures 2.8 and 2.9, respectively. Both curves are plotted over the exceedence curves estimated by the Corps of Engineers. The simulated Intermediate Regional flood, which has an average recurrence of one in one-hundred-years at Holley on the Calapooia River, is approximately 19,300 c.f.s. The simulated Intermediate Regional flood at Albany on the Calapooia River is approximately 48,000 c.f.s.

Reservoir and Channel Regulation

A major portion of the computer model involves operation of the proposed reservoir and the resulting regulation of flows downstream. The reservoir operation procedure as planned by the Corps of Engineers is designed to have the reservoir level low prior to the months of high precipitation and runoff. The regulation rule curve for the proposed Holley reservoir is shown in Figure 2.10. The months of the year are read off the horizontal axis and the volume of storage is read off the vertical axis. The conservation storage season is between February 1 and April 30 of each year. During this period water is stored at a fairly rapid rate. The pool is maintained until September 1, then lowered throughout a three-month period until November 30. This lowering

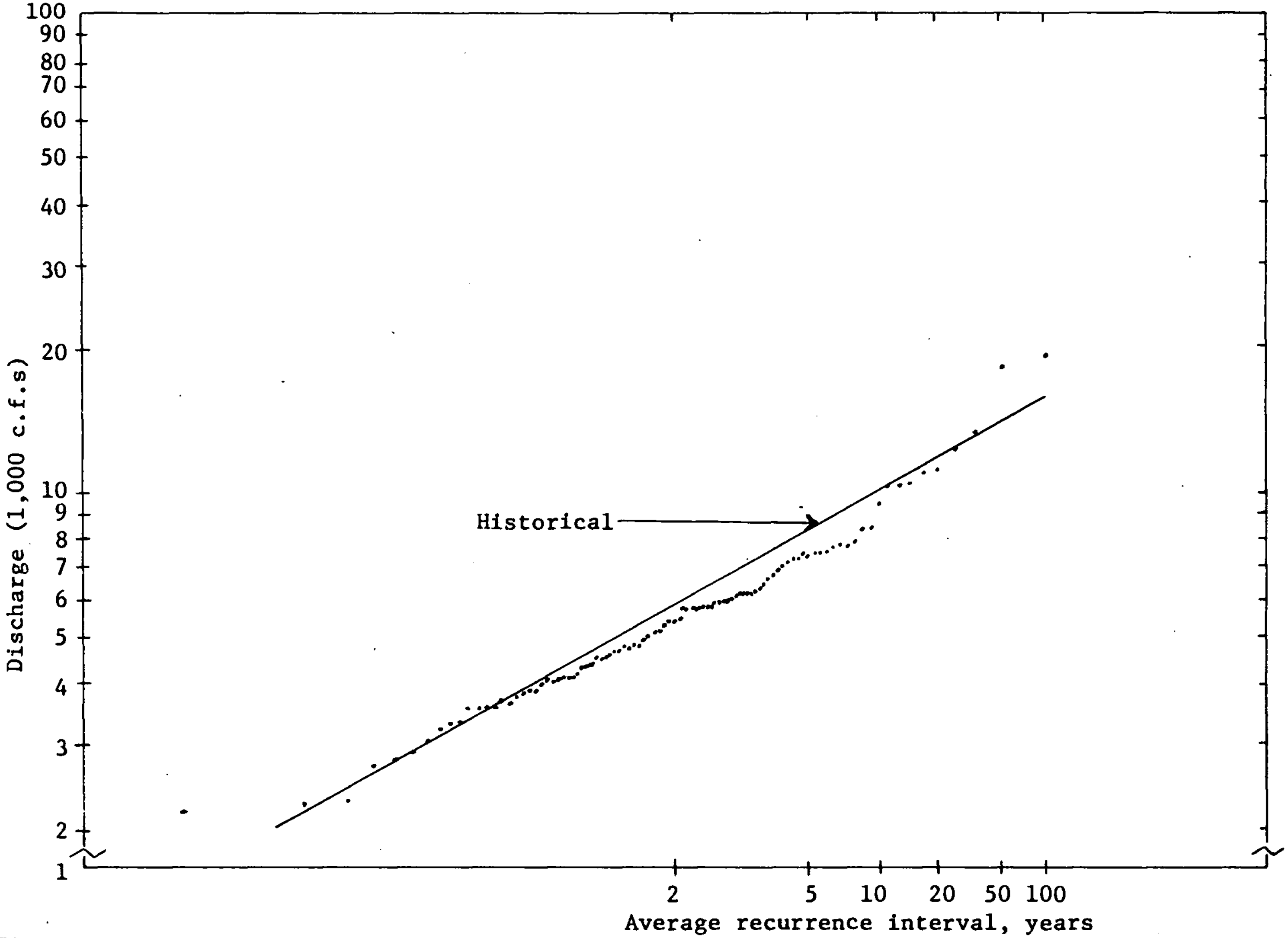

Figure 2.8. Simulated maximum annual discharge exceedence, Calapooia River at Holley, Oregon.

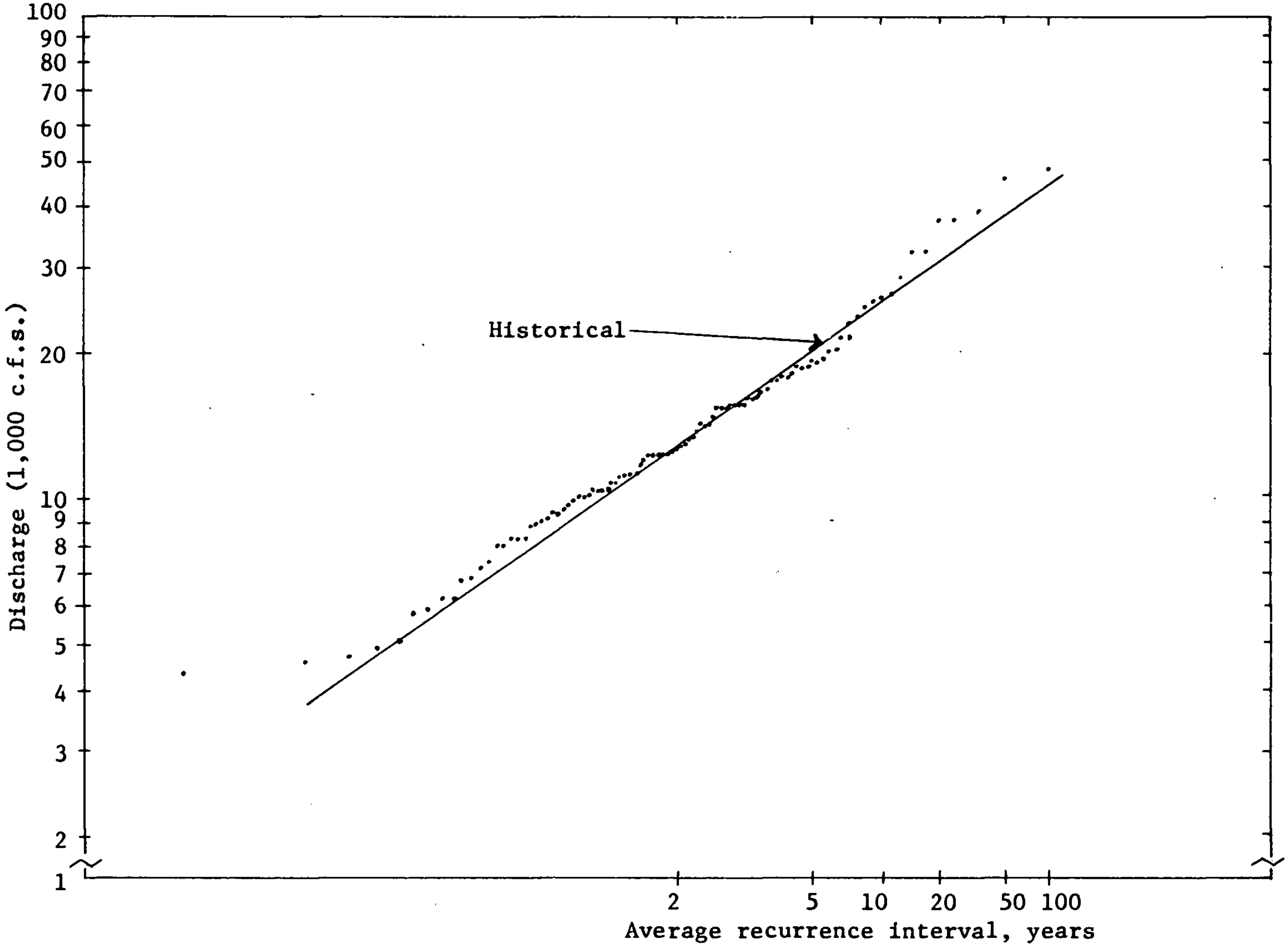

Figure 2.9. Simulated maximum annual discharge exceedence, Calapooia River at Albany, Oregon.

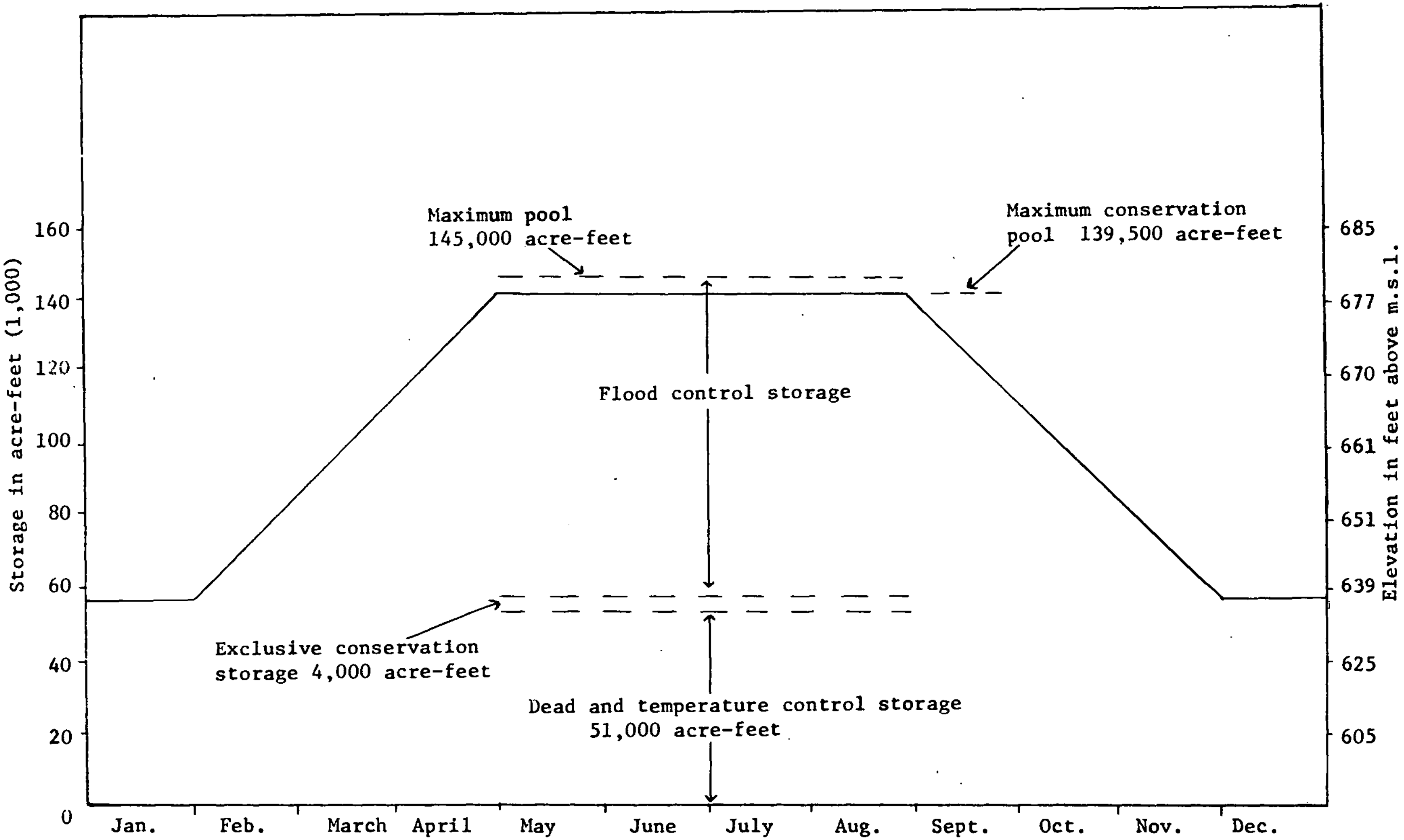

Figure 2.10. Regulation rule curve for Holley Reservoir.

of the pool is in anticipation of the major flood season which runs from December 1 to January 31. During the major flood season the level, according to the rule curve, should be kept at minimum flood control pool which is 55,000 acre-feet in volume. The flood control storage space available amounts to 90,000 acre-feet.

A flow diagram of the reservoir and channel operation algorithm is presented in Figure 2.11. The lines with arrows indicate the general direction of influence of one variable upon another in the algorithm.

In the computer model two equations compute the level of the reservoir and channel. Each day the reservoir and channel levels change depending upon the magnitude of the inflow and outflow rates per day. The main variables effecting the reservoir and channel levels are the hydrology generators and reservoir releases. Other variables affecting the reservoir and channel levels are municipal and industrial water releases, channel outflows into the Willamette River, evaporation, and irrigation return flows.

The initial step in reservoir operation is input of the upstream generated hydrology into the reservoir level equation. In the computer model the reservoir level equation is initialized at the rule operation level for October 1. Each day the actual reservoir level is checked to determine whether the level is at the desired rule. The desired release to get to the rule level is

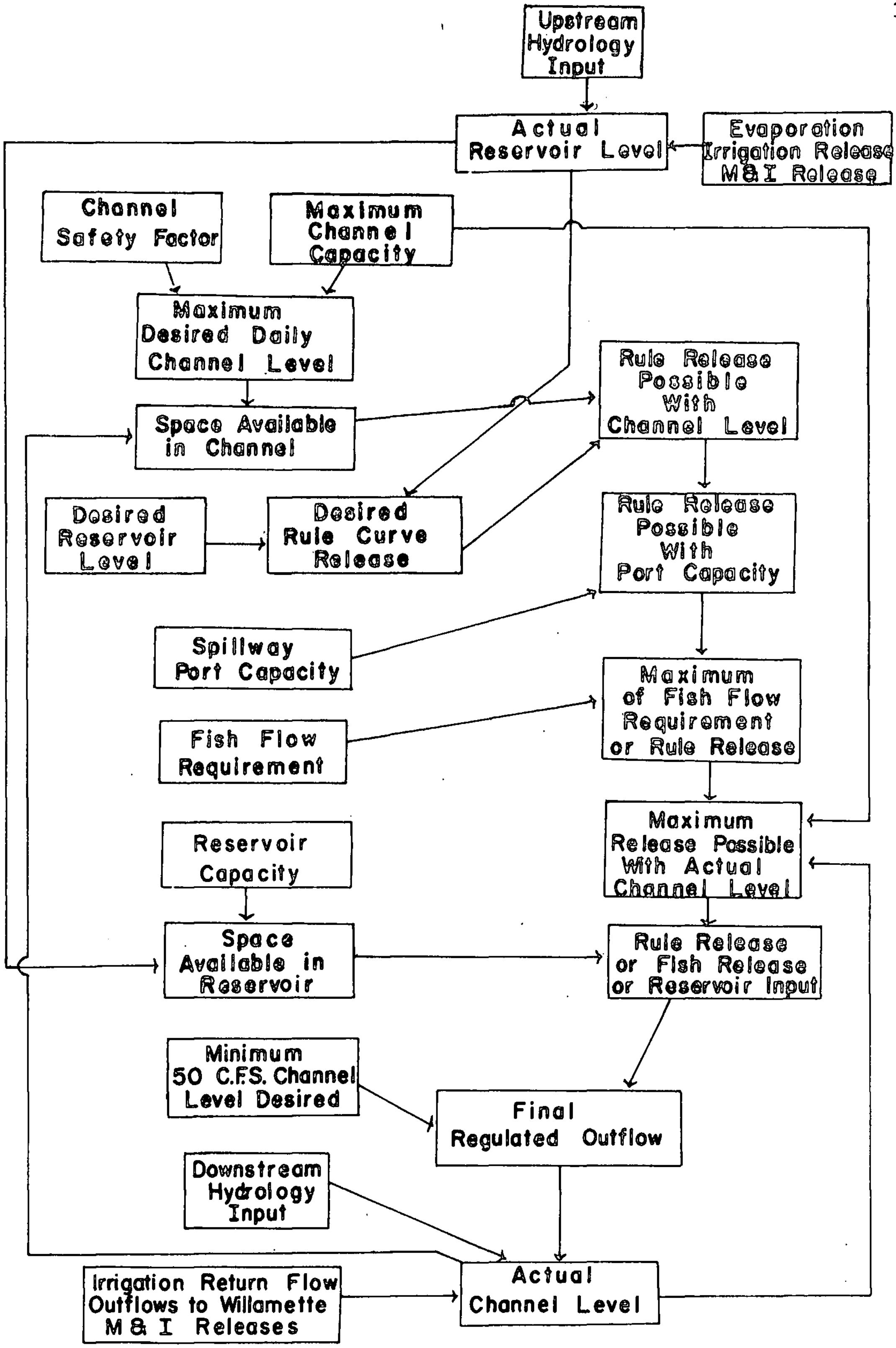

Figure 2.11. Flow diagram of reservoir and channel regulation.

determined by subtracting the desired reservoir level from the value of the actual reservoir level. The desired reservoir level is determined by taking a fraction of the reservoir capacity (145, 000 A. F.) calculated from the rule curve. If the actual reservoir level is less than the desired level the rule level release is zero. If the actual reservoir level is greater than the desired level then the algorithm proceeds to determine the magnitude of the release. In this case the objective of the algorithm is mainly in getting the reservoir level down to the rule curve.

Firstly, in getting to the rule curve the daily safe channel level is determined by subtracting a safety factor from the maximum channel capacity. (The maximum release from the reservoir is limited to 3500 c. f. s. because some reaches of the stream are bankfull at this capacity.) The space available in the channel is determined by subtracting the actual channel level from the desired daily safe channel. If the desired channel level is greater or equal to the actual channel level the rule release is a positive quantity, otherwise it is zero. If it is a positive quantity then the spillway port system is checked to see if it is sufficient to handle the rule release. If the rule level release is larger than the spillway ports the amount of the release becomes the total quantity the spillway ports will handle. Thirdly, the release, as determined to this point, is then compared to the fish flow requirement downstream. The maximum of these two quantities is taken since it was assumed that at least the fish requirement should be met each day of the simulation year. Finally, if the channel is full and the reservoir is full then the release is the upstream inflow into the reservoir regardless of the release determined to this point. If the channel is full and the reservoir is not full then the release is 50 c. f. s. which is the minimum flow requirement directly below the dam, as determined by the Corps of Engineers for fish life in the vicinity of the dam. If the channel is not full and the reservoir is not full then the final regulated release becomes the maximum as determined above.

The actual channel level is the sum of the regulated release, the downstream hydrologic input, the irrigation return flow, the outflow into the Willamette, and municipal and industrial releases. The unregulated channel level is also computed and compared with the regulated channel level to obtain the magnitude of floods. This procedure is discussed in the next section.

Simulated Floods and Flood Benefits

The main project purpose of the Holley Dam is in flood regulation and damage prevention. Potential floods are based upon the maximum annual channel flow without regulation. Actual floods are based upon the maximum annual channel flow with regulation. The computer model simulates the regulated and unregulated channel flows as described above. To compare the regulated flows with the unregulated flows, the maximum annual regulated flows are plotted as an exceedence function for a 50-year simulation period in Figure 2.12. The unregulated historical exceedence curve is also shown in Figure 2.12. (The unregulated simulated flows are shown in Figure 2.9.) A comparison of the simulated regulated flows can also be made with the regulation exceedence function as estimated by the Corps of Engineers by comparing Figure 2.12 with Figure 2.2. The close correspondence between the simulated regulation and that estimated by the Corps of Engineers should be noted as it provides the "best" test of the descriptive and predictive validity of the simulation model.

Flood Benefit Calculation. In the simulation model any day's downstream flow plus the previous days' upstream flow constitutes the maximum flow that could occur at any time. This unregulated flow is put through a maximization function to find the annual maximum. This flow which could occur in absence of the reservoir is the basis for estimation of the flood damages that could occur in the Calapooia reach of the Willamette system. Only the largest annual flood is used in calculating flood damages since most of the damage would occur during the largest flow. The peak flow is converted to stage height in feet at Shedd, Oregon. The Corps of

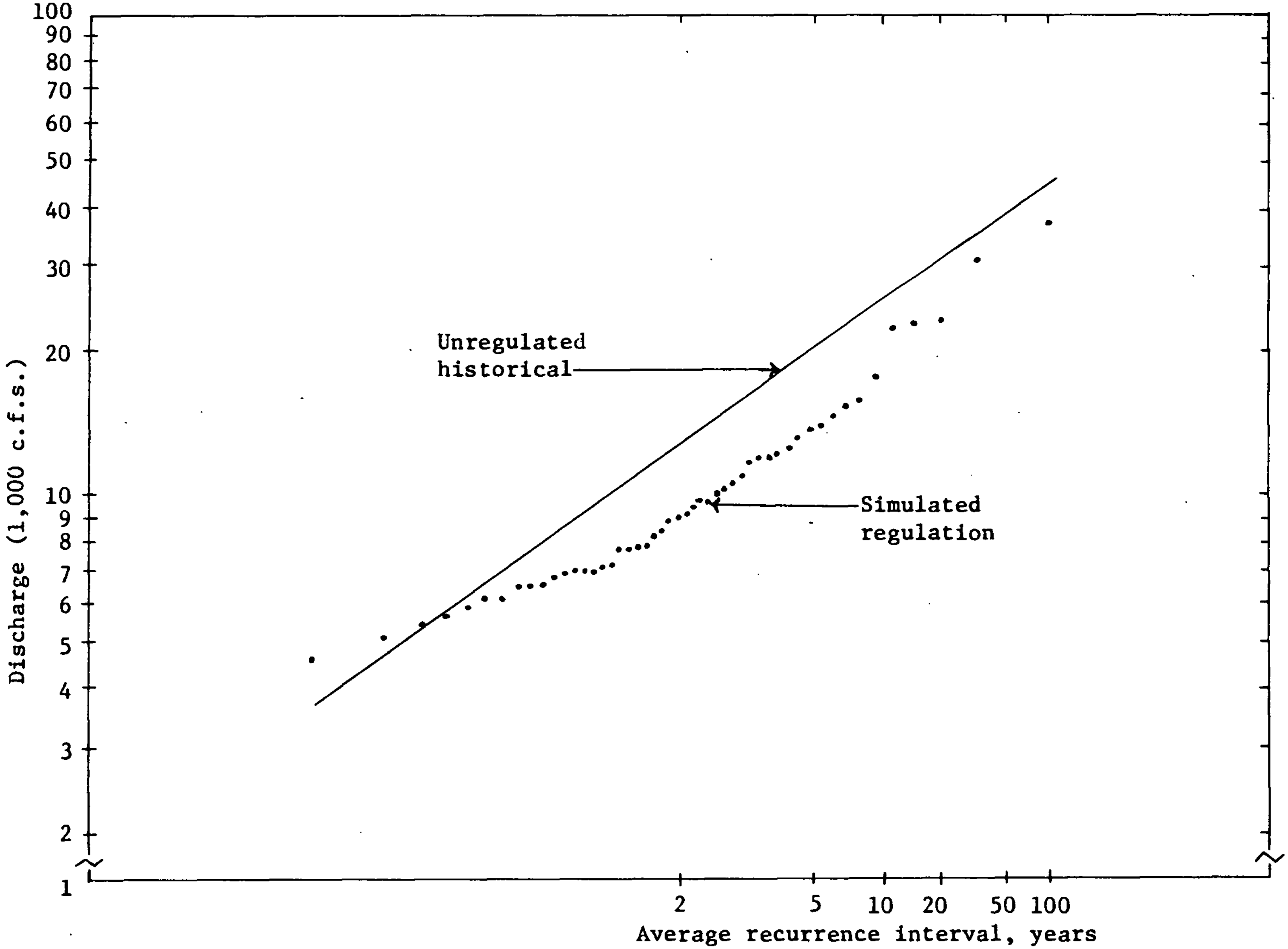

Figure 2.12. Simulated maximum annual regulated discharge exceedence, Calapooia River, Albany, Oregon.

Engineers uses Shedd as the point for estimating flood damages on the Calapooia. The stage height is converted to dollar damages according to the relationship as presented in Table 2.6. The simulated annual maximum flood with reservoir regulation is also converted to stage height in feet at Shedd, Oregon, and an estimate of the dollar damages is calculated. To obtain the annual flood benefits for the Calapooia River reach the flood damages prevented are determined by subtracting the regulated flood dollar damages from the unregulated flood dollar damages. The benefits thus derived are then discounted each year by the present value factor and compounded by a growth factor for that year and accumulated over the simulation run.[3/]

Since the Calapooia River is a tributary of the larger Willamette River the Corps of Engineers estimates flood damage contribution of the Calapooia to the flood potential of the Willamette River. It was found that floods of high magnitude flow and slight probability of occurrence contribute to the flood damage prevention estimated by the Corps of Engineers. The maximum potential benefits

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[3/] The present value of one dollar of benefits is calculated by the following formula:

$$P.V. = \frac{1}{(1 + i)^n}$$

where i = interest rate of 4.875 percent and n = year.

Table 2.6. Calapooia River reach, Albany mean daily and peak flows, Shedd stage heights, and resulting damages.

Albany mean daily flow	Albany peak flow	Stage height at Shedd	Damages a/
(c.f.s.)	(c.f.s.)	(feet)	(dollars)
5,702	6,000	13.50	0
6,168	7,500	14.25	1,000
7,072	8,600	15.00	2,000
10,280	12,500	16.00	8,000
14,392	17,500	16.40	23,000
16,448	20,000	16.60	68,000
20,559	25,000	16.75	159,000
32,895	40,000	17.20	398,000
41,119	50,000	17.30	964,000
45,231	55,000	17.40	1,600,000
49,343	60,000	17.50	2,179,000
53,454	65,000	17.60	2,481,000
61,678	75,000	17.75	3,484,000
65,790	80,000	17.85	4,618,000
74,014	90,000	18.00	5,302,000
86,349	105,000	18.25	6,397,000

a/ Based on Corps of Engineers' estimates in 1970 prices and 1980 development levels (year of project completion - 1980).

derivable from Holley reservoir on other reaches of the Willamette River are presented in Table 2.7. The total annual undiscounted benefits for the Willamette River are $248,600. Of this amount, $168,125 annually are benefits attributable to reduction of damages from floods greater than the magnitude of the one in one-hundred-years Intermediate Regional flood. In other words, approximately 68 percent of the annual benefits obtained on the Willamette River by construction of Holley Dam are based on floods with probability

Table 2. 7. Expected flood benefits on the Willamette River attributable to Holley reservoir by reach. a/

Reach of Willamette River	Annual dollar benefits for floods of up to 1 in 100 years magnitude	Annual dollar benefits for floods of up to 1 in 10, 000 years magnitude	Annual dollar benefits attributable to floods larger than 1 in 100 years magnitude
Albany	31, 955	48, 870	16, 915
Salem	24, 389	54, 757	30, 368
Grand Island	7, 994	29, 790	21, 796
Newberg	6, 914	7, 935	1, 021
Oregon City	3, 147	29, 502	26, 355
Portland	6, 076	77, 746	71, 670
Total	80, 475	248, 600	168, 125

a/ Calculated from data provided by Corps of Engineers.

of less than . 01 of occurrence.

The annual dollar benefits are the differences between the expected damages without regulation and with regulation. The expected damages are calculated from the frequency of exceedence curves and the estimated damage amounts associated with the various magnitudes of peak flows. These are adjusted for 1970 price level and stage of economic development to first year of reservoir operations, 1980.

The flood of one-in-10, 000-year magnitude is called the standard project flood by the Corps of Engineers. The regulation of this size of a flood, 30, 800 c. f. s. at Holley, is estimated by the Corps of Engineers under two assumptions: (1) the reservoir is at minimum flood pool level, 55,000 acre-feet, when the flood occurs, and (2) special reservoir regulation curves are used for routing.

In the hydrology generator used in the simulation model a one-in-10,000-year flood has a probability of occurring of .0001, while a one in one-hundred-year flood has a probability of occurring of .01. In a 100-year run of the simulation model the one in one-hundred-year flood will occur at least once. Since the probability of a one in one-hundred-year flood is 100 times the probability of a one-in-10,000-year flood, one would not expect the one-in-10,000-year flood to occur in a 100-year simulation run; however, since its probability is still positive it could occur, just as an actual one-in-10,000-year flood could occur during the expected 100-year life of the Holley Dam. However, if it did occur during the life of the project there is no reason for expecting it to occur when the reservoir level is at the minimum flood control pool. If it occurred when the reservoir level is not at the minimum flood pool then the damages prevented by Holley Dam on the Willamette River would not be as great as if the flood had occurred when the reservoir level is at minimum flood pool. Thus, the benefits attributable to floods larger than one in one-hundred-year magnitude, as given in Table 2.7, need to be adjusted for the possibility that the large flood magnitudes may occur at times when the reservoir is not at the "best" level for flood control. The Corps of Engineers has no way to tell at what reservoir level the large flood will occur. However, in the simulation model the reservoir level is calculated daily and can be compared with the desired minimum flood pool. One can tell on a daily basis the extent to which the remaining flood storage could contain a flow larger than the one in one-hundred-year flood should it occur at that level of the reservoir. In order to account for the possible lack of storage space for the large flood and thus the possibility of losing some of the potential flood benefits due to large floods, the simulation model finds the minimum ratio of:

$$\frac{\text{desired rule level}}{\text{desired rule level} + (\text{actual level} - \text{desired rule level})}$$

each day during the flood season. This minimum ratio for the year is then applied to the dollar benefits attributable to floods larger than one in one-hundred-years. This calculation is performed each year of the simulation; the benefits are then discounted each year by the present value factor and compounded by a normal growth factor for that year and accumulated over the simulation run.

Reservoir and Channel Costs

A summary of the costs of construction of Holley Dam and annual operation, maintenance, and repair costs are presented in

Table 2.8. Costs of the temperature control facilities for downstream fish enhancement are included in the section on anadromous fish in the next chapter. The total capital construction cost, excluding temperature control, is $24, 378, 500. The annual operation, maintenance, and repair costs are $179, 160. Capital costs of downstream channel improvement (Table 2.9) are $3, 012, 000, and the annual operation, maintenance, and repair costs are $23, 991.

In the simulation model provision is made for calculating the present value of annual operation, maintenance, and repair costs annually, accumulating for the length of the simulation, and averaging for the period. At the end of the period of simulation the total operation, maintenance, and repair costs are summed across flood control, anadromous fish, recreation, irrigation, and resident trout fishing. Then the amortized capital costs are added to provide the total average annual cost, exclusive of interest during construction. The costs associated with the other functions are discussed in the appropriate sections in the next chapter. A summary of all the costs is given in Chapter V.

Table 2.8. Reservoir and dam capital costs and annual operation, maintenance, and repair costs.

Item	Cost
Capital construction -	
Dam	
Embankment	$ 7,538,000
Spillway	1,529,300
Outlet works	2,446,400
Other costs a/	12,844,800
	$24,378,500 b/
Operation, maintenance, and repair (annual)	$179,160

a/ Other costs include: lands and damages, relocations, reservoir clearing, roads and bridges, buildings, grounds, utilities, permanent operating equipment, construction facilities, engineering, design, supervision, and administration.

b/ Total includes capital costs for irrigation storage.

Source: U. S. Army, Corps of Engineers, 1970.

Table 2.9 Channel improvement capital costs and annual operation, maintenance, and repair costs.

Item	Cost
Capital construction -	
Downstream channel improvement	$3,012,000
Operation, maintenance, and repair (annual)	23,991

Source: U. S. Army, Corps of Engineers, 1970.

III SIMULATION OF THE OTHER USES OF HOLLEY RESERVOIR WATER

The previous chapter described the hydrology and flood regulation and its simulation for the proposed Holley Dam. This chapter describes the other water use functions of the project and how they are handled in the simulation model. The bases for benefit calculations are given and the Corps of Engineers' cost estimates of providing the various uses are briefly outlined. The water use functions include: anadromous fisheries, recreation, resident trout fishing, and irrigation. The functions are discussed in order according to the magnitude of the benefits as estimated by the Corps of Engineers.

Anadromous Fisheries

The anadromous fish utilizing the Willamette River system for annual migration and spawning are Spring Chinook Salmon, Fall Chinook Salmon, Silver Salmon (Coho), and Winter Steelhead. These species of fish are similar in that they all spawn in fresh water streams, migrate out to sea sometime during their life cycles, and escape being caught as adults to return to their spawning area to produce offspring and then die.[1/] The distinguishing characteristic of these species is their instinctive behavior in returning to the fresh water tributary from which they were hatched and partially reared.

The fish conservation and enhancement measures incorporated into the Holley reservoir project plan include: collecting, holding, hauling, artificial spawning and hatching facilities, downstream fish passage through the dam at Holley, facilities for fish passage at a flow control structure downstream from the dam at the head of Sodom Ditch, augmentation of low summer flows, and water temperature control. The number of anadromous fish by species believed to utilize (or could utilize) the Calapooia River and the number anticipated with project fish mitigation and enhancement are presented by reach of the river in Table 3.1. The term fish mitigation refers to an attempt to alleviate the obstruction (in this case a dam) to the natural migration of anadromous fish to their natural spawning beds in the headwaters of the stream. Project fish enhancement includes introduction of greater numbers of spawners or new species of spawners into the immediate project

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1/ The escapement refers to those fish which escape commercial or sport harvest. A small percentage of Winter Steelhead migrate more than once.

Table 3. 1. Species and numbers of spawning anadromous fish without the project and with project fish mitigation and enhancement.

Reach or section of project area	Anadromous species	Estimated spawners without project fish mitigation or enhancement	Estimated spawners with the project and recommendations	Increase in spawners with project and recommendations
Downstream reach below Holley Dam	Fall Chinook Salmon	1, 000	1, 900	900 a/
	Spring Chinook Salmon	0	450	450 a/
	Winter Steelhead Trout	0	700	700 a/
Dam site or reservoir	Spring Chinook	0	6, 250	6, 250 a/
Upstream reach above Holley Reservoir	Fall Chinook Salmon	1, 200	1, 200 b/	0
	Spring Chinook Salmon	300	300 b/	0
	Winter Steelhead Trout	1, 400	1, 400 c/	0
	Silver (Coho) Salmon	600	600 b/	0

a/ Enhancement means increases in spawners or introduction of species.

b/ Mitigation means maintenance of spawners.

c/ Hatched and reared in the hatchery.

Source: U. S. Department of Interior, Bureau of Sport Fisheries and Wildlife, 1971.

affected area. In the downstream reach of the Calapooia River the estimated potential number of Fall Chinook Salmon present without the project is 1, 000 spawners.[2/] With Holley reservoir 900 additional Fall Chinook Salmon spawners are an enhancement feature of the project. Also, downstream an additional 450 Spring Chinook Salmon spawners and 700 Winter Steelhead spawners are to be introduced into the Calapooia River. Presently there are no spawners of these two species utilizing the downstream reach. A reservoir Spring Chinook Salmon rearing enhancement program is to produce 6, 250 returning spawners to the dam site annually. Mitigation of 1, 200 (potential) Fall Chinook Salmon, 300 Spring Chinook Salmon, and 600 Silver Salmon now utilizing the upstream spawning beds is proposed as a conservation measure. Winter Steelhead numbering 1, 400 spawners now using the upstream reach of Calapooia River will not be passed above the project. Evidence to date indicates that passage of steelhead above a reservoir is not an adequate mitigation measure for these fish. Thus the returning steelhead will be caught and hauled to the Santiam Salmon Hatchery where they will be artifically spawned, hatched, and reared,

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2/ The Fall Chinook Salmon are potential until such time as the fish passage at Willamette Falls is completed.

whereupon the smolts will be returned to the river below the dam.

Costs of fish mitigation and enhancement procedures for the Holley Dam project are shown in Table 3. 2. The total capital costs are $865, 000 and the annual operation, maintenance, and repair costs are $49, 000. The largest two capital cost items are: (1) the temperature control structure for the downstream anadromous fishery, and (2) the facilities for mitigating salmon above the dam and rearing of Steelhead in the hatchery.

Benefits from fish enhancement are based upon the number of spawners (escapement) returning to the project site. There are no benefits for mitigation of fish since this is a conservation measure and is not a project function. Enhancement benefits for commercial and sport value of the three species are shown in Table 3. 3. It is interesting to note the close correspondence between the figures provided by the Bureau of Sport Fisheries and Wildlife for sport value and those determined in a study of the value of the salmon-steelhead sport fishery of Oregon conducted by Singh (1964) of Oregon State University. Singh estimated that the total yearly durable and current expenditures (including licenses) of salmon-steelhead anglers was $18, 001, 500 in 1962. The anglers caught 412, 800 fish in 1962 giving a value expressed in expenditure terms of $43. 61 per fish. The Bureau of Sport

Table 3.2. Fish mitigation and enhancement, capital and annual operation, maintenance and repair costs.

Reach or section of project	Cost category	Cost	
Downstream	Capital cost for dam outlet flow temperature control structure	$200,000	
	Evaluation study of effects of Holley Dam on temperature control enhancement	80,000	
Reservoir	Capital costs for adult collecting, hauling, artificial spawning and hatching facilities	130,000	
	Annual operation, maintenance and repair costs		20,000
Upstream	Capital costs for adult collecting, hauling, spawning and hatching facilities to mitigate salmon and rear steelhead a/	405,000	
	Annual operation, maintenance and repair b/		26,000
	Evaluation study of effects of Holley Dam on mitigation	20,000	
	Capital costs for non-game fish eradication	30,000	
	Annual operation, maintenance and repair		3,000
	Total	$865,000	$49,000

Continued

Table 3.2 Fish mitigation and enhancement, capital and annual operation, maintenance and repair costs--Continued.

a/ Includes costs of hatchery and rearing pond expansion of the Santiam Salmon Hatchery at Foster, Oregon.

b/ Includes an estimated $10,000 annual cost to collect, hold, and haul Spring Chinook, Fall Chinook and Coho Salmon to upstream spawning areas.

Source: U. S. Department of Interior, Bureau of Sport Fisheries and Wildlife, 1971.

Table 3.3. Sport and commercial value per returning spawning salmon for Holley project.

Salmon species	Commercial value	Sport value	Total value
Spring Chinook	$25.39	$63.99	$89.38
Fall Chinook	42.84	45.00	89.84
Winter Steelhead	.25	7.99	8.24

Source: U. S. Department of Interior, Bureau of Sport Fisheries and Wildlife, 1971.

Fisheries and Wildlife estimates the total sport value of the three species of anadromous fish associated with the Holley project to be $451,147 and the total catch to be 10,400 fish giving an annual benefit of $43.38 per fish.

Fresh Water Life Cycle of Anadromous Fish

The freshwater life cycle of anadromous fish utilizing the Willamette River and its tributaries consists of the following five phases:

1. Adult migration upstream to freshwater spawning beds
2. Spawning
3. Incubation and hatching of fry
4. Rearing of fry
5. Migration downstream of fry or smolts to saltwater environment.

Following the downstream migration the various species of salmon and steelhead grow in the ocean for anywhere from 2 to 4 years. The age of returning adult salmon is approximately three years. Winter Steelhead return either as 4 or 5 year old fish. A calendar of the freshwater life cycle of the four anadromous species of fish utilizing the Calapooia River is presented in Figure 3.1. In all cases except for Fall Chinook Salmon the five period freshwater cycle is greater than one year. The various stages of the freshwater life cycle are shown from migration of adults to upstream spawning beds to migration downstream of fry or smolts to the saltwater environment. The ranges in temperature of downstream water for survival at each stage of the life cycle are also shown to the right of each of the five periods of the freshwater life cycle in Figure 3.1. [3/]

The discussion in the section below illustrates for Spring Chinook Salmon how to read the figure for all species.

Spring Chinook Salmon

The freshwater life cycle of Spring Chinook Salmon in the Calapooia River begins with migration of adult fish upstream from

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3/ These temperature ranges were obtained from discussions with the Oregon Fish Commission, Department of Fish and Wildlife at Oregon State University, and Marine Fisheries Services.

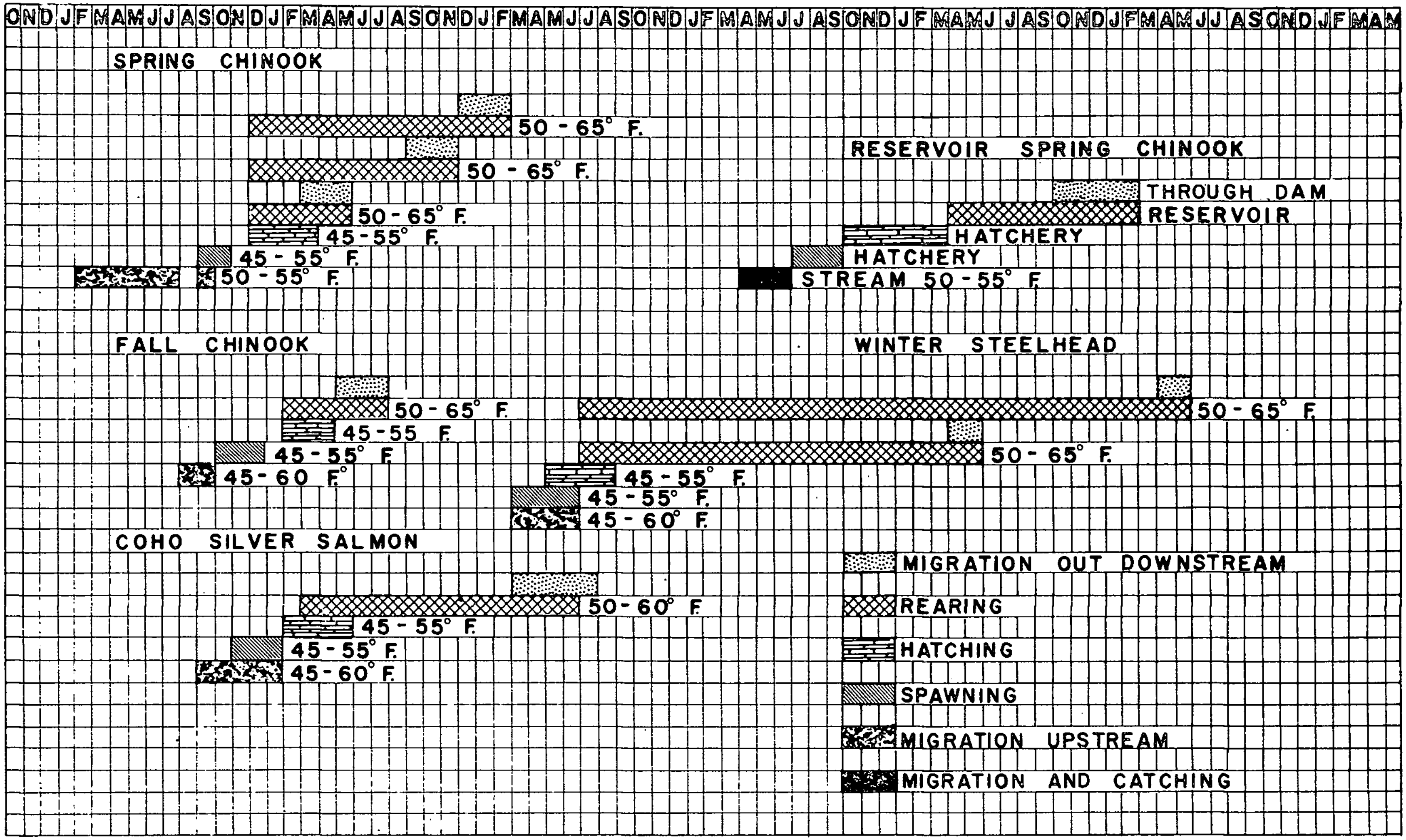

Figure 3. 1. Calendar of freshwater life cycle of anadromous fish.

the beginning of February through July. There is a slowdown of migration during August. The temperature required in the Calapooia River for migration of Spring Chinook Salmon is between 50° and 55°F. [4/] Spawning of Spring Chinook occurs in September and October and the temperature required for spawning is between 45° and 55°F. Hatching and emergence occurs from the beginning of December through March and the temperature required is between 45° and 55°F. Spring Chinook rear in the stream anywhere from 6 to 15 months. The downstream migration occurs heaviest after one year of rearing in the stream. The required temperature during the rearing period is 50°-65°F. The migration downstream occurs in the last three months of the rearing period. The greatest migration downstream of young Spring Chinook occurs from the beginning of September to the end of November.

The freshwater life cycle of the Spring Chinook reservoir rearing program is also shown in Figure 3.1. The adult Spring Chinook which will be in the reservoir rearing program are caught during their migration in May, June, and July. The same migration

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[4/] Fishes are cold blooded animals (poikilothermic), and their body temperatures are determined by the environmental temperature. Metabolism takes place within a narrow range of temperatures to which the animal is tolerant. Activity of poikilothermic animals increases as temperature rises (within narrow limits); as the temperature falls they become sluggish and lethargic.

temperature is required for these Spring Chinook adult spawners as for the natural spawners of this species downstream from the reservoir. The reservoir rearing adult Spring Chinook will be caught and artificially spawned in the hatchery beginning in August and going through October. Hatching of the eggs will occur from the beginning of October through March. It is assumed that optimum water temperatures will be provided in the artificial spawning and hatching phases to provide fry for the reservoir rearing program. The young Spring Chinook fry will be raised in the reservoir from approximately mid-April through February. Release of these fish through a specially designed structure in Holley Dam will occur from the beginning of October through February. The adult fish escapement will return to the dam to be collected and artificially spawned at an average of three years of age.

Flow and Temperature Requirements Below Holley Reservoir

The Bureau of Sport Fisheries and Wildlife has determined minimum hydrologic flows to be released from Holley Reservoir which are required for downstream fish enhancement. The minimum flows as estimated by the Bureau of Sport Fisheries and Wildlife are presented in Table 3.4.

Table 3.4. Required minimum flows downstream from Holley Reservoir.

Month	Flow
	(c.f.s.)
January	130
February	130
March	130
April	130
May	130
June	160
July	160
August	160
September	130
October	130
November	150
December	130

These minimum flow requirements are built into the reservoir regulation and release procedure of the simulation model as outlined in the previous chapter.

In conjunction with the minimum flow requirement below Holley Reservoir, the Bureau of Sport Fisheries and Wildlife has estimated the required temperature of flow releases. According to their estimates, temperatures of released water downstream from Holley Reservoir should be less than 55°F from September 15 to June 30 and less than 60°F from July 1 to September 14. No estimate of the minimum allowable temperature required has been made.

The temperature range required throughout the year for downstream waters released from Holley Reservoir was determined by placing the temperature requirements for the spawning and incubation phases of the life cycle in Figure 3.1 on the calendar of Figure 3.2. The bottom graph shows a 45° to $55^{\circ}F$ temperature range is required throughout the year. The temperature requirement of 45° to $55^{\circ}F$ was obtained by taking into consideration the requirements for the three anadromous fish species using the spawning beds below Holley Dam (Spring Chinook, Fall Chinook, Winter Steelhead). For example, in March and April the water temperature downstream from Holley Dam must be between 45° and $55^{\circ}F$ for Winter Steelhead to spawn. Any deviation from this range of temperature is not conducive to spawning. Although the previous year's Winter Steelhead, which are smolts when this year's adults are spawning, require only a range in temperature between 50° and $65^{\circ}F$, the spawning fish are the limiting factor and set the limits on temperature. Similar arguments can be made for the other species. The one obvious pattern in Figure 3.1 is that throughout the 12 months of the year, 1 of the 3 species of anadromous fish utilize the Calapooia River for spawning and/or incubation. The temperatures required for these two activities are in the range of 45° to $55^{\circ}F$. Temperatures out of this range will either inhibit egg incubation or emergence, or be conducive to disease infestation.

The temperature of water released from Holley Reservoir as calculated by a Corps of Engineers' computer model, and based on 1958 weather data at Eugene and the Bureau of Sport Fisheries and Wildlife estimates of desired temperatures, are shown in the upper portion of Figure 3. 2. From the Corps of Engineers' computed outflow temperatures, for this one set of conditions, it can be seen that from the beginning of June until the beginning of October the water is well above the desired temperature as indicated by the graph in the lower portion of Figure 3. 2. Also from January through March and various periods from the 15th of October through December the flow temperatures are below the minimum requirements for spawning and hatching as indicated in the graph in the lower portion of Figure 3. 2. It is apparent that the required temperature as determined by the Bureau of Sport Fisheries and Wildlife did not take into consideration the possibility of spawning and hatching of the three species of fish occurring during the entire year. The required maximum pattern as provided by the Bureau of Sport Fisheries and Wildlife is conducive to Spring Chinook but not necessarily to Fall Chinook and Winter Steelhead. The lack of a systems approach to determining water temperature requirements could lead to such mistaken setting of requirements.

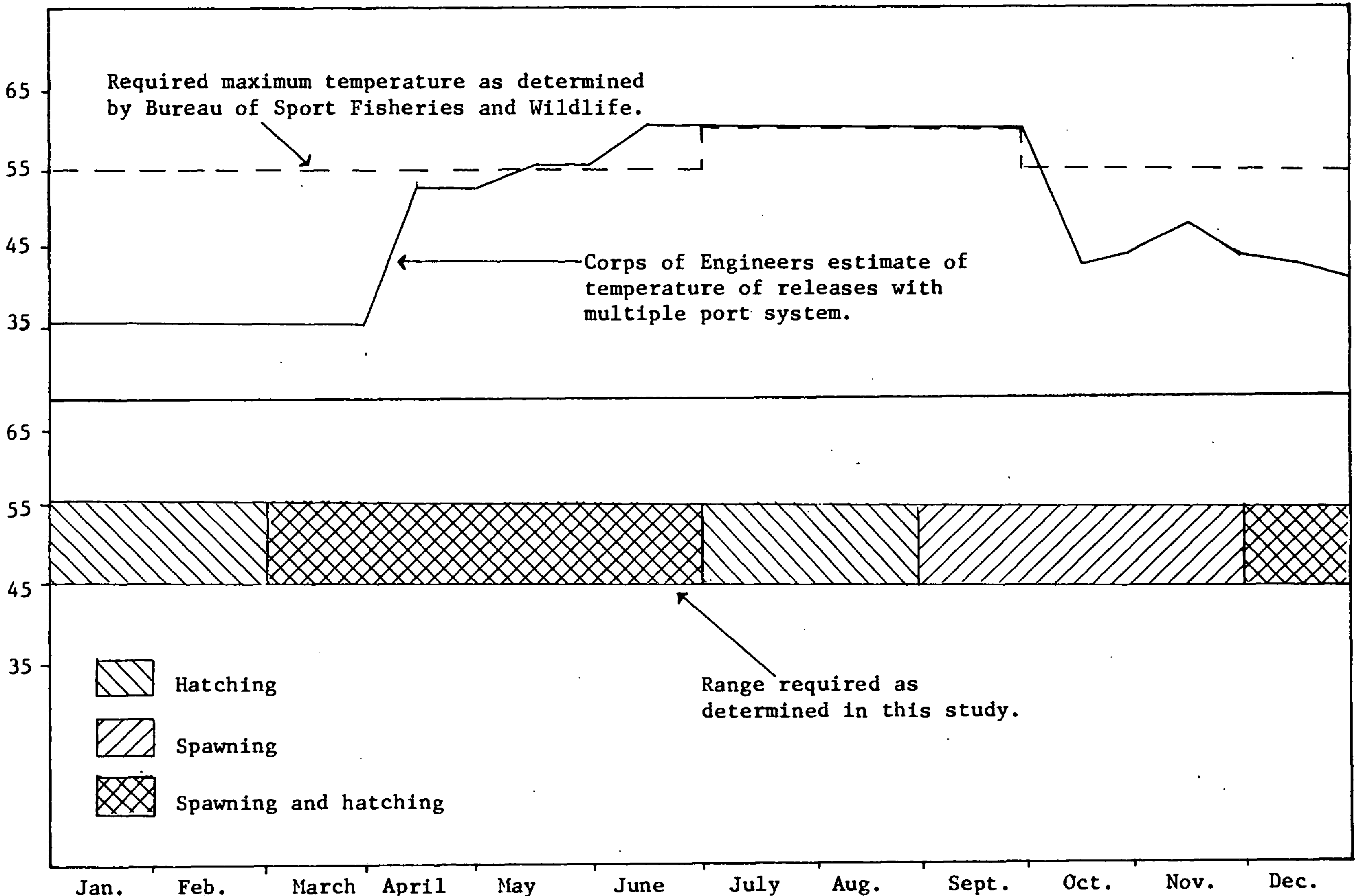

Figure 3.2. Downstream temperature requirements, and predictions as determined by the Corps of Engineers.

Simulated Temperature of Releases Downstream From the Dam

The Environmental Protection Agency (formerly the Federal Water Quality Administration) (1969) has determined temperatures of released water at various reaches of the Calapooia River downstream from Holley Dam. Their simulations based on an average hydrologic year (1958) indicate that water temperatures remain below the required temperature (upper portion of Figure 3.2) for only five miles below Holley Dam, then increase as the water progresses towards Brownsville. The predicted temperature at Brownsville, which is still within the potential spawning area was calculated as being above 67°F. If the calculations of the Environmental Protection Agency are correct, then the setting of the required temperature of releases by the Bureau of Sport Fisheries and Wildlife has not taken account of the heating factor as the water flows downstream from the dam.

It would be desirable to incorporate into the simulation model of this study the reservoir and downstream temperature aspects of anadromous fish enhancement. This requires building a simulation of the thermal conditions in the reservoir and downstream as a function of atmospheric conditions and reservoir regulation. While the Corps of Engineers have computer programs to simulate reservoir thermal conditions and downstream conditions, it was beyond the scope of this study to rewrite and incorporate these programs into the DYNAMO model. In addition, because of the conflict between what this study determines as the temperature requirements for downstream fish and what the Corps of Engineers is using for temperature requirements, it was felt that modeling efforts should be directed toward other aspects of the downstream fishery which the Corps of Engineers had not considered. Thus, in the next section a simulator of the downstream Fall Chinook Salmon population is discussed which considers stream conditions other than temperature.

Downstream Fall Chinook Model

It has been estimated by the Bureau of Sport Fisheries and Wildlife that there is a potential for return of 1,000 spawners of the Fall Chinook Salmon species to the Calapooia downstream spawning beds annually. As a fish conservation measure the project plan proposes that this fish run be maintained. In addition, 900 Fall Chinook spawners will be introduced into the downstream spawning areas as a fish enhancement purpose, for a total population of 1,900 Fall Chinook. Since Fall Chinook make up the largest number of downstream anadromous fish, this study concentrates on modeling this species. This section gives the details of the Fall Chinook simulation model which could be modified to model the Spring Chinook and Winter Steelhead populations if such modeling were considered a worthwhile addition to the findings of this study concerning the feasibility of a downstream anadromous fishery.

In order to study the effects of Holley Dam on the downstream salmon populations several factors were isolated and their impacts quantified. One of the main factors that appears to be critical in the case of the Calapooia River is the possibility of high stream flows over the spawning beds during spawning and incubation. According to the Corps of Engineers (and substantiated by the simulation results), with full flood control at Holley frequent overbank flows can still be anticipated due to the flatness of the land and the amount of runoff from the drainage area downstream from the reservoir.

High discharges during incubation of eggs appear to have some adverse effect on subsequent Pink Salmon catches on the Fraser River System in Canada, presumably as a result of streambed erosion and displacement of eggs during extreme flows (Vernon, 1962; NcNeil, 1969). This consideration was deemed necessary in studying the effects of Holley Dam on downstream salmon.

Studies indicate (Wickett, 1962) that freshwater factors imposing variations on salmon stocks are: discharge at the time spawners are migrating upstream, at the time when eggs are in the early stage of incubation, extreme discharge during the period that the eggs and alevins are in the gravel, and temperature. Wickett also suggests that the reproduction potential or maximum fry output of Pink Salmon populations is largely set by the permeability of stream gravel. His studies indicate that permeability of the spawning beds after a flood is markedly reduced and in many cases scouring and loss of stream bed gravel occurs. These studies were conducted on rivers which had no dams built on them. [5/]

Wickett also indicates that other environmental factors induce random stresses and fluctuations which normally prevent the spawning potential from being reached. Frequent flooding, as that which may be encountered on the Calapooia River, may also cause extreme silt movement and deposition. The agricultural lands which are expected to become irrigable from water from Holley Reservoir could also contribute to silting and sedimentation in the Calapooia River by drainage.

Another study by Koski (1966) indicates that the amount of fine sediments in the redd (spawning nest) had the highest correlation

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5/ The major source for downstream spawning bed gravel on the Calapooia River is above the reservoir site. When the dam is built the supply of gravel for downstream spawning beds will be cut off and in the event of loss by extreme flows these beds could not be replenished naturally.

with survival to emergence of all factors examined on three Oregon coastal streams. As the percentage of fine sediments (bottom material, < 3.327 mm) in the redds increased, the success of Coho (Silver Salmon) survival to emergence decreased. To the author's knowledge little consideration, if any has been given to the various factors mentioned above influencing salmon population survival in the Calapooia River when Holley Dam is built.[6/] However, the Bureau of Sport Fisheries and Wildlife is asking for $100,000 to study the impact of the dam on salmon after the dam is built (see Table 3.2).

In order to realistically represent the dynamics of the Fall Chinook spawners in the simulation model several survival relationships are introduced. These are: (1) normal survival of eggs to fry as a function of density of spawners, (2) survival of eggs to fry as a function of extreme streamflow conditions, and (3) survival of fry to returnees.

Normal Survival Rates

A normal survival rate of eggs to fry is used as a function of spawner density. The functional relationship of number of

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6/ In conversations with fisheries biologists during the course of this study, the influence of factors adversely affecting salmon productivity were not refuted for any of the species anticipated in the Calapooia River.

spawners per square yard of gravel to percent survival of eggs to fry for Fall Chinook as used in the simulator is shown in Figure 3.3.

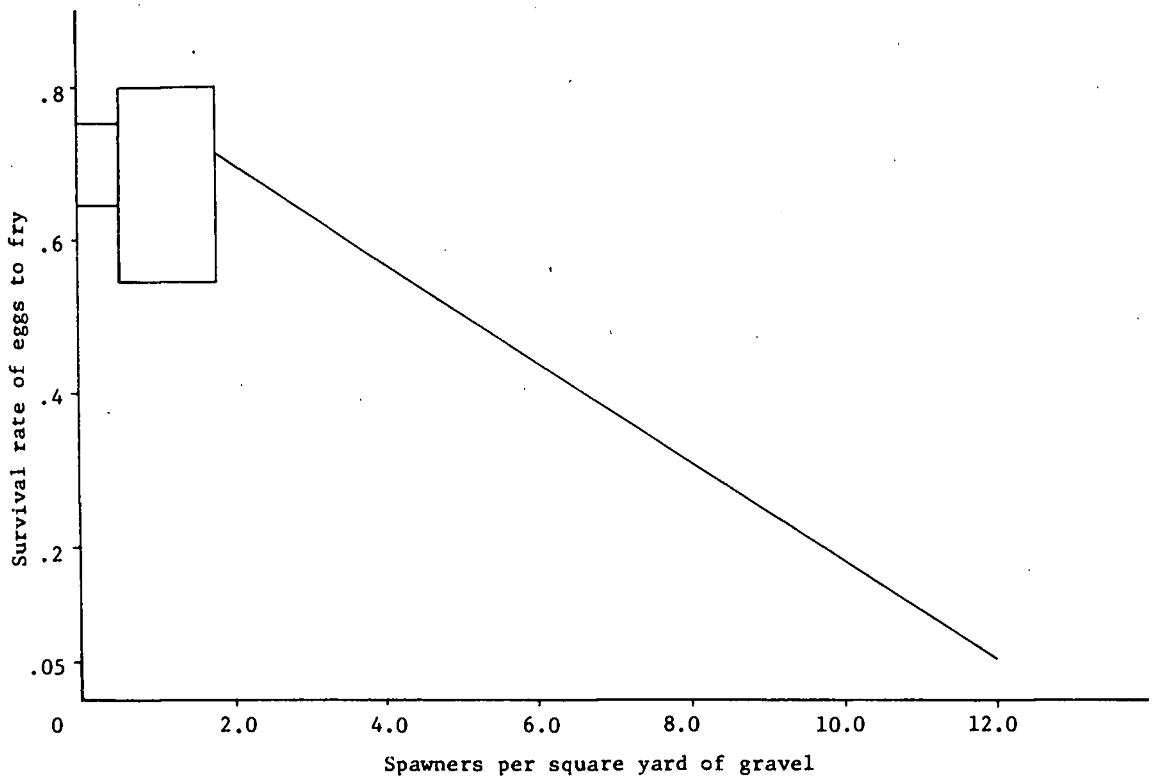

Figure 3.3. Normal Fall Chinook egg to fry survival rate.

The relationship follows that suggested by Vernon (1962) in his studies of Pink Salmon egg to fry survival and confirmed by fish biologists with Oregon State University and the Oregon Fish Commission. The first year of the simulation the initial number of Fall Chinook spawners returning to the Calapooia is assumed to to be equal to 1, 900. This optimal number of spawners corresponds to the optimal density of one spawner per square yard. The number of one spawner per square yard for Fall Chinook was provided by the Oregon Game Commission. The number of spawners initially is multiplied by 2, 500 eggs deposited per spawner giving the total number of eggs deposited. The density as determined by the number of initial spawners (1, 900) provides the independent variable on the horizontal axis in Figure 3. 3. Since one spawner per square yard lies in the range . 5 to 1. 8 the survival rate is randomly drawn from a uniform distribution between . 55 and . 80. The random number generated is the percent survival of eggs to fry. If, in a subsequent simulation year the density of spawners lies outside of the range . 5 to 1. 8 spawners per square yard (950 to 3, 420 spawners), a different uniform range of survival rates is assumed. For example, if the number of spawners returning in a simulation year is less than . 5 spawners per square yard then the survival rate is uniformly distributed between . 60 to . 75. In this low density range a greater number of eggs and emerging fry are subject to predation. If a greater number of spawners than 1. 8 per square yard of gravel return then crowding conditions lower survival to between . 70 and . 05. The lower survival rates result from spawners digging up of salmon eggs previously deposited during the same spawning period.

After the normal egg to fry survival rate is multiplied by the number of eggs deposited, an extreme survival rate due to flooding is determined in the simulation model.

Survival Rates Under Extreme Conditions

While fish biologists agree with the hypothesis that survival rates of eggs to fry are adversely affected by extreme flow conditions, it is difficult to get them to quantify the relationship for the Calapooia River. However, after showing them several runs with the model under various assumed parameters they agreed that the relationship of flood discharges to rates of survival of eggs to fry shown in Figure 3.4 is reasonable. The smallest channel capacity below Holley Dam on the Calapooia River is approximately 3,500 c.f.s. Any discharges from Holley Dam or from runoff below the dam causing overbank flooding are considered to have an extreme affect on survival of the eggs in the gravel or survival of fry. Each year of the simulation whenever a flood situation, as indicated by the channel level, is encountered in a critical time period an extreme survival rate was applied to the total number of eggs deposited. The first 180 days of each simulation year is considered the critical period of egg incubation when extreme conditions could occur for all species of anadromous fish in the Calapooia River. If the channel level is just greater than 3,500 c.f.s.

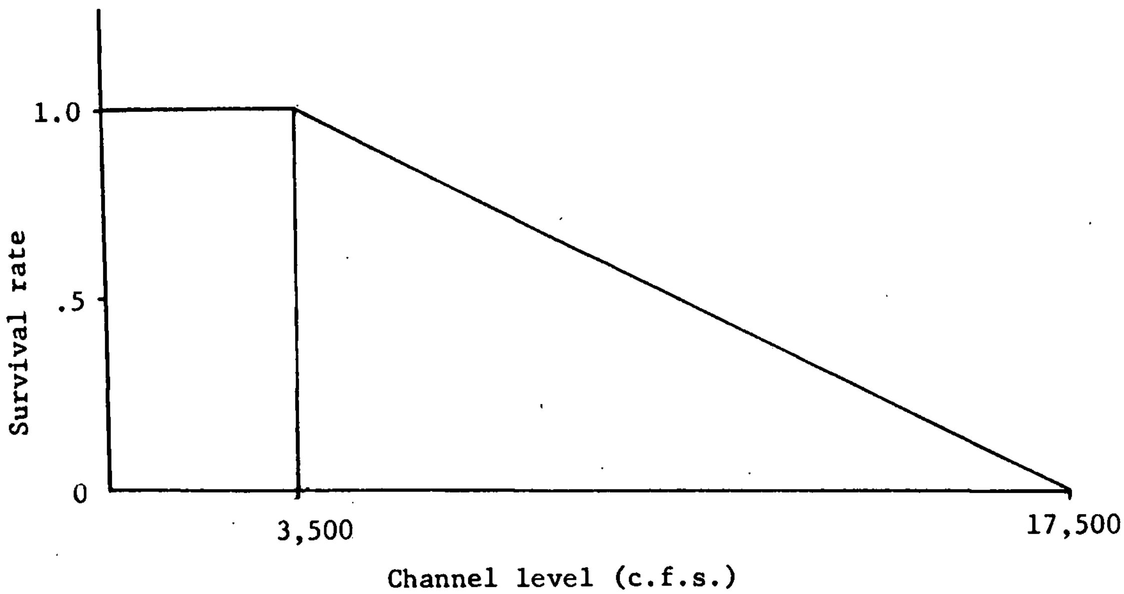

Figure 3.4. Fall Chinook egg to fry survival rate under extreme conditions.

the extreme survival rate is uniformly distributed between zero and one. At 17,500 c.f.s. the extreme survival rate is zero. Any discharge between 3,500 and 17,500 c.f.s. has an upper value interpolated from the line in Figure 3.4 and a lower value of zero.

Survival of Fry to Returnees

The number of fry migrating to the ocean is obtained after multiplying the above two survival rates times the number of eggs deposited. The potential number of spawners (returnees) is determined by multiplying the number of fry by a survival rate that takes into consideration the downstream migration mortalities, oceanic life cycle mortalities, and adult upstream migration mortalities.

The fry to returnee survival rate was provided by the Oregon Fish Commission and is based upon the Columbia River Hatchery Evaluation Program studies. The fry to returnee survival rate was determined to be uniformly distributed between 0 and .133 percent. A uniform distribution is employed since no other statistical distribution is known for this survival rate. The uniform distribution assumption seemed to be a fair assumption since the historical distribution of hatchery produced fry returning as adults has considerable variation and no apparent peak. The coefficient of variation of the historical survival percentage of fry to returnees is calculated as 74 percent. The Oregon Fish Commission's data on percentage of fry released to returning adults is presented in Table 3.5.

The resulting number of potential spawners is delayed by a 25th order delay function which spreads the returning numbers over a period of several years since all surviving fry do not return exactly three years later. The majority of Fall Chinook spawners return three years after emergence. The length of the delay is therefore set equal to three. The returning number of spawners determines the number of eggs deposited in the next

Table 3.5. Historical Columbia River Hatchery produced Fall Chinook Salmon percentage survival of fry to returnees.

Year	Percent survival of fry to returnees
1960	0.129
1961	0.125
1962	0.024
1963	0.133
1964	0.043

year of the simulation and is the independent variable in the spawning normal survival density function.

To obtain the benefits for Fall Chinook, 1,000 is subtracted from the number of returnees to represent the conservation number, and $87.84 is applied to the remainder to represent the enhancement benefits of the Holley project.

Reservoir Spring Chinook Salmon Rearing Model

Six thousand two hundred and fifty adult Spring Chinook Salmon spawners are expected to return to Holley Dam each year for collection, hauling, and artificial spawning and hatching at the Santiam Salmon Hatchery. The fry will be reared in Holley reservoir and released starting six months later through a structure in the dam to migrate downstream and out to sea. In order to realistically simulate this population of Spring Chinook several factors affecting the number of returnees are considered. These include: (1) the stocking rate of fry, (2) the survival rate in the reservoir, and (3) the survival of smolts to adults after release from the reservoir. The Oregon Fish Commission provided numerical estimates of these factors. Their information was based on records of a reservoir rearing program at Green Peter Dam on the Santiam River in Oregon.

The optimum stocking rate of fry varies greatly from reservoir to reservoir. Generally, if the surface area is less than desired when the fry are ready to be released the stocking rate is proportionately less. The Oregon Fish Commission indicated that the methods for determining stocking levels are imprecise. Since only one reservoir reared generation of Spring Chinook has returned to Green Peter Dam since the reservoir rearing program began, the stocking and survival rates are estimates based on limited experience. The stocking rate as estimated by the Oregon Fish Commission is 1,500 fry per acre surface area. Based on the information provided, the stocking rate function was developed for the simulation model and is shown in Figure 3.5. The optimum stocking rate of 1,500 fry per acre surface area is associated with 2,400 acres of surface area which is the surface area when the reservoir is operated in mid-April according to the rule curve operation. The lowest stocking rate of 891 fry per acre

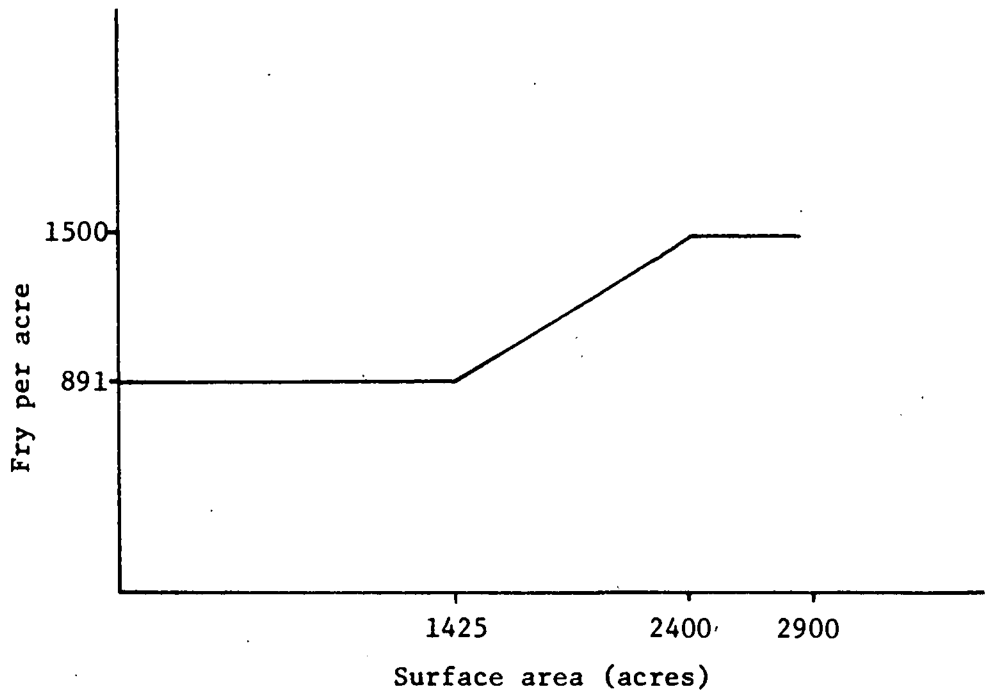

Figure 3.5. Spring Chinook Salmon fry reservoir rearing stocking rate.

of surface area occurs if the reservoir is at the minimum conservation pool of 51,000 acre-feet which has a surface area of 1,425 acres. The density or stocking function reflects food availability at various pool surface areas. The Department of Fish and Wildlife, Oregon State University, indicated that exposure of beach during variations in pool level reduces plankton production which is the source of food for reservoir fish. The fish density and competition for food are thus reflected in the stocking function. The Oregon Fish Commission also indicated that the magnitude of the predator population in a reservoir is unknown. They also indicated that excessive pool drawdown for other purposes (flood control) could necessitate releasing some fry before they reach smolt stage and thus decreasing the probability of survival.

In the simulation model each year's simulated mid-April reservoir level determines the stocking rate of Holley Reservoir with Spring Chinook fry. The total number of fry released is then determined by multiplying reservoir surface area by the stocking rate. The survival rates of fry to smolts are assumed uniformly distributed since no statistical distribution is available. This seemed to be a fair assumption since Oregon Fish Commission personnel indicated that the survival rate is highly variable from year to year with the range of rates being equally likely. The survival of smolts to returning spawners is also assumed uniformly distributed. In the simulation model both survival rates are drawn each year from uniform random numbers with the ranges presented in Table 3.6. The rates are applied to the total number of fry released in the reservoir and the result becomes the argument in a delay function. The delay function causes the greatest number of surviving adults to return at three years of age. Some Spring Chinook return at earlier and later ages, however, and the delay function spreads the potential returning escapement according to the order of the delay. The adult spawners returning are valued at $89.39 and the benefits are discounted and accumulated over the

Table 3.6. Survival rates for Spring Chinook Salmon reared in a reservoir.

Rate	Range
Survival of reservoir released fry to smolts	0-22%
Survival of smolts to returning fish (spawners)	0- 1.8%

project life to represent the enhancement benefit of the reservoir program.

Recreation

Reservoir recreation areas will be developed at Holley to accommodate activities such as swimming, water skiing, boating, fishing, picnicking, hiking, and overnight camping. The recreational potential of any man-made reservoir is influenced by the fluctuations in the level of the pool which result from the use of storage to serve other project functions. Shoreline characteristics vary with reservoir drawdown and have a marked effect on the potential for recreation. Research has been conducted to determine the effect of reservoir operation on recreation benefits. The California Department of Parks and Recreation made a study of Folsom Lake near Sacramento, California, to determine how pool fluctuations affect attendance for recreation (Kerri, 1969).

It was found that a significant relationship existed between attendance and reservoir operation for the recreational season. The relationship is shown in Figure 3.6. Many other factors such as distance from population centers, water quality, climate, and other environmental influences also affect the attendance at a given reservoir.[7/]

To reflect the possible influence of weather on attendance for this study the recreational period was restricted to a period of about four months. The weather at the Holley Dam site area is normally not conducive for recreational attendance throughout two-thirds of the year. An indication of this is seen in the average rainfall in Table 3.7. The rainfall in the Holley area averages 54.8 inches annually. The period conducive to recreation includes the low rainfall months of June, July, August, and September, and covers the traditional recreational and vacation period from Memorial Day to Labor Day. For the recreational activities anticipated this appears to be a reasonable assumption.

In the simulation model the estimated yearly attendance was spread over the potential user period of June, July, August, and

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7/ In the simulation model the supply of recreation days is a function of the operation of the reservoir. No attempt is made to simulate all the determinants of demand for recreation.

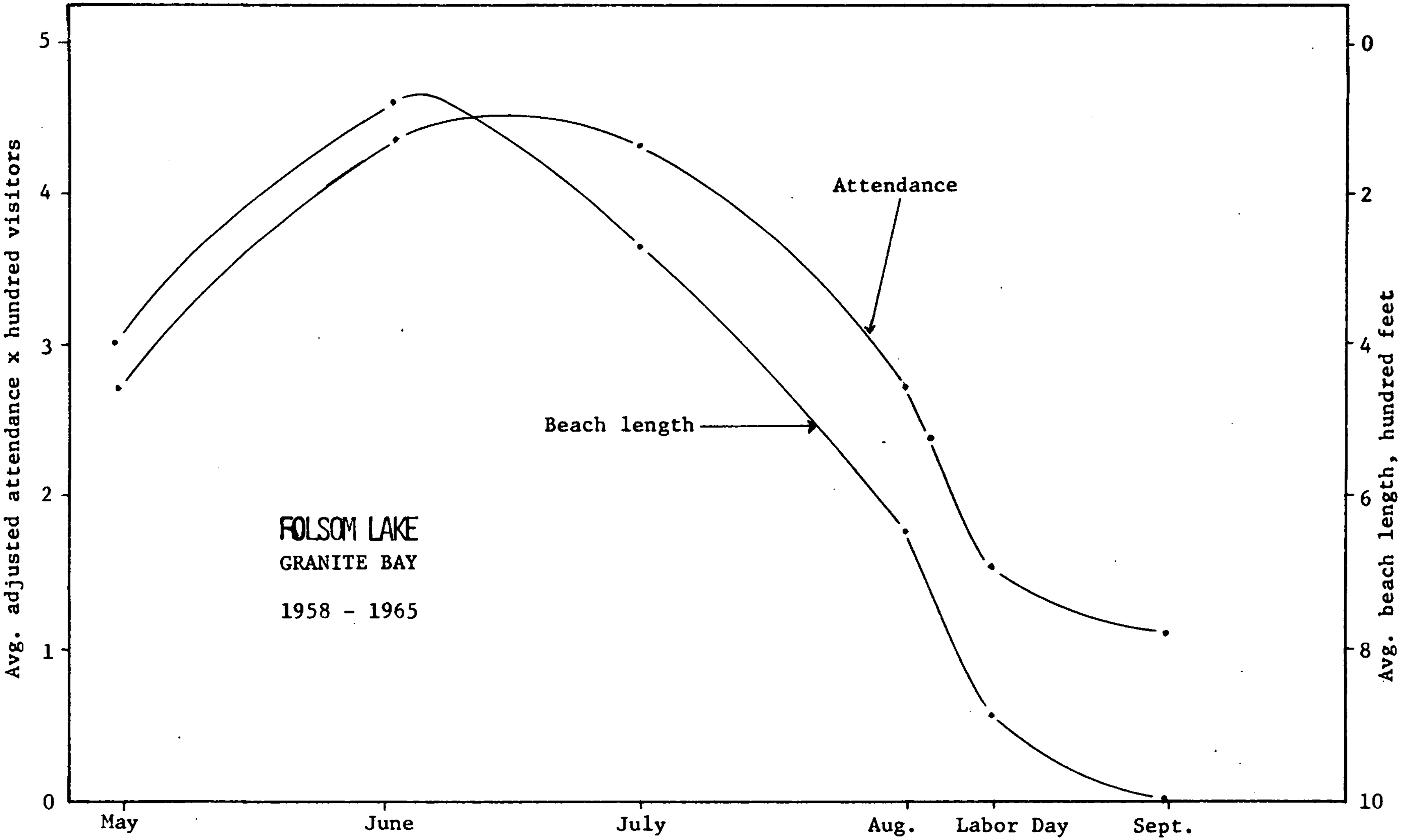

Figure 3.6. Relationship between average adjusted attendance and average beach length.

Table 3.7. Average precipitation by months for Holley, Oregon (dam site).

Month	Precipitation in inches
January	8.6
February	6.5
March	5.8
April	3.5
May	2.8
June	2.3
July	.5
August	.7
September	1.7
October	5.6
November	8.0
December	8.8
Total annual average	54.8

Source: U. S. Army, Corps of Engineers, 1970.

most of September. The yearly attendance is expected to grow over the project life from initially 113,000 user days annually to 645,000 user days annually. The projected annual recreational attendance is presented in Table 3.8.

Table 3.8. Annual recreation user days with the project.

	Initial	20th year	50th year	100th year
General recreation	113,000	290,000	450,000	645,000

Source: U. S. Army, Corps of Engineers, 1970.

A growth component is incorporated into the model to represent the change in number of user days per year under optimum conditions. However, to represent less than optimum conditions the number of users in any one day of the recreational period is a function of the length of beach or exposed ground. For each drop of one foot in pool level the beach is lengthened by a calculated factor. Since the user days presented in Table 3.8 are those expected under optimum conditions any daily deviation in pool level alters the optimum daily attendance. The relationship used in the simulation model of user days to length of beach is shown in Figure 3.7. A slope relationship is calculated in the computer program so that each day's change (fall) from maximum pool level at full pool (145,000 acre-feet) causes an amount of beach to be exposed (run). The amount of beach exposed is then converted to attendance (user days) for that day. The benefits are calculated by multiplying one dollar per user day times the number of days. These are accumulated over the recreation period, discounted, and accumulated over the life of the project.

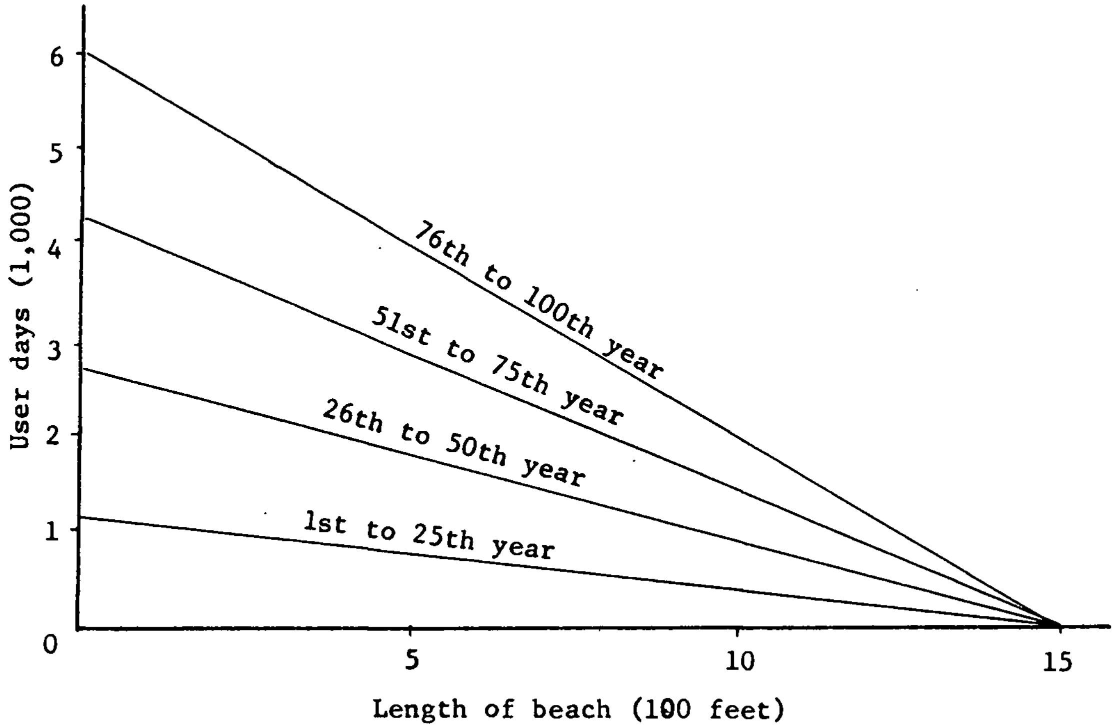

Figure 3. 7. Relationship between recreation user days and length of beach for various time periods.

Capital construction costs and operation, maintenance, and repair costs for recreation facilities are presented in Table 3. 9.[8/]

8/ Recreational facilities include: picnic and camping units, sanitary facilities, potable water, tables, stoves, parking spaces, boat docks, boat launching ramps, and hiking trails.

Table 3.9. Recreation facilities construction and operation, maintenance, and repair costs.

Capital construction a/	Cost
Initial	$830,000
Year 10	615,000
Year 30	650,000
Year 50	700,000
Year 70	700,000
Total	$2,666,000 b/
Annual operation, maintenance and repair	$88,100

a/ Includes interest during construction.

b/ The present worth of capital costs is $1,456,800.

Reservoir Resident Trout Fishery

Holley Reservoir is expected to provide trout fishing throughout the year. The Corps of Engineers includes resident trout fishing user day estimates and benefits into their recreation function. In this study the resident fishing functions are treated separately and benefits are determined separately to facilitate analysis of individual project functions. Two principal resident fishing areas are incorporated into the Holley Reservoir plan of development. Holley Reservoir is expected to provide 77,000 angler days annually over the project life under optimal conditions.

It would seem reasonable to assume that fishermen attendance at Holley Reservoir would be low in terms of angler days when the pool level is low and exposes undesirable beach and mud flats. This period of low pool is the major flood season of December to February. Other parts of the year are undesirable for fishermen use because of intense rainfall in the area of the dam. As in the recreation function the reservoir operation, reflecting the weather factor, is introduced. Thus, the number of angler days is a direct function of the length of beach which is a consequence of reservoir operation.[9/] In the simulation model the reservoir fishing angler days determined each day of the simulation are a function of the length of beach calculation made for recreation attendance. The relationship of reservoir fishing angler days to length of beach is presented in Figure 3.8.

The length of the beach at the highest point on the rule curve is approximately 400 feet. Any length of beach less than 400 feet

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9/ The Corps of Engineers' estimates of resident fishing angler days are based upon attendance at similar reservoirs in the Western Cascade foothills. To the author's knowledge, account has not been taken in planning this project of the competitive nature of reservoirs which are in close proximity. One reservoir's attendance records are not a desirable method for estimation of attendance at a proposed project in the same area because of the competitive nature of such projects.

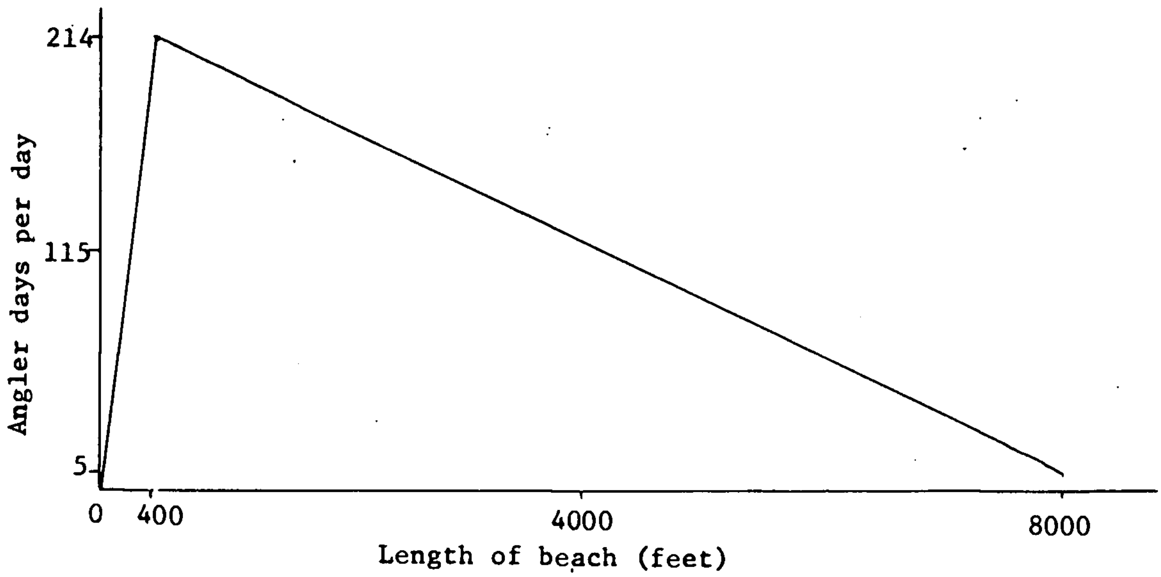

Figure 3.8. Relationship of reservoir trout fishing angler days to length of beach.

indicates flooding and a pool higher than the maximum allowable pool under normal conditions. At this extreme condition the angler days per day are zero when no beach is exposed. At 400 feet, the angler days per day are 214. At the other extreme, the angler days per day are calculated from a straight line with a slope of -.0275 angler days per added foot of beach to obtain a low of five angler days at the minimum conservation pool. At this point the exposed beach is on the average about 8,000 feet. The exposure of undesirable beach and the extreme distance to the water's edge is assumed to limit access to the water by fishermen. In the simulation program, each year, reservoir fishing angler days are accumulated and evaluated at $2 per angler day.

The costs for constructing facilities to maintain the trout fishery and the annual operation, maintenance and repair costs of such facilities are presented in Table 3.10. The construction costs for the trout facilities are $35,000 and annual operation, maintenance, and repair is $5,000.

Table 3.10. Capital construction costs and operation, maintenance, and repair costs for trout facilities. a/

Item	Cost
Capital construction	$35,000
Annual operation, maintenance and repair	5,000

a/ An estimated 5,000 lbs. of rainbow trout would be required annually to maintain the reservoir trout fishery. This amounts to .065 lbs. each year per angler assuming the planted fish are all caught. The number of fish per pound planted varies from 60 to 70.

Downstream Resident Trout Fishery

The driftboat fishery expected to develop downstream from Holley Reservoir will be mainly for trout fishing.[10/] However, at certain times of the year driftboats may be used to fish for anadromous fish in their migrations upstream. Limited boat launching access to the river would be available at Holley Dam and

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10/ According to the Bureau of Sport Fisheries and Wildlife there would be no increase in upstream trout fishing due to the project, therefore, no upstream trout fishing benefit functions are included in the simulation model.

various bridges downstream. A ramp is located at the river mouth in the City of Albany's Bryant Park which could be used as the end point of a downstream drift.

In the simulation model an attempt is made to relate downstream resident game fish angler days to streamflow conditions. It is assumed that under either flooding conditions or low channel conditions the driftboat fishing angler days decline from their optimum amount of approximately 20 angler days per day. The relationship used in the simulation of downstream resident game fishing angler days to the channel level at Albany is shown in Figure 3.9. The point on the Calapooia River (Albany) for which the channel level is computed is considered to give a good indication of driftboat use as it relates to streamflow conditions. Each day in the simulation model the downstream angler days are determined depending upon the channel flow conditions. When the channel is empty the angler days are zero. When the channel is flowing at the average daily rate of 625 c.f.s. (1/8 of full channel at Albany) the angler days are 10 per day. The maximum angler days of 20 per day are reached when the channel at Albany is 25 percent of capacity. This figure is based on the author's experience for acceptable streamflow conditions for driftboat fishing. However, further study of other streams in the area could provide another estimate of streamflow conditions which are conducive to

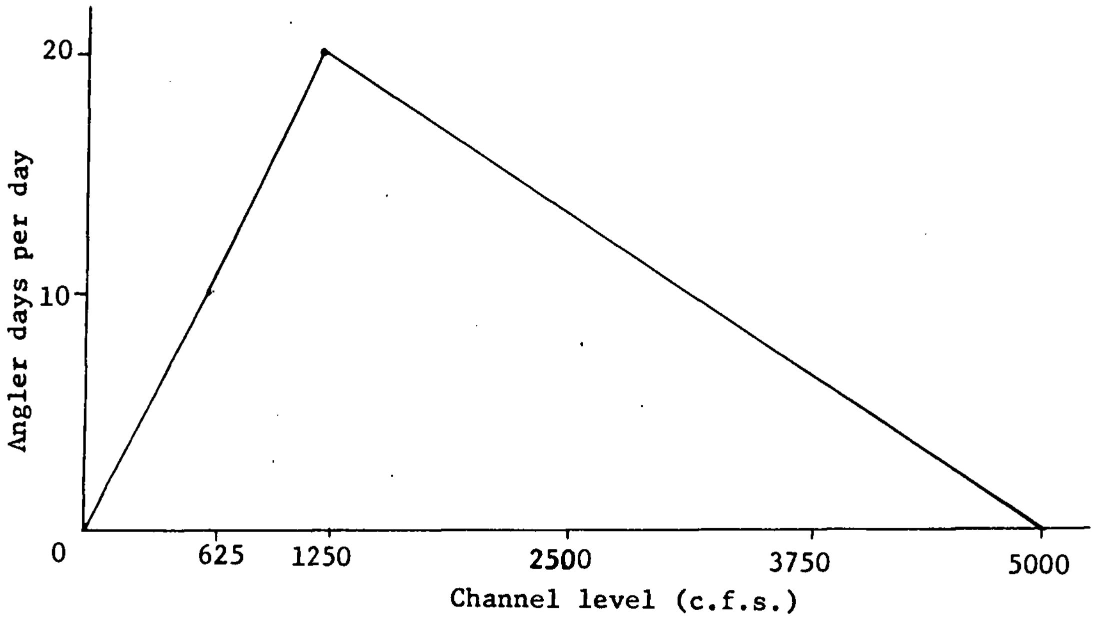

Figure 3. 9. Relationship of downstream resident game fish angler days per day to channel level at Albany.

driftboat fishing. From this optimum utilization the downstream angler day's function has an approximate slope of -. 005 user days per additional cubic foot per second of streamflow. The angler days is zero at bankfull of 5, 000 c. f. s. Each year in the simulation, total downstream angler days are valued at $3 per angler day, discounted and accumulated over the length of the simulation run.

Irrigation

The Corps of Engineers provided estimates from the Bureau of Reclamation that there are 8, 700 irrigable acres in the Brownsville area that can be supplied with water from Holley Reservoir. The irrigated area comprises what was originally designated construction stage one in the Calapooia Division which will eventually encompass 33, 400 acres. The area in the first stage lies along both sides of the Calapooia River from the Holley Dam site westward approximately 12 miles to Interstate 5. The proposed plan to supply full service to the 8, 700 acre area begins with the release of irrigation water from Holley Reservoir into the stream channel below the dam. Two pumping plants downstream will transmit the releases into pipeline distribution systems to at least one point on the border of each farm operating unit. A drainage system would also be constructed as part of the irrigation project works.

The acreage to be irrigated consists of class 1 lands, excellent quality for irrigation; class 2 lands, good quality but with a minor deficiency which will affect their productivity; and class 3 lands, most of which will require an extensive surface drainage system to insure successful irrigated agriculture. The intended crops for these lands are shown in Table 3. 11.

Table 3.11. Proposed cropping pattern for 8,700 acre irrigation project on the Calapooia River near Brownsville.

Crop	Percent of total acreage
Pasture and hay	62
Grain	8
Specialty crops	4
Orchard	2
Grass seed	18
Waste and farm ditches	6

Source: U. S. Department of Interior, Bureau of Reclamation, 1970a.

The maximum annual net irrigation benefits are listed in Table 3.12. The estimated annual net benefit per acre is $69.06. The estimated net benefits for livestock vary from $50.44 to $57.12 per acre; dairy cattle from $100.14 to $113.70 per acre; and specialty crops from $62.84 to $72.70 per acre. The total capital costs and annual costs for the distribution and drainage systems are listed in Table 3.12. The total costs of construction are $11.347 million, and the annual operations and maintenance costs are $85,000.

In 1966 when Halter and Miller constructed the first simulation model of the Calapooia River, irrigation and drainage were two important functions of Holley Dam project. The Bureau of Reclamation estimated that 53,400 acres would be irrigated from the 97,000 acre-foot reservoir. The annual net benefit was

Table 3.12. Irrigation costs and maximum use benefits, Calapooia River, 1970 dollars.

Investment and operation, maintenance, and repair costs	
Storage construction cost a/	$1,226,000.00
Storage operation, maintenance and repair cost (annual)	7,000.00
Distribution and drainage construction cost a/	10,121,000.00
Distribution and drainage operation, maintenance, and repair cost (annual)	78,000.00
Total construction costs	11,347,000.00
Total operation, maintenance, and repair costs (annual)	85,000.00
Annual maximum net benefits	
Irrigation capability (acres)	8,700.00
Annual net benefits, dollars per acre	69.06
Total annual net benefits	$601,000.00

a/ Includes interest during construction.

Source: U. S. Army, Corps of Engineers, 1970, and U. S. Department of Interior, Bureau of Reclamation, 1970b.

estimated at $10.35 per acre giving a total annual benefit of $552,690. There have been no spectacular events or are any foreseen today in the agricultural economy of Oregon or of the United States that would indicate that the net returns per acre of irrigated land would change from $10.35 to $69.06 from 1966 to 1990.[11/] The Bureau of Reclamation says it has prepared individual farm budgets that show these high returns to irrigated lands. It is not the purpose of this study to discredit the investigation of the Bureau of Reclamation or Corps of Engineers, but rather to construct a simulation model capable of evaluating the several functions of the project in various combinations and at different levels of use. Thus, the simulation model is flexible in that any returns per acre can be inserted and the total benefits of irrigation derived for the operation of the reservoir.

In preparing other estimates of the net benefits per acre, studies conducted by Oregon State University were utilized. In a study conducted by Middlemiss (1965) estimates of net returns for livestock were made for utilizing Willamette Valley floor lands for beef production. Estimated returns to management per cow or per feeder for selected production systems are shown in Table 3.13. There are three production systems that provide positive returns of $5.68, $16.41, and $13.60 per feeder. These systems involve buying feeders, pasturing them, and full feeding before slaughter.

11/ Indications are that by 1975 grass seed may become a smaller proportion of agricultural income than is currently the case.

Table 3.13. Returns to management per cow or per feeder for selected production systems in the Willamette Valley, 1965.

Type of system	Returns to management a/
Cow-calf system Calves sold at weaning	$-46.03
Cow-yearling system Yearlings sold off grass	-50.47
Cow-yearling system Yearlings fed for slaughter	-26.69
Feeders purchased in fall Wintered, sold off grass	-22.82
Feeders purchased in fall, Wintered, pastured, fed for slaughter	5.68
Late fall purchased feeders, Wintered, pastured, fed 120 days for slaughter	-5.77
Feeders purchased in spring Sold off grass	-14.21
Feeders purchased in spring Pastured, fed for slaughter	16.41
Feeders purchased in fall Fall fed on roughage and finished	-.14
Feeders purchased in fall Full fed on roughage	13.60

a/ Prices for livestock based on 1958-64 mid-month Portland market prices. The returns to management do not include cost of water to the producer.

Source: Middlemiss, 1966.

In another study conducted by Conklin and Bradshaw (1971) the cost and return figures from the Middlemiss study were updated to average 1959 to 1970 price conditions rather than for the less favorable period of 1958 to 1964 used in the previous study. The only changes in the results are that one additional system shows positive returns and one additional shows negative returns. The positive returns are for the system in which feeders are purchased in fall, full fed on roughage and finished. This system previously was almost a break-even proposition. The returns to the fall purchased feeders and full fed on roughage system show negative returns.

The three systems showing positive returns still involve feeder operations which require from 80, 000 to 130, 000 dollars worth of capital items to become operational. Associated with each system is a high degree of price risk both for feeders and for fat stock.

Irrigation Water Need

The simulation model can incorporate any schedule of monthly irrigation needs and if shortages occur can allocate the available irrigation water over the remaining irrigation days. The monthly irrigation need for the proposed 8, 700 acres and the return flows are shown in Table 3. 14.

Table 3.14. Monthly distribution of irrigation diversions and return flows.

Month	Irrigation diversions in acre-feet Near Crawfordsville	Near Brownsville	Return flow below Brownsville
May	440	1,660	280
June	1,250	4,400	660
July	1,350	4,740	930
August	1,120	3,930	990
September	580	2,030	710
Total	4,740	16,660	3,570
Less: return flow from Crawfordsville Diversions		1,020	
Net requirement	4,740	15,640	
Total net requirement		20,380	

Source: U. S. Army, Corps of Engineers, 1970.

The total irrigation requirement for the 8,700 acre area amounts to 21,400 acre-feet; however, 1,020 of the acre-feet required at Crawfordsville will be return flow into the channel and will reduce the amount required at Brownsville.[12/] The final return flow to the channel varies from a low of 12 percent

12/ The amount of acreage under irrigation in the development was estimated by the Bureau of Reclamation to reach full development 10 years after project construction. Therefore, in the model a growth component was incorporated to simulate the first 10 years of project life.

of diversions in June to a high of 29 percent of diversions in September.

Irrigation shortages occur when there is not enough water available to meet the need. In the simulation model the water available is a function of the reservoir level at the time of water need. When the water is not available to meet the need, shortages occur and the irrigation benefits decrease. In the simulation model the irrigation benefits are a linear function of the percentage of irrigation target met, i. e., if 20 percent of the target is met then 20 percent of the benefit is obtained, and so forth. The amount of water available for irrigation at any time is determined as that water in the reservoir which can safely be used without endangering the temperature control function of reservoir storage. The success of maintaining optimum temperatures in the reservoir and of released water for downstream fish depends upon how adequately the temperature control pool can be maintained. The largest irrigation need per day is determined in the simulation model. If a shortage is encountered the available water is prorated for release over a 30 day period.

Summary

In Chapter II the details of the hydrology generator were presented. It was shown how the daily streamflows at Holley and at Albany are generated in the model. The regulation according to the rule curve was shown to give rise to flood regulation. The operation of the reservoir also determines the level of the reservoir and the streamflow conditions downstream from the dam. In this chapter it has been shown how these two variables affect conditions determining the feasibility and extent of anadromous fish life, the supply of recreational user days, the supply of angler days, and the supply of irrigation water. The complete model was tested and run on an IBM 360 model 85 computer at McDonnell Automation in St. Louis, Missouri, via telephone transmission through the IBM 1130 computer at Cornell, Howland, Hayes, and Merryfield, Inc., in Corvallis, Oregon. The results of a number of computer runs are given in the next chapter.

IV RESULTS OF SIMULATION ANALYSIS

The purpose of this study is to show how the various components of the Holley Reservoir project interact. A computer simulation model was formulated to simulate the interactions among the four main functions of the project. To realistically analyze the results of the simulation the various outcomes and/or quantities resulting from the initial runs of the computer model are presented in this chapter. In order to add up the outcomes across functions, in light of a lack of an interpersonally valid common denominator, the various quantities are converted to dollars. Estimates of annual discounted average dollar benefits per year are presented and compared with Corps of Engineers' estimates. The initial runs of the total model were confined to 50 years in length and therefore the dollar benefits are averaged over 50 years.[1/]

The outcomes from the model for flood control, drainage, reservoir regulation, reservoir reared salmon, downstream Fall Chinook Salmon, recreation, resident trout fishing, and irrigation are presented in this chapter.

1/ Kerri (1969) concluded from analyses of 200 years of simulation runs with the earlier models that similar results could be obtained from 50 year runs in terms of the expected annual net benefits.

Flood Control

As discussed in Chapter II and shown in Figure 2.12, the flood control or simulated regulation function of Holley Dam produces a maximum annual discharge exceedence frequency curve at Albany below the historical exceedence relationship. The vertical distance between any two points on the regulated and unregulated exceedence curves is the average reduction in flooding for a given recurrence interval. The horizontal distance between any two points on the unregulated and regulated exceedence curves is the reduction in average years of recurrence for a given flow.

In order to make the reduction in frequency of a given flow more explicit frequency histograms of unregulated and regulated stage heights at Shedd, Oregon, were graphed. The frequency histograms of the unregulated and regulated flood stage heights are presented in Figures 4.1 and 4.2, respectively. The stage heights, in feet at Shedd, are shown as class boundaries along the horizontal axes of the histograms. The probability of occurrence of stage heights within the class intervals are shown on the vertical axes of the histograms. It is interesting to note that the probabilities of occurrence of stage heights greater than 16.19 feet have been reduced based on simulated regulation of the Calapooia River. There has therefore been a reduction in the probability of

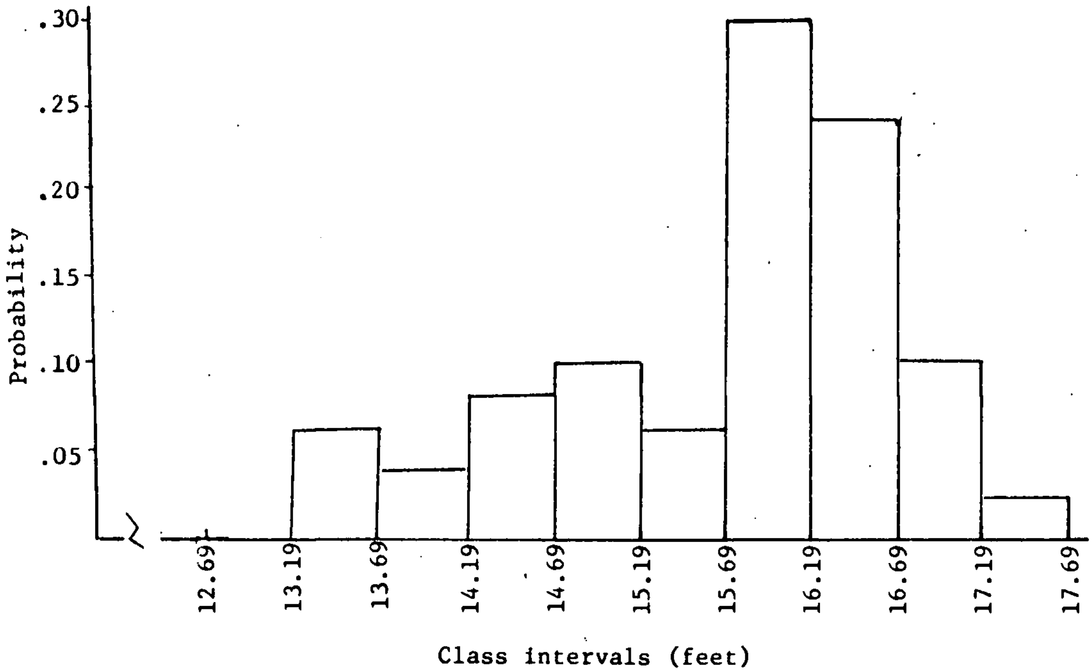

Figure 4. 1. Frequency histogram of simulated unregulated stage heights.

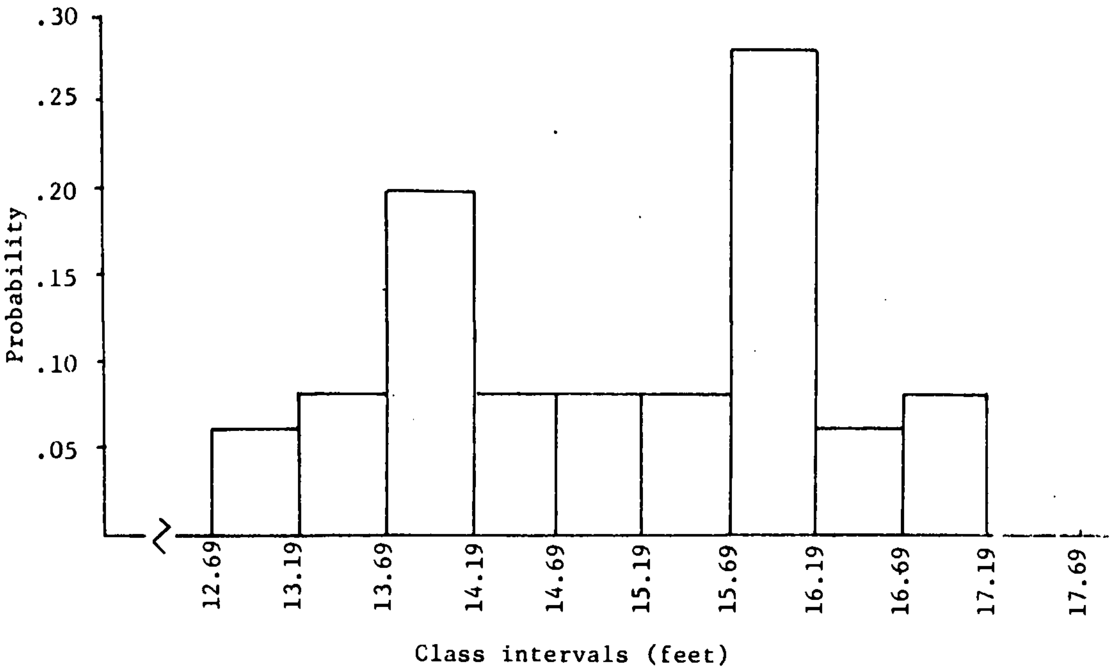

Figure 4. 2. Frequency histogram of simulated regulated stage heights.

occurrence of floods having stage heights greater than 16.19 feet. However, the probabilities of occurrence of the stage height class of 13.69 to 14.19 feet were increased based on the simulated regulation. These stage heights are associated with flows of non-flood proportion. Stage height frequency histograms can provide useful information for decision makers and particularly for farmers in the Calapooia flood plain in planning location of structures and new enterprises. Decision makers must keep in mind that while the dam provides some insurance against large floods, there is still the probability of stage heights occurring that may inflict damages to crops and structures.

The average annual dollar flood benefits for the Calapooia and Willamette Rivers are presented in Table 4.1. The flood benefits obtained for the Calapooia River are based on simulated regulated and unregulated peak flows. The present value of flood benefits based upon the simulated flows for the Calapooia River are $17,508 per year. The annual flood benefits for reaches of the Willamette River are based on dollar values provided by the Corps of Engineers (see discussion of Table 2.7, Chapter II) which were discounted, changed to stage of development by a 3.6 percent growth factor, and averaged in this study. The average annual discounted dollar benefits attributable to Holley Dam are $57,753 if Willamette River benefits are based upon floods up to and

Table 4.1. Average annual discounted flood control benefits on the Calapooia and Willamette Rivers for Holley Dam.[a/]

Calapooia simulated	Willamette up to 1-in-100 years flood	Willamette from 1-in-100 to 1-in-10,000 years flood	Total Holley Dam flood benefits
(dollars)	(dollars)	(dollars)	(dollars)
17,508	57,753	55,790[b/]	131,051

[a/] Based on discounting at 4-7/8 percent interest and an annual growth of 3.6 percent.

[b/] The ratio of desired rule curve level to the maximum reservoir level was applied (see Chapter II).

including the one in one-hundred-year flood. The average annual discounted dollar benefits attributable to Holley Dam are $55,790 if floods from the one in one-hundred-year flood up to and including the one in 10,000-year flood are included for the Willamette River reaches. The total of the three categories is $131,051 per year.

The average annual total flood benefits as estimated by the Corps of Engineers are $1,606,000 per year. The discrepancy between the results of this study and those of the Corps of Engineers can only be accounted for by two considerations. Firstly, the Corps of Engineers has added into their benefit estimate, dollar damages prevented by regulation of floods greater than the one in one-hundred-year flood in the Calapooia reach. Secondly, this study has reduced dollar damages due to the floods greater than the one in one-hundred year flood along Willamette River reaches by the ratio of the desired rule curve reservoir level to the maximum reservoir level during the flood season as discussed in Chapter II.

Drainage Effects

When Halter and Miller studied the Holley Dam project in 1966 one of the largest benefits was from improved drainage due to channel enlargement. The Corps of Engineers eliminated this function when local cash participation was not guaranteed. To investigate the consequences of the proposed 145, 000 acre-foot reservoir and 5, 000 c. f. s. channel on drainage along the Calapooia, the average level of regulated and unregulated flows in the channel over the period April through September are accumulated in the simulation model. The maximum average regulated and unregulated channel levels are plotted as exceedence curves in Figure 4. 3. The regulated average channel level exceedence curve lies below but approaches the unregulated average channel level at higher channel levels with lower recurrence intervals. The distance between the two exceedence functions is the average lowering of the channel from unregulation to regulation. This indicates, based on the simulated average channel levels, that some drainage benefits may be obtainable below regulated channel levels of about 1, 500 c. f. s.

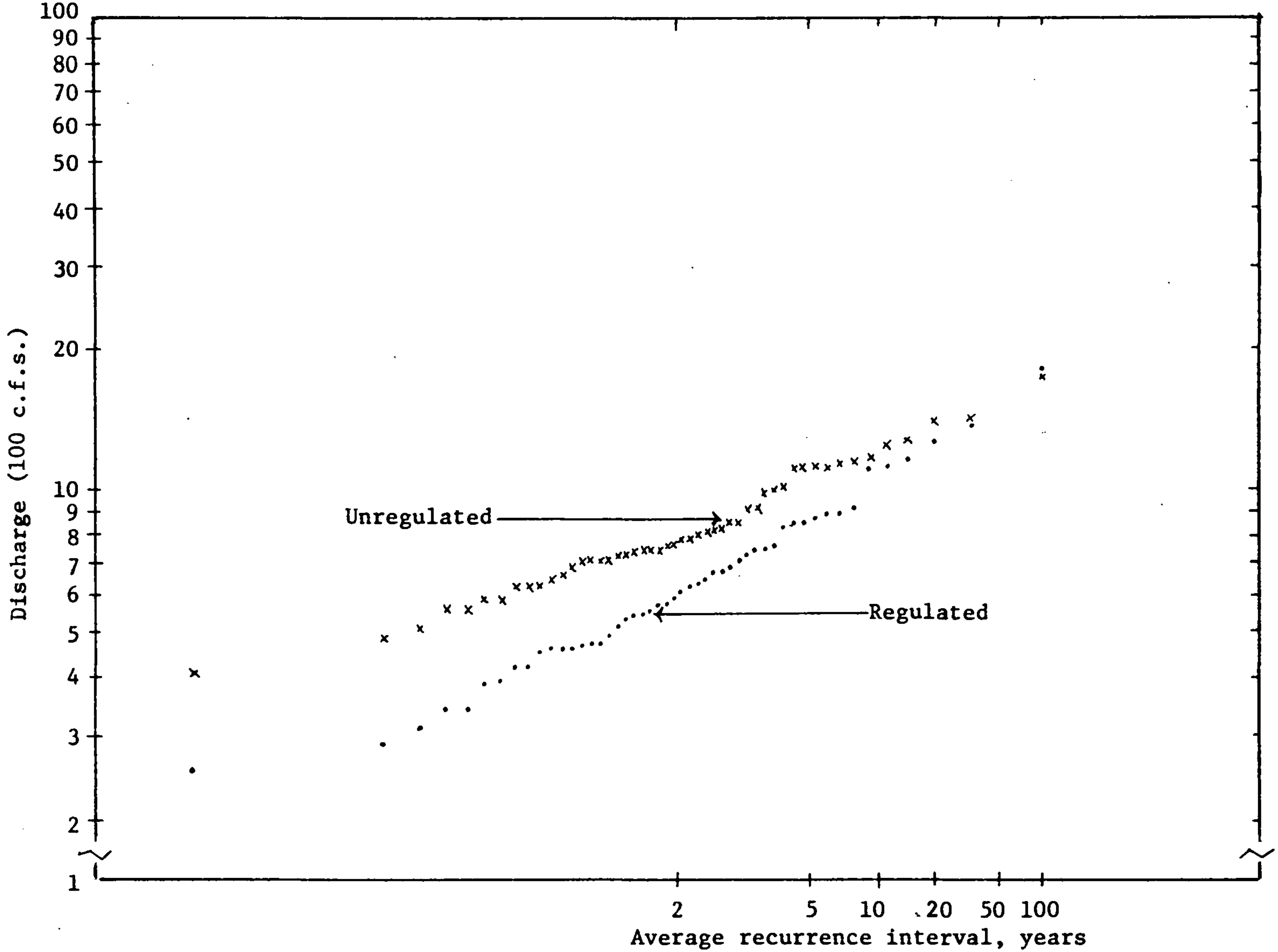

Figure 4.3. Regulated and unregulated average channel exceedence, Calapooia River at Albany, Oregon.

April through Stpember was assumed to be the critical drainage period for irrigable soils in the Calapooia River basin. This period begins one month before irrigation starts and extends throughout the irrigation period. When the full development of the 33, 400 irrigable acres is finished the drainage provided by the 5, 000 c. f. s. channel may not be adequate to handle the return flow. Further study would be required to determine if the reduction in the regulated channel level as indicated in Figure 4. 3 is sufficient to solve the drainage problem of the soils along the Calapooia River.

Reservoir Level Effects

Another outcome that is readily obtained from the simulation model is the minimum reservoir levels that occur each month. While this outcome has no direct consequences, the variability in the reservoir level does help to explain the variability in recreation benefits and in the reservoir fish benefits. The means and standard deviations of the minimum reservoir levels for a 50 year simulation run, by months, are given in Table 4. 2. The coefficients of variation by months are also given. The minimum reservoir means by months are plotted in Figure 4. 4 and the lowest sequence of monthly minimum reservoir levels found in the simulated results is also shown. These can be compared with the desired rule curve levels which are also given in Figure 4. 4.

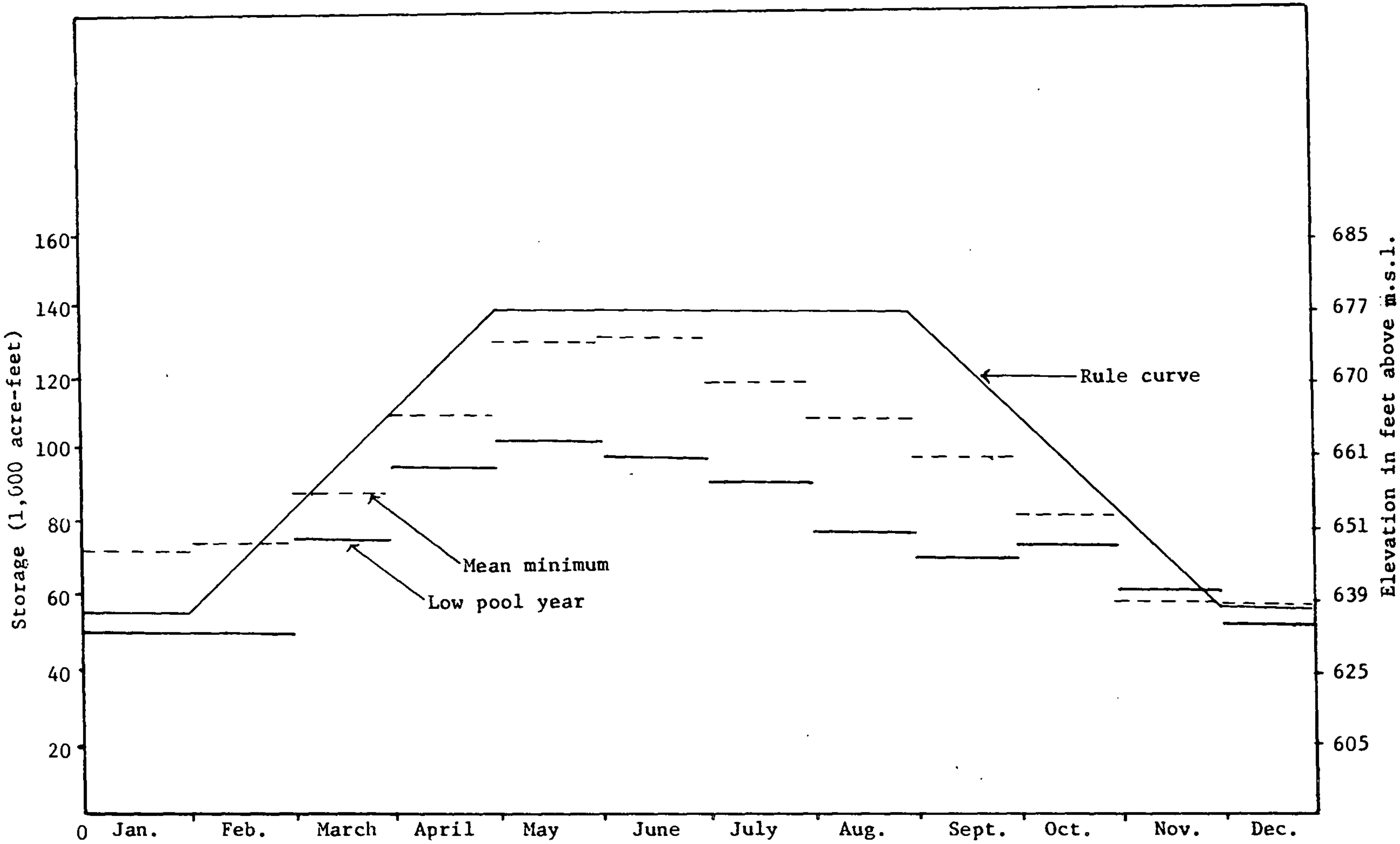

Figure 4.4. Reservoir levels: simulated mean minimum, simulated low pool, and rule curve.

Table 4.2. Means, standard deviations, and coefficients of variation by months for simulated minimum reservoir levels. a/

Month	Mean	Standard deviation	Coefficient of variation
	(acre feet)	(acre feet)	(percent)
January	72,309	32,497	44.94
February	73,244	33,120	45.22
March	88,609	19,667	22.20
April	109,783	9,708	8.84
May	130,225	7,842	6.02
June	130,632	8,526	6.52
July	119,230	9,563	8.02
August	107,119	9,828	9.17
September	98,866	9,495	9.60
October	81,902	3,097	3.78
November	58,658	4,740	8.08
December	57,346	11,908	20.77

a/ Simulation for a 50 year period.

During the recreation period of June to September the standard deviation of the simulated minimum reservoir levels as a percentage of the mean varies from 6.52 percent to 9.60 percent as shown by the coefficient of variation. Since the minimum reservoir level is important in determining the user days of recreation the variability of minimum pool levels is associated with the variability in recreation benefits. Reservoir fishing occurs year round and the variability of the minimum pool level is greater than for the shorter recreation period. The coefficient of variation ranges from 3.78 percent in October to 44.94 percent in January. Thus, the variability in angler days, affected by minimum pool levels, is expected to be large.

Anadromous Fish

Reservoir Spring Chinook Salmon

The results of simulating the reservoir reared Spring Chinook populations in Holley Reservoir are presented in Figures 4.5 and 4.6. The graphs show spawning escapement by years. These are the spawners returning to Holley Dam each year of a 50 year simulation run starting in year three with a first order delay and a third order delay for spawners, respectively. There is greater variability in the number of returning spawners with the third order delay. There is no estimate available of the coefficient of variation for reservoir reared Spring Chinook since there is only one year of data available from Green Peter Dam for this species. Data from the hatchery program on the Columbia River indicates that the coefficient of variation for the number of returning Spring Chinook is 89 percent.[2/] The coefficients of variation associated with the first order and third order delays from the simulated data

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[2/] The coefficient of variation calculated from data obtained from the Oregon Fish Commission is for the Marion Forks and Willamette hatcheries for the brood years 1956 to 1967.

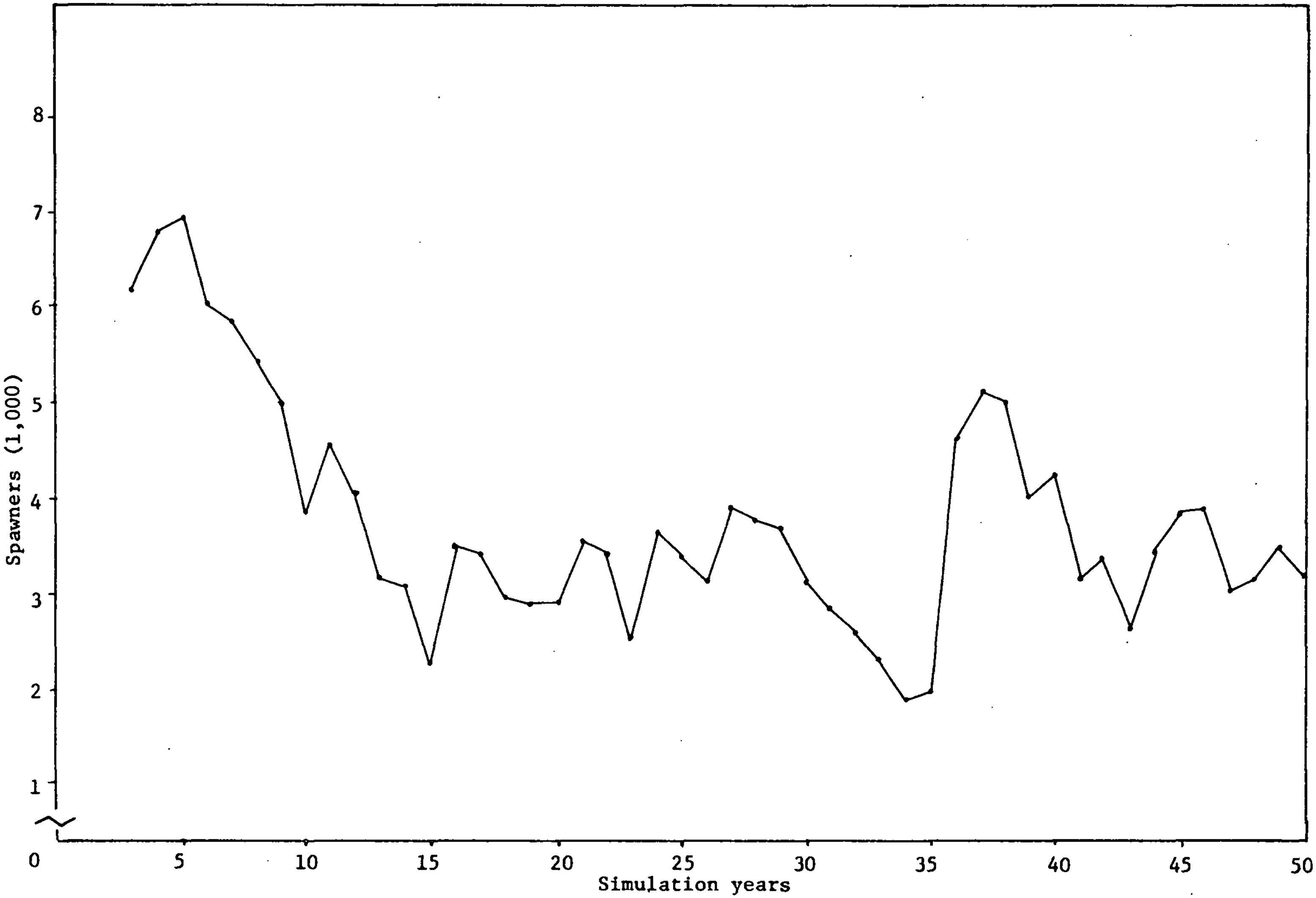

Figure 4.5. Simulated reservoir reared Spring Chinook escapement (1st order delay).

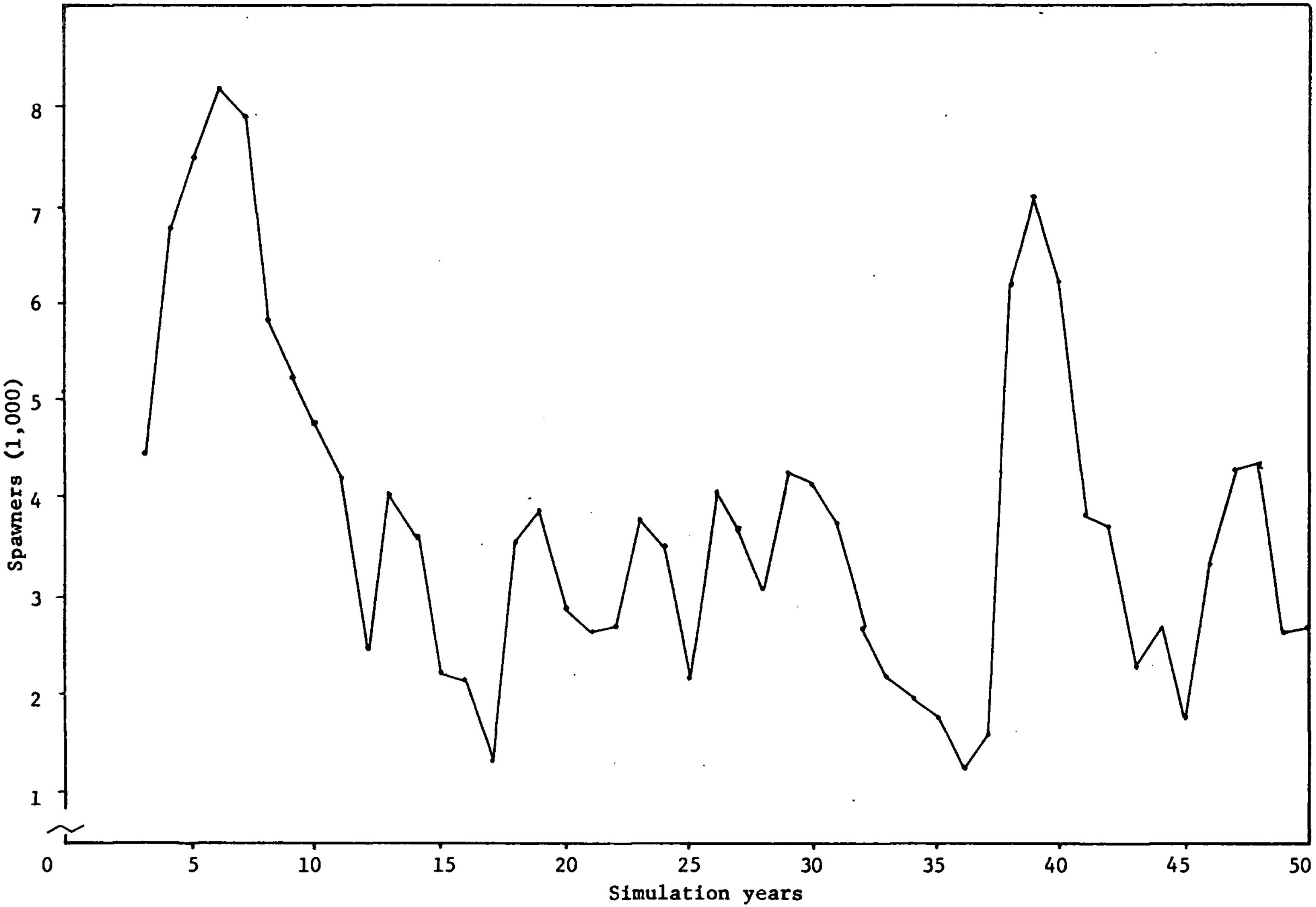

Figure 4.6. Simulated reservoir reared Spring Chinook escapement (3rd order delay).

are 32 and 46 percent, respectively. The higher coefficient of variation for the data from the Columbia River program in comparison to the simulated, indicates that a higher order delay should be used in the model. Results from the Fall Chinook Salmon simulation in the next section show the effect of using the higher order delay.

The average number of spawners returning each year and the average value of escapements for the two types of delays are presented in Table 4.3. The average annual escapement of

Table 4.3. Average annual escapements and valuation of reservoir reared Spring Chinook Salmon at Holley Dam.

Source	Average returning spawners	Average annual discounted value [a/]
		(dollars)
First order delay in returning spawners	3,728	98,328
Third order delay in returning spawners	3,852	129,312

[a/] Based on present value for 4-7/8 percent interest and a value of $89.39 per escapement.

reservoir reared Spring Chinook based on the simulation model with a first order delay in spawners returning is 3,728. Valued at $89.39 and discounted at 4-7/8 percent interest, this gives an average annual benefit of $98,328. With the third order delay the average annual escapement is 3,852 spawners and the discounted value per year is \$129, 312. The average escapements and average dollar benefits obtained from the simulation results are well below those estimated by the Corps of Engineers which are based on recommendations of the Bureau of Sport Fisheries and Wildlife. The Corps of Engineers has estimated that the benefits from the hypothesized 6, 250 spawners returning to Holley Dam annually are valued at \$530, 724. This study has taken into account the possibility of the reservoir level (and food supply) being other than at optimum conditions for stocking of Spring Chinook fry. Also, the estimates based on this simulation have taken into account the stochastic nature of salmon survival rates and employed relationships and meager records which were evidently not available to the Bureau of Sport Fisheries and Wildlife nor to the Corps of Engineers.

Downstream Fall Chinook Salmon

The results from the simulation of the downstream Fall Chinook population are presented as yearly escapements. The number of escapements did not justify calculation of average annual benefits. An indication of the variable nature of migrating escapements of Fall Chinook is given in this section for some initial 50 year runs of the simulation model. The coefficient of variation of escapement of 74 percent, provided by the Oregon Fish Commission, was set as a minimum target variation in tuning the model of returning spawners (see Table 3.5). Since the model is for natural spawning rather than for hatchery conditions a higher coefficient of variation was sought. Results of simulating 47 years of returning Fall Chinook spawners are presented in Figures 4.7 and 4.8. The difference in the two simulated runs is the difference in the hydrologic flows used. Comparison of the two figures shows how sensitive the simulated population of Fall Chinook are to extreme flooding conditions. The spawning escapement shown in Figure 4.7 is the result of the simulation model with 26 percent of the simulated years containing extreme flooding conditions (greater than 3,500 c.f.s.) downstream for the period October through March. This set of flooding conditions and the survival rates discussed in Chapter III produce a coefficient of variation of 83 percent. The mean annual escapement is 1,071 spawners. The graph of Figure 4.8 shows the escapement for a simulated hydrologic period with 46 percent of the years containing extreme flooding conditions. The coefficient of variation for this set of conditions is 127 percent and the mean annual escapement is 364 spawners.

The disappearance of the population is probably of greater significance than the average number of spawners returning over the life of the project. It is apparent from Figures 4.7 and 4.8 that the Fall Chinook fishery is affected severely by the extreme condition survival rates incorporated into the simulation model.

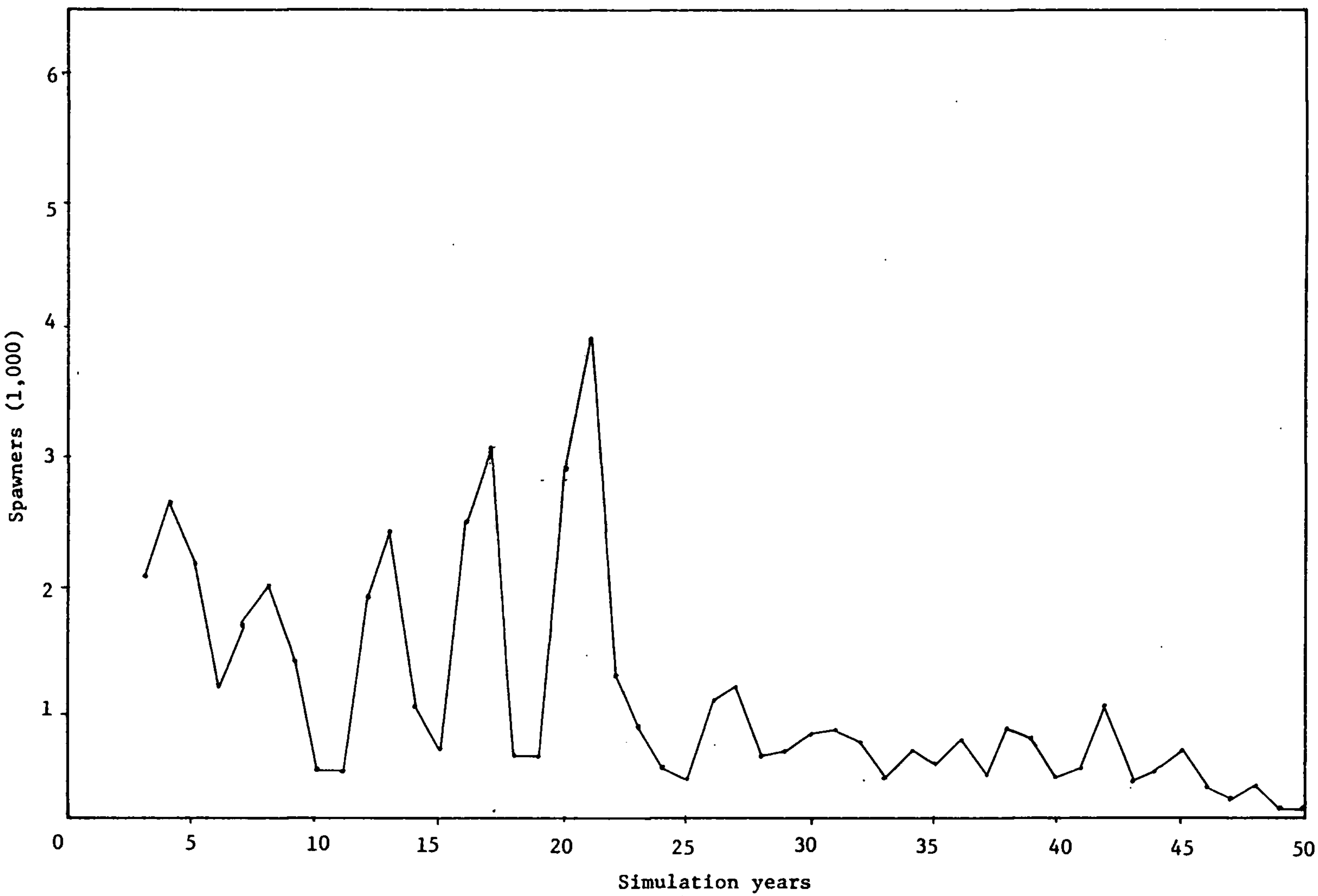

Figure 4.7. Fall Chinook Salmon returnees under extreme conditions (26 percent of years).

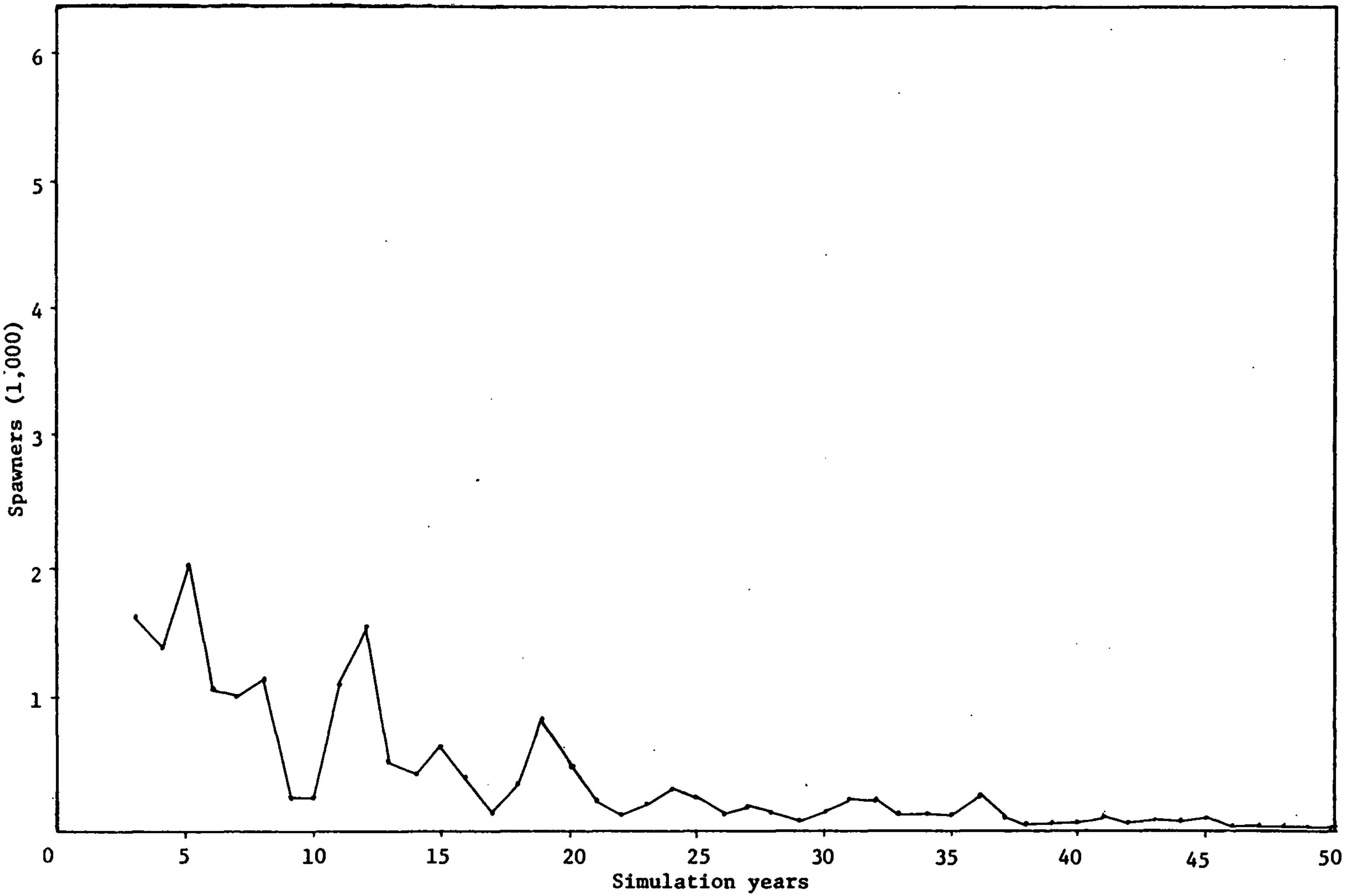

Figure 4.8. Fall Chinook Salmon returnees under extreme conditions (46 percent of years).

In the long run (about 35 to 40 years), as indicated by the simulation model, the Fall Chinook population of the Calapooia River could stabilize near zero spawners. Based on the simulation results there is serious doubt whether the potential Fall Chinook population of the Calapooia River can be maintained. The proposed project is intended to maintain 1, 000 spawners as a conservation measure and 900 spawners as an enhancement function. Since the Fall Chinook population is likely to disappear entirely there would be a mitigation loss and little grounds for making a benefit calculation for fish enhancement.

Recreation

The recreation potential of Holley Reservoir is a function of reservoir operation in the simulation model. Shoreline conditions and their influence on recreation attendance are incorporated in the simulation model as discussed in Chapter III. The effect of weather on recreation was incorporated indirectly into the simulation model.

The annual user day estimates of the Corps of Engineers are concentrated into a 110 day period of weather conditions conducive to recreational activity in the simulation model. A graph of the annual attendance for recreational purposes based on an initial simulation run is presented in Figure 4. 9. The average annual attendance and dollar benefits from this study and Corps of

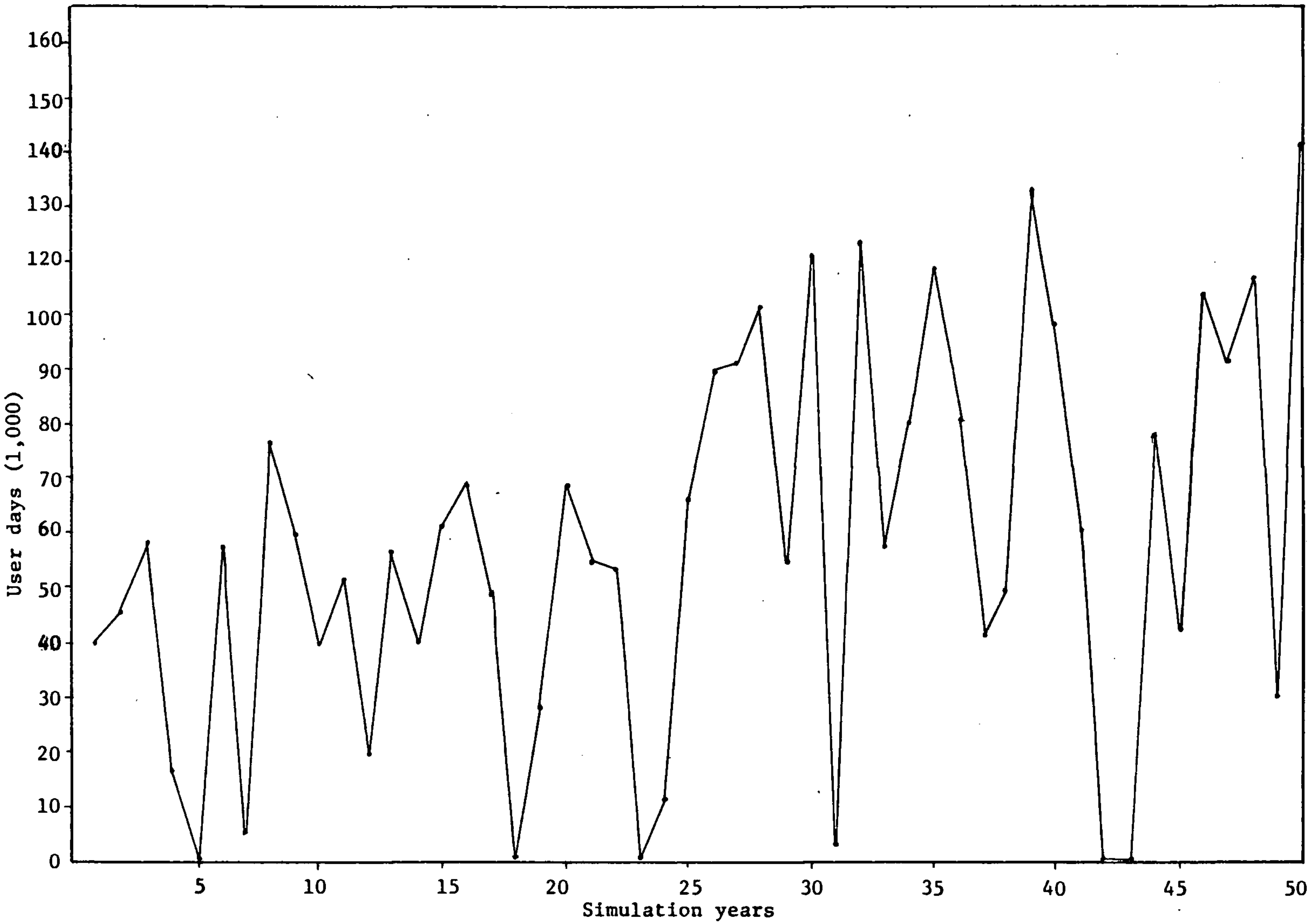

Figure 4.9. Simulated recreation user days.

Engineers' estimates are shown in Table 4.4. The average annual attendance based on the simulation model is 57,710 user days. The average annual discounted benefits are $18,249.[3/] In 5 of the 50 simulation years the total yearly recreation attendance was approximately zero as shown in Figure 4.9. In these years

Table 4.4. Simulated recreation attendance and benefits and Corps of Engineers' estimates for Holley Reservoir.

Source	Annual recreation	Benefits
	(user days)	(dollars)
Simulation (50 years)	57,710	18,249 a/
Corps of Engineers' estimates	708,300	419,000 b/

a/ Based on $1.00 per user day, eash year's benefits discounted and averaged.

b/ Includes reservoir trout fishing angler days. The simulated reservoir fishing benefits are given in Table 4.5.

the reservoir level was low and unsuited for recreational use. A constant pool elevation would provide optimum recreational use of the reservoir; however, other water uses require releases which

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3/ Since the simulation is only for 50 years the full recreation growth potential is not realized.

result in pool drawdown and considerable variation in recreation attendance from year to year as shown by the simulation results of this study. Low reservoir levels are also a result of low inflows.

Resident Game Fishing

The resident trout game fishing anticipated in Holley Reservoir on any day of the simulation is a function of the length of beach. The simulated pattern of reservoir trout fishing is presented in Figure 4.10. Several of the low yearly angler day values occur in the same simulation years that low recreational attendance occurs. However, there is not a close correspondence of the two because reservoir fishing angler days occur year round. The average annual reservoir trout fishing as determined in the simulation is 45,071 angler days as shown in Table 4.5. The average annual discounted benefits for simulated reservoir trout fishing are $33,778.

The downstream trout fishing angler days per year are shown in Figure 4.11. The average annual downstream trout fishing is 2,838 angler days as determined in the simulation. The simulation results and Corps of Engineers' estimates of average annual angler

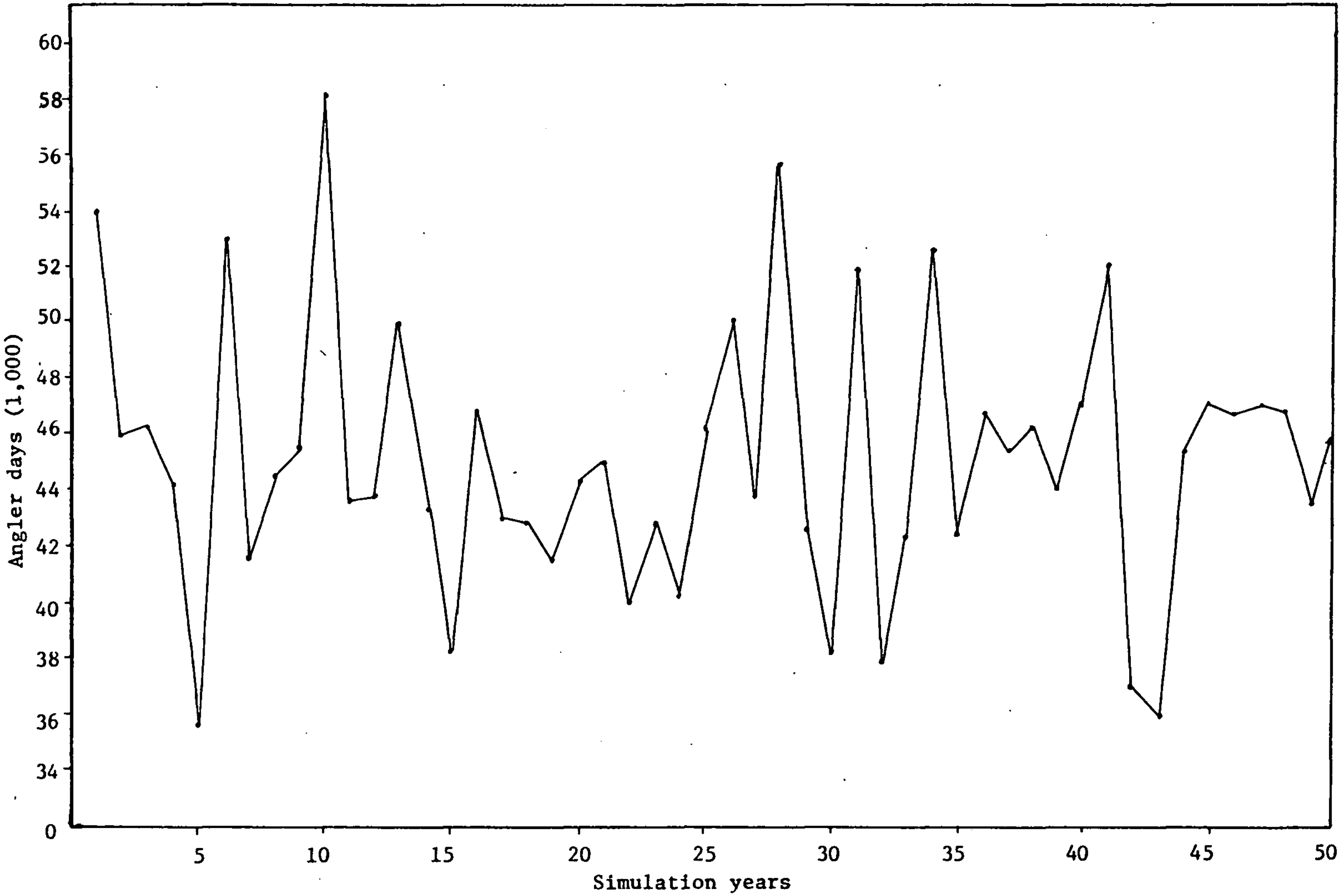

Figure 4.10. Simulated reservoir angler days.

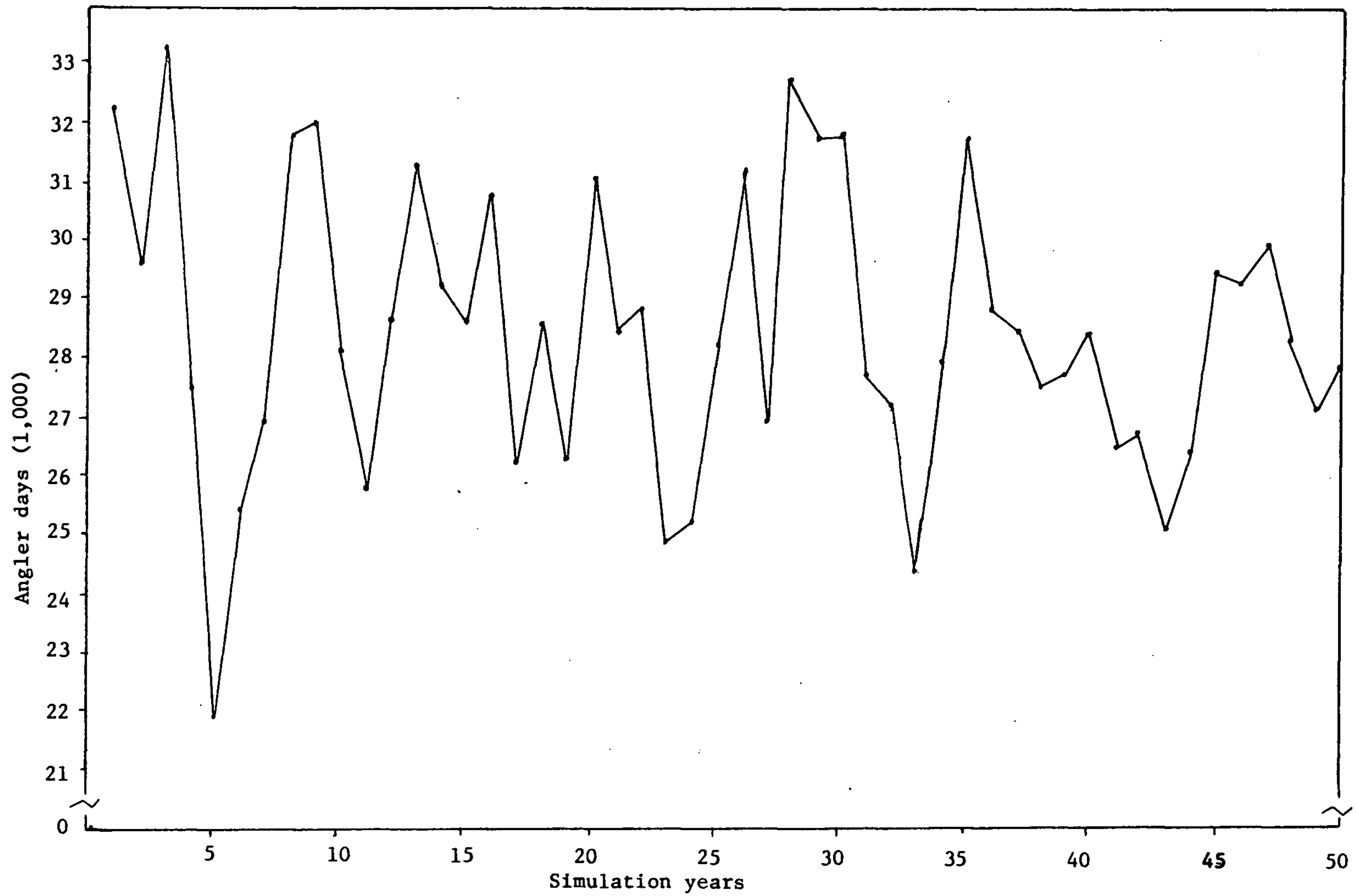

Figure 4.11. Simulated downstream angler days.

angler days and benefits are presented in Table 4.5. The average annual discounted benefits for simulated downstream trout fishing are $3, 192.

Table 4.5. Average annual resident game fishing angler days and benefits for Holley Reservoir.

Source	Average annual angler days	Average annual benefits (dollars)
Simulation (reservoir)	45, 071	33, 778
Corps of Engineers (reservoir)	77, 000	154, 000 a/
Simulation (downstream)	2, 838	3, 192
Corps of Engineers (downstream)	6, 800	20, 400 a/

a/ Corps of Engineers' benefits shown here are undiscounted. Reservoir fishing angler days are valued at $2 per angler day and downstream angler days are valued at $3 per angler day.

Irrigation

The water requirements from Holley Reservoir for irrigation are determined daily in the simulation model. If on any day there is a shortage the amount available for irrigation is prorated as described in Chapter III. No shortages occurred in initial simulation runs and all the irrigation benefits are obtained. The average annual benefits as determined in the simulation and those estimated by the Bureau of Reclamation are presented in Table 4.6. The average annual discounted benefits for irrigation from Holley Reservoir are $173,845 for distribution and storage.

The average annual benefits for irrigation storage in Holley reservoir are $17,008. The Bureau of Reclamation's estimates of irrigation benefits are not discounted to present value and are therefore not comparable to those obtained in the simulation.

Table 4.6. Average annual benefits for irrigation from Holley Reservoir.

Source	Benefits
	(dollars)
Simulation	
Distribution and storage	173,845
Storage	17,008
Bureau of Reclamation	
Distribution and storage	429,000 a/
Storage	60,000 a/

a/ Irrigation benefits estimated by the Bureau of Reclamation are adjusted for worth at time of construction but are not discounted to present value over the project life.

V SUMMARY AND CONCLUSIONS

The objectives of this study are to isolate and investigate the relationships of the four main water use functions of the proposed 145, 000 acre-foot reservoir at Holley, and to incorporate these functions into a revised computer model of the project. Based on studies of Halter and Miller (1966) and Kerri (1969), a simulation model, in the DYNAMO computer language, is formulated to determine the relationship and interaction of system variables.

In order to isolate the problem, decision-making theory under uncertainty is employed. The results of the decision-making approach are isolation of the four states of nature which become the critical factors in the decision problem (size of the reservoir). The minimum probabilities for occurrence of these states which maintain the preferred action as optimal are calculated in Chapter I. The main problem of this study is to gain prior information which could provide an indication of the probabilities for the four critical states of nature. Since the four states of nature all involve favorable conditions for anadromous fish enhancement the emphasis of the study is placed in finding information which could provide evidence as to the success of Holley Reservoir in providing an environment conducive to fish enhancement.

Summary of Simulation Model

In Chapters II and III details of the DYNAMO simulation model are presented. The model includes a hydrology generator, a reservoir regulation algorithm, and water use components of the four main functions including flood control, fish populations, recreation, and irrigation. The hydrology generator is a modification of the generator formulated by Kerri (1969). It is based upon a log-Pearson Type III probability distribution of daily streamflows at Holley and at Albany, Oregon. The modifications include: (1) changing the length of the simulation year from 364 to 360 days to facilitate programming, and (2) adjusting stream coefficients to obtain a closer correspondence between the simulated exceedence curves and those developed from historical data. A number of computer runs of the hydrology generator provides the basis for comparison of the simulated monthly means and exceedence curves of maximum and minimum annual flows with those of historical record. The simulated means and exceedence curves show a close correspondence with those based on the historical period and provides strong evidence of the validity of the hydrology generator.

The reservoir regulation algorithm is based upon the Corps of Engineers' rule curve regulation, design characteristics of the dam and channel, and the flow requirement for fish enhancement and conservation. The rule curve specifies the drawdown of the reservoir to obtain flood control storage prior to the flood season and the storing of water for the critical water use months following the winter flood season. Releases from the reservoir are restricted by the port facilities and by the channel capacity and desired channel level. Releases are also related to the quantity of surplus water in the reservoir and to the fish flow requirement downstream from the dam site. Validity of the reservoir regulation in the simulation model is indicated by the close correspondence of the exceedence curves of regulated maximum annual discharges of the simulated results and those hypothesized by the Corps of Engineers (see Figures 2.2 and 2.12). The model calculates flood benefits based on simulated regulated and unregulated annual flows. Thus, flood benefits are based on the size of the flood in the year of occurrence rather than based upon the exceedence curves which is the procedure of the Corps of Engineers. Extrapolation to the one-in-10,000-years flood is avoided since the longest run of the simulation model is for 100 years, the proposed life of the project. The potential damage reduction by regulation of floods of magnitude greater than one-in-one-hundred years along the Willamette River reaches is accounted for but reduced by the possible lack of storage in the reservoir at any given time.

The anadromous fish section of the model includes two parts:

(1) reservoir rearing of Spring Chinook Salmon, and (2) downstream spawning and rearing of Fall Chinook Salmon. Modeling of the reservoir rearing Spring Chinook program includes consideration of stocking rates (food supply), survival rates of fry to smolts, and survival rates of smolts to returning spawners. In investigating the factors affecting the downstream environment for anadromous fish life the following considerations are critical: (1) temperature, (2) streamflow, (3) food supply, (4) siltation, (5) turbidity, and (6) extreme flow conditions. Simulation of the temperature of water releases from the reservoir is not part of this model because research resources did not allow the collection of extensive meteorological data which would be necessary to simulate atmospheric conditions on a daily basis. The Corps of Engineers using 1958 meteorological data found that there would be adequate water of the required temperature stored in the reservoir. However, this study casts great doubt upon the validity of the downstream temperature requirement used in their thermal simulation model.

Minimum streamflow requirements for fish below the dam are included in the reservoir regulation section of the model. To make the other factors affecting downstream fish life more specific, the Fall Chinook life cycle is simulated. In this section of the model consideration is given to the following factors affecting Fall

Chinook populations: (1) normal egg to fry survival rates, (2) egg to fry survival rates under extreme flow conditions, and (3) fry to returning spawner survival rates.

Two factors considered in the model affecting recreational use of the reservoir are rainfall and reservoir pool level. The user days are concentrated into a 110 day period when rainfall is low relative to the remainder of the year. The attendance on any day is a function of the length of beach which is a function of reservoir level in the simulation model. Therefore, the yearly recreational use of the reservoir is as variable as the reservoir level.

The irrigation section of the model determines water releases for irrigation on a daily basis. Any time the total supply of water for irrigation is less than the requirement, the amount available is prorated over the remaining irrigation period.

Summary of Results

The emphasis of this study is in analyzing the 145, 000 acre-foot reservoir proposed for the Calapooia River at Holley. Therefore, the results are based on the systems simulation of this size project rather than other reservoir sizes and combinations of project functions.[1/] The average annual benefits and costs based on the simulation are presented in Table 5.1. The total average annual discounted benefits based on the simulation are $332, 590. The total annual costs of the 145, 000 acre-foot project including amortized construction costs, discounted operation, maintenance, and repair costs, and interest during construction are $1, 745, 225 when the operation, maintenance, and repair are discounted and averaged for 50 years. The total annual costs are $1, 685, 725 when the operation, maintenance and repair costs are discounted and averaged for 100 years.

No attempt is made to calculate a benefit-cost ratio for the Holley Reservoir project from the simulation results because such a ratio does not express the uncertainty aspect of the problem which is the emphasis of this study. In the decision making under uncertainty framework the probabilities of the states of nature and the criteria of choice are of at least equal importance to the numerical values in the payoff table, i. e., benefits and costs.

The annual benefits calculated by the Corps of Engineers are $2, 754, 000. The difference in financial procedures used in

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[1/] The simulation model is built to test the 97, 000 acre-foot reservoir also, but resources did not permit running the model with this alternative.

Table 5.1. Costs and simulated benefits for Holley Reservoir and Dam project.

Source	Benefit	Cost
	(dollars)	(dollars)
Anadromous fish	129,312	
Capital construction cost		865,000
Resident trout	36,970	
Capital construction cost		35,000
Recreation	18,249	
Capital construction cost		1,456,800
Flood control	131,051	
Capital construction cost		23,152,500
Irrigation	17,008	
Capital construction cost		1,225,000
Channel capital costs		3,012,000
Total capital cost		29,747,300
Annual operation, maintenance, and repair costs		352,251
Annual amortized construction cost a/		1,467,352
Discounted operation, maintenance and repair b/		131,138
Discounted operation, maintenance and repair c/		71,638
Total annual benefit d/	332,590	
Total annual cost e/		1,745,225
Total annual cost f/		1,685,725

Continued

Table 5.1. Costs and simulated benefits for Holley Reservoir and Dam project--Continued.

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a/ Amortized at 4-7/8 percent interest for 100 years.

b/ Based upon 50 year discounted average.

c/ Based upon 100 year discounted average.

d/ Does not include municipal and industrial benefits or benefits from navigation.

e/ Amortized construction, 50 year discounted operation, maintenance, and repair, and interest during construction.

f/ Amortized construction, 100 year discounted operation, maintenance, and repair, and interest during construction.

this study and those used by the Corps of Engineers account for some of the difference in the dollar benefits obtained. However, a greater part of the discrepancy is due to the differences in assumptions and basic parameter values in the simulation model. In the course of this study one of the financial procedural differences found involves calculation of irrigation benefits. The Bureau of Reclamation provided the Corps of Engineers with an estimate of annual equivalent benefits to storage of \$60, 000.[2/] This is based upon a total benefit to the irrigation project of \$601, 000 (\$429, 000 annual equivalent). It appears that the Corps of

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2/ Annual equivalent means that the ten year growth period to get to full irrigation development is accounted for in the annual average.

Engineers did not discount the $60, 000 to present value as in this study. The differences between the Corps of Engineers' results and those of this study due to differences in assumptions and parameter values are discussed in the next sections.

Anadromous Fish

The results of the anadromous fish population section of the simulation model indicate that the proposed project could create an environment which would be unconducive to maintaining and enhancing these fish. The results of the reservoir rearing Spring Chinook Salmon and downstream Fall Chinook Salmon sections of the model strongly indicate that the probability for success of anadromous fish enhancement could be less than .6 (see Chapter I). This means that the proposed 145, 000 acre-foot project may not be the preferred action based upon the simulation. The anadromous fish sections of the simulation model give results that show that the downstream Fall Chinook population may not be maintained nor enhanced, and that there may be fewer numbers of and considerable variation in the reservoir reared Spring Chinook returning spawners. The mean annual number of returnees of Spring Chinook are well below those anticipated and estimated by the Bureau of Sport Fisheries and Wildlife.

Other Water Use Outcomes

The recreation user days per year obtained in the simulation are eight percent of the number estimated to occur per year by the Corps of Engineers. This is due to the fluctuations in pool level and consequently in the length of beach exposed.

The number of resident trout fishing angler days are lower than those estimated by the Corps of Engineers expected to occur at Holley Reservoir and downstream. The pool drawdown requirements and fluctuations have a marked effect on use of the reservoir for fishing. The average angler days achieved in the simulation for reservoir fishing are 59 percent of the average angler days estimated by the Corps of Engineers. The downstream average annual resident fishing angler days obtained in the simulation are 42 percent of the average estimated by the Corps of Engineers.

The irrigation requirement is met throughout the simulation and no shortage is encountered. However, a considerable difference exists between annual benefits obtained in this study and those obtained by the Bureau of Reclamation. Also, evidence presented in this study shows that the Bureau of Reclamation's estimates of returns per acre to irrigated lands are inconsistent with a recent comprehensive study by Oregon State University on returns to various Willamette Valley irrigation enterprises. The benefits obtained in this study for irrigation are based upon the Bureau of Reclamation's estimates of returns to irrigated land.

Conclusions

In Chapter I, using a uniform probability distribution over eight states of nature, reflecting various favorable and unfavorable conditions, the preferred project for the Calapooia River is the 97, 000 acre-foot reservoir using maximum expected value as the criterion of choice. Further, it is shown that when the probability of any of four states of nature involving favorable conditions for anadromous fish enhancement is less than .6 then the preferred action is also the 97, 000 acre-foot project. Inasmuch as the Corps of Engineers is recommending a 145, 000 acre-foot reservoir it was the purpose of this study to investigate the feasibility of capturing the benefits associated with fish life enhancement with this size of project. As the decision framework of Chapter I implies, a great deal of uncertainty exists among the public agencies involved in planning the Holley Dam and Reservoir. Evidence accumulated and incorporated into a simulation model shows that there is uncertainty not only associated with the anadromous fish benefits, but also with other water use functions which interact with the main purpose of the dam, i. e., flood control. The results show that when the dam is operated for flood control it is unlikely that all of the benefits as proposed by the Corps of Engineers can be captured with the large reservoir. Data and simulation results shown in Chapters III and IV lead to the conclusion that the likelihood of obtaining benefits from anadromous fish enhancement is small. If a more definitive statement needs to be made, the conclusion is that the subjective probability of any of the four states of nature favorable to anadromous fish conservation and enhancement is less than .6.

Limitations and Further Research

Because research resources did not permit the 97,000 acre foot reservoir to be investigated, the conclusion does not imply that the 97,000 acre foot reservoir would be the preferred size. However, the simulation model is general enough to test the 97,000 acre foot reservoir as well as other sizes. Further computer runs need to be made to arrive at a more definitive conclusion relative to reservoir size, as well as to determine the feasibility of any reservoir on the Calapooia River.

The downstream temperature requirements are not programmed in the present model, but are a desirable component to have in river basin systems analysis. Therefore, the temperature component should be researched, programmed, and incorporated into the Calapooia River simulation model.

The 5, 000 c. f. s. channel is the only size tested in the present results. Other channel sizes can also be tested by the simulation model. If it is the case that downstream anadromous fish life cannot be maintained, then larger channel sizes, while losing the fish enhancement benefits, could provide greater flood control, drainage, and irrigation benefits that might offset the loss of the fish features. Some programming, and more computer runs would be necessary to test this hypothesis.

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APPENDIX

APPENDIX A

This appendix contains the full computer simulation model used in this study. The program is written in DYNAMO II, version 4. The main headings denoted by note statements divide the program into the main components. Statements on note cards that are indented define the variables in the equation immediately below the definition.

```
*       CALAPOOIA RIVER CONTINUOUS HYDROLOGY
NOTE
NOTE    DAYS COUNTER
NOTE
L       DAY.K=DAY.J+(DT)(DAIN.JK-DAOT.JK)
N       DAY=1
R       DAIN.KL=DAC
C       DAC=1
R       DAOT.KL=PULSE(360,360,360)
NOTE
NOTE    SEASON COUNTER
NOTE
L       SEA.K=SEA.J+(DT)(SEI.JK-SAO.JK)
N       SEA=1
R       SEI.KL=SIC
C       SIC=1
R       SAO.KL=PULSE(90,90,90)
NOTE
NOTE    YEARS COUNTER
NOTE
L       YEARS.K=YEARS.J+(DT)(YRSIN.JK+0)
N       YEARS=1
R       YRSIN.KL=PULSE(1,360,360)
NOTE
NOTE    UPSTREAM HYDROLOGY
NOTE    RESERVOIR IN AT HOLLEY
NOTE
NOTE       RESERVOIR INPUT - CFD
R       RIN.KL=(FRIN1.K)(86400)
NOTE       PEARSON III DISTRIBUTION FLOW - CFS
A       FRIN1.K=1.*EXP(LGRIN.K)
A       LGRIN.K=MRIN1.K+KR.K
A       KR.K=(KR1.K)(SRIN1.K)
NOTE       PEARSON III DEVIATE DIVIDEO BY STREAM COEFFICIENT
A       KR1.K=CLIP(KR2.K,KR3.K,KRIN.K,0)
NOTE       UPSTREAM COEFFICIENTS
A       KR2.K=KRIN.K/1.17
A       KR3.K=KRIN.K/1.35
NOTE       UPSTREAM DAILY MEANS - LOG
A       MRIN1.K=CLIP(ARM.K,ARMX.K,90,DAY.K)
A       ARMX.K=CLIP(BRM.K,BRMX.K,180,DAY.K)
A       BRMX.K=CLIP(CRM.K,DRM.K,270,DAY.K)
A       ARM.K=TABHL(ARMT,SEA.K,1,90,1)
A       BRM.K=TABHL(BRMT,SEA.K,1,90,1)
A       CRM.K=TABHL(CRMT,SEA.K,1,90,1)
A       DRM.K=TABHL(DRMT,SEA.K,1,90,1)
T        ARMT=3.816/3.755/3.718/3.757/3.793/3.803/3.854/3.913/4.023/4.170/
X       4.564/5.049/4.526/4.334/4.197/4.162/4.131/4.233/4.290/4.444/4.987/
X       5.883/5.501/5.229/5.038/4.885/4.801/4.677/4.740/4.860/4.889/5.065/
X       5.083/5.009/4.999/4.949/4.938/4.914/4.971/5.038/5.212/5.383/5.566/
X       5.915/6.491/6.249/6.051/5.878/5.650/5.579/5.672/6.159/6.952/7.492/
X       7.181/6.716/6.488/5.910/5.927/6.203/6.220/6.296/6.318/6.218/6.126/
X       6.042/6.054/6.063/6.094/6.298/6.982/6.701/6.504/6.313/6.204/6.088/
X       6.011/6.022/6.039/6.141/6.416/7.022/7.710/7.413/7.078/6.807/6.656/
X       6.475/6.357/6.284
T        BRMT=6.363/6.217/6.162/6.145/6.094/6.045/6.091/6.404/6.947/6.700/
X       6.541/6.352/6.167/6.047/5.992/5.983/6.131/6.379/6.925/7.452/7.172/
X       6.907/6.716/6.584/6.399/6.263/6.138/6.082/6.155/6.133/6.383/6.480/
X       6.360/6.251/6.172/6.270/6.454/7.163/7.773/7.468/7.159/6.977/6.775/
X       6.580/6.356/6.311/6.297/6.521/6.922/6.769/6.544/6.364/6.278/6.176/
X       6.114/6.062/6.062/6.017/6.218/6.240/6.177/6.131/6.345/6.578/6.505/
```

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X       6.415/6.285/6.207/6.148/6.092/6.044/6.028/6.053/6.129/6.358/6.724/
X       7.271/7.083/6.894/6.761/6.634/6.496/6.379/6.265/6.190/6.205/6.182/
X       6.243/6.377/6.594
T        CPMT=6.433/6.339/6.235/6.277/6.354/6.620/6.854/6.690/6.555/6.446/
X       6.374/6.260/6.151/6.073/6.045/6.065/6.223/6.437/6.350/6.249/6.121/
X       5.991/5.885/5.838/5.843/5.856/5.899/5.972/5.985/6.044/5.959/5.898/
X       5.903/5.984/6.228/6.496/6.304/6.170/6.075/5.970/5.898/5.821/5.792/
X       5.844/5.961/5.955/5.783/5.727/5.662/5.589/5.555/5.507/5.457/5.423/
X       5.393/5.374/5.349/5.361/5.420/5.471/5.460/5.403/5.328/5.314/5.252/
X       5.221/5.230/5.421/5.752/5.565/5.423/5.323/5.231/5.140/5.056/4.988/
X       4.931/4.903/5.029/5.270/5.119/5.023/4.953/4.892/4.843/4.779/4.734/
X       4.711/4.811/4.848
T        DRMT=4.718/4.652/4.615/4.577/4.553/4.529/4.489/4.473/4.439/4.408/
X       4.363/4.325/4.309/4.295/4.255/4.238/4.191/4.167/4.134/4.111/4.099/
X       4.063/4.042/4.021/4.020/4.035/4.040/3.976/3.937/3.917/3.900/3.892/
X       3.884/3.901/3.886/3.858/3.859/3.835/3.810/3.773/3.736/3.720/3.702/
X       3.692/3.675/3.679/3.633/3.626/3.607/3.589/3.599/3.622/3.632/3.675/
X       3.643/3.700/3.659/3.676/3.656/3.642/3.597/3.649/3.709/3.623/3.600/
X       3.671/3.630/3.593/3.569/3.542/3.545/3.605/3.596/3.628/3.623/3.737/
X       3.873/3.846/3.769/3.677/3.722/3.720/3.656/3.684/3.612/3.591/3.668/
X       3.743/3.722/3.695
NOTE       UPSTREAM DAILY STANDARD DEVIATION - LOG
A       SRIN1.K=CLIP(ARS.K,ARSX.K,90,DAY.K)
A       ARSX.K=CLIP(BRS.K,BRSX.K,180,DAY.K)
A       BRSX.K=CLIP(CRS.K,DRS.K,270,DAY.K)
A       ARS.K=TABHL(ARST,SEA.K,1,90,1)
A       BRS.K=TABHL(BRST,SEA.K,1,90,1)
A       CRS.K=TABHL(CRST,SEA.K,1,90,1)
A       DRS.K=TABHL(DRST,SEA.K,1,90,1)
T        ARST=.680/.595/.500/.540/.550/.554/.595/.674/.814/.891/1.009/1.08
X       4/.974/.902/.850/.901/.921/1.138/1.236/1.327/1.326/1.271/1.209/1.1
X       45/1.093/1.057/1.089/1.173/1.223/1.328/1.090/1.183/1.156/1.072/0.9
X       53/.884/.840/.831/.845/.882/.902/.921/.932/1.067/1.039/0.959/0.978
X       /.991/.915/.961/1.001/1.045/0.959/1.013/0.984/1.015/.951/1.037/.91
X       1/1.035/1.157/1.108/.960/.857/.785/.733/.719/.724/.811/.921/.763/.
X       763/.714/.667/.645/.629/.636/.736/.809/.899/1.003/1.127/1.070/.977
X       /.863/.746/.754/.699/.676/.670
T        BRST=.854/.756/.711/.742/.696/.690/.712/.772/.907/.838/.770/.673/
X       .600/.570/.575/.607/.740/.842/.917/.902/.781/.742/.660/.609/.555/.
X       518/.466/.532/.730/.810/.764/.779/.657/.562/.539/.551/.736/.763/.7
X       26/.517/.537/.495/.497/.482/.479/.455/.536/.596/.750/.684/.615/.59
X       8/.587/.570/.497/.467/.446/.570/.662/.619/.633/.583/.572/.608/.560
X       /.554/.470/.471/.457/.451/.447/.455/.514/.550/.636/.797/.622/.609/
X       .608/.584/.544/.544/.522/.487/.499/.470/.480/.564/.650/.720
T        CRST=.629/.567/.509/.474/.495/.518/.509/.475/.463/.442/.440/.422/
X       .412/.406/.426/.423/.481/.610/.582/.527/.475/.469/.474/.439/.432/.
X       439/.423/.431/.435/.548/.488/.445/.470/.513/.656/.763/.656/.577/.5
X       42/.523/.521/.505/.488/.561/.600/.588/.570/.549/.535/.511/.504/.49
X       2/.479/.463/.441/.428/.427/.497/.534/.536/.463/.398/.375/.365/.374
X       /.384/.428/.576/.667/.597/.535/.485/.439/.408/.389/.378/.371/.378/
X       .457/.546/.459/.407/.377/.358/.338/.315/.302/.304/.558/.551
T        DRST=.440/.396/.366/.329/.318/.324/.339/.330/.336/.361/.331/.316/
X       .298/.306/.317/.324/.288/.270/.265/.260/.264/.252/.243/.238/.263/.
X       325/.430/.326/.285/.275/.277/.285/.278/.289/.298/.274/.300/.308/.2
X       88/.261/.239/.227/.219/.222/.218/.231/.217/.221/.220/.237/.262/.31
X       1/.340/.415/.335/.382/.365/.310/.332/.351/.272/.360/.569/.403/.381
X       /.450/.444/.369/.347/.312/.293/.391/.448/.472/.443/.591/.719/.577/
X       .498/.417/.603/.601/.500/.555/.489/.437/.611/.717/.607/.572
NOTE       UPSTREAM DAILY SKEW - LOG
A       GRIN2.K=GRIN1.K/6
A       GRIN1.K=CLIP(ARG.K,ARGX.K,90,DAY.K)
A       ARGX.K=CLIP(BRG.K,BRGX.K,180,DAY.K)
```

```
A       BRGX.K=CLIP(CRG.K,DRG.K,270,DAY.K)
A       ARG.K=TABHL(ARGT,SEA.K,1,90,1)
A       BRG.K=TABHL(BRGT,SEA.K,1,90,1)
A       CRG.K=TABHL(CRGT,SEA.K,1,90,1)
A       DRG.K=TABHL(DRGT,SEA.K,1,90,1)
T        ARGT=1.622/1.352/.917/.523/.468/.527/.309/.335/.461/.556/.309/-.2
X       67/.323/.435/.432/.676/.848/1.271/1.171/.960/.346/-.485/-.513/-.45
X       9/-.337/-.270/.022/1.019/1.241/.826/.611/.410/.578/.457/.137/.072/
X       -.123/-.151/-.064/-.158/-.508/-.206/-.166/-.343/-.427/-.669/-.797/
X       -.703/-.633/-.646/-.81/-1.228/-.399/-1.332/-1.387/-2.178/-2.128/-1
X       .214/-1.312/-1.071/-.668/-.450/.174/.027/.050/.202/.410/.298/.564/
X       .373/-.133/-.446/-.445/-.292/-.294/-.245/-.064/.295/.443/.284/.135
X       /-.476/-.219/-.169/-.053/-.158/.203/.111/-.148/-.248
T        BRGT=1.154/.671/.399/.354/.302/.483/.551/.107/-.458/-.448/-.320/-
X       .232/-.397/.037/.334/.408/.293/.077/.086/-.093/-.210/-.311/-.406/-
X       .651/-.543/-.396/-.470/-.082/.611/.537/.233/.065/-.227/-.325/-.189
X       /-.449/-.028/-.517/-.680/-.826/-.792/-.662/-.077/-.025/.141/.484/.
X       418/-.283/-.323/-.269/-.217/-.086/-.079/-.055/.153/.332/-.104/.489
X       /.280/.119/.113/.207/-.612/-.393/-.493/-.387/-.896/-.752/-.513/-.5
X       03/-.418/-.362/-.246/-.424/-.667/-.377/-.446/-.282/-.378/-.490/-.5
X       28/-.263/-.449/-.250/.034/.109/-.181/-.191/.349/-.526
T        CRGT=-.487/-.599/-.754/-.573/-.690/-.750/-.607/-.890/-1.311/-1.13
X       9/-.386/-1.261/-.975/-.724/-.671/-.738/-.775/-.423/-.473/-.569/-.5
X       30/-.146/-.010/.108/.033/-.318/-.718/-1.000/-.924/.227/-.456/.079/
X       .476/.090/.109/.244/-.026/-.206/-.414/-.306/-.170/-.261/-.574/-.42
X       1/-.417/-.328/-.336/-.297/-.251/-.254/-.239/-.256/-.238/-.205/-.19
X       8/-.288/-.196/.341/.396/.050/-.100/.289/.399/.292/.479/.418/.421/.
X       289/.223/.153/.147/.028/-.092/-.121/-.089/-.020/.124/.215/.145/.00
X       4/-.241/-.266/-.332/-.451/-.418/-.420/-.174/-.239/2.410/1.562
T        DRGT=.598/.470/.384/.368/.230/-.073/.106/-.168/.223/.754/.436/.26
X       1/-.066/.061/.192/.412/.160/.081/.047/.066/.295/.093/.121/.138/.28
X       4/1.070/2.400/1.173/.587/.289/.309/.495/.041/.163/.310/-.014/.336/
X       .900/.454/.165/-.013/-.122/-.084/-.070/-.039/.110/-.040/.021/-.003
X       /.004/.608/.970/.870/1.221/.747/.966/1.254/.636/.879/1.367/.684/1.
X       311/3.047/2.311/1.818/1.331/2.009/1.413/1.528/.898/1.011/1.542/1.7
X       75/1.988/1.595/1.964/1.376/.885/.775/.933/2.041/1.777/1.471/1.356/
X       1.505/1.580/2.380/1.995/1.675/1.462
NOTE       CONVERTS STANDARD NORMAL TO PEARSON III DEVIATE
A       GRIN3.K=XRIN.K-GRIN2.K
A       GRIN4.K=1+(GRIN2.K)(GRIN3.K)
A       GRIN5.K=(GRIN4.K)(GRIN4.K)(GRIN4.K)
A       GRIN6.K=1/((3)(GRIN2.K))
A       KRN.K=(GRIN6.K)(GRIN5.K-1)
A       PKRN.K=-2/GRIN1.K
NOTE       PEARSON III DEVIATE
A       KRIN.K=SWITCH(XRIN.K,KRN1.K,GRIN1.K)
A       KRN2.K=KRN.K-PKRN.K
A       KRN3.K=CLIP(KRN.K,PKRN.K,KRN2.K,0)
A       KRN4.K=CLIP(KRN.K,PKRN.K,-KRN2.K,0)
A       KRN1.K=CLIP(KRN3.K,KRN4.K,GRIN1.K,0)
NOTE       STANDARD NORMAL DEVIATE
A       XRIN.K=(B2RIN.K)(YRIN.K)+(DRN2.K)(NDST1.K)
A       DRN1.K=1-DRIN.K
A       DRN2.K=1.*SQRT(DRN1.K)
NOTE       REGRESSION COEFFICIENTS PREVIOUS UPSTREAM
A       B2RIN.K=CLIP(ARB.K,ARBX.K,90,DAY.K)
A       ARBX.K=CLIP(BRB.K,BRBX.K,180,DAY.K)
A       BRBX.K=CLIP(CRB.K,DRB.K,270,DAY.K)
A       ARB.K=TABHL(ARBT,SEA.K,1,90,1)
A       BRB.K=TABHL(BRBT,SEA.K,1,90,1)
A       CRB.K=TABHL(CRBT,SEA.K,1,90,1)
A       DRB.K=TABHL(DRBT,SEA.K,1,90,1)
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T       ARBT=.772/.977/.964/.934/.955/.982/.957/.980/.965/.977/.934/.882/
X       .964/.984/.989/.977/.991/.986/.992/.977/.816/.824/.979/.991/.997/.
X       993/.970/.986/.936/.960/.956/.924/.972/.961/.898/.985/.977/.995/.9
X       82/.386/.921/.933/.954/.887/.900/.965/.967/.979/.935/.925/.951/.88
X       3/.755/.617/.930/.801/.820/.709/.863/.661/.964/.964/.959/.971/.989
X       /.984/.976/.970/.988/.944/.918/.974/.981/.970/.989/.982/.978/.935/
X       .990/.941/.909/.827/.856/.983/.969/.992/.993/.994/.983/.965
T       BRBT=.942/.874/.980/.860/.985/.973/.957/.840/.775/.978/.986/.940/
X       .344/.930/.946/.974/.906/.855/.823/.927/.982/.967/.988/.984/.963/.
X       978/.978/.788/.920/.952/.825/.881/.908/.966/.941/.817/.867/.448/.7
X       68/.355/.897/.914/.961/.951/.896/.925/.804/.849/.556/.982/.954/.96
X       5/.930/.988/.976/.979/.910/.866/.678/.906/.974/.913/.827/.902/.939
X       /.983/.944/.990/.988/.993/.958/.987/.961/.940/.887/.912/.804/.970/
X       .958/.960/.977/.942/.946/.912/.937/.851/.927/.876/.927/.831
T       CRBT=.974/.991/.374/.895/.905/.656/.962/.967/.977/.967/.984/.962/
X       .956/.988/.985/.943/.906/.906/.991/.987/.976/.948/.967/.986/.954/.
X       965/.959/.923/.915/.779/.939/.921/.971/.935/.915/.912/.963/.973/.9
X       92/.366/.995/.980/.956/.959/.932/.989/.994/.990/.996/.991/.998/.99
X       7/.937/.997/.991/.998/.984/.949/.948/.846/.914/.958/.957/.911/.877
X       /.982/.959/.841/.860/.983/.989/.993/.990/.990/.992/.995/.992/.988/
X       .821/.877/.978/.972/.992/.994/.996/.988/.990/.965/.795/.900
T       DRBT=.987/.997/.993/.989/.985/.968/.976/.921/.965/.993/.997/.995/
X       .974/.974/.973/.992/.992/.993/.996/.997/.969/.993/.992/.995/.963/.
X       974/.918/.918/.991/.996/.991/.989/.958/.939/.960/.967/.944/.979/.9
X       84/.390/.991/.990/.992/.993/.959/.966/.971/.991/.993/.984/.981/.88
X       3/.921/.916/.971/.819/.990/.963/.844/.921/.859/.680/.806/.929/.937
X       /.668/.854/.889/.962/.928/.907/.820/.969/.929/.801/.784/.842/.919/
X       .932/.973/.839/.855/.987/.872/.986/.951/.875/.931/.895/.951
NOTE       GENERATION OF STANDARD NORMAL DISTRIBUTION
A       AR01.K=SAMPLE(UND01.K,1,0)
A       UND01.K=NOISE()
A       AR02.K=SAMPLE(UND02.K,1,0)
A       UND02.K=NOISE()
A       AR03.K=SAMPLE(UND03.K,1,0)
A       UND03.K=NOISE()
A       AR04.K=SAMPLE(UND04.K,1,0)
A       UND04.K=NOISE()
A       AR05.K=SAMPLE(UND05.K,1,0)
A       UND05.K=NOISE()
A       AR06.K=SAMPLE(UND06.K,1,0)
A       UND06.K=NOISE()
A       AR07.K=SAMPLE(UND07.K,1,0)
A       UND07.K=NOISE()
A       AR08.K=SAMPLE(UND08.K,1,0)
A       UND08.K=NOISE()
A       AR09.K=SAMPLE(UND09.K,1,0)
A       UND09.K=NOISE()
A       AR010.K=SAMPLE(UND010.K,1,0)
A       UD010.K=NOISE()
A       AR011.K=SAMPLE(UND011.K,1,0)
A       UND011.K=NOISE()
A       AR012.K=SAMPLE(UND012.K,1,0)
A       UND012.K=NOISE()
A       SMU01.K=AR01.K+AR02.K+AR03.K+AR04.K+AR05.K+AR06.K
A       SMU02.K=AR07.K+AR08.K+AR09.K+AR010.K+AR011.K+AR012.K
NOTE       UPSTREAM RANDOM STANDARD NORMAL DEVIATE
A       NDST1.K=SMU01.K+SMU02.K
NOTE       UPSTREAM CORRELATION COEFFICIENT
A       DRIN.K=CLIP(ARD.K,ARDX.K,90,DAY.K)
A       ARDX.K=CLIP(BRD.K,BRDX.K,180,DAY.K)
A       BRDX.K=CLIP(CRD.K,DRD.K,270,DAY.K)
A       ARD.K=TABHL(ARDT,SEA.K,1,90,1)
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A       BRD.K=TABHL(BRDT,SEA.K,1,90,1)
A       CRD.K=TABHL(CRDT,SEA.K,1,90,1)
A       DRD.K=TABHL(DRDT,SEA.K,1,90,1)
T        ARDT=.591/.955/.928/.872/.912/.964/.916/.961/.930/.954/.872/.778/
X       .746/.968/.979/.954/.982/.973/.984/.954/.666/.679/.959/.982/.993/.
X       986/.941/.973/.877/.922/.915/.854/.944/.924/.807/.970/.955/.991/.9
X       64/.971/.848/.870/.911/.786/.810/.931/.935/.959/.874/.856/.905/.78
X       0/.585/.381/.865/.642/.672/.503/.744/.437/.929/.929/.920/.944/.977
X       /.967/.767/.941/.975/.892/.843/.949/.962/.941/.978/.964/.957/.874/
X       .981/.886/.826/.685/.732/.967/.939/.984/.986/.988/.967/.932
T        BRDT=.888/.764/.961/.739/.969/.947/.916/.706/.601/.956/.973/.884/
X       .892/.961/.894/.949/.821/.731/.677/.858/.964/.935/.977/.968/.928/.
X       957/.956/.622/.846/.907/.681/.776/.824/.934/.886/.668/.751/.201/.5
X       90/.912/.805/.835/.924/.905/.803/.855/.646/.720/.309/.963/.910/.93
X       4/.931/.977/.953/.959/.828/.750/.460/.820/.949/.833/.684/.813/.883
X       /.973/.892/.989/.976/.985/.917/.975/.923/.884/.787/.831/.646/.942/
X       .917/.922/.955/.887/.895/.831/.879/.724/.859/.767/.859/.691
T        CRDT=.948/.982/.949/.801/.818/.430/.925/.936/.955/.935/.969/.925/
X       .914/.977/.971/.890/.821/.821/.983/.974/.953/.899/.934/.973/.910/.
X       971/.920/.852/.836/.607/.881/.848/.943/.874/.838/.831/.927/.948/.9
X       84/.932/.991/,960/.914/.919/.868/.978/.988/.960/.992/.983/.996/.99
X       4/.934/.993/.982/.976/.969/.900/.899/.715/.835/.918/.916/.829/.770
X       /.963/.939/.705/.739/.965/.978/.986/.980/.979/.985/.990/.984/.977/
X       .674/.769/.956/.945/.984/.989/.992/.976/.979/.932/.632/.811
T        DRDT=.974/.994/.987/.978/.971/.938/.953/.847/.931/.987/.994/.990/
X       .949/.949/.947/.984/.984/.987/.992/.993/.940/.985/.984/.991/.928/.
X       949/.843/.842/.983/.991/.981/.978/.919/.883/.922/.936/.891/.959/.9
X       68/.981/.982/.981/.985/.987/.920/.933/.943/.982/.987/.968/.963/.78
X       0/.848/.839/.943/.671/.979/.928/.712/.848/.738/.462/.649/.863/.879
X       /.446/.746/.790/.925/.862/.822/.672/.939/.863/.641/.615/.709/.845/
X       .868/.947/.704/.732/.973/.760/.972/.904/.766/.867/.800/.905
R       YRIN1.KL=XRIN.K
N       YRIN1=0
A       YRIN.K=YRIN1.JK
N       YRIN=1
NOTE
NOTE    DOWNSTREAM HYDROLOGY
NOTE    CHANNEL IN AT ALBANY
NOTE
NOTE       CHANNEL INPUT - CFD
R       CIN.KL=(CIN1.K)(86400)
A       CIN1.K=CLIP(FCIN2.K,0,FCIN2.K,0)
NOTE       PEARSON III DISTRIBUTION FLOW - CFS
A       FCIN1.K=EXP(LGCIN.K)
NOTE       LOW FLOW ADJUSTMENT CONSTANT
A       CCN.K=CLIP(0,15,KCIN.K,0)
A       FCIN2.K=FCIN5.K-(RIN.JK/86400)-CON.K
A       FCIN5.K=CLIP(FCIN1.K,FRIN3.K,FCIN1.K,FRIN3.K)
A       LGCIN.K=MCIN1.K+KC.K
A       KC.K=(KC1.K)(SCIN1.K)
NOTE       PEARSON III DEVIATE DIVIDED BY STREAM COEFFICIENT
A       KC1.K=CLIP(KC2.K,KC3.K,KCIN.K,0)
NOTE       DOWNSTREAM COEFFICIENTS
A       KC2.K=KCIN.K/1.22
A       KC3.K=KCIN.K/1.45
NOTE       DOWNSTREAM DAILY MEANS - LOG
A       MCIN1.K=CLIP(ACM.K,ACMX.K,90,DAY.K)
A       ACMX.K=CLIP(BCM.K,BCMX.K,180,DAY.K)
A       BCMX.K=CLIP(CCM.K,DCM.K,270,DAY.K)
A       ACM.K=TABHL(ACMT,SEA.K,1,90,1)
A       BCM.K=TABHL(BCMT,SEA.K,1,90,1)
A       CCM.K=TABHL(CCMT,SEA.K,1,90,1)
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A       DCM.K=TABHL(DCMT,SEA.K,1,90,1)
T        ACMT=3.948/3.914/3.931/3.945/4.000/4.035/4.063/4.077/4.134/4.198/
X       4.214/4.655/4.962/4.593/4.504/4.434/4.465/4.433/4.491/4.572/4.836/
X       5.791/6.065/5.727/5.423/5.198/5.052/4.984/5.032/5.069/5.294/5.189/
X       5.257/5.301/5.262/5.229/5.257/5.281/5.300/5.266/5.334/5.504/5.677/
X       5.983/6.247/6.367/6.656/6.342/6.205/6.175/6.059/6.118/6.339/7.189/
X       8.110/7.790/7.337/7.108/6.852/6.691/6.786/6.820/6.755/6.719/6.670/
X       6.640/6.634/6.647/6.544/6.795/7.098/7.606/7.332/7.130/6.961/6.796/
X       6.665/6.580/6.624/6.715/6.942/7.339/7.995/8.463/8.244/7.871/7.563/
X       7.363/7.234/7.390
T        BCMT=7.080/6.943/6.855/6.742/6.653/6.774/6.953/7.221/7.523/7.757/
X       7.571/7.332/7.095/6.973/6.821/6.772/6.911/7.199/7.660/8.152/8.412/
X       8.082/7.758/7.542/7.357/7.169/7.019/6.896/6.833/6.853/7.179/7.299/
X       7.064/6.918/6.899/6.986/7.209/7.606/8.152/8.599/8.396/8.062/7.811/
X       7.573/7.354/7.061/7.051/7.066/7.387/7.650/7.473/7.257/7.118/6.912/
X       6.733/6.610/6.582/6.754/6.943/6.921/6.813/6.777/6.842/7.018/7.364/
X       7.235/7.066/6.886/6.813/6.686/6.638/6.629/6.630/6.729/6.985/7.284/
X       7.713/8.077/7.876/7.627/7.373/7.202/7.009/6.931/6.735/6.661/6.631/
X       6.705/6.992/7.292
T        CCMT=7.005/6.849/6.753/6.649/6.736/6.877/7.115/7.318/7.156/6.960/
X       6.843/6.756/6.628/6.512/6.429/6.349/6.480/6.687/6.925/6.794/6.649/
X       6.483/6.316/6.228/6.192/6.164/6.213/6.264/6.364/6.312/6.284/6.262/
X       6.244/6.249/6.394/6.685/6.935/6.746/6.507/6.389/6.296/6.194/6.105/
X       6.121/6.214/6.400/6.278/6.137/6.057/5.999/5.932/5.870/5.809/5.759/
X       5.730/5.702/5.669/5.622/5.628/5.706/5.783/5.728/5.667/5.635/5.581/
X       5.565/5.545/5.576/5.726/5.985/5.836/5.718/5.625/5.536/5.469/5.404/
X       5.355/5.308/5.304/5.383/5.575/5.458/5.377/5.315/5.269/5.228/5.203/
X       5.173/5.259/5.258
T        DCMT=5.128/5.101/5.066/5.025/4.993/4.986/4.959/4.939/4.925/4.885/
X       4.851/4.826/4.804/4.795/4.783/4.755/4.727/4.692/4.655/4.624/4.604/
X       4.580/4.558/4.544/4.578/4.549/4.553/4.544/4.519/4.493/4.412/4.404/
X       4.394/4.405/4.390/4.382/4.384/4.379/4.355/4.335/4.310/4.297/4.290/
X       4.272/4.259/4.251/4.234/4.213/4.195/4.170/4.151/4.147/4.158/4.141/
X       4.113/4.087/4.030/3.980/3.944/3.898/3.828/3.789/3.793/3.800/3.842/
X       3.796/3.737/3.800/3.798/3.779/3.770/3.794/3.786/3.774/3.788/3.876/
X       3.903/3.927/4.039/3.984/3.919/3.883/3.894/3.940/3.886/3.853/3.800/
X       3.932/3.945/3.945
NOTE        DOWNSTREAM DAILY STANDARD DEVIATIONS - LOG
A       SCIN1.K=CLIP(ACS.K,ACSX.K,90,DAY.K)
A       ACSX.K=CLIP(BCS.K,BCSX.K,180,DAY.K)
A       BCSX.K=CLIP(CCS.K,DCS.K,270,DAY.K)
A       ACS.K=TABHL(ACST,SEA.K,1,90,1)
A       BCS.K=TABHL(BCST,SEA.K,1,90,1)
A       CCS.K=TABHL(CCST,SEA.K,1,90,1)
A       DCS.K=TABHL(DCST,SEA.K,1,90,1)
T        ACST=.490/.475/.512/.507/.486/.572/.585/.624/.688/.735/.830/1.022
X       /1.078/.991/.909/.832/.891/.965/1.108/1.209/1.286/1.366/1.334/1.29
X       3/1.293/1.152/1.126/1.128/1.196/1.371/1.352/1.474/1.441/1.266/1.19
X       1/1.171/1.082/1.041/1.007/1.010/.969/.956/1.109/1.043/1.013/1.073/
X       1.148/1.128/1.099/1.021/1.039/1.141/1.168/1.405/1.197/1.293/1.347/
X       1.203/1.190/1.309/1.339/1.365/1.397/1.249/1.098/1.015/.939/.926/.9
X       14/.931/.964/.789/.774/.761/.740/.741/.713/.745/.803/.948/1.040/1.
X       074/1.035/1.053/1.007/.961/.874/.878/.897/.852
T        BCST=.921/.984/.871/.791/.655/.750/.827/.822/.924/.960/.937/.816/
X       .731/.692/.682/.722/.837/.930/.891/.947/.942/.905/.830/.799/.757/.
X       723/.712/.719/.770/.840/.885/.823/.669/.590/.494/.512/.556/.541/.6
X       59/.761/.700/.609/.589/.608/.628/.661/.654/.570/.714/.807/.781/.70
X       0/.658/.587/.535/.534/.534/.589/.813/.687/.621/.583/.600/.659/.672
X       /.643/.657/.613/.603/.585/.579/.621/.648/.753/.769/.797/.878/.690/
X       .675/.676/.677/.659/.652/.600/.567/.539/.571/.610/.805/.958
T        CCST=.780/.685/.599/.483/.492/.558/.640/.659/.658/.591/.564/.521/
X       .481/.475/.509/.490/.592/.667/.751/.707/.652/.604/.544/.476/.452/.
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X       460/.474/.527/.535/.488/.487/.532/.528/.551/.734/.922/.950/.847/.6
X       83/.518/.560/.557/.520/.572/.624/.689/.699/.617/.611/.602/.585/.54
X       0/.535/.527/.521/.545/.533/.542/.501/.596/.505/.442/.405/.386/.379
X       /.382/.409/.442/.538/.609/.560/.499/.447/.399/.366/.353/.337/.323/
X       .334/.367/.453/.394/.346/.331/.314/.305/.297/.281/.463/.440
T        DCST=.390/.357/.325/.327/.303/.297/.306/.304/.311/.313/.309/.310/
X       .302/.304/.319/.302/.294/.281/.273/.268/.262/.263/.253/.250/.272/.
X       323/.391/.408/.365/.334/.287/.289/.287/.293/.289/.288/.298/.309/.2
X       99/.287/.282/.276/.268/.264/.264/.270/.281/.267/.263/.259/.257/.26
X       3/.304/.327/.330/.337/.319/.286/.281/.300/.250/.292/.300/.339/.453
X       /.404/.323/.361/.370/.345/.340/.383/.362/.361/.473/.495/.593/.560/
X       .556/.491/.442/.427/.549/.507/.527/.484/.452/.675/.612/.600
NOTE       DOWNSTREAM DAILY SKEW - LOG
A       GCIN2.K=GCIN1.K/6
A       GCIN1.K=CLIP(ACG.K,ACGX.K,90,DAY.K)
A       ACGX.K=CLIP(BCG.K,BCGX.K,180,DAY.K)
A       BCGX.K=CLIP(CCG.K,DCG.K,270,DAY.K)
A       ACG.K=TABHL(ACGT,SEA.K,1,90,1)
A       BCG.K=TABHL(BCGT,SEA.K,1,90,1)
A       CCG.K=TABHL(CCGT,SEA.K,1,90,1)
A       DCG.K=TABHL(DCGT,SEA.K,1,90,1)
T        ACGT=1.075/.466/.723/.525/.405/.275/.423/.507/.598/.662/.410/.430
X       /.140/.178/.233/.220/.536/.797/1.293/1.409/.974/.402/-.142/-.075/-
X       .060/-.051/.053/.414/.889/1.587/1.185/.909/.661/.877/.748/.342/.45
X       7/-.107/-.230/-.257/-.202/-.604/-1.013/-.200/.174/-.410/-.593/-.62
X       7/-.724/-.556/-.513/-.552/-.456/-.595/-1.173/-1.837/-1.439/-1.494/
X       -1.126/-1.044/-.532/-.585/-.541/-.297/.078/.061/.099/.227/.346/.06
X       8/-.170/-.088/-.268/-.343/-.389/-.497/-.367/-.049/.147/.229/.142/-
X       .106/-.431/-.400/-.419/-.242/-.092/.208/.348/.416
T        BCGT=1.086/1.087/.644/.457/-.121/-.008/-.038/-.203/-.498/-.564/-.
X       396/-.295/.038/.260/.574/.647/.566/.220/-.291/-.200/-.658/-.785/-.
X       525/-.647/-.447/-.223/-.028/.162/.199/.591/.263/-.242/-.263/-.276/
X       .065/.254/-.159/-.646/-.966/-.653/-1.290/-1.485/-.969/-.009/.323/.
X       585/.547/.195/-.327/-.488/-.321/-.310/-.208/-.157/.121/.228/.452/.
X       366/.593/.169/.199/.489/.283/-.156/-.508/-.455/-.519/-.719/-.605/-
X       .106/.187/.493/.736/.727/.325/-.239/-.858/-.498/-.421/-.411/-.399/
X       -.352/-.186/-.128/.122/-.230/-.152/.099/.308/.203
T        CCGT=.056/.271/.306/.112/-.005/-.115/-.197/-.156/-.173/-.413/-.38
X       3/-.444/-.659/-.416/.059/.520/.767/.210/-.269/-.288/-.277/-.048/-.
X       091/-.026/-.043/-.123/-.166/.282/-.148/-.610/-.508/.239/.770/.609/
X       .888/.627/.273/.149/.071/-.153/0.019/.018/-.095/.184/.432/.081/.08
X       9/-.118/-.009/-.006/.053/-.106/-.040/.052/.116/.276/.291/.335/.053
X       /.624/.451/.550/.506/.243/.378/.360/.526/.326/.051/.198/.189/.094/
X       -.027/-.240/-.313/-.245/-.195/-.041/.025/-.019/-.100/-.351/-.373/-
X       .366/-.337/-.315/-.197/-.281/2.132/1.346
T        DCGT=.857/.453/.250/.141/.105/-.006/.090/.067/.093/.227/.448/.378
X       /.102/-.104/.035/.255/.528/.360/.260/.227/.235/.169/.309/.326/.220
X       /.663/1.352/1.567/.935/.679/.057/.090/.079/.005/-.081/-.113/-.037/
X       .15/.031/-.03/-.015/.065/.128/.111/.058/-.019/.214/.106/.061/.045/
X       -.053/-.078/.252/.857/.752/1.405/1.416/.934/.495/.964/.019/.998/1.
X       529/1.793/3.034/2.673/2.405/1.738/1.893/1.461/1.477/.880/.633/1.10
X       2/1.947/1.561/2.046/1.852/1.037/1.147/1.231/1.471/2.091/1.370/1.32
X       8/1.360/1.363/2.323/1.904/1.414
NOTE       CONVERSION OF STANDARD NORMAL TO PEARSON III DEVIATE
A       GCIN3.K=XCIN.K-GCIN2.K
A       GCIN4.K=1+(GCIN2.K)(GCIN3.K)
A       GCIN5.K=(GCIN4.K)(GCIN4.K)(GCIN4.K)
A       GCIN6.K=1/((3)(GCIN2.K))
A       KCN.K=(GCIN6.K)(GCIN5.K-1)
A       PKCN.K=-2/GCIN1.K
NOTE       PEARSON III DEVIATE
A       KCIN.K=SWITCH(XCIN.K,KCN1.K,GCIN1.K)
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A       KCN2.K=KCN.K-PKCN.K
A       KCN3.K=CLIP(KCN.K,PKCN.K,KCN2.K,0)
A       KCN4.K=CLIP(KCN.K,PKCN.K,-KCN2.K;0)
A       KCN1.K=CLIP(KCN3.K,KCN4.K,GCIN1.K,0)
NOTE        STANDARD NORMAL DEVIATE
A       XCIN.K=(1)(B2CIN.K)(YCIN.K)+(1)(B3CIN.K)(XRIN.K)+(1)(DCIN2.K)(NAST
X       1.K)
A       DCIN3.K=1-DCIN1.K
A       DCIN2.K=1.*SQRT(DCIN3.K)
NOTE        REGRESSION COEFFICIENT PREVIOUS DOWNSTREAM
A       B2CIN.K=CLIP(ACB2.K,ACB2X.K,90,DAY.K)
A       ACB2X.K=CLIP(BCB2.K,BCB2X.K,180,DAY.K)
A       BCB2X.K=CLIP(CCB2.K,DCB2.K,270,DAY.K)
A       ACB2.K=TABHL(ACB2T,SEA.K,1,90,1)
A       BCB2.K=TABHL(BCB2T,SEA.K,1,90,1)
A       CCB2.K=TABHL(CCB2T,SEA.K,1,90,1)
A       DCB2.K=TABHL(DCB2T,SEA.K,1,90,1)
T        ACB2T=.772/.408/.418/.708/.645/.366/.853/.870/.818/.707/.648/.691
X       /.247/.656/.749/.630/.376/.682/.467/1.018/.782/.581/.162/.696/.733
X       /.480/.642/.579/.394/.666/.184/.927/.622/.850/.833/.826/.564/.594/
X       .715/.822/.849/.706/.621/.710/.903/.208/.994/.702/.812/.450/.940/.
X       849/.892/.669/.354/0.952/.588/.680/.967/.778/.230/.674/.697/.764/.
X       591/.623/.877/.760/.903/.905/.764/.551/.984/.846/.759/.766/.672/.8
X       56/.389/.903/.827/.586/.640/.435/.894/.821/.941/.876/.923/.743
T        BCB2T=.559/.762/.895/.849/.724/.796/.634/.935/.528/.792/.976/.823
X       /.774/.918/.918/.716/.826/.751/.532/.614/.703/.604/.681/.951/1.009
X       /1.039/.945/.823/.538/.654/.162/.298/.823/.985/.902/.876/.742/.652
X       /.591/.283/.937/.657/.894/.980/.907/.837/.852/.774/.471/.748/.973/
X       1.065/.930/.757/.676/.633/.559/.656/.181/.363/.735/.662/.670/.868/
X       .566/.921/.904/.694/.692/.291/.926/.849/.761/.996/.822/.832/.684/.
X       568/.949/.842/.638/.747/.708/.784/.820/.795/.761/.628/.487/.748
T        CCB2T=.716/.735/1.017/.695/.538/.598/.475/.516/.886/.790/.824/.89
X       3/.835/.733/.952/.660/.743/.646/.780/.964/.901/.742/.499/.667/.906
X       /.852/.501/.703/.600/.820/.743/.858/.922/.842/.540/.494/.345/.804/
X       .783/.842/.773/.874/.893/.663/.807/.576/.941/.716/.773/.926/.975/.
X       834/.870/.901/.969/.735/.952/.950/.713/.510/.235/.587/.766/.857/.8
X       60/.656/.621/.825/.540/.140/.480/.789/1.065/.965/.834/.948/.923/1.
X       134/.791/.622/.268/.601/.520/.996/1.094/1.017/.939/.734/.579/.380
T        DCB2T=.683/.962/.990/1.014/.908/.893/.867/.723/.951/.864/.906/1.0
X       19/.942/.858/.851/.878/.991/1.038/1.033/1.040/1.017/1.004/.960/.99
X       3/.798/.841/1.004/1.026/.942/.965/.736/.964/.961/.869/1.042/.866/.
X       828/.980/.974/1.038/1.039/1.007/.992/.996/1.021/.960/.982/.996/.98
X       7/.999/1.004/.913/.748/.850/.890/.871/.995/.980/.849/.953/1.016/.7
X       96/.853/.839/.016/.897/.602/.723/.859/.602/.617/.384/.817/.825/.99
X       2/.537/.664/.511/.632/.615/.810/.812/.529/.062/.940/.922/.684/.320
X       /.285/.555
NOTE        REGRESSION COEFFICIENT TODAY≠S UPSTREAM
A       B3CIN.K=CLIP(ACB3.K,ACB3X.K,90,DAY.K)
A       ACB3X.K=CLIP(BCB3.K,BCB3X.K,180,DAY.K)
A       BCB3X.K=CLIP(CCB3.K,DCB3.K,270,DAY.K)
A       ACB3.K=TABHL(ACB3T,SEA.K,1,90,1)
A       BCB3.K=TABHL(BCB3T,SEA.K,1,90,1)
A       CCB3.K=TABHL(CCB3T,SEA.K,1,90,1)
A       DCB3.K=TABHL(DCB3T,SEA.K,1,90,1)
T        ACB3T=.105/.606/.568/.268/.356/.630/.149/.124/.179/.296/.344/.302
X       /.742/.322/.247/.363/.628/.317/.522/-.031/.220/.394/.833/.303/.268
X       /.516/.361/.424/.615/.228/.836/.061/.399/.165/.175/.145/.476/.415/
X       .293/.183/.132/.246/.297/.283/.083/.737/-.002/.281/.189/.545/.038/
X       .139/.054/.287/.61/-.084/.407/.202/-.001/.233/.762/.339/.311/.245/
X       .418/.362/.109/.263/.095/.067/.206/.454/-.003/.153/.235/.242/.307/
X       .149/.595/.068/.135/.380/.296/.577/.100/.150/.055/.129/.069/.259
T        BCB3T=.450/.185/.111/.152/.281/.165/.343/-.001/.471/.166/.019/.18
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X       3/.133/.083/.054/.257/.108/.170/.448/.372/.299/.413/.298/.037/-.02
X       7/-.068/.046/.182/.480/.359/.809/.700/.080/-.010/-.000/.052/.025/.
X       316/.331/.591/-.004/.310/.045/-.023/.101/-.041/.166/.158/.486/.233
X       /.001/-.132/.069/.253/.328/.351/.435/.237/.797/.593/.236/.309/.260
X       /.093/.321/.094/.100/.325/.324/.701/.067/.143/.221/-.016/.154/.195
X       /.317/.392/.037/.142/.379/.262/.284/.196/.161/.169/.211/.344/.444/
X       .143
T        CCB3T=.29/.253/-.025/.288/.493/.373/.555/.477/.117/.196/.177/.112
X       /.164/.276/.026/.322/.247/.384/.176/.033/.064/.273/.516/.322/.077/
X       .151/.494/.270/.393/.208/.271/.143/.079/.151/.474/.502/.660/.203/.
X       220/.163/.228/.123/.112/.292/.184/.316/.064/.312/.237/.075/.018/.1
X       71/.129/.104/.030/.258/.048/.045/.282/.500/.780/.413/.236/.156/.13
X       9/.357/.376/.199/.499/.858/.517/.205/-.073/.134/.170/.048/.080/-.1
X       62/.221/.364/.751/.395/.469/-.015/-.105/-.026/.065/.295/.344/.679
T        DCB3T=.327/.029/.002/-.024/.071/.101/.126/.289/.027/.146/.094/-.0
X       23/.058/.151/.149/.122/-.006/-.054/-.047/-.056/-.028/-.013/.042/-.
X       037/.222/.169/-.021/-.039/.058/.026/.180/.036/.030/.154/-.070/.145
X       /.137/.016/.009/-.058/-.061/-.014/.008/.003/-.048/.043/.019/.002/.
X       015/-.000/-.010/.100/.266/.134/.112/.139/-.018/.025/.173/.051/-.04
X       8/.211/.026/.200/.775/.092/.471/.273/.145/.429/.373/.392/.182/.147
X       /-.057/.354/.218/.560/.332/.426/.184/.231/.465/.907/.056/.071/.276
X       /.710/.719/.429
NOTE       DOWNSTREAM CORRELATION COEFFICIENT
A       DCIN1.K=CLIP(ACD.K,ACDX.K,90,DAY.K)
A       ACDX.K=CLIP(BCD.K,BCDX.K,180,DAY.K)
A       BCDX.K=CLIP(CCD.K,DCD.K,270,DAY.K)
A       ACD.K=TABHL(ACDT,SEA.K,1,90,1)
A       BCD.K=TABHL(BCDT,SEA.K,1,90,1)
A       CCD.K=TABHL(CCDT,SEA.K,1,90,1)
A       DCD.K=TABHL(DCDT,SEA.K,1,90,1)
T        ACDT=.713/.842/.904/.894/.915/.931/.984/.965/.966/.963/.926/.879/
X       .965/.963/.976/.962/.982/.985/.963/.977/.927/.886/.961/.982/.991/.
X       981/.986/.979/.980/.781/.978/.964/.965/.987/.948/.900/.963/.973/.9
X       82/.989/.938/.845/.763/.835/.939/.830/.983/.930/.972/.914/.950/.92
X       5/.857/.786/.802/.809/.863/.706/.934/.963/.934/.975/.976/.986/.979
X       /.943/.936/.966/.969/.918/.841/.870/.962/.956/.939/.964/.905/.973/
X       .923/.932/.888/.880/.830/.953/.972/.921/.982/.984/.968/.952
T        BCDT=.939/.864/.976/.937/.925/.880/.876/.873/.851/.870/.961/.970/
X       .871/.973/.925/.866/.842/.760/.783/.885/.938/.965/.923/.969/.969/.
X       963/.968/.907/.878/.927/.885/.916/.801/.956/.813/.828/.572/.674/.7
X       18/.851/.873/.829/.854/.927/.947/.663/.832/.717/.789/.903/.948/.93
X       6/.953/.888/.894/.902/.928/.728/.920/.883/.904/.856/.782/.862/.638
X       /.970/.969/.955/.980/.953/.977/.961/.924/.966/.881/.954/.909/.832/
X       .962/.933/.959/.944/.932/.925/.913/.866/.870/.866/.782/.765
T        CCDT=.969/.952/.990/.871/.884/.770/.925/.922/.987/.959/.976/.991/
X       .957/.953/.950/.878/.919/.950/.883/.985/.915/.937/.930/.933/.950/.
X       979/.926/.905/.894/.938/.951/.950/.974/.951/.912/.901/.964/.993/.9
X       83/.986/.977/.979/.993/.875/.927/.747/.987/.983/.991/.990/.984/.98
X       6/.983/.997/.995/.970/.992/.976/.928/.870/.946/.969/.977/.984/.976
X       /.965/.950/.969/.901/.966/.980/.982/.987/.984/.989/.987/.993/.984/
X       .918/.844/.953/.961/.959/.964/.990/.987/.992/.983/.705/.983
T        DCDT=.969/.979/.983/.984/.947/.963/.954/.932/.949/.967/.970/.990/
X       .981/.962/.953/.964/.973/.988/.990/.990/.993/.989/.982/.976/.947/.
X       956/.979/.990/.980/.972/.781/.984/.967/.969/.985/.947/.937/.985/.9
X       63/.989/.993/.997/.993/.997/.980/.980/.990/.995/.993/.997/.995/.94
X       3/.832/.906/.945/.910/.969/.989/.926/.967/.956/.917/.749/.947/.621
X       /.878/.883/.853/.956/.917/.868/.553/.908/.881/.914/.672/.634/.857/
X       .792/.954/.900/.957/.891/.919/.986/.978/.846/.920/.955/.927
R       YCIN1.KL=XCIN.K
N       YCIN1=0
A       YCIN.K=YCIN1.JK
N       YCIN=1
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R       NBST1.KL=NDST1.K
N       NBST1=0
NOTE       DOWNSTREAM RANDOM STANDARD NORMAL DEVIATE
A       NAST1.K=NBST1.JK
N       NAST1=1
R       FRIN4.KL=FRIN1.K
N       FRIN4=0
A       FRIN3.K=FRIN4.JK
NOTE
NOTE    RESERVOIR AND CHANNEL LEVEL
NOTE
NOTE       ACTUAL RESERVOIR LEVEL - AF
L       RLVA.K=RLVA.J+(DT)(1/43560)(RIN.JK-ROUT.JK-IROUT.JK-EVAPO.JK-MIOUT
X       .JK)
N       RLVA=109333
NOTE       ACTUAL CHANNEL LEVEL - CFD
L       CLVA.K=CLVA.J+(DT)(LROUT.JK+CIN.JK+IRRIN.JK-COUT.JK+LMIOUT.JK)
N       CLVA=11232E3
R       EVAPO.KL=EVAP1.K
NOTE       EVAPORATION - CFD
A       EVAP1.K=(EVAP2.K)(43560)
A       EVAP2.K=(EVAP3.K)(RSA1.K)/(1000)
NOTE       EVAPORATION PERIOD
A       EVAP3.K=CLIP(0,EVAP4.K,181,DAYS.K)
A       EVAP4.K=TABHL(EVAP,DAYS.K,182,377,15)
T       EVAP=4/6/8/10/11/12/16/17.2/16/14/12/9.2/6.4/5
NOTE       RESERVOIR SURFACE - ACRES
A       RSA1.K=TABHL(RSA,RLVA.K,0,200000,20000)
T       RSA=0/800/1225/1580/1875/2150/2400/2625/2825/3000/3200
NOTE
NOTE    RESERVOIR RELEASES
NOTE
NOTE       LAGGED RELEASE - CFD
R       LROUT.KL=ROUT.JK
NOTE       RULE RELEASE OR SPILL CAPACITY - CFD
A       ROUT1.K=CLIP(SPICP.K,RWOPC.K,RWOPC.K,SPICP.K)
NOTE       CHANNEL LEVEL CHECK
A       ROUT2.K=CLIP(0,ROUT3.K,CLVAS.K,CCAP.K)
NOTE       RESERVOIR LEVEL CHECK
A       ROUT4.K=CLIP(RIN.JK,ROUT2.K,RLVA.K,RCAP.K)
NOTE       RELEASE - CFD
R       ROUT.KL=CLIP(ROUT4.K,432E4,ROUT4.K,432E4)
N       ROUT=11232E3
NOTE       MAX CHANNEL RELEASE - CFD
A       RWOPC.K=CLIP(RWOP.K,CDLC.K,CDLC.K,RWOP.K)
NOTE       ACTUAL CHANNEL CAPACITY - CFD
A       CDLC.K=CLIP(CCPLA.K,0,DCHLV.K,CLVA.K)
NOTE       SPACE IN CHANNEL - CFD
A       CCPLA.K=DCHLV.K-CLVA.K
NOTE       CHANNEL SAFETY FACTOR - CFD
A       SAFNO.K=SAFNU
C       SAFNU=1296E+05
NOTE       SPILL PORT CAPACITY - CFD
A       SPICP.K=SPICA
C       SPICA=38016E+04
NOTE       DESIRED DAILY CHANNEL CAPACITY - CFD
A       DCHLV.K=CCAPD.K-SAFNO.K
NOTE       RULE CURVE PROPORTION
A       RWOPP.K=TABHL(WOPT,DAYS.K,1,361,15)
T       WOPT=.754/.656/.553/.449/.348/.348/.348/.348/.348/.449/.553/.645/.
X       754/.855/.960/.960/.960/.960/.960/.960/.960/.960/.960/.855/.754
NOTE       DESIRED RESERVOIR LEVEL - AF
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A       RWOPL.K=(RCAP.K)(RWOPP.K)
NOTE       DIFFERENCE OF ACTUAL RES LEVEL AND DESIRED - CFO
A       RWOPA.K=(RLVA.K)(43560)+(-RWOPL.K)(43560)
NOTE       RULE RELEASE - CFD
A       RWOP.K=CLIP(RWOPA.K,0,RLVA.K,RWOPL.K)
NOTE       MAX RULE RELEASE OR FISH REQUIREMENT - CFD
A       ROUT3.K=MAX(ROUT1.K,MINXX.K)
A       MINXX.K=(RMFF.K)(86400)
NOTE       FISH REQUIREMENT - CFS
A       RMFF.K=TABHL(RMFT,DAYS.K,1,361,15)
T       RMFT=130/130/130/130/130/130/75/75/40/40/70/70/105/105/130/130/160
X       /160/160/160/160/160/130/130/130
NOTE
NOTE    ANAD FISH RES REARING
NOTE
NOTE       SURFACE AREA - ACRES
A       RSA2.K=TABHL(RSA,RLVA.K,0,200000,20000)
NOTE       STOCKING RATE
A       STOCK.K=TABHL(STK,RSA2.K,1425,2400,975)
T       STK=891/1500
A       STOCKR.K=PULSE(STOCK.K,195,360)
NOTE       SURVIVAL OF FRY TO SMOLTS
A       SMS.K=(SUPR.K)(STOCKR.K)(RSA1.K)
NOTE
NOTE    FRY SURVIVAL
NOTE
A       R1.K=NOISE()
A       R.K=CLIP(2.*R1.K,-2.*R1.K,R1.K,0+
A       SUPR.K=TABHL(SURT,R.K,0,1,1)
NOTE       SURVIVAL RATE OF FRY TO SMOLTS
T       SURT=0/.22
NOTE
NOTE    SMOLT SURVIVAL
NOTE
A       RR1.K=NOISE()
A       RR.K=CLIP(2.*RR1.K,-2.*RR1.K,RR1.K,0)
NOTE       SURVIVAL RATE OF SMOLTS TO RETURNEES
A       SUSR.K=TABHL(SUST,RR.K,0,1,1)
T       SUST=0/.018
NOTE       POTENTIAL SPAWNERS
R       FBACK.KL=SUSR.K*SMS.K
L       FBACK1.K=FBACK1.J+(DT)(FBACK.JK-FBACKO.JK)
N       FBACK1=0
R       FBACKO.KL=PULSE(FBACK1.K,555,360)
A       FBACK2.K=FBACK1.K/360
NOTE       DELAYED RETURNEES
R       ESC.KL=DELAY3(FBACK2.K,1080)
NOTE       ANNUAL ESCAPEMENT
L       AESC.K=AESC.J+(DT)(ESC.JK-ESCO.JK)
N       AESC=0
R       ESCO.KL=PULSE(AESC.K,360,360)
NOTE
NOTE    PROJ ESCAPEMENT AND BENEFITS
NOTE
NOTE       PROJECT ESCAPEMENT
A       PESC1.K=CLIP(AFSC.K-300,0,DAYS.K,360)
A       PESC.K=CLIP(PESC1.K,0,PESC1.K,0)
NOTE       RESERVOIR SPRING CHINOOK BENEFITS
A       SCHRB.K=(PESC.K)(39.385)
NOTE       BENEFITS DISCOUNTED
R       PVALSC.KL=(PVF.K)(SCHRB.K)
NOTE       ACCUM ANNUAL BENEFITS DISCOUNTED
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L       AASCHB.K=AASCHB.J+(DT)(PVALSC.JK+0)
N       AASCHB=0
NOTE
NOTE    RESERVOIR RESIDENT FISH
NOTE
NOTE       DAILY RESERVOIR ANGLER DAYS
A       RATND.K=TABHL(RATNDT,LNBCH.K,0,8000,400)
T       RATNDT=0/214/203/192/181/170/159/148/137/126/115/104/93/82/71/60/4
X       9/38/27/16/5
R       RRATE2.KL=RATND.K
NOTE       ANNUAL RESERVOIR ANGLER DAYS
L       ARFUD.K=ARFUD.J+(DT)(RRATE2.JK-RRATE4.JK)
N       ARFUD=0
R       RRATE4.KL=PULSE(ARFUD.K,361,360)
A       RFIB1.K=(ARFUD.K)(VALRF.K)
NOTE       ANNUAL VALUE RESERVOIR ANGLER DAYS
A       RFIB.K=PULSE(RFIB1.K,361,360)
A       VALRF.K=VAL1
NOTE       VALUE PER ANGLER DAY
C       VAL1=3
NOTE
NOTE    DOWNSTREAM RESIDENT FISH
NOTE
NOTE       DAILY STREAM ANGLER DAYS
A       SATND.K=TABHL(SATNDT,CLVAS.K,0,5000,625)
T       SATNDT=0/10/20/16.6/13.3/10/6.7/3.3/0
R       SRATE2.KL=SATND.K
NOTE       ANNUAL STREAM ANGLER DAYS
L       ASFUD.K=ASFUD.J+(DT)(SRATE2.JK-SRATE4.JK)
N       ASFUD=0
R       SRATE4.KL=PULSE(ASFUD.K,361,360)
NOTE       ANNUAL VALUE STREAM ANGLER DAYS
A       SFIB1.K=(ASFUD.K)(VALSF.K)
A       SFIB.K=PULSE(SFIB1.K,361,360)
A       VALSF.K=VAL2
NOTE       VALUE PER ANGLER DAY
C       VAL2=3
NOTE       TOTAL RESIDENT FISHING VALUE
A       TRFIB.K=RFIB.K+SFIB.K
NOTE
NOTE  ACCUM RESIDENT FISH BENEFITS
NOTE
NOTE       PRESENT VALUE OF RESIDENT FISHING BENEFITS
R       PVARFIB.KL=(TRFIB.K)(PVF1.JK)
NOTE       ACCUM ANNUAL RESIDENT FISHING BENEFITS
L       AARFIB.K=AARFIB.J+(DT)(PVARFIB.JK+0)
N       AARFIB=0
NOTE
NOTE    PRESENT VALUE FACTOR
NOTE
NOTE       INTEREST RATE
C       INTRA=.04875
A       INT1.K=INTRA
A       INT2.K=1+INT1.K
A       PV1.K=YEARS.K*LOGN(INT2.K)
A       PV2.K=1.*EXP(PV1.K)
NOTE       PRESENT VALUE FACTOR
A       PVF.K=1/PV2.K
R       PVF1.KL=PVF.K
NOTE       AMMORTIZATION FACTOR
A       INT7.K=(50)LOGN(INT2.K)
A       INT8.K=EXP(INT7.K)
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A       AMORT.K=(INT1.K)(INT8.K)/(INT8.K-1)
NOTE
NOTE    MUNICIPAL AND INDUSTRIAL WATER RELEASES
NOTE
NOTE       MONTHLY NEED - AF
A       MMID.K=TABHL(MIDT,YEARS.K,1,121,30)
T       MIDT=42/92/92/92/92
NOTE       DAILY NEED - AF
A       DMID.K=(MMID.K)(MIFT.JK)/(30)
NOTE       RELEASE - CFD
R       MIOUT.KL=(DMID.K)(43560)
NOTE       MONTHLY DISTRIBUTION FACTOR
R       MIFT.KL=SAMPLE(MIFTT.K,30,.79)
A       MIFTT.K=TABHL(MIFTB,DAYS.K,0,360,30)
T       MIFTB=.79/.76/.74/.70/.68/.69/.75/1.05/1.66/1.91/1.38/.89/.79
R       MIB.KL=(DMID.K)(VALMI.K)
A       VALMI.K=VAL4
NOTE       VALUE PER - AF
C       VAL4=40
NOTE       ANNUAL BENEFITS
L       AMIB.K=AMIB.J+(DT)(MIB.JK-AMIO.JK)
N       AMIB=0
R       AMIO.KL=PULSE(AMIB.K,361,360)
A       YMIB.K=PULSE(AMIB.K,361,360)
NOTE       ANNUAL DISCOUNTED BENEFITS
R       PVYMIB.KL=(YMIB.K)(PVF1.JK)
NOTE       ACCUM ANNUAL DISCOUNTED BENEFITS
L       AAMIB.K=AAMIB.J+(DT)(PVYMIB.JK+0)
N       AAMIB=0
NOTE       LAGGED RELEASE - CFD
R       LMIOUT.KL=MIOUT.JK
NOTE
NOTE    FLOWS INTO WILLAMETTE RIVER
NOTE
A       COUTS.K=CLVAS.K
NOTE       OUT AT ALBANY - CFD
R       COUT.KL=(COUTS.K)(86400)
NOTE
NOTE    IRRIGATION RELEASES
NOTE
NOTE       IRRIGATION RETURN FLOW - CFD
R       IRRIN.KL=(PERRF.K)(IROUT.JK)
NOTE       PERCENT RETURN FLOW
A       PERRF.K=SAMPLE(PERFT.K,30,0)
A       PERFT.K=TABHL(PERFTT,DAYS.K,0,360,30)
T       PERFTT=0/0/0/0/0/0/0/.15/.12/.16/.21/.29/0
NOTE       IRRIGATION RELEASE - CFD
R       IROUT.KL=CLIP(IRRND.K,IRRA.K,MRLVA.K,IRRNA.K)
NOTE       MONTHLY IRRIGATION NEED GROWN - AF
A       IRRN1.K=(IRNM.K)(IRRNT)(IRRG.K)
NOTE       MONTHLY IRRIGATION WATER AVAILABLE GROWN - AF
A       IRRN2.K=(IRNM.K)(MRLVA.K)(IRRG.K)
A       MRLVA.K=CLIP(RLVA.K-51E3,0,RLVA.K-51E3,0)
NOTE       DAILY IRRIGATION NEED - CFD
A       IRRND.K=(IRRN1.K)(43560)/30
NOTE       PRORATED DAILY NEED - CFD
A       IRRA.K=(IRRN2.K)(43560)/(NDYCT.K)
NOTE       GROWTH IN DEVELOPMENT
A       IRRG.K=TABHL(IRG,YEARS.K,1,21,10)
T       IRG=.35/1.0/1.0
NOTE       TOTAL NEED FOR REST OF YEAR GROWN - AF
A       IRRNA.K=(IRRNB.K)(IRRG.K)
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NOTE      IRRIGATION PERIOD
A       IRRN3.K=TABHL(IRNT,DAYS.K,210,360,30)
T       IRNT=20380/18460/13000/7180/2410/0
NOTE      TOTAL YEARLY IRRIGATION NEED - AF
C       IRRNT=20380
NOTE      MONTHLY DISTRIBUTION OF TOTAL YEARLY NEED
A       IRNM.K=SAMPLE(IRNMT.K,30,0)
A       IRNMT.K=TABHL(IRNMTB,DAYS.K,0,360,30)
T       IRNMTB=0/0/0/0/0/0/0/.094/.268/.286/.234/.118/0
NOTE      DAY OF MONTH FOR PRORATION
A       NDYCT.K=SAMPLE(NDYCTT.K,1,30)
A       NDYCTT.K=TABHL(NDYCTB,DAM.K,1,30,1)
T       NDYCTB=29/28/27/26/25/24/23/22/21/20/19/18/17/16/15/14/13/12/11/10
X       /9/8/7/6/5/4/3/2/1/30
NOTE
NOTE    DRAINAGE
NOTE
NOTE      AVERAGE REGULATED CHANNEL LEVEL AT ALBANY
L       ACLVA.K=ACLVA.J+(DT)((RCLVA.JK/120)-CLVAO.JK)
N       ACLVA=0
NOTE      DRAINAGE PERIOD
R       RCLVA.KL=CLIP(CLVAA.K,0,DAYS.K,150)
A       CLVAA.K=CLIP(0,CLVA.K,DAYS.K,270)
R       CLVAO.KL=PULSE(ACLVA.K,361,360)
NOTE      AVERAGE UNREGULATED CHANNEL LEVEL AT ALBANY
L       URD.K=URD.J+(DT)((URCH.JK/120)-URDO.JK)
NOTE      DRAINAGE PERIOD
R       URCH.KL=CLIP(URCH1.K,0,DAYS.K,150)
A       URCH1.K=CLIP(0,FCIN10.K,DAYS.K,270)
R       URDO.KL=PULSE(URD.K,361,360)
N       URD=0
NOTE
NOTE    REGULATED AND UNREG. FLOODS
NOTE
NOTE      UNREGULATED PEAKFLOW AT ALBANY
A       TRCIS.K=TABHL(PKFLO,FCIN5.K,0,105000,5000)
T       PKFLO=0/5146/11226/17306/23387/29467/35548/41628/47709/53789/59870
X       /65950/72030/78111/84191/90272/96352/102433/108513/114594/120674/1
X       26755
A       MTIN.K=MAX(MIN.JK,TRCIS.K)
NOTE      MAX YEARLY UNREGULATED PEAKFLOW
R       MIN.KL=CLIP(0,MTIN.K,DAYS.K,360)
N       MIN=0
NOTE      FLOOD DAMAGES - DOLLARS
A       FLDLP.K=TABHL(FLDLT,FLDSH.K,13.5,18.25,.25)
T       FLDLT=0/333/667/1000/1333/1667/2000/2500/5000/6500/8000/17000/5315
X       0/153000/278500/775000/2179000/3484000/5302000/6397000
NOTE      UNREGULATED DAMAGES
A       FDLPR.K=CLIP(FLDLP.K,0,DAYS.K,360)
NOTE      UNREGULATED FLOOD STAGE AT SHEDD - FT
A       FLDSH.K=TABHL(FLDST,MTIN.K,0,105000,5000)
T       FLDST=13.95/15.75/16.35/16.6/16.75/16.92/17.05/17.14/17.23/17.32/1
X       7.4/17.49/17.58/17.66/17.75/17.83/17.92/18.0/18.08/18.16/18.25
NOTE      ACTUAL CHANNEL LEVEL - CFS
A       CLVAS.K=CLVA.K/86400
NOTE      REGULATED PEAKFLOW AT ALBANY
A       CLVAI.K=TABHL(PKFLO,CLVAS.K,0,105000,5000)
A       MCLVA.K=MAX(MCLV.JK,CLVAI.K)
NOTE      MAX YEARLY REGULATED PEAKFLOW
R       MCLV.KL=CLIP(0,MCLVA.K,DAYS.K,360)
N       MCLV=0
NOTE      REGULATED FLOOD STAGE AT SHEDD - FT
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A       AFLDS.K=TABHL(FDST1,MCLVA.K,0,105000,5000)
T       FDST1=13.95/15.75/16.35/16.6/16.75/16.92/17.05/17.14/17.23/17.32/1
X       7.4/17.49/17.58/17.66/17.75/17.83/17.92/18.0/18.08/18.16/18.25
NOTE       REGULATED DAMAGES
A       FDLAR.K=TABHL(FLDLT,AFLDS.K,13.5,18.25,.25)
A       FDLR.K=CLIP(FDLAR.K,0,DAYS.K,360)
NOTE
NOTE    FLOOD BENEFIT CALCULATION
NOTE
NOTE       DIFF OF UNREG AND REG DAMAGES - DISCOUNTED
R       PVAFDB.KL=(FDLPR.K-FDLR.K)(PVF.K)(GR.K)
NOTE       ACCUM ANNUAL BENEFITS CALAPOOIA REACH DISCOUNTED
L       AAFDB.K=AAFDB.J+(DT)(PVAFDB.JK+0)
N       AAFDB=0
NOTE       GROWTH DEVELOPMENT FACTOR
A       GR.K=EXP((YEARS.K-1.)*LOGN(1.+.036))
NOTE
NOTE    WILLAMETTE FLOOD BENEFITS
NOTE
NOTE       WILLAMETTE REACHES 1 IN 100 BENEFITS
C       WILFB=80475
NOTE       ANNUAL BENEFITS GROWN AND DISCOUNTED
A       WILFB1.K=(WILFB)(PVF.K)(GR.K)
NOTE       ACCUM ANNUAL BENEFITS
L       AWILFB.K=AWILFB.J+(DT)(WILFB2.JK+0)
N       AWILFB=0
R       WILFB2.KL=PULSE(WILFB1.K,360,360)
NOTE
NOTE    RESIDUAL FLOOD BENEFITS
NOTE
NOTE       WILLAMETTE REACHES GTEATER THAN 1 IN 100
C       CWILFB=158125
A       RESID.K=RWILFB.K*CWILFB
NOTE       ANNUAL MINIMUM REDUCTION RATIO
A       RWILFB.K=MIN(RATIO.K,RAT1.JK)
NOTE       ANNUAL REDUCTION RATIO
A       RATIO.K=RWOPL.K/(RWOPL.K+INSUF.K)
R       RAT1.KL=CLIP(1E6,RWILFB.K,DAYS.K,360)
NOTE       DIFF OF ACTUAL AND DESIRED RESERVOIR
A       DIFAD.K=(RLVA.K-RWOPL.K)
A       INSUF.K=CLIP(DIFAD.K,0,DIFAD.K,0)
NOTE       ANNUAL BENEFITS GROWN AND DISCOUNTED
A       RESID1.K=(RESID.K)(PVF.K)(GR.K)
NOTE       ACCUM ANNUAL BENEFITS
L       ARESID.K=ARESID.J+(DT)(RESID2.JK+0)
N       ARESID=0
R       RESID2.KL=PULSE(RESID1.K,360,360)
NOTE
NOTE    RECREATION FUNCTION AND BENEFITS
NOTE
NOTE       POOL LEVEL - FT MSL
A       PLEVL.K=TABHL(PLEV,RLVA.K,0,200000,20000)
T       PLEV=560/605/625/639/651/661/669/677/685/692/699
NOTE       POOL LEVEL AT MAX POOL - FT MSL
A       MXPL.K=TABHL(PLEV,PCAP.K,0,200000,20000)
NOTE       DIFF OF MAX POOL AND ACTUAL POOL
A       PLDIF.K=MXPL.K-PLEVL.K
NOTE       LENGTH OF BEACH
A       LNBCH.K=(PLDIF.K)(SLP.K)
A       SLP.K=TABHL(SLOPE,PCAP.K,97000,145000,48000)
T       SLOPE=148/176
NOTE       ATTENDANCE USER DAYS
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A       ATND1.K=TABHL(ATTND,LNBCH.K,0,1500,1500)
T       ATTND=6000/0
NOTE       ATTENDANCE WITH GROWTH
A       ATND.K=(ATND2.K)(RECGR.K)
A       ATND2.K=CLIP(ATND1.K,ATND3.K,RCAP.K,98000)
NOTE       ATTENDANCE AT 97000 AF
A       ATND3.K=(ATND1.K)(.65)
NOTE       GROWTH IN REC USER DAYS
A       RECGR.K=TABHL(RGR,YEARS.K,1,101,25)
T       RGR=.18/.45/.71/1.0/1.0
NOTE       RECREATION PERIOD
A       RATD1.K=CLIP(ATND.K,0,DAYS.K,240)
A       RATD2.K=CLIP(0,RATD1.K,DAYS.K,350)
R       RATD3.KL=RATD2.K
NOTE       ANNUAL USER DAYS
L       AREC.K=AREC.J+(DT)(RATD3.JK-RATD4.JK)
N       AREC=0
R       RATD4.KL=PULSE(AREC.K,361,360)
NOTE       YEARLY USER DAY VALUE
A       RECB.K=(AREC.K)(VALRC.K)
A       VALRC.K=VALR
NOTE       VALUE PER USER DAY
C       VALR=1
A       ANRECB.K=PULSE(RECB.K,361,360)
R       PVARECB.KL=(ANRECB.K)(PVF1.JK)
NOTE       ACCUM ANNUAL RECREATION BENEFITS DISCOUNTED
L       AARECB.K=AARECB.J+(DT)(PVARECB.JK+0)
N       AARECB=0
NOTE
NOTE    IRRIGATION BENEFITS
NOTE
NOTE       POTENTIAL ANNUAL IRRIGATION BENEFITS
R       ANIB.KL=(IRCON)(IRRG.K)
NOTE       ANNUAL BENEFIT ESTIMATE
C       IRCON=601000
NOTE       ANNUAL IRRIGATION BENEFITS
A       ANIBH.K=(PERTM.JK)(ANIB.JK)
NOTE       PERCENT OF TARGET MET
R       PERTM.KL=(TIRO.K)/(IRRNT*IRRG.K)
NOTE       ACCUM OF DAILY RELEASES - CFD
L       TIROT.K=TIROT.J+(DT)(IROUT.JK-ACIRO.JK)
N       TIROT=0
R       ACIRO.KL=PULSE(TIROT.K,361,360)
NOTE       ANNUAL IRRIGATION RELEASES - AF
A       TIRO.K=TIROT.K/43560
A       ANIRB.K=PULSE(ANIBH.K,361,360)
NOTE       ACCUM ANNUAL IRRIGATION BENEFITS DISCOUNTED
L       AANIB.K=AANIB.J+(DT)(PVAIRB.JK+0)
N       AANIB=0
R       PVAIRB.KL=(ANIRB.K)(PVF1.JK)
NOTE
NOTE    RESERVOIR COSTS
NOTE
NOTE       RESERVOIR OMR
A       DAOMC.K=TABHL(DAOM,RCAP.K,97000,145000,48000)
T       DAOM=133689/179160
A       DAOMC1.K=CLIP(DAOMC2.K,DAOMC.K,YEARS.K,10)
A       DAOMC2.K=DAOMC.K+7000
A       PVDAOM.K=(DAOMC1.K)(PVF.K)
NOTE       RESERVOIR CAPITAL
A       DACC.K=TABHL(RESCT,RCAP.K,97000,145000,48000)
T       RESCT=17276396/23152500
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R       ADAOM.KL=CLIP(PVDAOM.K,0,DAYS.K,360)
L       AADAOM.K=AADAOM.J+(DT)(ADAOM.JK+0)
N       AADAOM=0
A       KDAC.K=CLIP(DACC.K,0,TIME.K,18001)
A       TDAC.K=AADAOM.K+KDAC.K
NOTE
NOTE    IRRIGATION COSTS
NOTE
NOTE       DISTRIBUTION AND STORAGE OMR
A       IROMC.K=TABHL(IROM,RCAP.K,97000,145000,48000)
T       IROM=85000/85000
A       PVIROM.K=(IROMC.K)(PVF.K)
A       IRCC.K=TABHL(IRC,RCAP.K,97000,145000,48000)
NOTE       DISTRIBUTION AND STORAGE CAPITAL
T       IRC=11347000/11347000
R       AIROM.KL=CLIP(PVIROM.K,0,DAYS.K,360)
L       AAIROM.K=AAIROM.J+(DT)(AIROM.JK+0)
N       AAIROM=0
A       KIRC.K=CLIP(IRCC.K,0,TIME.K,18001)
A       TIRC.K=AAIROM.K+KIRC.K
NOTE
NOTE    RECREATION COSTS
NOTE
NOTE
NOTE       RECREATION OMR
A       RCMC.K=TABHL(ROM,RCAP.K,97000,145000,48000)
T       RCM=58930/88100
A       PVROM.K=(ROMC.K)(PVF.K)
NOTE       RECREATION CAPITAL
A       RCC.K=TABHL(RC,RCAP.K,97000,145000,48000)
T       RC=974454/1456800
R       AROM.KL=CLIP(PVROM.K,0,DAYS.K,360)
L       AAROM.K=AAROM.J+(DT)(AROM.JK+0)
N       AAROM=0
A       KRC.K=CLIP(RCC.K,0,TIME.K,18001)
A       TRC.K=AAROM.K+KRC.K
NOTE
NOTE    FISH ENHANCEMENT COSTS
NOTE
NOTE       ANADROMOUS AND TROUT OMR
A       FOMC.K=TABHL(FOM,RCAP.K,97000,145000,48000)
T       FCM=54000/54000
A       PVFOM.K=(FOMC.K)(PVF.K)
NOTE       ANADROMOUS AND TROUT CAPITAL
A       FCC.K=TABHL(FC,RCAP.K,97000,145000,48000)
T       FC=900000/900000
R       AFOM.KL=CLIP(PVFOM.K,0,DAYS.K,360)
L       AAFOM.K=AAFOM.J+(DT)(AFOM.JK+0)
N       AAFOM=0
A       KFC.K=CLIP(FCC.K,0,TIME.K,18001)
A       TFC.K=AAFOM.K+KFC.K
NOTE
NOTE    CHANNEL COSTS
NOTE
NOTE       CHANNEL OMR
A       CHOMC.K=TABHL(CHOM,CCAP.K,5000,25000,5000)
T       CHOM=23991/30000/65000/118000/160000
A       PVCHOM.K=(CHOMC.K)(PVF.K)
NOTE       CHANNEL CAPITAL
A       CHCC.K=TABHL(CHC,CCAP.K,5000,25000,5000)
T       CHC=3012000/4100000/9600000/15100000/20600000
R       ACHOM.KL=CLIP(PVCHOM.K,0,DAYS.K,360)
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L       AACHOM.K=AACHOM.J+(DT)(ACHOM.JK+0)
N       AACHOM=0
A       KCHC.K=CLIP(CHCC.K,0,TIME.K,18001)
A       TCHC.K=AACHOM.K+KCHC.K
NOTE
NOTE    NET BENEFITS
NOTE
A       TB.K=AAPETB.K+AAMIB.K+AAFDB.K+AARECB.K+AANIB.K+AWILFB.K+AASCHP.K+A
X       RESID.K+ADVEC.K
A       TC.K=TDAC.K+TIRC.K+TRC.K+TFC.K+TCHC.K
A       NB.K=TB.K-TC.K
NOTE       AVERAGE ANNUAL NET BENEFITS
A       TKC.K=KDAC.K+KIRC.K+KRC.K+KFC.K+KCHC.K
A       AMK.K=AMORT.K*TKC.K
A       AOMR.K=AADAOM.K+AAIROM.K+AAROM.K+AAFOM.K+AACHOM.K
A       IDC.K=AMK.K*IDCR
C       IDCR=.1
A       AVAC.K=(AMK.K+IDC.K)+AOMR.K/(YEARS.K-1))
A       AVTB.K=TB.K/(YEARS.K-1)
NOTE
NOTE    STRUCTURE SIZES
NOTE
C       CHCAP=5000
A       CCAPD.K=(CCAP.K)(86400)
A       CCAP.K=CHCAP
A       RCAP.K=RECAP
C       RECAP=145000
NOTE
NOTE    ANADROMOUS FISH DOWNSTREAM FROM THE DAM
NOTE
NOTE       FLOW BELOW DAM - CFD
A       TOUT.K=(ROUT.JK+IROUT.JK+MIOUT.JK+(.24*CIN.JK))/86400
NOTE       FIRST HALF OF YEAR MAX FLOW BELOW DAM - CFD
A       MXRO.K=MAX(TOUT.K,MXRO1.JK)
R       MXRO1.KL=CLIP(-1.0,MXRO.K,DAYS.K,180)
N       MXRO1=-1.0
NOTE
NOTE    NORMAL SURVIVAL
NOTE
A       NEGG.K=PULSE(FCEGG,180,360)
NOTE       FALL CHINOOK EGGS PER SPAWNER
C       FCEGG=2500
A       PFRY.K=(NSPNR.K)(NEGG.K)(NSUR.K)(EXSUR.K)
NOTE       DENSITY DEPENDENT SPAWNERS
A       NSUR.K=CLIP(RSUR3.K,RSUR.K,NSPNR.K,3420)
A       ULSUR.K=TABHL(ULT,NSPNR.K,3420,20000,16580)
T       ULT=.70/.05
A       RSUR3.K=(ULSUR.K)(R.K)
A       RSUR.K=CLIP(RSUR2.K,RSUR1.K,NSPNR.K,950)
A       RSUR2.K=TABHL(SUR2,R.K,0,1,1)
T       SUR2=.55/.80
A       RSUR1.K=TABHL(SUR1,R.K,0,1,1)
T       SUR1=.60/.75
NOTE
NOTE    EXTREME CONDITION SURVIVAL
NOTE
A       EXSUR.K=CLIP((EXSUR1.K,1,MXRO.K,3500)
NOTE       EXTREME SURVIVAL RATE
A       ULEXS.K=TABHL(ULET,MXRO.K,3500,17500,14000)
T       ULET=1.0/0.0
A       EXSUR1.K=(ULEXS.K)(RR.K)
NOTE       POTENTIAL SPAWNERS
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R       PNSPI.KL=(SUPFR.JK)(PFRY.K)
N       PNSPNR=0
L       PNSPNR.K=PNSPNR.J+(DT)(PNSPI.JK-PNSPO.JK)
NOTE       SURVIVAL OF FRY TO RETURNEES
R       SUPFR.KL=TABHL(SFR,RR.K,0,1,1)
T       SFR=0/.00133
NOTE       DELAYED RETURNEES
R       NSPNRI.KL=DELAY3((PNSPNR.K/360),1080)
R       PNSPO.KL=PULSE(PNSPNR.K,540,360)
NOTE       ANNUAL ESCAPEMENT
L       NSPNR.K=NSPNR.J+(DT)(NSPNRI.JK-NSPNRO.JK)
N       NSPNR=1900
R       NSPNRO.KL=PULSE(NSPNR.K,540,360)
A       SPNR1.K=CLIP(NSPNR.K-1000,0,DAYS.K,540)
A       SPNR.K=CLIP(SPNR1.K,0,SPNR1.K,0)
A       NSPNR2.K=NSPNR2.J+(DT)(NSPNR3.JK-NSPN3O.JK)
N       NSPNR2=0
R       NSPNR3.KL=PULSE(NSPNR.K,539,360)
R       NSPN3O.KL=PULSE(NSPNR2.K,720,360)
NOTE       DOWNSTREAM FALL CHINOOK BENEFITS
A       DFCB.K=(SPNR.K)(87.84)
R       DPVFC.KL=(PVF.K)(DFCB.K)
NOTE       ACCUM ANNUAL BENEFITS DISCOUNTED
L       ADVFC.K=ADVFC.J+(DT)(DPVFC.JK+0)
N       ADVFC=0
SPEC    DT=1/LENGTH=18005/PRTPER=360/PLTPER=0
RUN     BASIC
PRINT 1)NB/2)TC/3)TB/4)AVTB/5)AVAC/6)NSPNR2/7)AESC/8)ASFUD/9)ARFUD/10)AR
X       FC/11)ACLVA/12)URD/13)AFLDS
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