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Title: Computer Simulation of Irrigation System Improvements: An Analysis of Income, Risk and Offsite Impacts

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Policy analysts designing programs to improve the efficiency and expand the use of water in the irrigation of farm lands often enlist benefit-cost analysis as a means of assessing impacts and feasibility. While on-site comparisons of costs and benefits are important factors in project assessment, other dimensions such as risk, income distribution and offsite impacts may be overlooked.

In this research a more complete approach to project analysis was sought. A simulation model of a river basin was developed. Paris Creek, Idaho, an area studied recently by the U.S. Soil Conservation Service, was the representative project location analyzed. An important design goal was to provide an analytical data processing template applicable to future studies.

Paris Creek farmers are directly dependent on water available from Paris Creek. However, most years the flow is

insufficient to provide adequate irrigation with present methods. High pumping costs, high seepage losses in delivery systems and low on-farm irrigation efficiencies compound the problem. A proposed improvement plan is analyzed, involving piped gravity-fed delivery systems and conversion from surface to sprinkler irrigation. Installation and government consulting costs are to be shared by the farmers and S.C.S.

The computer model simulated monthly stream flows, irrigated crops, measured impacts, computed production benefits, and compiled costs and benefits affecting farmers and society. A 50-year project life was assumed, and statistics were collected for 25 separate iterations.

It was determined that north group farmers are almost always better off with the project when annual comparisons were made between conditions. Only in years of very low stream flow would farmers lose more money with the project. However, substantially higher variability in annual income could be expected, a condition of greater risk to farmers. Society as a whole was also found to experience an increase in net benefits, but not as great as for farmers and with greater annual variability.

The model was effective in providing information about risk and income distribution. However, difficulty remains in assessing offsite impacts because there lacks an effective approach and appropriate data.

Computer Simulation of Irrigation System Improvements: An Analysis of Income, Risk and Offsite Impacts

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> "...It is true, of course, that cost-benefit analysis of all sorts of things, whether of water projects, other pork-barrel items, or in more recent years weapon systems, can be manipulated to meet the previous prejudices of people who are trying to influence the decisions. Nevertheless, the fundamental principle

that we should count all costs, whether easily countable or not, and evaluate all rewards, however hard they are to evaluate, is one which emerges squarely out of economics and which is at least a preliminary guideline in the formation of the moral judgment, in what might be called the 'economic ethic.'"

- Kenneth E. Boulding, 1969

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I. PURPOSE AND ORGANIZATION

A. Introduction

Policy alternatives designed to positively affect one or more dimensions of an agriculture problem often fail to consider important external and interactive effects or impacts of that policy. In addition, other dimensions of the problem such as risk and income distribution are important to farmers and other affected parties but are often overlooked by policy analysts.

This condition is characterized in decisions affecting the irrigation of farm lands. Benefit-cost analysis is one means of assessing impacts and feasibility of policies designed to improve efficiency and expand use of water, conserve soil, and enhance farmer and regional incomes. Determining whether the target group or persons are actually "better off", however, requires more than just comparing costs with benefits. If annual expected incomes are more variable (and hence, less certain), whether one or more persons or groups becomes worse off, and whether other parties incur external costs under a proposed change can ultimately affect the conclusions of the analysts.

Background. Water availability is a major concern in regions that use irrigation. Crosson (1982), Teigen (1981) and Whyte (1981) report that in many areas aquifers are being drained faster than replenished. Better water management techniques must be developed. The use of sprinkler irrigation systems is gaining popularity over surface or flood irrigation because of its greatly improved water efficiency (Teigen, 1981; Thomas, 1984).

The introduction of an improved irrigation system affects more than just the acreage receiving water. Many of these effects result from changes in water flow, allocation, and distribution, and may cause unanticipated and undesired economic impacts on other parties. The economic or social weight placed on those affected may have an important role in a plan's evaluation.

Probably the most direct physical impact of changes in irrigation practices is the effects on stream flow levels during the season. The environmental effects may be positive or negative, depending upon whether and how much the flow is reduced, how long, and what time of year it takes place. If the water usage program involves an improvement in water delivery efficiency for irrigators (such that less water is lost through seepage), the net change in withdrawal amounts may not be significant.

A decline in stream flow level will increase the concentrations of pollution or foreign substances, as well as raise water temperature. Crosson (1982) indicates both conditions can have "devastating" effects on riverine biological life. Downstream uses may also be altered by withdrawal patterns. When that river or stream is a primary source of water for freshwater wetlands, the results can be particularly serious.

Because of these long-term ecological and economic impacts, recommendations have been made for the development of a soundly-based methodology for quantifying impacts to wetlands that would aid in defining mitigation requirements.

One of the more serious consequences of surface or flood irrigation is the erosion of soil from the field. (This condition is more serious on grainland and less so on hayland.) Converting from flood irrigation to sprinklers is a proven method for reducing the threat of excessive soil erosion under most circumstances. Yet, Carlile (1982) points out:

> "It is ironic that, because of sediment pollution and the associated problems, many farmers are reluctant to convert from furrow to sprinkler irrigation. At the same time, total conversion to sprinkler irrigation would be a major step toward alleviating sediment pollution." (p. 78)

The economic benefits achieved (in terms of long-term productivity, soil viability, etc.) can be substantial.

<u>Problem statement.</u> From its water and land resource studies on the Snake and Bear River basins in Idaho, as well as other studies, the U.S. Department of Agriculture indicated a need for detailed analysis of irrigation water distribution and on-farm use. Several irrigation groups, districts and companies have made requests of the Idaho

Department of Water Resources (DWR), soil conservation districts and the Soil Conservation Service for assistance in "determining the opportunities for improving the distribution and on-farm use of their irrigation water." (USDA, 1984)

A series of cooperative studies between the Idaho D.W.R. and U.S.D.A. (including the Soil Conservation Service, Economic Research Service, and the Forest Service) were authorized to evaluate alternative methods of improving both the delivery and on-farm irrigation distribution systems and management. Impacts are assessed for environmental quality enhancement and national economic development. It is intended that the findings be used as information for irrigation district members upon which long-term planning decisions can be made.

While carefully outlined goals and procedures have been developed for evaluating the on-site economic effects, there is no comprehensive assessment procedure for measuring the off-site economic impacts of irrigation proposals. Furthermore, an analysis of annual income variability (risk) is generally not included in these studies. It is possible that, were these impacts included in a benefit cost analysis framework, the decisions among alternatives for irrigation and delivery systems could be affected. Even if the actual changes in costs and benefits were found to be non-substantial, distribution of income and risk are worthy of consideration in the final decisions.

B. Objectives

The objectives of this project are as follows: (1) to provide U.S.D.A. with a conceptual and practical economic model applicable to other irrigation or related studies; (2) to provide U.S.D.A. and the State of Idaho information about external effects, externalities, and non-market valuation methods associated with irrigation practice alternatives. These may be applied to the Paris Creek Irrigation District and elsewhere, for the purpose of utilizing cost-benefit analysis in the decision-making process; and (3) to provide further understanding of the distribution of costs and benefits on the site and the impacts affecting other areas.

C. Scope

This study will (1) develop a technical, detailed stream-basin model, incorporating hydrologic, engineering and irrigation features and relationships, which will allow U.S.D.A. personnel to evaluate the implications of proposed irrigation plans; (2) apply the model framework to a simulation of the Paris Creek irrigation district in Bear Lake County, Idaho, which will be used to assess the impacts of a proposed improvement in the irrigation water delivery system; and (3) discuss the role that risk, distribution of income, and offsite impacts, as determined by the simulation model runs, play in the decision process.

A preliminary development in this model consists of the utilization of measured hydrologic data to generate stream flows. These flows form the basis for irrigation water use and subsequent crop production, as well as the associated impacts on recreational fishing, waterfowl production, pheasant populations, and related recreation. Because these impacts are not exchanged directly in the market, assessing the economic value associated with these changes requires the use of a set of economic indicators; these are usually prices and cost valuations. Determining the appropriate valuation tools for each impact is a principle goal of this study.

D. Project Area Description

Bear Lake County is situated in the southeast corner of Idaho and borders on both Utah and Wyoming. Elevations range from 5,930 feet at Bear Lake to 10,541 feet at Meade Peak, giving the highest average elevation for a county in the state. The terrain consists of flatland, rolling hills and mountains, covering 924 square miles.

The Paris Creek Irrigation Study area is located in the vicinity of the town of Paris, intersected by U.S. Highway 89 running north-south (figure I.1). It is bounded on the

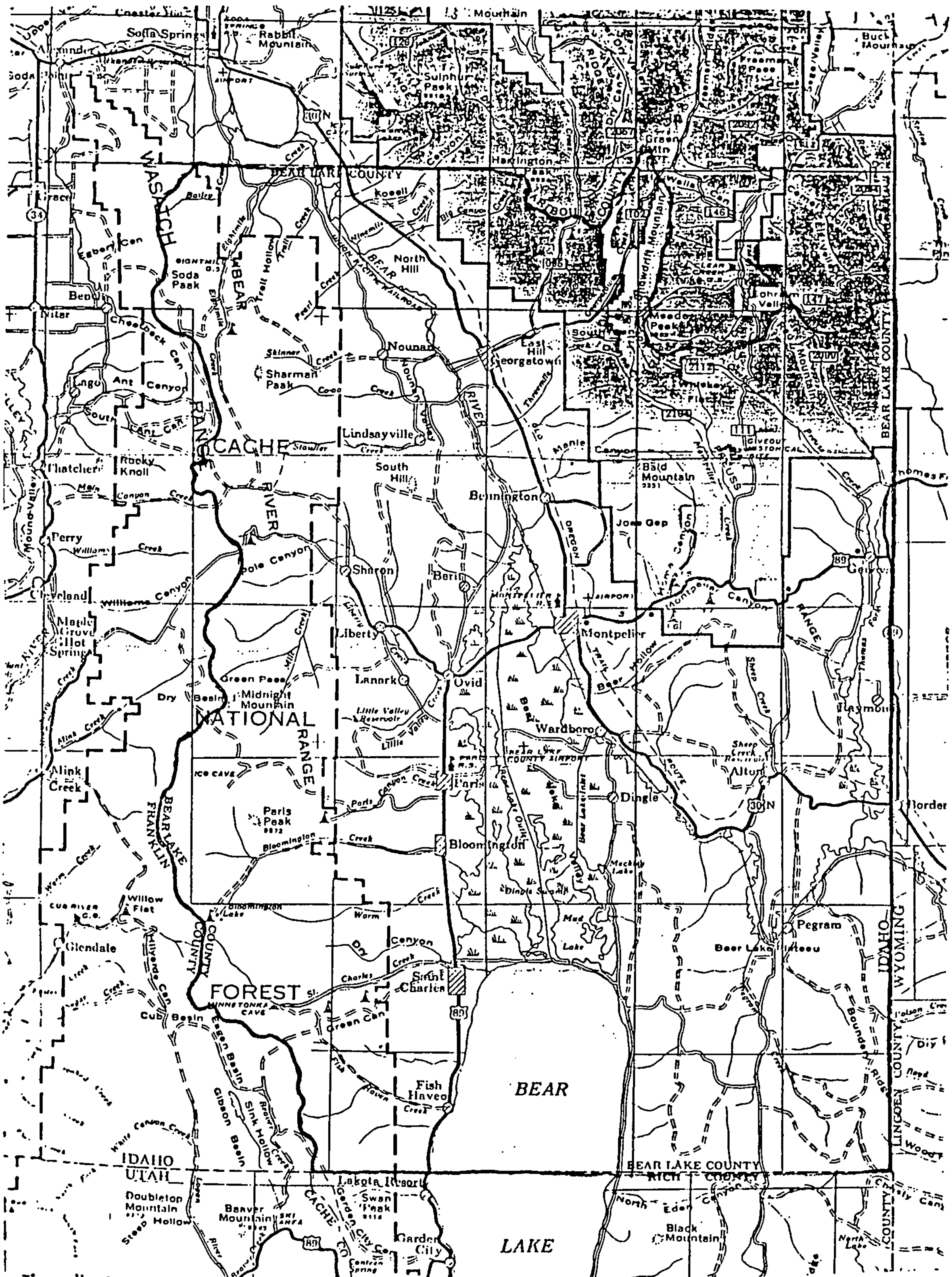

Figure I.1 - Project location, Paris Creek, Idaho.

west by the Cache National Forest and on the east by the Bear Lake National Wildlife Refuge Area, the outlet of the Paris Creek drainage. The creek flows west to east through the study area.

Bear Lake is the largest naturally-formed body of water in the state and is becoming increasingly important for tourism and recreation. The wetland area to its north is an important link in the Pacific Flyway, as home for many varieties of waterfowl; at least 22 species of ducks, 41 species of non-game water and shore birds as well as Canadian geese, snow geese and trumpeter swans (Idaho D.W.R., 1975). It is also a popular hunting and fishing ground.

The study area is important to a variety of wildlife species, fish and upland game. The Idaho Department of Water Resources noted a number of species of special concern, including the Peregrine Falcon (an endangered species); white-faced Ibis (resides in marsh areas; only location in the Bear River area); cutthroat trout (very sensitive to stream habitat changes), and Ring-necked pheasant (survival influenced by irrigation practices).

Paris Creek originates from two springs 50 feet apart as block fault outlets. This means the source is primarily a groundwater release and is less subject to seasonal fluctuations. However, rain and snowmelt in April, May, and June add considerably to the flow during those months.

The Paris Creek irrigation study area involves approximately 2425 acres of irrigated alfalfa, pasture / hayland, and grain (mostly barley). In addition, meadow hay is harvested from seasonally flooded regions at the base of Paris Creek drainage, in the upper Bear River wetland area. Irrigation water comes from Paris Creek, and is diverted into the delivery system some 3 miles upstream from the study area. Irrigation is essential for the production of a full crop of forage and barley most years, due to the short growing season (averaging only 90 days). Water losses in the distribution system, physical layout of the system and land topography, however, result in inadequate water for irrigation. Poor distribution on farm land also tends to reduce yields -- high areas in the field receive inadequate water, while low lying areas too much.

Presently, 1280 acres are surface-irrigated, and 1145 acres are irrigated with sprinklers.

The project plan would replace present delivery ditches with a gravity pressurized distribution system and improved diversion structures, to increase delivery efficiency. It would also require that present surface irrigation be replaced with sprinklers and present sprinkler systems be upgraded to provide better water-use efficiency (figure I.2). The objective of this plan is to provide better irrigation capabilities; some acreage could have an additional annual irrigation, while all will benefit from more adequate water distribution.

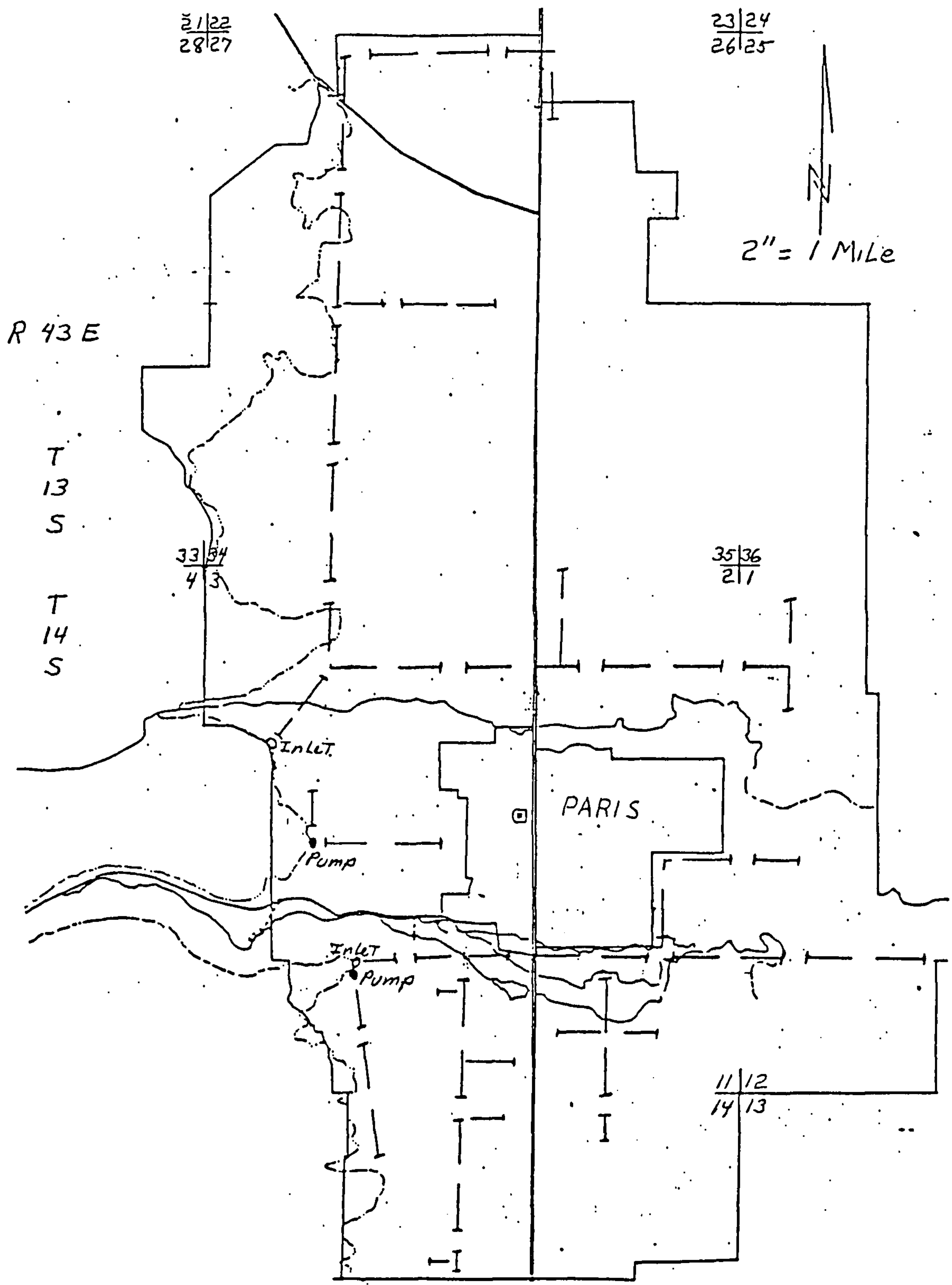

Figure I.2 - Proposed project layout.

Idaho maintains a water rights system of "prior appropriation". At present, irrigation water is distributed by volume to those with shares in the Paris Creek Irrigation Company. Under the proposed plan, rights will be pooled and distribution based on proportionate acreage served.

E. Thesis Organization

This thesis is organized into five chapters and appendices. The next chapter begins with a review of simulation methods applied to water resource systems, and an overview of recent literature relevant to offsite impact valuations. A detailed discussion of benefit-cost analysis follows. Chapter III outlines the methodology used in formulating the simulation model. It outlines the basis and assumptions used for generating stream flows, and for calculating the costs and benefits of crop production on the site. This is followed by a thorough discussion of the valuation methods used in this simulation for computing the off-site impacts of the irrigation program.

Empirical results and analysis is the focus of Chapter IV. A discussion of the model output's implications in terms of risk and income distribution will be included.

Finally, the summary and research conclusions are discussed in Chapter V.

II. Review of Related Material

A. Introduction

This chapter will survey past works in the area of modeling and computer simulation of water resource development, including background and techniques. It will then explore the myriad of literature on non-market valuation, as related to recreation and wildlife habitats. Included is an analysis of current methods of evaluation.

A discussion of benefit-cost analysis is then presented, which includes methods for incorporating on-site and off-site assessments. Finally, a brief synopsis of unresolved issues are discussed.

B. Literature

Simulation methods. The use of simulation as a tool for planning and experimentation has been used for many years in hydrology in the study of wave properties (Carr and Underhill, 1974). However, it has been only in the last 25 years that simulation modeling has been used to represent complex interactions inherent in water resource systems. While the U.S. Army Corps of Engineers did simulation experiments of the Missouri River in 1953, the first formal usage of simulation was for the Nile Valley plan in 1955 by

Morrice and Allan, involving up to 17 reservoirs on a 48-year planning horizon. The objective function maximized the volume of irrigation water without regards to economic feasibility.

The potentials offered by computers in water resource planning prompted the development of formal design manuals. Perhaps the best known work on water resource simulation and methodology was developed by the Harvard Water Program in the late 1950's (Maass, et al., 1962). The authors attempted to combine economic, engineering, and public administration techniques and objectives in developing mathematical and computer simulation models for water development projects. Not only are the objectives, methods, and techniques of analysis presented, but a comparison is also made of conventional and simulation methods as applied to a river basin system. Marglin (one principal author) calls efficiency and income distribution the most important ways in which water resource development can contribute to national welfare (p. 18).

An efficiency objective defined in terms of Pareto optimality holds that no deviation will make any member better off without making some other worse off. However, this does not allow optimization among alternatives, since more than one could fulfill this criterion. A ranking function of the Kaldor-Hicks criterion is used: (p.24)

$$W(A) = E(y) - C(x) \quad \text{where } f(x,y) = 0$$

and $W(A)$ is the aggregate net willingness to pay of everyone affected by design A

$E(y)$ are the aggregate benefits, obtained from the vector of outputs y

$C(x)$ are the aggregate costs, as a function of the vector of inputs x

Simply stated, a project is worthwhile if the gains to the gainers exceed the losses to the losers.

The income distribution objective addresses the issue that a dollar of net income to a millionaire is not as socially desirable as one to a tenant farmer. It is more difficult to translate an objective of income distribution into a design criterion than it is with efficiency; its ranking function is:

$$I(A) = G(A) - R(A)$$

where $I(A)$ = annual net income from A

$G(A)$ = gross income

$R(A)$ = system revenues

While these two objectives may be in direct conflict, the authors find each of importance in defining national welfare.

In their studies of simulation techniques, the authors point out important limitations to systems modeling: (1) all possible combinations of a multi-variable system cannot be examined feasibly; (2) operating procedures are fixed within the program and thus lack flexibility; and (3) hydrologic data availability can pose limitations on accuracy.

Sampling (either systematic or random) can reduce the need for examining all combinations by providing a close approximation of the optimal design.

A simplified river basin system was created using parts of Clearwater River, Idaho as a model base. Climactic and crop data from the Lewiston area were used, and irrigation levels were fixed at 5.0 acre-feet per crop per year, distributed from April through October. The irrigation benefit loss function, from years in which full water was not available, "was based on judgement and practical experience." (p. 275)

Analysis of their results indicated a number of features worthy of note. The simplifying assumptions required to create a working system further emphasized the complexity and interactiveness of water resource systems. And despite the simplification, the net benefit response surface was detailed and complex. They were also able to overcome difficulties in variable definition and sampling methods, and suggested other problems and improvements characteristic of early modeling efforts.

Hufschmidt and Fiering (1966) present a detailed and concise set of procedures for simulating water resource development projects. Their approach presents practical modeling variations tailored to the specific needs and intentions of the designers. Recognizing the varied uses for water models and problems in obtaining accurate and indicative stream flow data, they present a series of regression models for generating flows in simulation, including a monthly hydrology generator, seasonal variation model, and a method for incorporating multiple-site data into a flow model.

A system is defined by the supply of water resources, demand for water products and development measures. Supply consists of surface and groundwater flows, and other natural storage. These must be further defined in terms of quantity, quality and availability with respect to time and location. Relationships between land and water must also be made explicit: erosion, siltation and evaporation characteristics, as well as other analytical relationships such as hydrology, climatology, geology, topography and soils.

Water demands arise from commercial, domestic and industrial sources, irrigation, navigation, zones of power demand, recreation, fish and wildlife, and flood hazards. Each aspect within the goals of the project must be defined accordingly.

Different approaches exist for modeling stream flows, and their usage depends upon the purposes of the model as well as available data. For example, in studying flood control alternatives the modeler is advised to generate "mean three-hour flows" rather than "mean monthly flows."

The other components of simulation models are categorized by the authors as design variables, invariant physical functions, parameters, and constants. Design variables include physical facilities (irrigation canals, water supply aqueducts, pumping plants, recreational facilities at reservoirs), system outputs (demands for electric energy, irrigation, levels of water quality), and operating policy parameters (rules for storing, releasing or routing water through the system). These are the mechanisms through which alternative plans of action may be simulated and compared.

Invariant physical functions, parameters and constants are those relationships which are effectively not controllable by system designers; physical features such as reservoir evaporation loss, natural capacity of streams, parameters that define the rate of return flow from irrigated acres, and evapotranspiration (water consumption by plants) fall into this category.

Construction of cost and benefit functions are addressed next and generally focus on the need for designers to develop functions which can associate specific benefit and cost values with outputs generated by the system. Implementation usually takes the form of a matrix of values.

The final major area of discussion by Hufschmidt and Fiering is arranging for economic analysis. Two types of investments are possible: static (single-period) and dynamic (investments spread over time). Benefits may be discounted from the year they occur, or annual benefits may be summed and averaged, generating a stream of equal annual benefits discounted to the present.

Carr and Underhill (1974) present a "practical introduction" in the use of simulation modeling, focusing on irrigation planning. The authors outline much of the same methodology in abbreviated form, and in fact base their presentation on the two previous works. They do, however, manage to blend these concepts with grass roots techniques for obtaining necessary data, undoubtedly focusing their efforts on regions lacking sophisticated measuring devices.

The elements of a simulation study, according to Carr and Underhill, include components, relationships, variables, and a time interval. The variables are both state (their values change during the course of a run) and input (including physical and exogenous, beyond the control of the planner).

The objective function of the project may be difficult to express, due to the fact that some "intangible" effects are not easily expressible in monetary units. They point out that controversy does exist over whether these impacts should be included in the objective function. One view is that the objective function should obtain an optimum plan, and therefore all water resource objectives must be evaluated. Another view acknowledges the importance of "intangible effects" but would not attempt to value them in the economic analysis, instead relying on the "final subjective judgement."

The authors find simulation a flexible tool, and quote the authors of the Wash Estuary study of England as saying: "at present simulation is the only possible technique for analyzing a water resource system as large and complex as the one under study." They did point out four disadvantages over other techniques:

(1) lengthy computer programs with large amounts of input and output data are required;

(2) programs tend to be highly specific, applicable only to a particular basin;

(3) simulation does not automatically optimize, but rather presents a set of scenarios; and

(4) it is somewhat rigid in its treatment of system operation rules, as a decision variable, because the rule must be "built in" to the simulation program.

The applicability of simulation in evaluating water resource development projects were tested by Halter and Miller (1966). They used the DYNAMO simulation model to generate streamflows for the Calapooia River Basin of the Willamette Valley, Oregon.

In designing the frequency function for stream flows, the authors noted that the median flow during the month is always to the left of (less than) the mean, indicating that most flows are less than the month's average flow. Therefore, for each simulated day a number is drawn randomly from a normal distribution, using the median as the mean value and all other parameters (including standard deviation) as calculated.

The results of their model's generated flows with actual data from the Calapooia compared reasonably well, and they concluded simulation modeling had potential for water development studies.

A more recent usage of simulation modeling in water resources was done by Brockway and de Sonneville (1973). They looked at a 96,000 acre tract in the Idaho Falls area of eastern Idaho to develop alternatives for alleviating high water table problems. They used a water budget complete with diversions for irrigation, system losses and crop consumption in their simulation. The primary water source was groundwater. The authors used a fixed year for water level calibration, since they determined annual amplitude was nearly constant year to year.

Across this simulated year, 13 alternatives were studied in terms of technical feasibility. Their simulation narrowed this list down to two. There was no regard for economic feasibility, however.

<u>Non-market valuation.</u> Much has been written about non-market valuations in the past twenty-five years. The majority of the literature has focussed on recreation valuation, though some more recent works have studied the benefits of environmental quality (see Freeman, 1982). Offsite impacts, however, are not necessarily limited to recreation. Soil erosion, stream flora and fauna damages,

and non-game wildlife reduction are impacts that can impose damages not easily accounted for.

Among the valuation literature, no clear consensus exists as to methodology for computing or collecting data. For this and other reasons, offsite valuations by government agencies are either subject to criticism or ignored completely.

One early discussion of the economics of outdoor recreation was by Clawson and Knetsch (1966). They state that outdoor recreation involves costs in terms of dollars, time and travel. Trade-offs often occur between time and money, and in travel time. Though travel to a recreation site may be a cost for some and a benefit to others, for most activities dollars, hours and miles are closely correlated, allowing dollars to serve as an index for all three (p. 62).

The total direct economic value of public recreation areas is the sum of two sets of values: (1) the user benefit or the values which people receive from visits that involve travel to the area, and (2) the values capitalized in land near the recreation area. The proper use of proxies is important in measuring these values.

The authors outline five methods used and offer the following criticisms:

(1) Gross expenditure method - all associated expenses are summed to give a value of recreational experiences. However, gross value is less important to analysts than the value added by a particular recreational opportunity.

(2) Market value of fish - used as a proxy for the value of a fishing day experience. This is simply incorrect, as it measures a fish price, not the activity value.

(3) Cost method - sum total of expenses required to participate. It assumes the value of outdoor recreation is equal to the cost of generating it. This method makes it difficult to determine the value of a contemplated loss of recreational opportunities.

(4) Market value method - that is, the price of admission times attendance. Though it was the most common method used by government agencies, it is not always an accurate measure. It does not account for the various travel costs of participants, and presents an incorrect comparison of public and private facilities. Public fees are not generally set by market conditions.

(5) Direct interview method - while theoretically the most accurate valuation method, it is expensive to conduct and due to its subjective nature, has a tendency towards biased results.

Dwyer, Kelley, and Bowes (1977) attempt to offer improvements in the ways in which agencies value recreation. Most estimate recreation's contribution to National economic development by the "interim unit day value approach". That is, a value is chosen from a range of unit day values and is multiplied by an estimate of expected use. Often times there is no theoretical or empirical basis for these values, and no explanation is given (p. 23).

The interim unit day value approach divides recreational activities into "general" and "specialized" recreation. General recreation involves primarily those activities attractive to most recreationists. It includes the majority of all recreational activities associated with water projects. Specialized recreation involves limited opportunities, low intensity use, and large personal expense. Big game hunting and salmon fishing are two examples of specialized recreation.

General recreation days are valued at $0.75 to $2.25. A specialized recreation day is valued at $3.00 to $9.00 (p. 20-21).

(The Soil Conservation Service calculates benefits in a similar manner. Any lost recreational opportunity as well as gains from a proposed project should be assessed. Unit day values are assessed on a point system based on recreational experience, development scale, degree of site modification, and environmental quality.)

The authors are critical of the current approach for the following reasons (p. 23):

(1) The range of values given is wide with no clear guidance within; will almost certainly lead to a misallocation of resources.

(2) A departure from this range is permissible, "if a full explanation is given."

(3) Updating of ranges is not specified; it does not account for inflation, which may be different for demand and supply of recreational goods than for other goods.

(4) No definition of a "recreation day" is provided.

(5) Procedures for estimating the number of recreation days is not given.

Dwyer, Kelley and Bowes offer the survey method and an improved travel cost method as advantageous alternatives to the unit day value approach. They offer detailed explanations of each.

The survey method has advantages over the travel cost method in that it (1) considers the value of small changes in quality at existing sites which would not be expected to affect travel costs; (2) estimates the value of a site or area that is one of many destinations visited on a trip; and (3) considers the effects of congestion on a site (p. 55).

The travel cost method is the preferred approach of the authors in that it derives estimates based on actual market behavior rather than responses to questions or the opinion of planners, and it recognizes spatial characteristics of markets where a variety of prices face users. This approach is appropriate when (1) there is sufficient variation in travel costs to allow estimation of demand; (2) the proposed changes are significant enough to alter the travel cost for some individuals; and (3) travel expenses have been made mainly for the purpose of recreation at the resource evaluated.

Freeman (1982) assessed and summarized methods for measuring the benefits of air and water pollution control; his discussion however is pertinent to other aspects of water resource development as well.

A three-stage method of benefits is realized from improved water quality: a reduction of discharges cause changes in the physical, chemical, and biological indicators of water quality. These in turn induce changes in the human uses of that water, which affects the users' willingness to pay for those resources.

Market approaches to measurement include surveys, voting on referendums and assigning arbitrary prices or values. Each has some disadvantages, according to Freeman. Surveys are subject to bidding games, strategic bias, and lack of information which detract from accurate representations of value. Voting behavior is a beneficial approach for some public services, but is limited in its applicability to environmental quality services. It is beneficial when payments are directly from a voter's pockets and not also subsidized by the private sector. And assigning values requires knowledge of the judgmental nature of the values assigned, and do not reflect aggregate values.

Benefit estimation of non-market environmental quality improvements is difficult because of a lack of information on possible consequences or causes of observed adverse effects, the stochastic nature of discharges and environmental processes; perceptions of environmental quality and their relationships to human uses of the environment vary among users and experts, and the synergistic and antagonistic relationships among polluting substances and their influences on human uses are not well understood (p. 23-27).

Freeman categorizes benefits into four groups: (1) recreation - fishing, swimming, boating, waterflow hunting, picnicking, hiking and nature observation; (2) non-user - amenity, aesthetic and ecological benefits not directly associated with activities on or adjacent to the water body or with diversionary uses of the water and could include preservation benefits, option values and changes in property values; (3) diversionary uses - drinking water and health; and (4) commercial fisheries - where abatement of pollutants could result in increased producer rents and/or lower prices of fisheries products to consumers.

Meyer (1983) critiques three estimating procedures for valuing riparian habitat. Indirect inferential evaluation, where values of selected end users of habitats are prorated back through their relationships, are vulnerable to criticism because the values are not associated with the habitat itself. By indirect empirical evaluation, travel cost is used as a proxy to derive a demand curve for resources. Though an improvement, it requires a strong data base and is "not particularly useful in addressing issues of major short term habitat alteration or of cumulative impacts." (p. 4)

The preferred method of the author is direct valuation, whereby local citizens are asked directly to value habitat for recreational and aesthetic purposes. He points out, however, that the data are sensitive to the number of residents living in adjacent areas with higher values attained in more populated areas.

A different approach to non-market valuations is presented by Wolfley, Matulich, Davies and Shrew (1979), which attempts to assess the benefits of wildlife enhancement in irrigated agriculture by means of a joint products model:

> "The capability of the joint production framework to capture the unintended by-product character of

> externalities, as well as to evaluate technological trade-offs between market goods and the non-market by-products, suits it particularly well to the study of the wildlife externality in irrigated agriculture." (p. 65)

The standard model approach is defined:

$$Q_j = f(V_1, V_2, \ldots, V_n) \qquad X_j = h(a_j)$$

where Q_j = intentionally produced output

V_i = factors of production

X_i = unintentionally produced output

In this case, once the output is set, the externality is fixed; no altering of the production process can change the externality. A more realistic approach, however is one in which the total output and production process affect externalities:

$$X_j = h(Q_j, V_n, V_{n+1}, \ldots, V_z)$$

An application of this model is presented through an econometric model which assessed the physical impact of irrigation and capitalization of farm inputs on pheasant populations. When assessed as a joint output (ie, pheasant enhancement was an objective of the planners), an additional acre of cropland would increase the quantity of pheasant 1 to 1.2 birds. Assessed as a joint input, conversion from gravity to sprinkler-irrigation was estimated to reduce the pheasant population 1.57 to 1.69 birds per acre.

When the objective was pheasant enhancement, the opportunity cost of retaining the same number of pheasant under changing on-farm conditions was $7-8 for small farms.

Surveys were conducted among recreationists to obtain demand curve estimates for pheasant hunting, waterfowl hunting, fishing and non-consumptive use. Results of this questionnaire are presented in table II.1.

	Cumulative % of population			
Marginal Day Value	Pheasant Hunting	Waterfowl Hunting	Fishing	Nonconsump. Use
$15	6.2	2.6	3.7	
10	10.8	3.3	5.6	
9	14.4	5.3	6.8	
8	23.7	9.3	9.9	
7	32.0	15.2	18.5	
6	40.7	21.9	29.6	
5	52.6	33.1	42.0	
4	65.5	44.9	55.6	0.0
3	74.2	64.9	76.5	5.0
2	85.1	85.4	92.0	20.0
1	100.0	100.0	100.0	100.0
mean	$5.44	$3.94	$4.44	$0.97

Table II.1 -- Survey results indicating value of a marginal recreation day for various activities.

Marginal values of pheasants ranged from $39.96 to $0.57 with a mean of $5.83; marginal day values for pheasant hunting from $40.03 to $0.37, with a mean of $5.44. For waterfowl hunting, from $18.23 to $0.21, with a mean of $3.94. For fishing, from $15.61 to $0.58, with a mean of $4.44. And for non-consumptive use, from $3.27 to $0.02

with a mean of $0.97. The authors contend that these valuations are useful:

> "Marginal values developed ... can be thought of as wildlife value estimates which can be applied in assessing benefits and trade-offs among competitive users. The marginal pheasant values can be applied directly to valuation of enhancement efforts." (p.211)

Another application of benefits valuation was offered by Abelson (1979) with regards to a soil conservation project. "Internal" and "external" benefits were analyzed and costs were separated into public and private (landowner). Intangible effects (such as water quality, flood mitigation, increased knowledge through research, soil fertility) were also discussed in terms of relative costs and benefits (slight, some, or significant). In addition to the cost results, analysis of the distributional effects were made in terms of landowners, government, the local region and the nation. In other words a subjective and judgmental approach was made to analyze project feasibility, in contrast to previous studies.

In recent years it has become clear that natural scientists play an important role in helping to assess project impacts. While economists may be able to place a value on the complete elimination of a wetland, wildlife, or recreational area, valuing marginal changes in that area often requires analysis beyond their scope of expertise. A look at physical impact assessment methods may help.

In response to various needs for such an evaluation techniques, the U.S. Fish and Wildlife Service (1981) developed the Habitat Evaluation Procedures (HEP). The HEP modeling process quantifies a given habitat in terms of specific requirements of wildlife species based in habitat units (HU). The overall productivity of a given area is the sum of habitat units made for each species.

In selecting species to evaluate, efforts should be made towards those with economic or high public interest value, and the broader, ecologically important species. A Habitat Suitability Index (HSI) is selected for each species, as a measure of a habitat's ability to support or produce that species; values are unitless, ranging from 0.0 to 1.0. The HSI can be further broken down into weighted components representing food, nesting, and migratory qualities.

Habitat units for each species are computed by multiplying the habitat area by the species HSI. Overall habitat units for the region are the sum of species' HU's.

HEP has tremendous potential not only for quantifying and comparing of habitats in universal units, but also for impact and marginal change assessment. This provides rationale and objectivity in the mitigation of potentially damaged habitat areas.

An application of HEP was produced for a wetland area in the Malad Valley of Southern Idaho (BIO/WEST, 1982). They identified and defined 12 wetland types in the study area and developed HSI values for the waterfowl, birds and wildlife considered important. Use and/or potential of each area for nesting, food, and migratory activities were assessed and formed each wetland's HSI. The weighting was formulated as follows: (p. 22)

$$HSI_i = (3N_i + 2F_i + 1M_i) / 6$$

where HSI_i = value of i^{th} wetland type

N = nesting, F = food, M = migratory activity

The values N, F, and M were assigned 0.1 (poor), 0.5 (fair), or 1.0 (excellent) for each wetland type, and division by 6 normalized the HSI values.

Though inadequate data prevented a meaningful quantification, impacts in terms of HU's could reflect negative or positive change, or could be defined in percentage of HU's lost.

Utilizing HEP to analyze wildlife habitats in an economic framework was the goal of Matulich and Hanson (1983). They recognized that conflicts between agricultural development and the natural environment have continued due to the failure to integrate biological principles into economic development plans. They continue:

> "Economists, recognizing the paucity of data, have retreated to generic Pigouvian remedies of environmental spillovers rather than detailed interdisciplinary plans. Continued lack of cooperation between the biological and economic communities can only further environmental degradation. The potential exists for cooperative project planning thereby facilitating mitigation of impacts before they occur. However, to be successful, new tools are needed which

can accommodate the interdisciplinary facets of the planning process." (p. 1)

The authors had the "proverbial non-market benefit valuation problem" when developing an economic choice criterion. Rather than focus on non-market valuations and recreational value (generally unacceptable to biologists), they attempted to minimize costs per unit of habitat (HU's) produced.

While mitigation costs are often very expensive (involving land acquisition, fencing and development), habitat units could distinguish quality versus quantity and allow ordinal comparisons of plans. This multi-agency approach can aid decision-makers by providing a continuum of cost effectiveness measures.

At a time when continued loss of valuable freshwater wetlands was growing in the public awareness, Goldstein (1971) studied ways in which to assess wetland values. The productive "prairie potholes" region of the Midwest and Canada was the focus of the analysis, where the social benefits derived from an acre of wetland (in terms of ducks produced for hunting) (V_w) was compared with the value of an acre of drained land (V_a) minus the cost of draining the wetland (I_s). If $V_w > V_a - I_s$, it is socially desirable to leave the land as wetland; otherwise the land should be allocated to the agriculture sector (p.6).

The proper method for computing V_w was one of Goldstein's objectives. In the process he criticized two previously used methods. The sum of expenditures for hunting divided by the number of ducks bagged does not reveal the "value of a duck" because this does not reflect the value of the recreational activity of duck hunting; rather it expresses an "expenditure per duck", which may not be related to valuation. It also does not include the public cost of resources.

Private fee hunting charges are also an invalid measure because the value of hunting is highly related to distance traveled by hunters, and this is not reflected in these charges.

The relationship and sensitivity of waterfowl to wetlands was also tested, but with some difficulty in data acquisition. Using a microanalysis regression of the Waubay National Refuge in South Dakota, he tried to determine the importance of temporary (seasonal) wetlands to breeding, and found that those temporary wetlands that existed near permanent marshes were of considerable value for breeders (p. 66-68); in fact, the estimate is a value of 1.8567 additional breeding pairs for every additional acre of temporary wetlands (given the levels for all other variables). They concur that:

> "... A combination of many small and temporary water areas near other areas that hold water throughout the summer appears to be best for maximum waterfowl production .... They are essential to the maintenance of the waterfowl breeding population...." (Grady E. Mann, "Ducks and Their Water Home", The Conservation Volunteer, May-June 1957, p. 28)

While migrating waterfowl will search for new habitat in which to breed farther north, they are markedly less prolific when forced north and consequently the population size is not maintained (p. 85).

Hammack and Brown (1974) elaborated on Goldstein's findings and tried to formalize the theory of marginal valuation of waterfowl. They developed an analytical optimal control model to determine the number of ponds to maintain and the hunter's bag limit, given hunters' demand function, pond cost and a Mallard population model.

The net value of hunting during a season is a product of N hunters and their individual valuation functions:

$$NV\ (D,Y,S,E)$$

where D = seasonal bagged waterfowl kill

Y = disposable income

S = seasons hunted

E = hunter's cost per season

The Mallard population model is

$$W = -W + S_2\ (I + S_1W - C_3ND)$$

and is defined as follows: the young (I) plus surviving breeders (S_1W) make up the fall flight from which total kill (C_3ND) is subtracted to obtain the wintering population. A fraction of the wintering population (S_2) survives to return north. If this number is greater than the original number of breeders (W), then W is positive.

Then the optimal control model is

$$H = \{NV\ (D,Y,S,E) - C(P) - \quad [W - S_2(I + S_1W - C_3ND)]\}\ e^{-rt}$$

where is the imputed value of a marginal change in the waterfowl population (p. 66-70).

Upon testing this model empirically, the authors estimated average annual pond costs of $4.76 for ponds in Alberta. The opportunity cost of lands for which wetlands are the best alternative to agriculture was $17 per wetland acre. They conclude: "If this number is accurate, it establishes a sort of upper bound on the value of marginal wetlands." (p. 84-85)

A later attempt to value "wildlife experiences" was made by Shulze, d'Arge and Brookshire (1981). They defined the outdoorsman's utility function as:

$$U = U\ (\#\text{ of encounters with wildlife, time})$$

The authors used a random sample of hunting and fishing license lists from the Wyoming Game and Fish Department, and recorded serious instrument bias in their results.

Finally, Vaughan and Russell (1982) used the travel cost method to estimate the value of a fishing day. They used published travel cost studies and the "1975 National Survey of Hunting, Fishing and Wildlife Associated Recreation", by the U.S. Dept. of Interior. The value of a fishing day was defined as a function of travel and socioeconomic characteristics, and attractiveness of the site. The value of a trout was estimated at $10.96 excluding, and $15.60 including resource costs. If the opportunity cost of travel time is included these values are boosted to $19.49 and $24.09 respectively. Important variables in the econometric model were average number of fish caught per visitor day, average weight of fish caught per visitor day, species mix, aesthetic quality of site, accessibility, weather, and congestion.

In recent years biologists and ecologists have attempted to specify values more clearly by deriving methods to evaluate wetlands and wildlife areas. The U.S. Fish and Wildlife Service (1984) defined and categorized the major wetland values as fish and wildlife habitat, environmental quality values and socio-economic values. Though these values represent benefits, no economic assessment is suggested.

In wetlands near urban areas or under the influence of speculation, aesthetic and cultural values are significant; yet these are the most difficult types to assess. Smardon (1983) produced a model for assessing the visual-cultural values of wetlands in Massachusetts. A series of resource characteristics were evaluated including: landform contrast diversity, surrounding land-use contrast and diversity, internal wetland contrast and wetland size. These were weighted and summed to produce a "visual resource value."

Economic valuation was based on land purchase data in Massachusetts. Average price was $1608 per acre. Resource economists in the study team used $5000 per acre as a "fair maximum willingness to pay" for high quality open space land (p. 165-66).

Smardon categorized and ranked ordinally values in terms of type of benefits, capitalized over n years and produced dollar values for wetlands.

No explicit basis for these assessments was presented beyond the $5000 per acre base.

C. Benefit-cost Analysis

Background. Because unlimited supplies of land, labor, and capital do not exist, societies must make decisions as the best use of their resources. Benefit-cost analysis is an application of welfare economics and is directed toward improving the economic efficiency of resource allocation. The economic values of society are relied upon to evaluate specific proposals (Hufschmidt, et al., 1983).

The benefits of a project are the values of incremental outputs and services, including environmental services, made possible by a project. Costs are the values of incremental real resources used by the project. In a water development or related project, the costs include not only the monetary costs of development and maintenance but also an accounting of benefits lost by reallocating water related uses from their present uses. Externalities arise when the social costs and benefits of effects on the environment are not taken into consideration by the person or group that creates the effects.

Benefit-cost analysis has been applied to water resource issues since its conception in the 1930's. The Harvard Water Group (Maass, et al., 1962) was instrumental in refining benefit-cost analysis for water resource systems. Since then the literature and applications have expanded not only in water resource systems but also to pollution control (Kneese and Bower, 1968), natural resources and other fields (Mishan, 1976).

Concepts of value. Computing the benefits of a proposed project requires an analysis in terms of welfare change. Two measures of welfare change that account for an individual's utility are compensating variation (CV) and equivalent variation (EV). Compensating variation asks what compensating payment or offsetting change in income is necessary for indifference between an old and new price set. It is the maximum willingness to pay for the opportunity to consume at the new price set. Equivalent variation asks what change in income is required that would lead to the same utility change as the change in price of a good. It is also the minimum lump sum payment an individual is willing to accept to forego the opportunity to purchase at the new price set.

The difference between CV and EV is that compensating variation measures willingness to pay for an improved bundle of goods, while equivalent variation measures willingness to accept payment for an inferior set of goods.

The two may be illustrated as follows. Suppose a person is at point A in figure II.1. If the price goes up to OP_2, consumption would fall to OX_2. Lost consumer surplus would be P_2BAP_1 due to the substitution effect, or the shift in consumption from good X to all other goods caused by a price increase. The higher price, however, represents a loss of income (less may be purchased with the same money). To maintain the same utility level, a "compensating variation" (via extra money) must be provided. Some of this income could be spent on good X, leading to a final equilibrium at C.

Equivalent variation is shown in figure II.2. An increase in price (from P_1 to P_2) for good X puts the consumer on a different utility curve at B. The equivalent loss of income, given the same price OP_1, is the equivalent variation.

Policies affecting recreational amenities which are unpriced (e.g., no fee is exacted, travel time remains the same, etc.) usually involve changes in quantity of an environmental good or service rather than price, so the welfare effects are somewhat different. In figure II.3, BC is the compensating variation and AD is the equivalent variation (Kneese and Bower, 1968).

Though CV and EV are generally assumed to be equal, empirically willingness to sell is greater than willingness

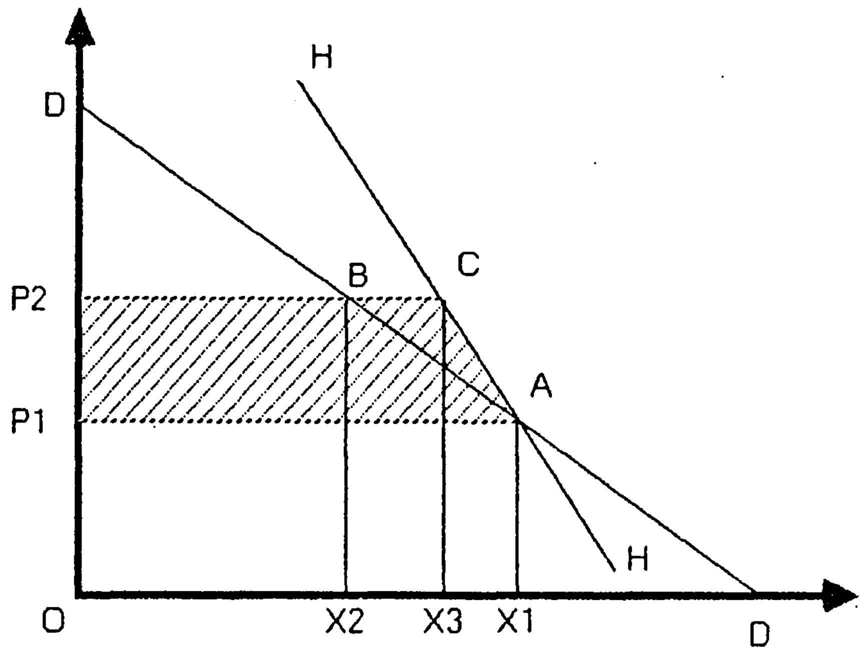

Figure II.1 - Compensating variation.

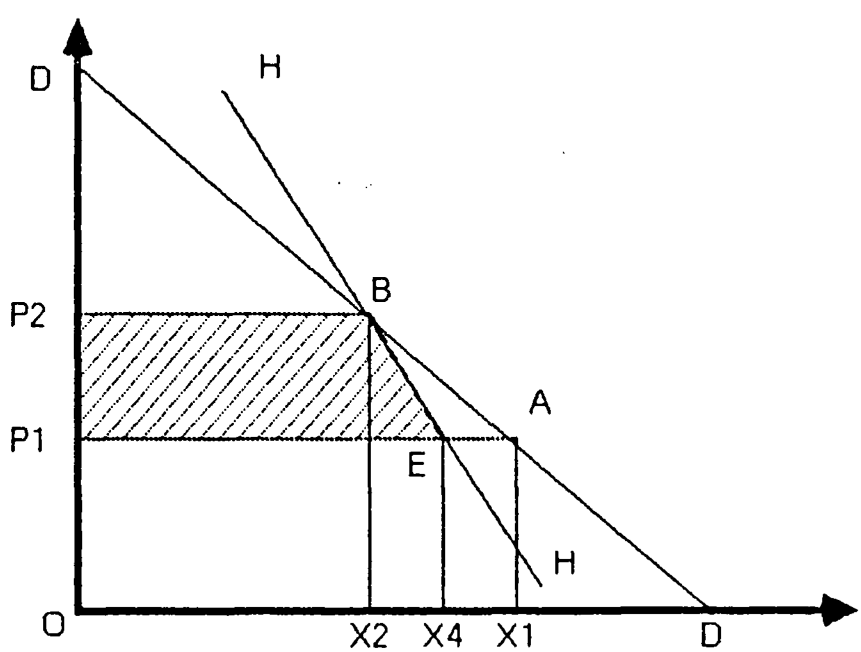

Figure II.2 - Equivalent variation.

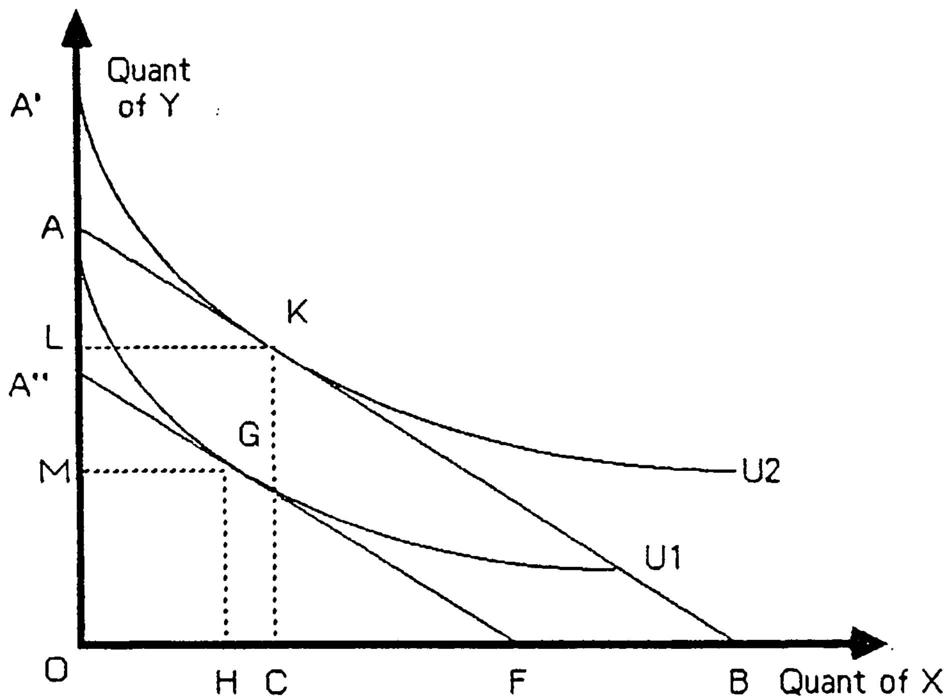

Figure II.3 - Combined compensating and equivalent variation.

to pay far in excess of the expected difference. This is not necessarily a failing of theory, however, as the difference may lie in the nature of utility curves (where AD far exceeds BC in figure II.3) (Dwyer, Kelley, and Bowes, 1977).

<u>On-site (market) assessment.</u> Measurement of benefits and costs in a market-oriented framework is easier and generally less controversial than a non-market framework. The benefits of a project are the sum of changes in revenue for affected parties, and the costs are the monetary costs of real resources and maintenance incurred by affected parties. However, a set of assumptions is generally associated with market-based benefit-cost analysis: (Maass, et al., 1962)

(1) that no individual derives economic gain or loss from the provision of goods for another's consumption (i.e., no external effects);

(2) that prices throughout the economy equal marginal costs; and

(3) that other prices will remain constant.

Under most situations, assessment of on-site benefits and costs involves merely comparing the sum of discounted benefits with the sum of discounted costs to determine the net benefit income flow. When a simulation of water resource systems is designed, however, these values must be developed within the model and involve a more complex arrangement. Cost and benefit functions must be constructed for those affected parties: irrigators, recreationists, power consumers, and for water quality. The benefits associated with a range of target outputs are made explicit, either in functional form or through a table of values. These include the production of exact target outputs, along with values associated with underproduction and overallocation (losses and gains, respectively).

Economic loss functions are of the same form but should reflect supply conditions. For example, a reduction in water supply should cause a shifting to reserve supplies or altering of operations. Recreation should be related to drawdown levels: the more shore exposed in a reservoir, the fewer visitors (Hufschmidt and Fiering, 1966).

The summary economic analysis is either static or dynamic. In a static analysis, all capital facilities are assumed installed at the beginning of the first year of the period. Target outputs remain fixed for all periods. As such, capital costs require no discounting, but Operation, Maintenance and Replacement costs are discounted to year one. Essentially, benefits and costs are analyzed at one point.

Dynamic analysis assumes capital inputs and target output levels may change at selected times in the period. Benefits are discounted from the year of occurrence, or as a stream of equal values (Hufschmidt and Fiering, 1966).

<u>Offsite (non-market) impact assessment.</u> Non-market analysis involves public goods and those private goods not transferred in the marketplace that exist as externalities.

They can include impacts on recreation, environmental quality, wildlife habitat, and other social values. Because they involve costs and benefits not explicitly defined in monetary terms, they are difficult to quantify economically. To do so is nevertheless important in evaluating a project for its net social benefit.

Traditional analyses of non-market externalities have focused on recreation because its impacts are more readily apparent and measurable. Recently, however, applications to water quality management, environmental quality, and natural systems have been performed.

For benefits associated with most recreational activities, willingness to pay measurement includes entry and use fees, plus an estimate of the maximum amount in excess of these charges that users could be induced to pay. Net willingness to pay is the appropriate measure of additional benefits received by those individuals who gain from using a recreational facility. This is approximately the area above the market price, below the demand curve, or the consumer surplus.

How can this demand curve be measured and calculated? The two most highly regarded methods are the Clawson-Knetsch (C-K) travel cost method, and the direct survey method.

The travel cost method derives a demand curve for a specific recreation site rather than recreation in general. First, geographic zones are established as concentric circles around a recreation site. Visitors are sampled according to zone of origin and visitation rates calculated. Then travel costs are measured to indicate cost of travel from each zone of origin to the site and back. The series of rates are regressed on travel costs and socioeconomic variables such as average income and education (testing the hypothesis that visitation rates depend in part on travel costs). This represents one point on the demand curve; other points are developed by assuming different admission prices (Freeman, 1982).

The travel cost method assumes individuals react to fee increases as they would a travel cost increase, and that net benefits derived from travel are zero. But there are difficulties in using the travel cost method (Dwyer, Kelley, and Bowes, 1977):

(1) there is too little difference in user's costs for good approximations;

(2) if travel is not made for the single purpose of visiting that site, then it is difficult to decide how much of the travel cost should be attributed to that site; and

(3) when small changes occur which would have little impact on trip-making behavior but might alter an individual's valuation of a recreation experience, the survey method is more appropriate.

The survey method should be conducted in two phases for a particular site. The first survey attempts to elicit valuations and collect data on explanatory variables. The second survey is used to estimate values for the explanatory variable for the complete user population. The method is predicated on two assumptions: (1) that consumers are able to assign an accurate value; and (2) this valuation can be elicited from them with a properly constructed series of questions.

Deriving non-recreational benefits is even more difficult in most circumstances due to a lack of methodology and their nature of subjectivity. Such is the case with wildlife valuation. Expenditure surveys are used heavily by wildlife managers, but these reveal only costs and not benefits. Bart, Allee and Richmond (1979) suggest that selection of a method to evaluate wildlife should include a management goal and data use objective, and selection of a specific wildlife group and set of wildlife experiences to be evaluated. Travel cost and surveys are applicable methods, but disaggregation of wildlife benefits is difficult in the travel cost method, and user estimates in surveys are subject to political scrutiny.

Determining the opportunity cost of maintaining or enhancing a certain objective is another method of computing costs. For instance, a study of the opportunity costs of on-farm pheasant enhancement in Eastern Washington were estimated to be $7-8 per pheasant on a 160-acre farm and $10-12 for a 320-acre farm, by providing strips of semi-permanent cover on less-intensively farmed, low-value crop rotations (Wolfley, et al., 1979).

Valuing damages to freshwater wetlands can prove difficult due to the wide range of benefits they provide. (For instance, most freshwater fish can be considered wetland dependent, either for food or spawning; they also provide waterfowl habitat, water quality maintenance, aesthetics and recreation (USFWS, 1984).) Progress has been made in valuing the wetlands as a whole, but considerable difficulty still remains in marginal analysis; that is, when a wetland area is partially damaged rather than completely removed.

D. Unresolved Issues

The preceding survey of literature and relevant theory indicates a serious lack of cohesiveness. Important and detailed methodology has been developed for simulating the mechanics of water resource systems. Hydrology models, variant and invariant design variables, relationships among components have been well defined and, to a great extent, well-modeled. But traditional approaches to economic evaluation of water systems have been somewhat incomplete. Some analyses have completely ignored economic considerations (see Morrice and Allan, 1955; or Brockway and de Sonneville, 1973), while others attempt too narrowly define to the scope of economic analysis (by studying only selected impacts) or to come up with a range of values only to neglect explaining their meaning. Though a model is, by definition, a simplification of reality, some discussion of risk and variation in annual income flows is discernible from simulation results.

Inherent in the assumptions of not just simulation designs but of most benefit-cost analyses is that which states that "external effects" do not occur. Offsite impacts of water resource projects are generally ignored, primarily because they are thought to be insignificant and (more appropriately) are difficult to measure. The former may not always be true; the latter usually is.

Offsite or non-market impacts are generally measured through recreation benefit analysis. But within the literature no clear consensus (and even some conflict) exists as to appropriate measures. The travel cost and survey methods are the two most highly regarded, but each is appropriate under different circumstances, and each has important limitations. Valuation of non-recreation benefits is hindered for a variety of reasons by a general lack of substantive data and information on bioeconomic relationships and methodology. The method used by most government agencies (the "interim unit day approach") lacks an economic basis and should be revised (Dwyer, et al., 1977).

Finally, a search of the literature revealed no attempt at producing a simulation model of water resource systems with (1) the flexibility to model similar stream basins using the same program by changing the appropriate data, thereby spreading the fixed costs associated with model development; and (2) the mobility afforded by building a simulation model fully self-contained on a micro-computer.

III. INVESTIGATIVE PROCEDURES

A. Introduction

This chapter contains the components of the simulation program developed for this study. The assumptions made for simulating the physical behavior and interactions of the elements are explored, and the economic basis for deriving the results developed.

A general description, set of assumptions, and reasons for selection of the basic model are presented. An overview of the hydrology generator, data base and model implications follows. The methods used to distribute water to crops, calculate crop production, and their economic implications are reviewed next. Included is a discussion of relevant assumptions and implications.

The procedures for simulating physical offsite effects and their subsequent economic valuation are described next, focusing on three specific areas: fish, pheasant, and waterfowl. Finally, a detailed discussion of the input format for data used in this program is included.

B. Model Selection

Selection of a suitable model depends upon the goals of the simulation and available data. In the case of U.S.D.A.

River Basin Studies, there is an emphasis on the cost-effectiveness of improving water delivery and irrigation systems. As such, the method chosen should trace, in some detail, water use as it is transferred from the supply source to the farms and applied to crops. This requires an appropriate accounting of production costs, yield potential, and yield attainment, as well as water needs and availability.

Data provided by the Soil Conservation Service met some of these needs. The additional goal of quantifying offsite impacts required an extension of the production model and, in some cases, external estimations, where data were unavailable.

Figure III.1 outlines in graphic form the algorithm of the water resource simulation. The primary components of the system are the hydrologic stream flow generator base, the monthly flow generation section, the annual/seasonal flow simulation, and the summary cumulative analysis. The system simulates a "present condition" situation and estimates a predefined "future condition."

A stream flow generator was developed exogenous to the base simulation. This generator used hydrologic flow data for the region of study (Paris Creek, Idaho) to form the components of a monthly flow generator.

Within the simulation, each month of the season had a flow generated as the base flow for that month. Irrigation water was diverted for use according to a specified monthly

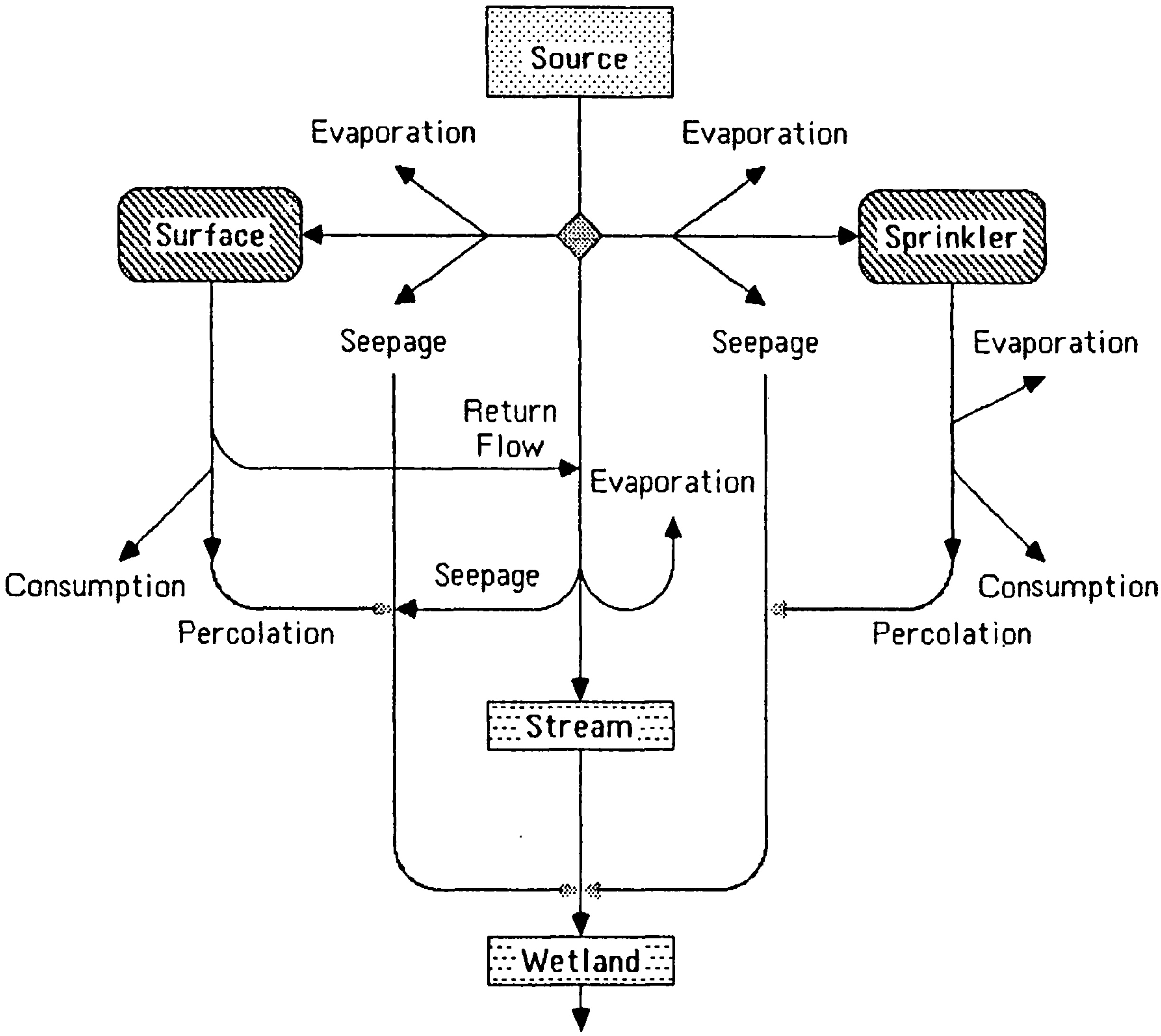

Figure III.1 - Water-use algorithm for water resource simulation.

irrigation schedule. This schedule was defined for both a present and future condition situation; each condition is computed and analyzed separately. The applications and requirements of the crops are noted for each month, and these results are used to compute the on-site benefits from production for both the present and future conditions.

Water is either applied directly to crops, or is lost to evaporation or through seepage. The remaining water in the system is traced from the source through the stream and eventually to the wetlands. These flows are combined for each month to form the basis for calculating offsite impacts of changing from the present condition to the future.

The annual summary requires combining the on-site benefits and offsite impacts with the annualized costs of the project to compute the net social benefits and net benefits to the farmer for that year's production.

This cycle is repeated for a specified number of years, with the annual results retained for each year. After the last year is generated, the simulation combines the yearly results and presents a series of relevant statistics on the overall nature of the year-to-year income and outflow patterns. These statistics are later used to analyze a variety of conditions, circumstances, and issues related to the initiation of such a project.

The basic model format assumes a number of responses about the direction and concerns of the modelers. The most important assumption is that offsite impacts do occur and can be measured and economically quantified. As such, they should be included in the calculation of social benefits.

Another important consideration is that the project area is analyzed as a single indivisible entity. This precludes any discussion comparing the net benefits of one tract of land with another within the project area. Similarly, the entire project area is assumed to have homogeneous hydrologic and land characteristics.

C. Hydrologic Simulation

The hydrologic system consists of the generation of streamflow for Paris Creek, and the use of water within the stream basin. This includes an accounting of water diversions for irrigation, return flow, seepage and deep percolation, evaporation, and evapotranspiration. Figure III.2 shows the components of a typical hydrologic system with a surface water source for irrigation (Law, Skogerboe, and Demit, 1972). Initial flow is measured at an upstream point. Water then is diverted for irrigation and transferred or transported to individual farms via a delivery system. Evaporation (which represents a net water loss) and deep percolation (water lost for irrigation use but retained within stream basin) of the delivery canal are estimated and used in obtaining farm gate irrigation availability levels, or the actual quantity of water usable

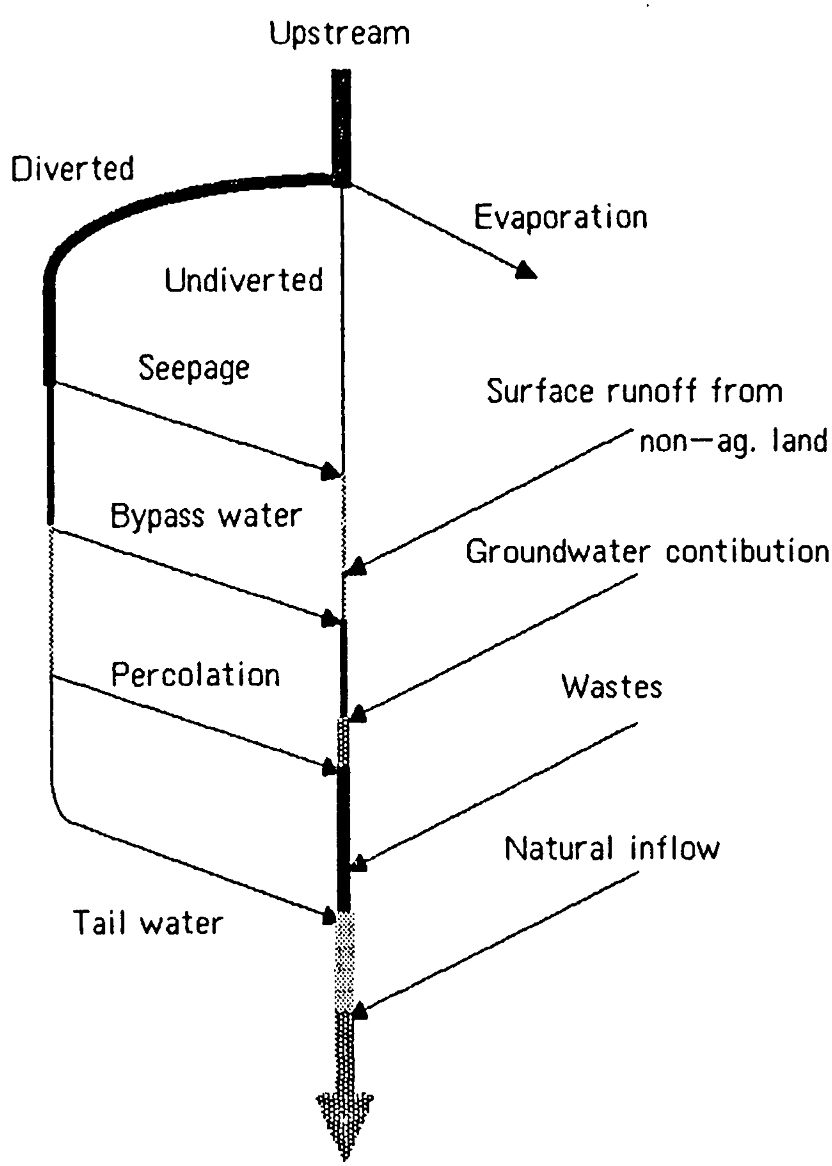

Figure III.2 - Components of a typical hydrologic system with a surface water source.

by farmers. Water then is consumed by plants, evaporates, seeps into the subsoil, or is returned to the stream as return flow or tailwater.

Undiverted stream water is again calculated at a checkpoint downstream from the first. Seepage, evaporation, and return flow are the outputs and input, respectively, for this computation.

Finally, stream water combines with delayed groundwater and flows into the wetland, where its contribution to the total wetland is measured.

Flow measurements are recorded for the initial flow, and for stream and wetland checkpoints in the present and future condition.

Water-use terms. Certain commonly used terms are defined below to avoid confusion:

* Consumptive use, or evapotranspiration - the sum of volumes of water used by vegetative growth of a given area. The measurement is given as depth in acre-inches per acre.

* Consumptive water requirements - amount of water potentially required to meet evapotranspiration needs of vegetative areas.

* Conveyance efficiency - irrigation water reaching farm gate as a proportion of quantity diverted.

* Irrigation efficiency - percent of irrigation water stored in soil and available for consumptive use by crops. When measured at the farm headgate, it is called the "farm irrigation efficiency;" at the point of diversion it is called "project efficiency."

* Irrigation water requirement - consumptive water requirement as a proportion of irrigation efficiency.

<u>Thomas-Fiering model.</u> Paris Creek originates from groundwater-fed block faults. As such, month to month variation in flow is not as great as it would be if fed by snowmelt alone. Variations within any given month are likewise not substantial (Fox, 1984).

The best available data for Paris Creek are monthly stream flow levels collected by Utah Power and Light.

An appropriate hydrology model must incorporate monthly flow levels, variation from year to year in selection of a value, and the relationship between months. The Thomas-Fiering hydrology model fits these criteria.

The model is defined as follows (Raudkivi, 1979):

$$Q_{i+1} = Q_{i+1} + b_i\ (Q_i - Q_i) + t_i s_{i+1}\ \ 1 - r_i^{\ 2}$$

where

	Q_{i+1}	is the flow in period i+1
	Q_{i+1}	is the mean flow for period i+1
	b_i	is the regression coefficient
	t_i	is a standardized random variate
	s_{i+1}	is the population standard deviation
	r_i	is the correlation coefficient between flows in successive time periods (i and i+1)

The skewness of t_i corresponds with that of the monthly flow; that is, if Q_i is derived from a gamma distribution, then it is necessary and sufficient that t_i be gamma distributed with skewness dependent upon the skewness of Q_i.

<u>Data base and final model.</u> Records of stream flow at Paris Creek have been kept by Utah Power and Light since 1913, measured at the source and again at its power plant located 3 miles from the source. Several records during this time are missing; however, a Soil Conservation Service hydrology computer program was able to generate estimated monthly flow levels for the entire 69 years. The records for the six months of the irrigation season (April through September) were used to determine the base values for the simulation model.

Noting that the skew values for each month are different, thus adding greater complexity to the model, an attempt was made to transform the data by taking the logarithm (base 10) of each month's stream flow and allowing the random variate to be distributed normally. The new model became:

$$\log_{10}(Q_{i+1}) = \log_{10}(Q_{1+1}) + b_i \; (\log_{10}(Q_i) - \log_{10}(Q_i))$$
$$+ \; t_i s_{i+1} \;\; 1 - r_i^{\,2}$$

where $\quad t_i$ (N; 0, 1)

A short computer program (see Appendix A) performed the required operations on the data.

The mean, variance, standard deviation, regression coefficient, and correlation coefficient are given in table III.1 for each of the six months, based on 69 years of transformed data. These were the actual values used in the simulation program.

	April	May	June	July	Aug	Sept
Mean	2.0920	2.5030	2.5650	2.3830	2.2390	2.1340
Variance	0.0254	0.0532	0.0692	0.0479	0.0260	0.0163
Stand. dev.	0.1593	0.2306	0.2631	0.2189	0.1614	0.1278
Regress. coeff.		0.8472	0.8412	0.7138	0.7211	0.7662
Correl. coeff.		0.5855	0.7370	0.8580	0.9781	0.9675

Table III.1 -- Statistics for actual monthly stream flow for Paris Creek, Idaho; 69 years of data.

<u>Validation of the model.</u> An accurate hydrologic simulation is one capable of generating artificial stream flows closely reflecting those occurring naturally. A test of this condition was performed for the modified Thomas-Fiering model.

A second computer program used the statistics of the base data to generate 500 years worth of stream flows, April through September for each year. The resulting flows were tabulated as for the base data. Table III.2 shows the statistics for the generated flows.

The modified Thomas-Fiering model provided a very accurate representation of actual Paris Creek flows, as indicated by the similarity of mean and standard deviation values.

	April	May	June	July	Aug	Sept
Mean	2.1080	2.5200	2.5740	2.3890	2.2450	2.1400
Variance	0.0255	0.0553	0.0724	0.0498	0.0264	0.0162
Stand. dev.	0.1597	0.2351	0.2691	0.2233	0.1624	0.1274
Regress. coeff.		0.8508	0.8811	0.7247	0.7123	0.7582
Correl. coeff.		0.5781	0.7699	0.8734	0.9792	0.9666

Table III.2 -- Statistics for synthetically generated stream flows using model parameters and 500 years of data.

<u>Water usage and losses.</u> The Soil Conservation Service estimated conveyance efficiency for the Paris Creek system to be about 70%, the surface field irrigation efficiency at 10-15%, and the potential for sprinkler system field efficiency to be between 55 and 60% (Fox, 1984). Losses in surface irrigation occur from seepage, runoff and distribution problems. Losses in the sprinkler system are primarily from evaporation and misplaced spray. Delivery system losses result from seepage and evaporation.

Keeping track of water use losses is important in identifying the differences in the conservation capabilities of each system, for both present and with-project conditions. Table III.3 shows the percentage values assumed for systems in this simulation. Most are based on local conditions but some (e.g., on-farm system efficiencies) are obtained from more general, standardized sources.

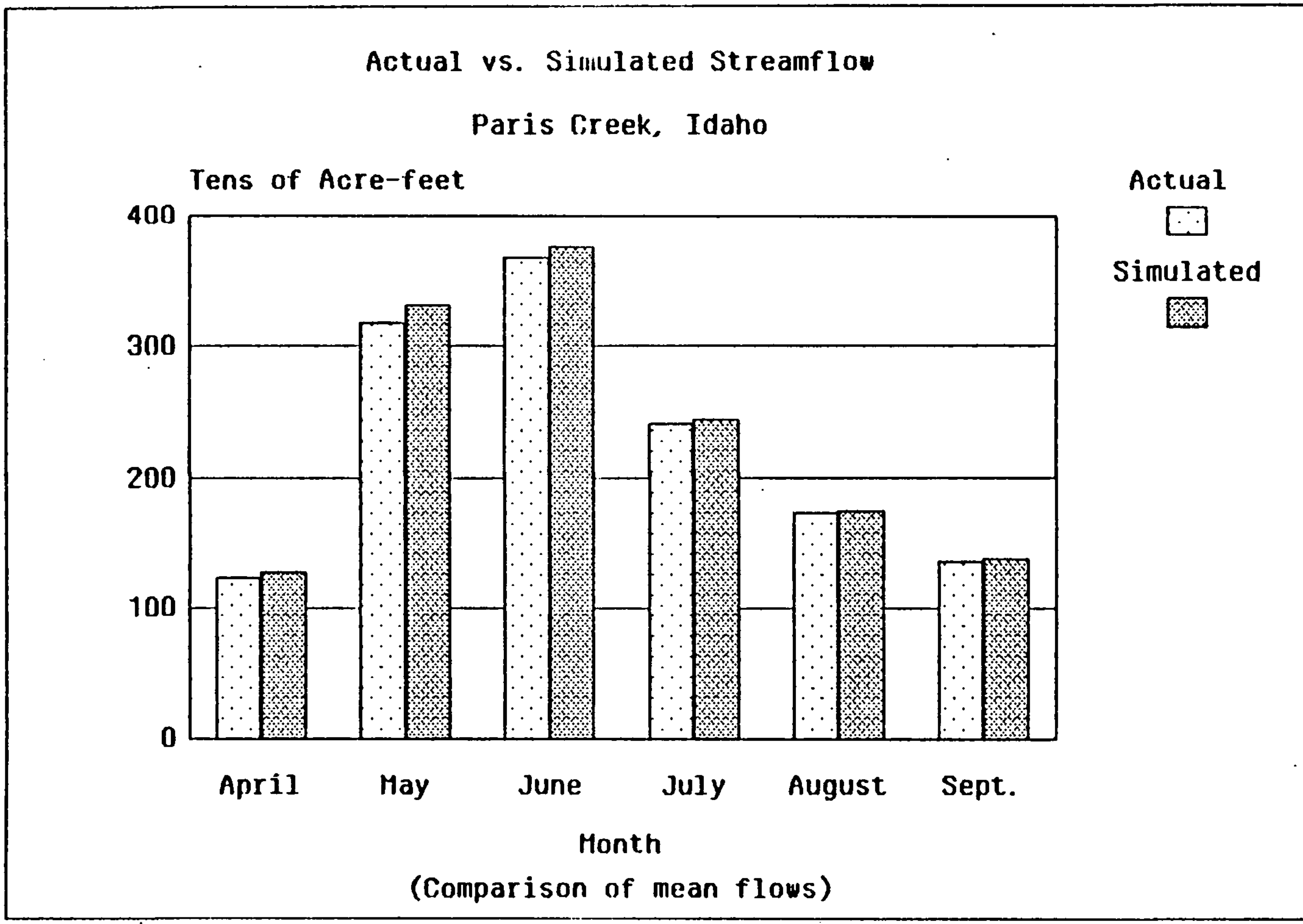

Figure III.3 - Comparison of actual versus simulated stream flow levels.

		Stream	Delivery	Sprinkler	Surface
Evaporation	- present	0.10	0.20	0.10	0.00
	- future	0.10	0.00	0.10	0.00
Seepage	- present	0.10	0.10	0.40	0.30
	- future	0.10	0.00	0.25	0.20
Return flow	- present	0.00	0.00	0.00	0.40
	- future	0.00	0.00	0.00	0.30

Table III.3 -- Percentage values used in the simulation for specific water losses in the stream, delivery and irrigation systems.

Consumptive use of water by plants (evapotranspiration) represents a net loss of water by the system. Estimates of this rate of use for each crop on a monthly basis for the Bear Lake region have been made by the Soil Conservation Service, and are incorporated in this study.

Water that percolates below the surface to the underwater aquifer is assumed to remain within the system; however, just how long it takes for this water to reach the basin sink (or wetland area) is unknown and unmeasured. The valley floor has many different soil types, and the percolation time in one section of land may be relatively short (one day), while much longer in another (perhaps 3 months) (Fox, 1984). In this model, the actual delay time is not critical, affecting only the length of time it takes groundwater to reach the wetland. The delay was assumed to be one month.

Assumptions. The hydrologic system of the basin has important characteristics. Water remains in a closed system unless it (a) evaporates, or (b) is consumed through plant evapotranspiration. Water that percolates through the soil is not lost from the system but flows eventually to the wetland or basin sink. This is not necessarily applicable to other basins.

Surface systems, sprinkler systems, delivery canals, and soils remain homogeneous throughout the project area, allowing uniform rates of water usage and loss to be applied.

D. On-site Benefits

Crop production and sale of commodities are the measured on-site benefits. Soil Conservation Service computation procedures are followed. The benefits of a project are the net increase in income from all commodities sold in the project area. These are compared to the annualized costs of implementing and maintaining the new system. A benefit-cost (B-C) ratio above 1.0 indicates positive net benefits overall; below 1.0 indicates costs exceed benefits.

The Paris Creek Basin study represents two separate project areas, the North system and South system. In the preliminary analysis, these systems were evaluated both separately and as a unit. After this initial assessment, farmers in the South system opted to no longer participate in the project. However, in order to simulate activities in the North section for this study, those in the South must also be monitored. This is because Paris Creek provides water for both groups and subsequently impacts the basin as a whole.

Crops are "produced" in the simulation according to a functional relationship based on water availability for the crop in both quantity and period of plant growth. Preliminary cost of production and yield information for Paris Creek were developed through interviews with farmers and from judgement of S.C.S. personnel. Crop budgets were created using the Oklahoma State Budget Generator. Table III.4 presents the summary of cost and yield data.

Given that water needs are not met for all crops every year, crops in the model are irrigated on a priority basis; that is, higher value crops will receive priority for available irrigation water. The priority is alfalfa, barley and pasture/hayland. Sprinkler- and surface-irrigated lands received water without priority.

Water is allocated to each crop according to need (in acre-inches) based on a predefined irrigation schedule.

	Sprinkler			Surface		
	Alfalfa (T.)	Barley (bu.)	Past. (T.)	Alfalfa (T.)	Barley (bu.)	Past. (T.)
Dryland						
cost ($)	128.53	113.54	60.00	89.62	100.00	70.85
yield/acre	1.5	25.0	1.5	1.5	25.0	1.5
1st irrig						
add'l cost	34.06	3.94	5.17	41.65	14.94	3.85
add'l yield	2.0	40.0	0.3	1.0	25.0	0.3
2nd irrig						
add'l cost	34.05	3.94	--	41.65	--	--
add'l yield	1.0	20.0	--	0.5	--	--
3rd irrig						
add'l cost	34.05	--	--	--	--	--
add'l yield	1.0	--	--	--	--	--
4th irrig						
add'l cost	18.75	--	--	--	--	--
add'l yield	0.5	--	--	--	--	--

Table III.4 -- Cost and yield data assumptions. Figures include costs and yields of dryland farming, and the additional costs and yields associated with irrigation.

<u>Production functions.</u> Two production functions are utilized in this simulation. Both use "month" as the independent variable, and "yield" as the dependent variable.

Figure III.4 illustrates the first function type, applicable to alfalfa and pasture land, and figure III.5 the second, for small grains. In each graph, curve A is the yield potential given a full water supply and on-schedule irrigation. Curve B represents the yield potential for dryland farming of the same crop.

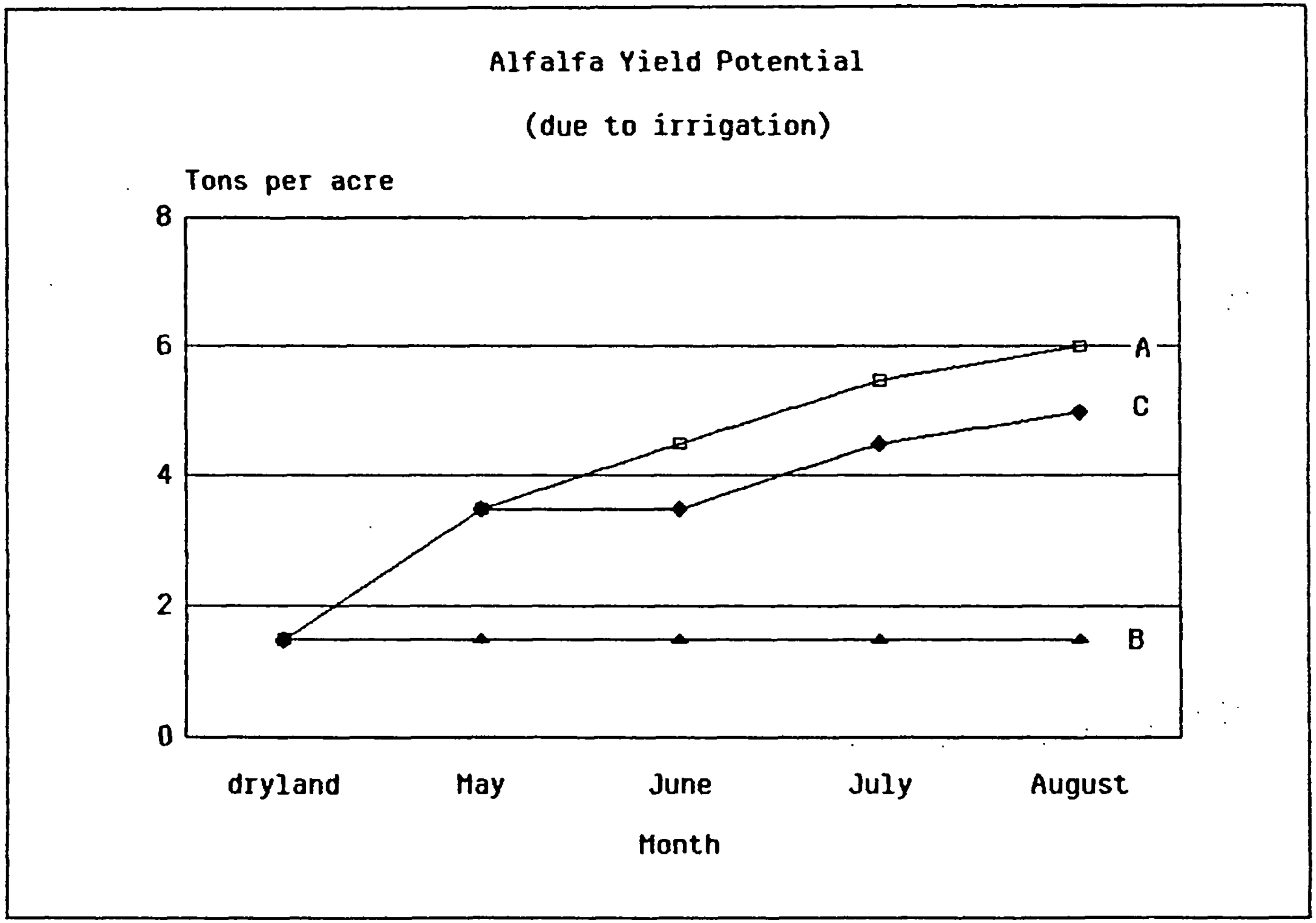

Figure III.4 - Functional form of alfalfa production.

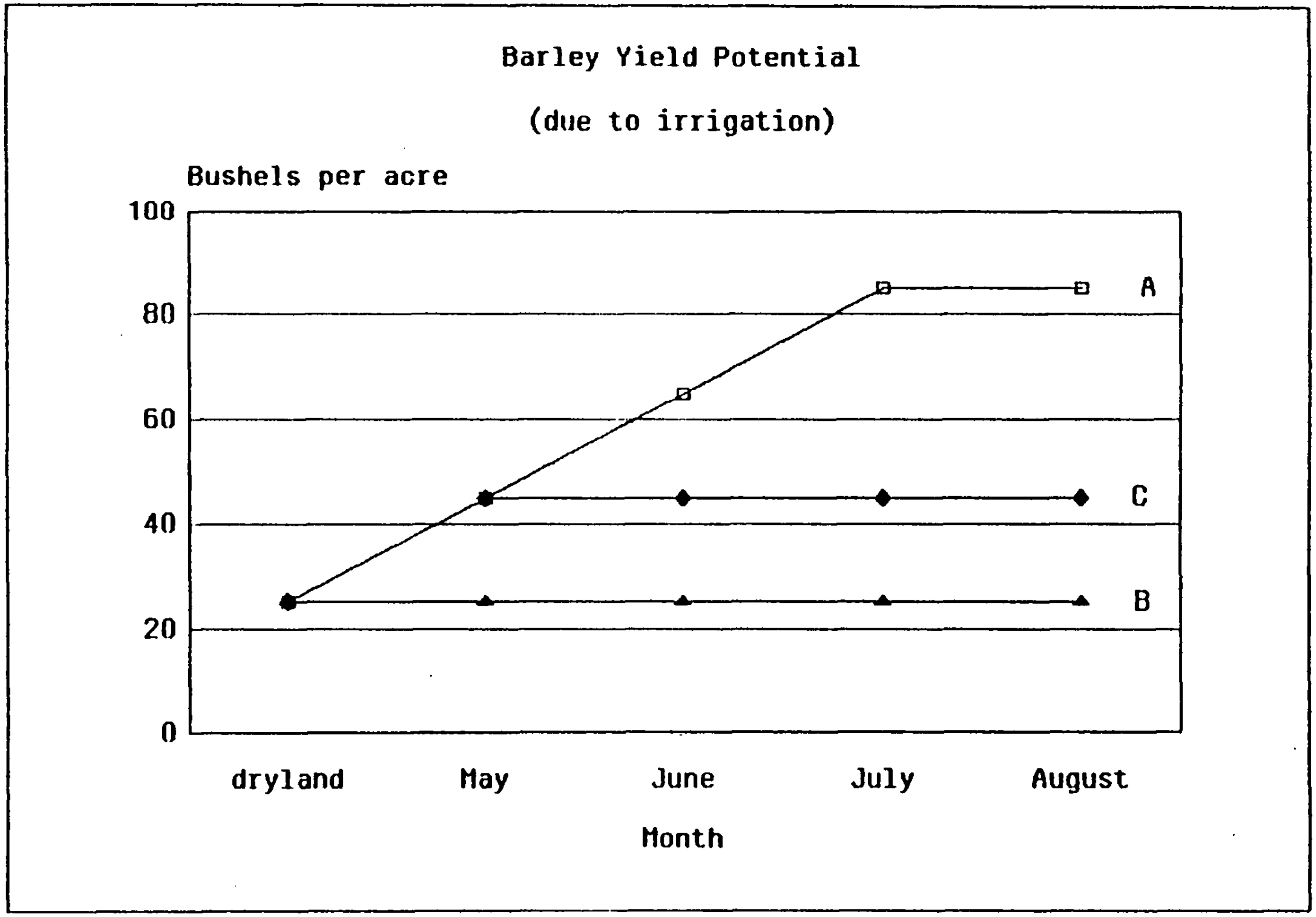

Figure III.5 - Functional form of barley production.

For curve C, assume no water is available to irrigate as required in June, but full water is available for subsequent months. In III.4, no carryover effect occurs and the yield potential for later months remains unaffected. But as shown in III.5, grain crops are subject to a "critical water period;" if not supplied as needed, the crop does not recover.

Yield potentials for each month are assumed to be affected directly proportional to the water supply; for example, if only 75% of the need is supplied to the first crop, the yield potential is reduced to 75%.

Evaluation process. At the end of each year of simulation, costs and yields for each crop (under sprinkler and surface irrigation) are compiled. Costs are the sum of cost-per-acre times acres for each irrigation. Total yields combine a factor of water availability with yield-per-acre and acres.

The net revenues received for each crop are summed to return a total net revenue. At the end of each year four "on-site net benefit" totals are calculated: present and future conditions for each the north and south groups. These net revenue figures are combined for the north and south in each the present and future social net benefits comparisons. They cannot, however, be compared independent or irrespective of other costs (offsite, project, or otherwise).

Assumptions. Only two types of production functions are used in this simulation; in fact, actual plant growth behavior may or may not apply as closely as implied. Some research on the relationship of irrigation to crop production has indicated a linear relationship may exist between yield and spring wheat evapotranspiration (Hanks and Retta, 1982). In the interest of data availability, however, more general functions were assumed for each crop in this simulation.

An important assumption is made regarding farmer behavior and transfer of water rights. The project area is treated as a single decision-making body, in which water is always first allocated to the highest valued crops. For this to occur provision for the transfer of rights among farmers would be necessary, as those with the most senior rights do not always raise the higher-valued crops. No transfer provision presently exists, and it is unclear what pooling arrangements within the irrigation district would take place if the project were implemented (Thomas, 1984; and Fox, 1984).

The implication of this assumption is that the results may be biased in favor of higher returns (in both present and future conditions) than would realistically occur.

E. Valuation of Offsite Impacts

The focus of the offsite analysis is on three areas: fisheries and stream habitats, wetlands and waterfowl, and wildlife habitat. These areas are thought to be the most significant for this particular project.

For this area of analysis the physical impacts are evaluated in terms of losses to recreation income and opportunities.

Fisheries and stream habitat. Paris Creek flows into a wetland area surrounding the Bear Lake National Wildlife Refuge. Though the stream experiences very low flow levels during the summer of some years, cutthroat trout and rainbow trout use Paris Creek and other local streams for food and upstream spawning. In years of low water, this capacity is reduced; while the overall population of trout may not decline appreciably (given the plentiful alternative spawning sites), recreational fishing in Paris Creek itself is affected.

Binns and Eiserman (1979) developed a model for predicting fluvial trout habitat in Wyoming streams. The model uses ratings of particular stream habitat attributes to produce trout biomass. Table III.5 summarizes how these ratings were generated.

TABLE 5.—*Stream habitat attributes used in the Habitat Quality Index, the characteristics used to rate them, and their multiple regression correlation coefficients (R) from a multiple regression analysis of their relationship to trout standing crop. R values followed by an asterisk (*) are significantly different from zero at the α = 0.95 level (R = 0.378 from Table A-30a, Dixon and Massey 1969). ADF = average daily flow for the water year, obtained from gauging station records, if available; CPF = average daily flow during August and the first half of September only, from gauging station records, if available; SAV = submerged aquatic vegetation, includes algae and moss growing on rocks.*

			Rating characteristics		Rating characteristics		
Attribute	Symbol	R	0 (worst)	1	2	3	4 (best)
Late summer stream flow	X_1	0.36	Inadequate to support trout (CPF < 10% ADF)	Very limited; potential for trout support is sporadic (CPF 10–15% ADF)	Limited; CPF may severely limit trout stock every few years (CPF 16–25% ADF)	Moderate; CPF may occasionally limit trout numbers (CPF 26–55% ADF)	Completely adequate; CPF very seldom limiting to trout (CPF > 55% ADF)
Annual stream flow variation	X_2	0.80*	Intermittent stream	Extreme fluctuation, but seldom dry; base flow very limited	Moderate fluctuation, but never dry; base flow occupies up to two-thirds of channel	Small fluctuation; base flow stable, occupies most of channel	Little or no fluctuation
Maximum summer stream temperature (C)	X_3	0.28	<6 or >26.4	6–8 or 24.2–26.3	8.1–10.3 or 21.5–24.1	10.4–12.5 or 18.7–21.4	12.6–18.6
Nitrate nitrogen (mg/liter)	X_4	0.69*	<0.01 or >2.0	0.01–0.04 or 0.91–2.0	0.05–0.09 or 0.51–0.90	0.10–0.14 or 0.26–0.50	0.15–0.25
Fish food abundance (number/0.1 m²)	X_5	0.57*	<25	26–99	100–249	250–500	>500
Fish food diversity (D_s)[a]	X_6	0.57*	<0.80	0.80–1.19	1.20–1.89	1.90–3.99	>4.0
Cover (%)[b]	X_7	0.55*	<10	10–25	26–40	41–55	>55
Eroding banks (%)[c]	X_8	0.45*	75–100	50–74	25–49	10–24	0–9
Substrate	X_9	0.44*	SAV lacking	Little SAV	Occasional patches of SAV	Frequent patches of SAV	Well developed and abundant SAV
Water velocity (m³/second)[d]	X_{10}	0.38*	<8 or >122	8–15.4 or 106.6–122	15.5–30.3 or 91.4–106.5	30.4–45.5 or 76.1–91.3	45.6–76
Stream width (m)	X_{11}	0.38*	<0.6 or >46	0.6–2.0 or 23–46	2.1–3.5 or 15.1–22.9	3.6–5.3 or 6.7–15	5.4–6.6

[a] For the purpose of the Habitat Quality Index, Diversity Score (D_s) is defined as follows: D_s = antilog$_{10}\bar{D}$, where D is calculated for each taxon from the formula: $D = P_i \log_{10} P_i$. When P_i is defined as $1/N$, and N is the number of organisms, then the formula reduces to $D = \log_{10} N$, as discussed in Watt (1968). $\bar{D}$ is the mean of all the D values for the sample.

[b] % cover = total amount of cover (m²)/total area in study section (m²).

[c] % eroding banks = total length (m) of eroding stream banks (both sides) in section/total length (m) (one side) of study section.

[d] Time-of-travel water velocity, determined with fluorescent dye. Velocity = thalweg length/time required for dye to traverse section.

Table III.5 - Ratings criteria for trout streams.

The model used is given by the expression:

$$\log_{10}(Y + 1) = [(-0.903) + (0.807)\log_{10}(x_1 + 1) + (0.877)\log_{10}(X_2 + 1) + (1.233)\log_{10}(x_3 + 1) + (0.631)\log_{10}(F + 1) + (0.182)\log_{10}(S + 1)] \; [1.12085]$$

where Y = predicted trout standing crop;

X_1 = late summer stream flow;

X_2 = annual stream flow variation;

X_3 = maximum summer stream temperature;

F = food index = $X_3(X_4)(X_9)(X_{10})$;

S = shelter index = $X_7(X_8)(X_{11})$;

X_4 = nitrate nitrogen;

X_7 = % cover;

X_8 = eroding stream banks;

X_9 = substrate;

X_{10} = water velocity; and

X_{11} = stream width.

(Trout standing crop is a measure of the volume of fish in a given area; in this case as kg/hectare.)

In the Paris Creek study, not all the needed data were readily available, and certain assumptions were necessary. In particular, the maximum summer temperature (X_3) was estimated based on the late summer flow rating and annual stream variation. Nitrate nitrogen, cover, substrate, water velocity, and stream width were estimated exogenously and assumed not to change during the project life. And stream bank erosion was estimated using the July and August stream flow.

Once the standing crop values are generated for both the present and future conditions, an economic value was placed on the difference between the two conditions. Difficulties arose in two specific areas: (1) lack of data for Bear Lake area on fishermen, recreation-days, fishing success, or value of recreation-days; and (2) lack of a transformation function for kg/hectare to fishing success.

The recreation survey by Wolfley, et. al (1979) resulted in a mean marginal day value estimate of $4.44 for fishing. By assuming an "average" fishing day to be equivalent to a catch of approximately 1 kg/hectare (2.2 lbs./day) of trout, a value of $5.00 per kg/hectare was derived.

<u>Wetlands and waterfowl.</u> The upper wetland area at the base of Paris Creek is for the most part fed by the stream; by the end of the summer most of this area has drained and farmers harvest wild meadow hay. Goldstein (1971) asserted the importance of these temporary wetlands, especially those in the neighborhood of permanent marshes, for waterfowl breeding. Therefore, a potential impact of reduced flows is the loss of breeding pairs with the reduction in actual wetland ponds.

Goldstein's survey of a refuge in South Dakota indicated a loss of 1.8567 breeding pairs per acre of temporary wetland lost (p. 68). Since Bear Lake Refuge is very productive relative to others in the region, a lower value of 1.5 breeding pairs per acre was assumed. Stream flow contributes to the creation of temporary ponds, considered important to waterfowl, and a "temporary pond" was defined to consist of 30 acre-inches of water. Therefore, the calculation of "waterfowl pairs lost" would be based on total reduction of stream source water and subsequent "acres" of wetland lost, times the number of birds lost per acre.

Based on empirical testing of their optimal control model, Hammack and Brown (1974) placed a value of $5.60 per acre as the average annual payment made for acquired easement land for ponds. This value was used for this simulation because it was derived from the pond's production value.

Pheasant habitat. Surface-irrigated cropland is ideal pheasant habitat. An extensive system of open ditches and channels provide sufficient breeding ground, food, water, and shelter. When surface irrigation is replaced by an improved pipe delivery system and sprinklers, this habitat is effectively eliminated. Wolfley, et al. (1979) estimated this shift reduced the pheasant population by 1.57 to 1.69 birds per acre in eastern Washington. The cost of maintaining the current population (by providing specialized habitat) is a sufficient measure of the impacts on pheasant.

While no specific data on pheasant populations were available for the Bear Lake area, a value of 1.3 birds per acre was used. Considerations included the possibility that some birds may effectively relocate to other areas.

The study by Wolfley, et al. suggested the minimum cost of enhancement would be $7-8 per enhanced pheasant on a 160-acre farm, by providing cover strips of low-valued crop rotations (p. 167-8). Seven dollars per pheasant lost was considered appropriate in this simulation.

Other impacts. It is anticipated that impacts will occur other than those discussed; however, they are not explicitly treated in this manuscript. Reductions in soil erosion is one change likely to take place under a conversion of surface to sprinkler irrigation. Not only will this impact take place on the sloping farmland of the Bear Lake region, but also to some degree in the streams where irrigation return flow is also reduced. (Streambank erosion has been identified as a problem along more than 1000 bank-miles of stream channel in the area (U.S. Water Resources Council, 1978).) While these impacts involve very real economic changes, measurement of such impacts required more data than was feasibly available for this study.

Other issues that must be discerned from the cumulative results are the associated changes in regional income and distribution of local income among affected parties. Regional income analysis is also an important measure from a state or federal agency standpoint. Net social benefits are a good indicator of regional change.

Distribution of income is implied at a somewhat broad scale through the breakdown of components in social benefits. Net gains and losses are readily recognized for farmers, recreational fishermen, those interested in waterfowl and to some degree society as a whole, in terms of total offsite impacts.

F. Input Data Formulation

A detailed listing and summary explanation of the simulation program used for this study is contained in Appendix B. The general user may not need a complete understanding of the internal workings of this program. However, for those who do, this section contains the actual format and formulation of information used for the Paris Creek River Basin Study.

Input data and initialization routines are stored within lines 8000 to 9500 of the simulation program. Data of specific interest to users will be outlined below.

Hydrologic information is located in lines 8110 to 8170.

```
8110 REM * data
8120 DATA 2.092, 0.0254, 0.1593, 0.8472, 0.5855
8130 DATA 2.503, 0.0532, 0.2306, 0.8412, 0.7370
8140 DATA 2.565, 0.0692, 0.2631, 0.7138, 0.8580
8150 DATA 2.383, 0.0479, 0.2189, 0.7211, 0.9781
8160 DATA 2.239, 0.0260, 0.1614, 0.7662, 0.9675
8170 DATA 2.134, 0.0163, 0.1278, 0, 0
```

Each line represents the mean flow, variance, standard deviation, regression coefficient and correlation coefficient for a month. The months included are April through September.

The acreage and irrigation schedule is defined in lines 8420 to 8490 for both north and south groups.

```
8420 REM  north acres
8430 DATA 585,0,585,240,0,   1616,1616,1584,1023,846
8431 DATA 172,0,172,0,0,     808,0,808,642,0
8440 DATA 388,0,388,0,0,     0,0,0,0,0,
     603,0,603,216,0,    0,0,0,0,0
8450 DATA 178,0,178,0,0,     0,0,0,0,0,
     498,0,498,0,0,      0,0,0,0,0
8460 REM  south acres
8470 DATA 235,0,235,118,0,   235,0,235,118,0,
     69,0,69,0,0,        69,0,69,0,0
8480 DATA 143,0,143,0,0,     143,0,143,0,0,
     235,0,235,84,0,     235,0,235,84,0
8490 DATA 69,0,69,0,0,       69,0,69,0,0,
     342,0,342,0,0,      342,0,342,0,0
```

Each block of five values represent a single crop, irrigation system type and situation. Present and future conditions lie in adjoining five-value blocks.

Line 8430 defines the first priority crop (sprinklered alfalfa). The first value (585) is the number of acres of the project in that crop at present. The next four values represent the number of acres presently irrigated in the months May through August. At Paris Creek, 585 acres are irrigated in June, but only 240 acres are irrigated in July.

In the future condition, there are 1616 acres of sprinklered alfalfa. The whole crop area is irrigated in May, 1584 acres in June, 1023 acres in July and 846 acres in August.

The next two blocks of five numbers (line 8431) are the present and future condition values for sprinklered barley. Similarly, sprinklered pasture, and surface-irrigated alfalfa, barley and pasture follow in lines 8440 and 8450.

In the same crop priority order, the south system acreage is defined in lines 8460 to 8490.

Lines 8500 and 8530 define the number of acre-inches applied to crops and the monthly consumptive use rates for each crop.

```
8500 DATA 7.0,5.8,6.0,  12.0,10.0,10.0,  7.0,5.8,6.0,
     12.0,10.0,10.0
8530 DATA 2.1,4.4,6.2,5.8,  1.6,4.5,5.3,1.2,
      2.5,3.6,5.2,4.5
```

The crops are defined in the same ordering as above for line 8500: sprinklered alfalfa, barley and pasture, and surface-irrigated alfalfa, barley and pasture for the present condition; followed by the same crops in the future condition.

Consumptive use values for May, June, July and August are defined for alfalfa, barley and pasture. They are specified in terms of acre-inches per acre.

Hydrologic parameters are defined in line 8610:

```
8610 DATA .10,.10,.10,.40,.40,.30,
     .00,.00,.10,.25,.30,.20,  .10,.10,1
```

The first group of six values are for the present condition, the second for the future. They are the percentage rates for: delivery system evaporation, delivery system seepage, sprinkler system evaporation, sprinkler deep percolation, surface system return flow and surface system deep percolation. The last three values in 8610 are the stream evaporation and stream seepage rates, and the groundwater conveyance time (in months).

Costs of production for crops is determined by lines 8910 to 8960.

```
8910 DATA 128.53,0.00,34.06,34.05,0.00,
     34.06,34.06,34.05,18.75
8920 DATA 113.54,0.00, 3.94, 0.00,0.00,
      0.00, 3.94, 3.94, 0.00
8930 DATA  60.00,0.00, 5.17, 0.00,0.00,
      0.00, 5.17, 0.00, 0.00
8940 DATA  89.62,0.00,41.65,41.65,0.00,
      0.00, 0.00, 0.00, 0.00
8950 DATA 100.00,0.00,14.96, 0.00,0.00,
      0.00, 0.00, 0.00, 0.00
8960 DATA  70.85,0.00, 3.85, 0.00,0.00,
      0.00, 0.00, 0.00, 0.00
```

This set of values is arranged as were the acreage and irrigation schedule, by crop (from line to line) and by condition (present and future). For sprinklered alfalfa (line 8910) the first value indicates the dryland cost of \$128.53 (which assumes a particular yield, defined below). The next four values are the increase in cost (from additional irrigation and harvest costs) for irrigation in each of May through August. For example, an additional cost of $34.06 is incurred for irrigation in June and the subsequent yield increase, and in July for the present situation.

The future condition assumes the same dryland cost of production ($128.53) but allows for increases in cost from irrigation during May, June, July and August.

Prices per unit received by farmers for crops (sprinklered alfalfa, barley and pasture, and surface-irrigated alfalfa, barley and pasture) are defined in line 8990.

```
8990 DATA 71.15,2.94,50.00,  71.15,2.94,50.00,
     42973.,  72974.
```

The last two values in line 8990 are the annual costs of installing and maintaining the project, as incurred by the public ($42,973) and privately ($72,974).

Yield data is supplied in lines 9000 to 9030.

```
9000 REM ... data for yields
9010 DATA 1.5,0,2.0,1.0,0,  2.0,1.0,1.0,0.5,
     25,0,40,0,0,  0,40,20,0
9020 DATA 1.5,0,0.25,0,0,   0,0.25,0,0,
     1.5,0,1.0,0.5,0,  0,1.0,0.5,0
9030 DATA 25,0,25,0,0,    0,25,0,0,
     1.5,0,0.25,0,0,   0,0.25,0,0
```

These values correspond directly with the cost data and represent yield potentials for irrigation in each month. For example, sprinklered alfalfa yields 1.5 tons (T) per acre with no irrigation, but increases by 2.0 T (to 3.5 T/acre) if irrigated in June, and another 1.0 T if irrigated in July. The future condition shows enhancements of 2.0 T/acre for irrigation in May, 1.0 T/acre in June, 1.0 T/acre in July, and 0.5 T/acre in August as the maximum yield possible given full water availability.

Offsite impact predefined values are given in lines 9180 and 9220.

```
9170 REM * data: nitrogen, substrate, velocity, width
9180 DATA 2, 2, 3, 3
9190 REM * pheasant and waterfowl data
9200 READ PHEASANT[1], PHEASANT[2], FOWL[1], FOWL[2]
9210 REM * birds/acre, enhance cost, inches/pond,
     birds/acre
9220 DATA 1.3, 7.0,   30, 1.5
```

As indicated, line 9180 defines the ratings of particular stream attributes for Paris Creek. Line 9120 defines the number of pheasant lost per acre of converted irrigation system (1.3), enhancement cost ($7.00), number of acre-inches defining a temporary pond (30), and waterfowl lost per acre of pond water (1.5).

IV. EMPIRICAL RESULTS AND ANALYSIS

A. Introduction

This chapter is presented in three parts. The first gives a detailed explanation of the computer output for a single year, and presents the results of the initial simulation runs. An analysis of these results in terms of cost-benefit analysis, risk, income distribution, and offsite impacts is included.

The second part discusses the changes that take place in the analysis when water management assumptions are altered. A "shared-shortage" system of water distribution is compared with a "priority" system.

An arbitrary reallocation of water rights is studied in the third part. By changing these assumptions it may be possible to assess values associated with these water rights.

B. Results of Initial Run

The proposed system improvement project has an expected life of 50 years. To facilitate an accurate representation of the project, a simulation of a set of 50-year periods was generated. The associated installation and technical assistance costs were amortized over this period at 8 $^{5}/_{8}$%

interest, the government- secured interest rate for project loans, and presented as annual costs assessed to project farmers and the government. All benefits, costs and damages ascertained each year were compiled in the program, and a cumulative report of these values was presented at the end. Statistics included the mean, standard deviation, and high and low values for north and south group benefits, offsite impacts and net benefits to society.

Validation of the inner workings of the simulation program are possible by verifying the operations, allocations and transactions in a detailed program report. Such a report may be initiated through an option presented at the start of a simulation.

The output from a single year's simulation is illustrative of the rationale and logic used in developing output values, and is explained in the next section.

A single-year report. The program begins all simulation runs by printing the assumed hydrologic parameters. These values signify the proportion of water assumed to be lost to evaporation, deep percolation and return flow. (Please refer to figure IV.1.)

The seasonal records begin in Month 4 (April) of the year. A random value is generated internally and compared with a standardized normal distribution. The resulting "z-value" (in this case +.2) indicates the value generated was .2 standard deviations above the mean. When included in the

```
River Basin Economic Impacts Simulation Model
Paris Creek, Bear Lake County, Idaho
15:03:44      01-01-1980


***   Hydrologic Parameters   ***

                               Stream     Delivery     Sprinkler     Surface
Evaporation - Present           .10         .20           .10          .00
            - Future            .10         .00           .10          .00
Seepage     - Present           .10         .10           .40          .30
            - Future            .10         .00           .25          .20
Return Flow - Present           .00         .00           .00          .40
            - Future            .00         .00           .00          .30

Month # 4
   Z-value:    .2
   Flow level:           (mean = 123.59)           133.00
   Paris City municipal right                       14.91
   North / South water right:              58.98           59.12
* Present condition
North system
   Return flow:                                      0.00
North total diversions:                     0.00            0.00
South system
   Return flow:                                      0.00
South total diversions:                     0.00            0.00
Resultant flow (incl. return flow):                118.09
Stream, delay, wetland:   94.47            11.81           94.47
* Future condition
North system
   Return flow:                                      0.00
North total diversions:                     0.00            0.00
South system
   Return flow:                                      0.00
South total diversions:                     0.00            0.00
Resultant flow (incl. return flow):                118.09
Stream, delay, wetland:   94.47            11.81           94.47

Month  4.            Base Flow: 1,330.0 ac. ft.

          Stream flow    :          944.7 ac. ft.       944.7 ac. ft.
          Delayed flow   :          118.1 ac. ft.       118.1 ac. ft.
          Wetlands flow  :          944.7 ac. ft.       944.7 ac. ft.

Month # 5
   Z-value:     .6
   Flow level:           (mean = 318.42)           438.69
   Paris City municipal right                       14.91
   North / South water right:             211.63          212.14
* Present condition
North system
   Sprink. & surface needs: alfalfa :       0.00            0.00
      Farm gate levels:                     0.00            0.00
      Remaining water available:                   211.63
   Sprink. & surface needs: barley  :       0.00            0.00
      Farm gate levels:                     0.00            0.00
      Remaining water available:                   211.63
   Sprink. & surface needs: pasture :       0.00            0.00
      Farm gate levels:                     0.00            0.00
      Remaining water available:                   211.63
   Return flow:                                      0.00
North total diversions:                     0.00            0.00
South system
   Sprink. & surface needs: alfalfa :       0.00            0.00
      Farm gate levels:                     0.00            0.00
      Remaining water available:                   212.14
```

Figure IV.1 - Report for single-year simulation.

```
   Sprink. & surface needs: barley  :     0.00              0.00
      Farm gate levels:                   0.00              0.00
      Remaining water available:                   212.14
   Sprink. & surface needs: pasture :     0.00              0.00
      Farm gate levels:                   0.00              0.00
      Remaining water available:                   212.14
   Return flow:                                      0.00
South total diversions:                   0.00              0.00
Resultant flow (incl. return flow):                423.78
Stream, delay, wetland:  339.02          42.38            350.83
* Future condition
North system
   Sprink. & surface needs: alfalfa :    94.27              0.00
      Farm gate levels:                  94.27              0.00
      Remaining water available:                   117.37
   Sprink. & surface needs: barley  :     0.00              0.00
      Farm gate levels:                   0.00              0.00
      Remaining water available:                   117.37
   Sprink. & surface needs: pasture :     0.00              0.00
      Farm gate levels:                   0.00              0.00
      Remaining water available:                   117.37
   Return flow:                                      0.00
North total diversions:                  94.27              0.00
South system
   Sprink. & surface needs: alfalfa :     0.00              0.00
      Farm gate levels:                   0.00              0.00
      Remaining water available:                   212.14
   Sprink. & surface needs: barley  :     0.00              0.00
      Farm gate levels:                   0.00              0.00
      Remaining water available:                   212.14
   Sprink. & surface needs: pasture :     0.00              0.00
      Farm gate levels:                   0.00              0.00
      Remaining water available:                   212.14
   Return flow:                                      0.00
South total diversions:                   0.00              0.00
Resultant flow (incl. return flow):                329.51
Stream, delay, wetland:  263.61          32.95            275.42

Month  5               Base Flow: 4,386.9 ac. ft.

          Stream flow     :        3,390.2 ac. ft.     2,636.1 ac. ft.
          Delayed flow    :          423.8 ac. ft.       329.5 ac. ft.
          Wetlands flow   :        3,508.3 ac. ft.     2,754.2 ac. ft.

Month # 6
   Z-value:    -.5
   Flow level:           (mean = 367.28)           391.87
   Paris City municipal right                       14.91
   North / South water right:            188.25           188.71
* Present condition
North system
   Sprink. & surface needs: alfalfa :    48.75              86.14
      Farm gate levels:                  34.13              60.30
      Remaining water available:                    53.36
   Sprink. & surface needs: barley  :    11.88              21.19
      Farm gate levels:                   8.31              14.83
      Remaining water available:                    20.30
   Sprink. & surface needs: pasture :    27.71              59.29
      SHORTAGE; portion of need satisfied:     23.32807 %
      Farm gate levels:                   4.53               9.68
   Return flow:                                     23.07
North total diversions:                  67.09             121.16
South system
   Sprink. & surface needs: alfalfa :    19.58              33.57
      Farm gate levels:                  13.71              23.50
      Remaining water available:                   135.55
   Sprink. & surface needs: barley  :     4.76               8.21
      Farm gate levels:                   3.34               5.75
      Remaining water available:                   122.57
```

Figure IV.1 - Continued

Sprink. & surface needs: pasture :	10.21		40.71
Farm gate levels:	7.15		28.50
Remaining water available:		71.65	
Return flow:		18.84	
South total diversions:	34.56		82.50
Resultant flow (incl. return flow):		113.56	
Stream, delay, wetland: 90.84	62.44		133.22
• Future condition			
North system			
Sprink. & surface needs: alfalfa :	92.40		0.00
Farm gate levels:	92.40		0.00
Remaining water available:		95.85	
Sprink. & surface needs: barley :	39.05		0.00
Farm gate levels:	39.05		0.00
Remaining water available:		56.80	
Sprink. & surface needs: pasture :	0.00		0.00
Farm gate levels:	0.00		0.00
Remaining water available:		56.80	
Return flow:		0.00	
North total diversions:	131.45		0.00
South system			
Sprink. & surface needs: alfalfa :	19.58		33.57
Farm gate levels:	13.71		23.50
Remaining water available:		135.55	
Sprink. & surface needs: barley :	4.76		8.21
Farm gate levels:	3.34		5.75
Remaining water available:		122.57	
Sprink. & surface needs: pasture :	10.21		40.71
Farm gate levels:	7.15		28.50
Remaining water available:		71.65	
Return flow:		18.84	
South total diversions:	34.56		82.50
Resultant flow (incl. return flow):		147.29	
Stream, delay, wetland: 117.83	65.82		150.78

Month 6 Base Flow: 3,918.7 ac. ft.

	SHORTAGE	
Stream flow :	308.4 ac. ft.	1,178.3 ac. ft.
Delayed flow :	624.4 ac. ft.	558.2 ac. ft.
Wetlands flow :	1,332.2 ac. ft.	1,507.8 ac. ft.

Month # 7

Z-value: .7			
Flow level: (mean = 241.55)		303.25	
Paris City municipal right		14.91	
North / South water right:	144.00		144.34
• Present condition			
North system			
Sprink. & surface needs: alfalfa :	20.00		30.86
Farm gate levels:	14.00		21.60
Remaining water available:		93.14	
Sprink. & surface needs: barley :	0.00		0.00
Farm gate levels:	0.00		0.00
Remaining water available:		93.14	
Sprink. & surface needs: pasture :	0.00		0.00
Farm gate levels:	0.00		0.00
Remaining water available:		93.14	
Return flow:		4.08	
North total diversions:	20.00		30.86
South system			
Sprink. & surface needs: alfalfa :	9.83		12.00
Farm gate levels:	6.88		8.40
Remaining water available:		122.51	
Sprink. & surface needs: barley :	0.00		0.00
Farm gate levels:	0.00		0.00
Remaining water available:		122.51	

Figure IV.1 – Continued

```
   Sprink. & surface needs: pasture :     0.00                 0.00
      Farm gate levels:                   0.00                 0.00
      Remaining water available:                     122.51
   Return flow:                                        1.12
South total diversions:                   9.83                12.00
Resultant flow (incl. return flow):                  220.84
Stream, delay, wetland:  175.68          26.53               239.12
• Future condition
North system
   Sprink. & surface needs: alfalfa :    59.68                 0.00
      Farm gate levels:                  59.68                 0.00
      Remaining water available:                      84.32
   Sprink. & surface needs: barley  :    31.03                 0.00
      Farm gate levels:                  31.03                 0.00
      Remaining water available:                      53.29
   Sprink. & surface needs: pasture :     0.00                 0.00
      Farm gate levels:                   0.00                 0.00
      Remaining water available:                      53.29
   Return flow:                                        0.00
North total diversions:                  90.71                 0.00
South system
   Sprink. & surface needs: alfalfa :     9.83                12.00
      Farm gate levels:                   6.88                 8.40
      Remaining water available:                     122.51
   Sprink. & surface needs: barley  :     0.00                 0.00
      Farm gate levels:                   0.00                 0.00
      Remaining water available:                     122.51
   Sprink. & surface needs: pasture :     0.00                 0.00
      Farm gate levels:                   0.00                 0.00
      Remaining water available:                     122.51
   Return flow:                                        1.12
South total diversions:                   9.83                12.00
Resultant flow (incl. return flow):                  176.92
Stream, delay, wetland:  141.53          22.14               207.35

Month  7               Base Flow: 3,032.5 ac. ft.

          Stream flow    :        1,766.8 ac. ft.     1,415.3 ac. ft.
          Delayed flow   :          265.3 ac. ft.       221.4 ac. ft.
          Wetlands flow  :        2,391.2 ac. ft.     2,073.5 ac. ft.

Month # 8
   Z-value:     .9
   Flow level:            (mean = 173.38)            219.02
   Paris City municipal right                         14.91
   North / South water right:           101.93               102.18
• Present condition
North system
   Sprink. & surface needs: alfalfa :     0.00                 0.00
      Farm gate levels:                   0.00                 0.00
      Remaining water available:                     101.93
   Sprink. & surface needs: barley  :     0.00                 0.00
      Farm gate levels:                   0.00                 0.00
      Remaining water available:                     101.93
   Sprink. & surface needs: pasture :     0.00                 0.00
      Farm gate levels:                   0.00                 0.00
      Remaining water available:                     101.93
   Return flow:                                        0.00
North total diversions:                   0.00                 0.00
South system
   Sprink. & surface needs: alfalfa :     0.00                 0.00
      Farm gate levels:                   0.00                 0.00
      Remaining water available:                     102.18
   Sprink. & surface needs: barley  :     0.00                 0.00
      Farm gate levels:                   0.00                 0.00
      Remaining water available:                     102.18
   Sprink. & surface needs: pasture :     0.00                 0.00
      Farm gate levels:                   0.00                 0.00
      Remaining water available:                     102.18
```

Figure IV.1 - Continued

Return flow:		0.00	
South total diversions:	0.00		0.00
Resultant flow (incl. return flow):		204.11	
Stream, delay, wetland: 163.28	20.41		189.82
* Future condition			
North system			
Sprink. & surface needs: alfalfa :	49.35		0.00
Farm gate levels:	49.35		0.00
Remaining water available:		52.58	
Sprink. & surface needs: barley :	0.00		0.00
Farm gate levels:	0.00		0.00
Remaining water available:		52.58	
Sprink. & surface needs: pasture :	0.00		0.00
Farm gate levels:	0.00		0.00
Remaining water available:		52.58	
Return flow:		0.00	
North total diversions:	49.35		0.00
South system			
Sprink. & surface needs: alfalfa :	0.00		0.00
Farm gate levels:	0.00		0.00
Remaining water available:		102.18	
Sprink. & surface needs: barley :	0.00		0.00
Farm gate levels:	0.00		0.00
Remaining water available:		102.18	
Sprink. & surface needs: pasture :	0.00		0.00
Farm gate levels:	0.00		0.00
Remaining water available:		102.18	
Return flow:		0.00	
South total diversions:	0.00		0.00
Resultant flow (incl. return flow):		154.76	
Stream, delay, wetland: 123.80	15.48		145.95

Month 8 Base Flow: 2,190.2 ac. ft.

Stream flow :	1,632.8 ac. ft.	1,238.0 ac. ft.
Delayed flow :	204.1 ac. ft.	154.8 ac. ft.
Wetlands flow :	1,898.2 ac. ft.	1,459.5 ac. ft.

Month # 9

Z-value: -.4			
Flow level: (mean = 136.14)		158.06	
Paris City municipal right		14.91	
North / South water right:	71.49		71.66
* Present condition			
North system			
Return flow:		0.00	
North total diversions:	0.00		0.00
South system			
Return flow:		0.00	
South total diversions:	0.00		0.00
Resultant flow (incl. return flow):		143.15	
Stream, delay, wetland: 114.52	14.32		134.93
* Future condition			
North system			
Return flow:		0.00	
North total diversions:	0.00		0.00
South system			
Return flow:		0.00	
South total diversions:	0.00		0.00
Resultant flow (incl. return flow):		143.15	
Stream, delay, wetland: 114.52	14.32		130.00

Month 9 Base Flow: 1,580.6 ac. ft.

Stream flow :	1,145.2 ac. ft.	1,145.2 ac. ft.
Delayed flow :	143.2 ac. ft.	143.2 ac. ft.
Wetlands flow :	1,349.3 ac. ft.	1,300.0 ac. ft.

Figure IV.1 – Continued

```
Trout impacts
   Late summer flow rating (X1):               3
   Annual stream variation rating (x2):        2
   Max summer temperature rating (X3):         3
   Nitrate nitrogen (X4):     2
   Amount of cover (X7):      2
   Streambank erosion (X8):   2
   Substrate (X9):            2
   Water velocity (X10):      3
   Stream width (X11):        3
   Food index (X3•X4•X9•X10):                  36
   Shelter index (X7•X8•X11):                  12
Trout standing crop:          146.8666
   Late summer flow rating (X1):               3
   Annual stream variation rating (x2):        2
   Max summer temperature rating (X3):         3
   Nitrate nitrogen (X4):     2
   Amount of cover (X7):      2
   Streambank erosion (X8):   2
   Substrate (X9):            2
   Water velocity (X10):      3
   Stream width (X11):        3
   Food index (X3•X4•X9•X10):                  36
   Shelter index (X7•X8•X11):                  12
Trout standing crop:          146.8666
Pheasant impacts
   Present, future surface acres:              1279           0
   Birds lost/acre, total birds lost:          1.3            1662.7
Waterfowl impacts
   Reduced water, acres lost:                  138.433        34.60825
   Birds lost/acre, total birds lost:          1.5            51.91237
   Net On-site benefits
   Present condition - north yields and costs
   Initial yield: 1.5 • 585 = 877.5          Initial cost: 128.53 • 585 = 0
   Plus: 0 • 0 • 1 = 877.5                   Plus: 0 • 0 = 75190.05
   Plus: 2 • 585 • 1 = 2047.5                Plus: 34.06 • 585 = 95115.15
   Plus: 1 • 240 • 1 = 2287.5                Plus: 34.06 • 240 = 103289.6
   Plus: 0 • 0 • 1 = 2287.5                  Plus: 0 • 0 = 103289.6
      Net revenue, North alfalfa:               59466.08
      Net revenue, South alfalfa:               24688.85
   Initial yield: 25 • 172 = 4300            Initial cost: 113.54 • 172 = 0
   Plus: 0 • 0 • 1 = 4300                    Plus: 0 • 0 = 19528.88
   Plus: 40 • 172 • 1 = 11180                Plus: 3.94 • 172 = 20206.56
   Plus: 0 • 0 • 1 = 11180                   Plus: 0 • 0 = 20206.56
   Plus: 0 • 0 • 1 = 11180                   Plus: 0 • 0 = 20206.56
      Net revenue, North barley :               12662.64
      Net revenue, South barley :               5079.781
   Initial yield: 1.5 • 388 = 582            Initial cost: 60 • 388 = 0
   Plus: 0 • 0 • 1 = 582                     Plus: 0 • 0 = 23280
   Plus: .25 • 388 • .2332807 = 604.6283     Plus: 5.17 • 388 = 25285.96
   Plus: 0 • 0 • 1 = 604.6283                Plus: 0 • 0 = 25285.96
   Plus: 0 • 0 • 1 = 604.6283                Plus: 0 • 0 = 25285.96
      Net revenue, North pasture:               4945.451
      Net revenue, South pasture:               3193.191
   Initial yield: 1.5 • 603 = 904.5          Initial cost: 89.62 • 603 = 0
   Plus: 0 • 0 • 1 = 904.5                   Plus: 0 • 0 = 54040.86
   Plus: 1 • 603 • 1 = 1507.5                Plus: 41.65 • 603 = 79155.81
   Plus: .5 • 216 • 1 = 1615.5               Plus: 41.65 • 216 = 88152.21
   Plus: 0 • 0 • 1 = 1615.5                  Plus: 0 • 0 = 88152.21
      Net revenue, North alfalfa:               26790.62
      Net revenue, South alfalfa:               10441.88
   Initial yield: 25 • 178 = 4450            Initial cost: 100 • 178 = 0
   Plus: 0 • 0 • 1 = 4450                    Plus: 0 • 0 = 17800
   Plus: 25 • 178 • 1 = 8900                 Plus: 14.94 • 178 = 20459.32
   Plus: 0 • 0 • 1 = 8900                    Plus: 0 • 0 = 20459.32
   Plus: 0 • 0 • 1 = 8900                    Plus: 0 • 0 = 20459.32
      Net revenue, North barley :               5706.68
      Net revenue, South barley :               2212.14
```

Figure IV.1 – Continued

```
Initial yield: 1.5 * 498 = 747          Initial cost: 70 * 498 = 0
Plus: 0 * 0 * 1 = 747                   Plus: 0 * 0 = 34860
Plus: .25 * 498 * .2332807 = 776.0435   Plus: 3.85 * 498 = 36777.3
Plus: 0 * 0 * 1 = 776.0435              Plus: 0 * 0 = 36777.3
Plus: 0 * 0 * 1 = 776.0435              Plus: 0 * 0 = 36777.3
   Net revenue, North pasture:             2024.871
   Net revenue, South pasture:             4668.301
Future condition - north yields and costs
Initial yield: 1.5 * 1616 = 2424        Initial cost: 128.53 * 1616 = 0
Plus: 2 * 1616 * 1 = 5656               Plus: 34.06 * 1616 = 262745.5
Plus: 1 * 1584 * 1 = 7240               Plus: 34.06 * 1584 = 316696.5
Plus: 1 * 1023 * 1 = 8263               Plus: 34.05 * 1023 = 351529.6
Plus: .5 * 846 * 1 = 8686               Plus: 18.75 * 846 = 367392.1
   Net revenue, North alfalfa:             250616.8
   Net revenue, South alfalfa:             24688.85
Initial yield: 25 * 808 = 20200         Initial cost: 113.54 * 808 = 0
Plus: 0 * 0 * 1 = 20200                 Plus: 0 * 0 = 91740.32
Plus: 40 * 808 * 1 = 52520              Plus: 3.94 * 808 = 94923.84
Plus: 20 * 642 * 1 = 65360              Plus: 3.94 * 642 = 97453.32
Plus: 0 * 0 * 1 = 65360                 Plus: 0 * 0 = 97453.32
   Net revenue, North barley :             94705.09
   Net revenue, South barley :             5079.781
Initial yield: 1.5 * 0 = 0              Initial cost: 60 * 0 = 0
Plus: 0 * 0 * 1 = 0                     Plus: 0 * 0 = 0
Plus: .25 * 0 * 1 = 0                   Plus: 5.17 * 0 = 0
Plus: 0 * 0 * 1 = 0                     Plus: 0 * 0 = 0
Plus: 0 * 0 * 1 = 0                     Plus: 0 * 0 = 0
   Net revenue, North pasture:             0
   Net revenue, South pasture:             3193.191
Initial yield: 1.5 * 0 = 0              Initial cost: 89.62 * 0 = 0
Plus: 0 * 0 * 1 = 0                     Plus: 0 * 0 = 0
Plus: 1 * 0 * 1 = 0                     Plus: 0 * 0 = 0
Plus: .5 * 0 * 1 = 0                    Plus: 0 * 0 = 0
Plus: 0 * 0 * 1 = 0                     Plus: 0 * 0 = 0
   Net revenue, North alfalfa:             0
   Net revenue, South alfalfa:             10441.88
Initial yield: 25 * 0 = 0               Initial cost: 100 * 0 = 0
Plus: 0 * 0 * 1 = 0                     Plus: 0 * 0 = 0
Plus: 25 * 0 * 1 = 0                    Plus: 0 * 0 = 0
Plus: 0 * 0 * 1 = 0                     Plus: 0 * 0 = 0
Plus: 0 * 0 * 1 = 0                     Plus: 0 * 0 = 0
   Net revenue, North barley :             0
   Net revenue, South barley :             2212.14
Initial yield: 1.5 * 0 = 0              Initial cost: 70 * 0 = 0
Plus: 0 * 0 * 1 = 0                     Plus: 0 * 0 = 0
Plus: .25 * 0 * 1 = 0                   Plus: 0 * 0 = 0
Plus: 0 * 0 * 1 = 0                     Plus: 0 * 0 = 0
Plus: 0 * 0 * 1 = 0                     Plus: 0 * 0 = 0
   Net revenue, North pasture:             0
   Net revenue, South pasture:             4668.301

***  ANNUAL SUMMARY  :  YEAR  1

Hydrologic summary
     April - September base flows:             16,438.9 ac. ft.
     Net seasonal stream flow  :   9,788.2 ac. ft.     8,557.7 ac. ft.
     Wetland seasonal flow     :  11,424.0 ac. ft.    10,039.6 ac. ft.
```

Figure IV.1 - Continued

On-Site Benefits - North

	Yield	Price	Revenue	Total cost	Net Revenue
Present					
alfalfa	2,288	71.15	162,755.60	103,289.60	59,466.08
barley	11,180	2.94	32,869.20	20,206.56	12,662.64
pasture	605	50.00	30,231.41	25,285.96	4,945.45
alfalfa	1,616	71.15	114,942.80	88,152.21	26,790.62
barley	8,900	2.94	26,166.00	20,459.32	5,706.68
pasture	776	50.00	38,802.17	36,777.30	2,024.87
Total	--	--	405,767.30	294,170.90	111,596.40
Future					
alfalfa	8,686	71.15	618,008.90	367,392.10	250,616.80
barley	65,360	2.94	192,158.40	97,453.32	94,705.09
pasture	0	50.00	0.00	0.00	0.00
alfalfa	0	71.15	0.00	0.00	0.00
barley	0	2.94	0.00	0.00	0.00
pasture	0	50.00	0.00	0.00	0.00
Total	--	--	810,167.30	464,845.50	345,321.90

On-Site Benefits - South

	Yield	Price	Revenue	Total cost	Net Revenue
Present					
alfalfa	941	71.15	66,916.58	42,227.73	24,688.85
barley	4,485	2.94	13,185.90	8,106.12	5,079.78
pasture	250	50.00	12,512.50	9,319.31	3,193.19
alfalfa	630	71.15	44,788.93	34,347.05	10,441.88
barley	3,450	2.94	10,143.00	7,930.86	2,212.14
pasture	599	50.00	29,925.00	25,256.70	4,668.30
Total	--	--	177,471.90	127,187.80	50,284.14
Future					
alfalfa	941	71.15	66,916.58	42,227.73	24,688.85
barley	4,485	2.94	13,185.90	8,106.12	5,079.78
pasture	250	50.00	12,512.50	9,319.31	3,193.19
alfalfa	630	71.15	44,788.93	34,347.05	10,441.88
barley	3,450	2.94	10,143.00	7,930.86	2,212.14
pasture	599	50.00	29,925.00	25,256.70	4,668.30
Total	--	--	177,471.90	127,187.80	50,284.14

Offsite Impacts

Trout standing crop - present	147 kg/ha	
- future	147 kg/ha	
- change	0 kg/ha	
Recreational fishing losses		0.00
Pheasant population losses	1663 birds	
Restoration cost		11,638.90
Waterfowl losses	52 pairs	
Damages		1,038.25
Total damages		12,677.15

ANNUAL TOTALS

	Present	Future
Onsite benefits - North	111,596.40	345,321.90
Project cost - private share	0.00	-72,974.00
NET PRIVATE BENEFITS - NORTH	111,596.40	272,347.84
NET PRIVATE BENEFITS - SOUTH	50,284.14	50,284.14
Offsite damages	0.00	-12,677.15
Project cost - public share	0.00	-42,973.00
NET SOCIAL BENEFITS	161,880.48	266,981.84

Figure IV.1 - Continued

hydrologic function the flow value for April became 133.0 tens-of-acre-feet (T.A.F.), as compared with a mean flow for April of 123.59 T.A.F. The city of Paris has culinary rights to 2.38 cubic feet per second, which is piped directly from Paris Spring. This amounts to an annual average of 1789.4 acre-feet, or 149.1 acre-feet (14.91 T.A.F.) per month.

Of the remaining water, the rights allocation of the north and south groups are legally defined as a proportion of Paris Creek flow: the north group is allotted 49.94% and the south 50.06% (U.S.D.A., 1984). Though no irrigation takes place in April, the respective rights to water are 58.98 T.A.F. north and 59.12 T.A.F. south.

The present condition situation is presented first, divided by north and south sections. No water is diverted, so no water returns to the stream as tailwater (return flow). The "resultant flow" is the gross amount of water in the stream after irrigation diversions. As indicated, this amount (118.09 T.A.F.) is the initial flow minus the Paris municipal diversion.

The next line tells the monthly net flow levels at the stream and wetland checkpoints (presumably below the irrigation diversion points), and the amount of water within the groundwater system from the initial flow. It is assumed this delayed amount reaches the wetland during the next month.

Because there is no water management change for the future condition, the situation is identical to the present, as expected.

The next section of the output is a summary of hydrologic checkpoints: the initial flow level, the net stream flow level in the present and future conditions, and the delayed volume and wetland flow levels.

Month 5 begins with a z-value of .6 standard deviations above the mean, for an initial flow level of 438.69 T.A.F., as compared with a mean of 318.42 T.A.F. Note that this amount is higher than it would be if April's flow had been "average" (a z-value of 0). The Paris municipal right is extracted and the resulting north/south rights are shown as 211.63 T.A.F. and 212.14 T.A.F., respectively.

Once again, in the present situation no irrigation takes place, and the gross stream flow level remains the same (423.78 T.A.F.). The net stream level is 339.02 T.A.F. and wetland level 350.83 -- which includes 11.81 T.A.F. from April.

In the future condition the north group irrigates 1616 acres of alfalfa -- the entire crop. The water need is defined in terms of the irrigation requirements and delivery system; in this case farmers apply 7.0 acre-inches per acre and lose no water in transit to the farm gate: (7.0 * 1616) / 12 = 942.7 acre-feet, or 94.27 T.A.F. Also specified, all cropland is sprinkler-irrigated and none is surface-irrigated, hence, no "surface need."

After delivery of water for alfalfa, 117.37 T.A.F. remain for other crops in the north, if necessary; however, no other crops are irrigated in May. The south irrigates no crops in May, so the resultant stream flow is 329.51 T.A.F.

Month 6 (June) is indicative of the the model's handling of irrigation, as all crops grown are irrigated during this month. The z-value generated is -.5 (below the mean) which creates an initial flow level of 391.87 T.A.F., compared with a mean of 367.28 T.A.F. The "season" therefore began abundantly, and is now "tapering off" a bit in June, though still remaining above average. The north and south group rights are 188.25 and 188.71 respectively.

In the present situation, alfalfa, barley, and pastureland are irrigated in the north and south, for both types of irrigation systems. In the case of alfalfa, 7.0 acre-inches are applied to 1584 acres of sprinklered alfalfa, and 12.0 acre-inches to 808 acres of surface crop. This amounts to farm-level needs of 34.13 T.A.F. and 60.30 T.A.F., respectively. However, with only a 70% conveyance efficiency, more water must be diverted than actually needed; hence, the crop needs for alfalfa are 48.75 T.A.F. for sprinkler and 86.14 T.A.F. for surface systems.

After water is allocated to alfalfa, the water that remains is 53.36 T.A.F. (188.25 - (48.75 + 86.14) = 53.36). Barley diversion requirements are 11.88 sprinkler and 21.19 surface, leaving 20.30 T.A.F. for pastureland. However, 87.00 T.A.F. are necessary for full irrigation of pasture, so a shortage of water is encountered; in fact, only 23.3% of the water need is satisfied. Program assumptions are such that the entire acreage area is thus irrigated with only 23.3% of need, and the irrigation systems receive proportional water.

Note that the total return flow for the north is 23.07 T.A.F. This results from tailwater of the surface-irrigated land, returning to the stream but unusable for further irrigation.

South group acreages are also irrigated fully. It is interesting to note, however, that they experience a tremendous surplus of water after irrigation (71.65 T.A.F.).

Under the future conditions, improved delivery, reduced per-acre needs, and fewer acres irrigated allows for a surplus of water, even in the north. Additionally, water remaining in the stream and reaching the wetlands is greater during June, unlike previous and subsequent months.

Similar arrangements take place in July, August and September. Water supply is above average in all months and no more shortages occur.

The next section provides the computation bases for offsite impacts. For trout impacts, the final ratings for each variable are made explicit and the standing crop (or volume) computed. These calculations are presented for both the present and future situations. In this case, there is no impact on trout populations from the project's management.

The variables influencing pheasant impacts are also given: present and future surface-irrigated acreage, number of birds lost per acre, and the total birds lost in the project area. Similarly, those influencing factors on waterfowl are presented.

The next set of calculations are the net on-site benefits. Only details for the north group are presented. The left column is the yield computation and the right the cost of production. Yields are calculated as such: the initial yield is the "dryland" yield times the project area acreage. This is added to the additional yield gained from irrigation in each month, times the number of acres irrigated, times a factor (ranging from 0 to 1) indicating water availability. Thus, for most crops in each month, water was 100% available. However, for pastureland in the present condition, only 23.3% of water was available in June, and its yield was affected accordingly. This situation is noted for both sprinklered and surface-irrigated lands.

Costs are calculated in a similar manner, with initial cost times acres, plus additional cost for each month times acreage.

The final section reports a summary of the annual calculations: hydrology, on-site benefits, offsite impacts and annual totals. The hydrology summary prints the seasonal base stream flow, plus the present and future net stream flows, and wetland levels.

On-site benefits are divided between north and south, and between present and future. Each crop is presented with its total yield, price received, gross revenue, cost and net revenue. These net revenues are summed over all crops (sprinkler- and surface-irrigated) to give the on-site net benefit. Present and future benefits may be compared for analysis.

Offsite impacts are broken down into the four resource areas, with the physical quantity values in the left column and dollar damages on the right.

Finally, the annual totals are presented as three different net benefit values. "Net private benefits - north" is the farmers' direct profit in the present and future situations, including the crop sales revenue and annual costs from the project. "Net private benefits - south" will, of course, be the same in present and future conditions as no management change takes place.

Net social benefits are measured from a regional perspective, including the private benefits from each group and the direct and indirect public costs. These figures may be compared for analysis.

Fifty-year runs. A set of 25 fifty-year simulations were generated for the priority-system irrigation management scheme. The mean, standard deviation, high and low values for selected categories are presented in table IV.1. Mean value is the average annual net benefit or return over each particular 50-year period. Standard deviation indicates the variation in income over the life.

	North group Present	North group Future	South group	Social Present	Social Future
Mean range - low	76,267	191,053	47,010	124,667	183,361
Mean range - high	97,458	229,041	49,252	145,991	222,208
St. Dev. range - low	36,664	74,283	2,508	39,076	76,294
St. Dev. range - high	46,364	112,224	10,334	54,424	119,517
High net bens.	120,088	272,348	50,284	170,372	267,346
Range of lowest - high	5,343	23,119	37,786	43,129	10,451
Range of lowest - low	(45,620)	(153,267)	(2,638)	(48,258)	(193,590)

Table IV.1 -- Results of 25 fifty-year simulations, using priority crop management.

Under current U.S.D.A. analysis practices, calculation of onsite benefits is based on a single specific water supply, the 70% chance flow. (That is, the monthly flows which will be equalled or exceeded in seven years out of ten.) A management scheme is arranged based on those flow levels, and expected income computed.

In this simulation analysis, the acres irrigated and income generated under the 70% supply management scheme are assumed. They represent maximum income potential, even if more water is available. In other words, no additional acreage is irrigated in any month even under surplus conditions.

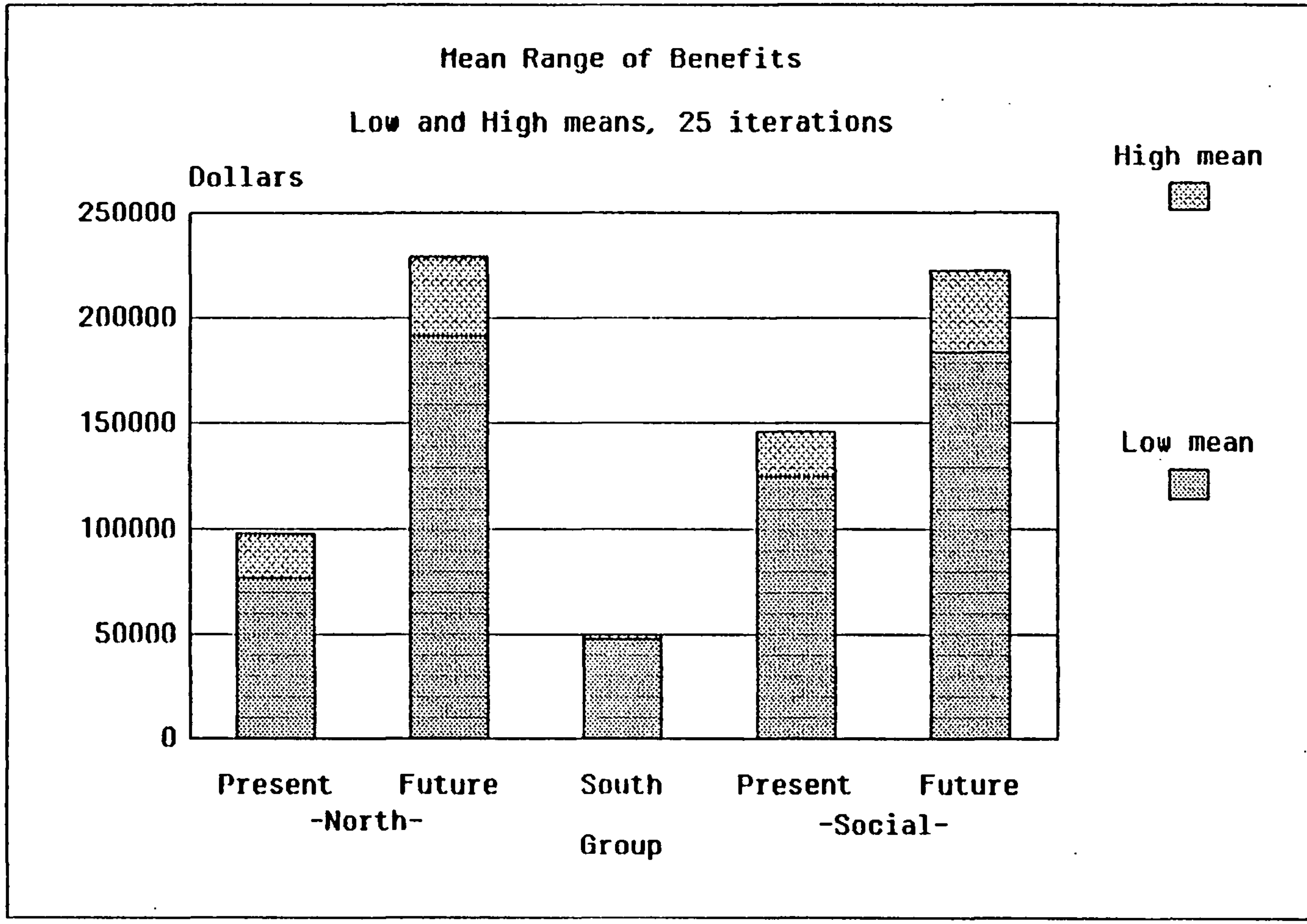

Figure IV.2 - Range of mean annual benefits for 25 iterations of 50 years.

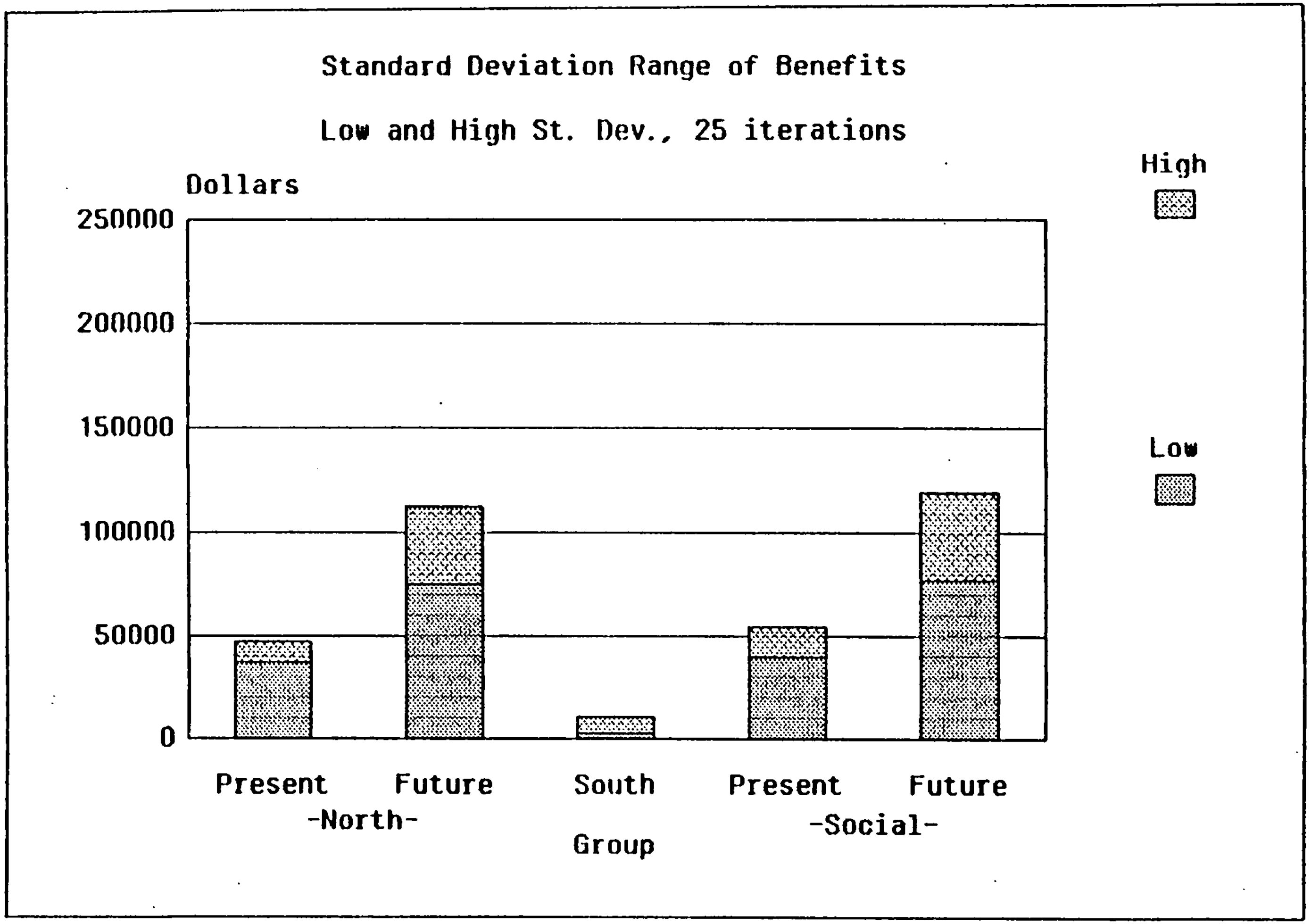

Figure IV.3 - Range of standard deviations for 25 iterations of 50 years.

The result of this condition is an overall lower mean annual income in the simulation than that assumed for current analyses: $76-97,000 for north group farmers as compared with $120,088 under current methods. If a management system using more water, irrigating more acreage, and obtaining higher yields were assumed in the simulation, this discrepancy would undoubtedly narrow. However, the problem of shortages in dry years intensifies: what farmers and which crops get water? An optimal management may imply differences in the marginal use of water and thus complicate the model further.

Though the mean incomes may be considered "low," the median in each set is significantly higher. In fact, at a selection of 70% chance flow level, at least 7 out of 10 simulated years should have incomes at the "full water supply" amount. This indicates a <u>median</u> income of $120,088 for north group farmers.

The range of "offsite impact" values had a low mean of $12,838 and a high mean of $13,135, a discrepancy of only $257. This is a surprising result, given the inherent difficulties in measuring offsite benefits and costs in general. However, much of this difficulty and uncertainty was eliminated by the selection of particular base ratios and values. The major portion of the offsite values (see table IV.2) was the pheasant population damages. These were not dependent upon streamflow but on acreage irrigated and thus remained constant throughout the simulation. The relatively high standard deviations associated with recreational fishing valuations are to be expected due to its sensitivity to great fluctuations in stream flows.

		Offsite Total	Recr. Fishing	Waterfowl & Wetlands	Pheasant Habitat
Mean range	- low	12,878	319	875	11,639
	- high	13,135	565	1,028	11,639
St. Deviation range	- low	413	417	215	0
	- high	621	479	275	0
Range of highest	- low	13,795	891	1,265	11,639
	- high	14,357	1,339	1,383	11,639
Range of lowest	- high	12,313	0	674	11,639
	- low	11,931	(80)	417	11,639

Table IV.2 -- Offsite impact summary for 25 fifty-year simulations, using priority crop management.

The damage assessment to waterfowl and wetlands was very interesting, if not a significant part of the offsite package. The values obtained (means ranged from $875 to $1,028) for the most part represent damages to those individuals outside the study area. This is because wetlands are production areas and the waterfowl breeding there are migratory in nature.

It is also interesting to note that overall offsite damages are greater in the years of abundant water, and less in low water years. This is due to the <u>relative</u> impacts being greater in abundant flow years.

It is clear by the statistics that in most years both the farmers involved in the project and society as a whole are better off in the proposed future condition. In some instances this is not the case. Table IV.3 presents the number of years in each run of 50-years in which farmers and society, respectively, are made worse off with the project. This is done by comparing net benefits in the present and future condition.

run	On-farm losses	Social losses	run	On-farm losses	Social losses
1	4	8	14	7	11
2	3	9	15	1	4
3	4	6	16	6	9
4	3	5	17	2	4
5	5	12	18	6	9
6	1	8	19	2	12
7	4	5	20	3	8
8	3	8	21	4	10
9	5	9	22	5	12
10	1	6	23	4	5
11	1	4	24	7	11
12	6	10	25	4	9
13	5	6			

Table IV.3 -- Number of years in each fifty-year simulation in which net losses occur in income from present to future condition.

At least 1 and at most 7 years in each 50-year period were "bad" for project farmers, and at least 4 and at most 12 were "bad" for society as a whole. One fact always remained true: a bad year for farmers -- a year in which farmers were made worse off by being involved in the project

-- always left society worse off. The cases in which this happened were always in years of very poor stream flow amounts. Farmers did not always incur a net loss in combined income for them to be worse off. But in those very low water years, great losses occurred for "with project" farmers.

Society fared poorly in years of marginal success for project farmers or farmer losses. This is because of the "additional burdens" of public cost share for the project and the offsite damages.

The results of the runs and discussion to this point makes clear the issue of income distribution. First and foremost, project development would result in an income subsidy by society -- national and regional -- to the farmers of the north group through the public share program of the Soil Conservation Service. However, it also represents generated income for the region as a whole, and society is thus made better off. A shift in income is also evident by those parties affected by offsite impacts -- in this case, primarily recreationists -- to north group farmers. At least some of these recreationists live outside the region.

Because the region as a whole is made better off through income generated and respent in the communities, even south group farmers not directly involved in the project will benefit.

In times of water shortages, the scenario changes slightly. When north group farmers retain a net gain but overall society incurs a loss, a shift in income and net loss to society takes place. Gains to north group farmers do not offset the annual cost of the project or the offsite impacts incurred by other sectors. In the worst case scenario (area farmers and society observe a net loss in income), the situation is emphasized, but even north group farmers lose. (It is interesting to note that their loss would be even greater were it not for the public cost share.)

Perhaps one of the striking statistics is the level of variation in incomes from year to year, as indicated by the standard deviations in tables IV.1 and IV.2. The higher values in the future condition are associated with less certainty of future annual income and a greater risk potential. The possibility of losing a substantial amount of money in very low flow years (the 1 in 10 or 1 in 20 cases) may be more risky than farmers -- or society -- are willing to accept.

The primary reason for this tremendous variation (the standard deviations of income in the future condition are more than twice that of the present situation) is the fixed cost incurred every year by the farmers and the federal government. Regardless of the revenue received by farmers for crops sold in any given year, the annual project repayment cost of $72,974 must be paid. At the federal level, a fixed cost of $42,973 exists for the project, and an offsite damage of $11-14,000 per year incurred.

Farmers could effectively hedge against the possibility of severe losses through some sort of insurance. Saving a portion of income every year to compensate for "bad" ones is one way to self-insure. But whether self-insured or through an agent, the effect is the same: it is not without cost. Required premiums could be computed, but nevertheless must be assessed as an additional fixed cost, thus lowering expected net benefits. In the case of the Paris Creek area farmers, this would be a likely undertaking.

In short, because north group farmers are not required to pay the entire cost of the project to improve irrigation, it is likely to be to their advantage to engage in the project; annual incomes are considerably higher and the risk of a poor year are small enough to warrant an improved status. This is even true if some of those benefits must be used for risk leveling purposes.

Evaluation of the project for society requires more complex reasoning. If "typical" or overall "average" scenarios are used as criteria, the project is worthwhile in the long run. If there is considerable aversion to great fluctuations in annual income, or to years of great loss, or if worst case scenarios are considered solely, the project proves less beneficial. In addition, considerations of offsite impacts in the decision can further hamper acceptability of the project, if these interests are to be considered.

From a regional standpoint, the project appears to be favorable, as a substantial burden of cost is to be shifted outside the area while the benefits are concentrated locally.

C. A New Management System

The initial simulation run made an important assumption common to other simulation models of this sort: that of an assumed priority crop system. All the acreage in a particular crop was irrigated before any of an assumed lower priority crop.

While there is some economic basis for doing so -- water is delivered to the crop with the highest marginal value -- it may not accurately reflect reality. Farmers with senior rights may own land of a lower use value than others.

In an attempt to discover the effects of an alternative management, the assumption was made that all farmers in the project area owned crops in the same relative proportion. Furthermore, water shortages were shared on an equal, proportional basis over all crops. (This system will be referred to as a "shared-shortage" management system.)

A fifty-year simulation run yielded the results shown in table IV.4. The results show very low means and very high standard deviations for the north and south groups and the social net benefits -- but only in the present situation. The future condition reveals average means and standard deviations, as compared with the priority system, though they are still greater than at present. This results in a greater preference for project acceptance for both the north farmers and in terms of society.

	Mean	St. Dev.	High	Low
North, present	59,779	51,120	120,088	(30,552)
future	211,520	95,936	272,348	(80,157)
South	42,570	13,132	50,284	5,534
Social, present	102,349	61,911	170,372	(24,748)
future	198,079	108,611	267,346	(137,830)
Offsite, total	13,038	500	13,819	12,233
- Rec. fishing	455	427	898	0
- Waterfowl	943	250	1,351	594

Table IV.4 -- Results of a 50-year simulation, under shared-shortage management system.

The reason for the great disparity is that the present situation maintains a situation where acreages are spread closely between crops (alfalfa, barley, and pasture) while the with-project management scheme maintains only high-valued crops. Therefore, at present some land of lower economic value (i.e., pastureland) is irrigated in place of cropland.

An attempt to trace and compare the effects of below average stream flow levels on each the priority and shared-shortage management systems. Six years of data were generated for each system with monthly stream flow amounts prearranged at fixed fractions below the mean. These were defined as 0 to 1.5 standard deviations below the mean, decreased by .3 each year.

Table IV.5 presents selected results of these runs. As was the case with the other simulation, the shared-shortage management received far less income than the priority system, for the present situation. However, slightly greater income was generated on the shared system than priority system in the future for the cases between 0 and 1.0 standard deviations below the mean. This was probably due to the fact that the marginal benefit of irrigating alfalfa and barley partially exceed that of spreading those last units of water entirely on alfalfa. In the case of extreme shortages, applying all the water available to alfalfa was preferable in order to reduce losses.

D. Altered Water Rights Allocations

It is clear from the simulations generated up to this point that the north group is water-short relative to the

year		Present priority	Present shared	Future priority	Future shared	z-value
1	North NB	110,033	67,257	272,348	272,348	0.0
	South NB	50,284	50,284	50,284	50,284	
	Offsite	--	--	(13,652)	(13,647)	
	Net social	160,317	117,541	266,007	266,012	
2	North NB	68,413	34,565	248,153	253,749	-0.3
	South NB	50,284	50,284	50,284	50,284	
	Offsite	--	--	(14,297)	(14,268)	
	Net social	118,697	84,850	241,166	246,792	
3	North NB	34,885	10,585	135,353	160,683	-0.6
	South NB	47,237	35,107	47,237	35,107	
	Offsite	--	--	(13,591)	(13,561)	
	Net social	82,122	45,692	126,025	139,257	
4	North NB	5,864	(11,432)	25,371	29,101	-0.9
	South NB	43,175	19,477	43,175	19,477	
	Offsite	--	--	(13,271)	(13,242)	
	Net social	49,040	8,045	13,302	(7,638)	
5	North NB	(18,386)	(30,524)	(57,836)	(63,655)	-1.2
	South NB	24,064	8,011	24,064	8,011	
	Offsite	--	--	(13,142)	(13,128)	
	Net social	5,698	(22,513)	(89,987)	(111,745)	
6	North NB	(36,189)	(44,580)	(122,699)	(130,523)	-1.5
	South NB	9,550	(1,527)	9,550	(1,527)	
	Offsite	--	--	(12,069)	(12,069)	
	Net social	(26,639)	(46,107)	(168,181)	(187,092)	

Table IV.5 -- Results of 6 simulated runs for priority and shared-shortage management systems, with monthly stream flow fixed.

south group. In fact the instances of actual water shortages for the south group are few, as indicated by the high mean income values, low standard deviation and modest "low" income values.

No mechanism currently exists for transferring water rights from the south group farmers to the north. However, a few interesting questions arise from this issue: would the project be even more acceptable to the north group (and society) if their share of water was greater? How would the south group be affected? Would society be even better off? How much is it worth to the north group farmers to allow a transfer of rights, if they could buy them?

Based on future needs for water for both the north and south, an equivalent allocation of rights based on need would give the north 61.5% of the flow. A fifty-year simulation run was generated based on the assumption of these rights. The cumulative totals are shown in table IV.6.

	Mean	St. Dev.	High	Low
North, present	96,304	34,376	120,088	7,652
future	236,706	70,822	272,348	(22,342)
South	46,905	7,028	50,284	17,576
Social, present	143,209	40,749	170,372	25,227
future	227,709	77,266	267,346	(60,324)
Offsite, total	12,930	490	13,776	12,213
- Rec. fishing	386	460	898	(486)
- Waterfowl	905	263	1,377	674

Table IV.6 -- Results of 50-year simulation, under altered water rights allocation (north = 61.5% of flow).

Based on this single execution, the mean value of income for the north group was above average, compared to the present allocation, in both the present and future conditions. The future condition mean was $7,665 to $45,653 above the means for 25 runs in the present allocation. The social net benefits were also higher -- $5,501 to $44,398 above the mean. They also experience relatively low deviations from the mean in this case.

The south group under this scenario would experience a lower mean annual income -- $46,905 a year. This is, however, only $105 to $2347 below the range of mean values in the present scenario.

This situation would be very acceptable to north group farmers by comparison: their expected annual income would be higher, their risk reduced and their losses perhaps not as severe in dry years. The south group would be worse off but not facing a significant increase in risk. Society as a whole would be better off, with greater income generated overall at reduced uncertainty.

There is, in fact, incentive for north group farmers to purchase water rights from the south, if such a practice were legally possible. The value of such rights to society would be equivalent to the marginal improvement in income by the north group farmers, minus the compensation necessary for income lost by south group farmers. The additional benefit would range from $5,318 to $44,293, based on the averages generated in this simulation.

V. Summary and Conclusions

A. Summary

Decisions involving irrigation and delivery system improvements require economic evaluations covering a number of different areas. Current methods of evaluation used by U.S. Department of Agriculture effectively assess on-site economic effects of proposed projects; however, procedures for measuring the economic impacts of improvements on other parties are lacking, and an analysis of income variability and risk is generally not included in these studies.

This thesis tried to investigate these deficiencies and develop an appropriate analysis tool which would allow these issues to be addressed. The approach included a simulation model of a river basin, and a comparison of annual incomes received by farmers under a "with" and "without" project scenario. The goal was to provide information on the level and variability of annual incomes as they are affected by improvements in irrigation systems.

In Chapter II the background theory and past simulation modeling approaches were explored. Some early documents included comprehensive methodologies for water resource simulation that are still relevant today. A precise detailing of water supply, demand sources, design variables, and invariant physical facilities is an important aspect of simulation model design.

A survey of the many practical applications of non-market valuation was also presented. The travel cost and contingent market survey methods are two widely used techniques for such measurement, but have important limitations. Some empirical results, however, did provide useful information.

Chapter III provided a step-by-step progression towards the computer model development, from the stream flow generator to the final assessment at the end of the season. The hydrologic properties of the creek simulated were modeled according to the Thomas-Fiering hydrology model, with reasonable success. This provided for considerable confidence in the model's ability to make an accurate representation.

Irrigation diversions and delivery systems were controlled by hydrologic parameters and management assumptions. When water was not fully available to serve crop needs in any particular month, a method of crop priority was implemented, giving the higher-valued crops their share of water first.

Monitoring of water levels throughout the system were maintained. These water levels formed the basis for computing offsite impacts.

At the end of the season, value of crops grown and sold was calculated based on water availability and yield assumptions. Offsite impacts were "measured" and the costs and benefits associated with both the present and future situations were compiled, giving the final comparison values for that year. This pattern was repeated for 50 years and the cumulative statistics computed including mean annual incomes, standard deviations, and net social benefits.

A set of 25 simulation iterations, each containing data for 50 years, was generated for the initial run. It was found that farmers in the north group are almost always better off when involved in the proposed project, above their present situation, but that some additional variation in annual income could be expected. Society as a whole was somewhat better off in the long run. But because society bears some of the fixed annual cost of installing the new system, and for offsite impacts, its' gains are not as significant. In general, a shift in income takes place from recreationists and society members outside the economic region to project farmers and the local area.

A trial run with a new water management system -- where water shortages are shared equally among crops -- reinforced these results. Incomes in the present situation were computed to be considerably lower on average and much more variable, while the with-project situation remained roughly the same, when compared with priority management. This result made the project appear even more acceptable. The cause for the differences is based on the present and projected crop distributions, with a higher proportion of low-valued pasture irrigated in the present situation than the future.

A second trial run was created by shifting some of the water rights from the south group to the north, according to needs rather than legal allocation. The results, as anticipated, indicated significantly higher annual incomes for north group farmers and only slightly lower incomes for south group farmers. This indicated a willingess-to-pay by north group farmers of $5,501 to $44,398 for the rights they would receive from the south.

B. Observations

The simulation results reinforced the role played by risk in the decision-making process. Farmers who must decide whether or not to engage in an irrigation project can be presented additional information about the nature of expected income. It becomes more apparent that under these circumstances a farmer tends to lose more income proportionally in a year of low flow than he would at present. This lack of certainty may be unacceptable to the farmer and must be stressed. Land management decisions made on short term expectations (as a single "expected annual income" value implies) could lead to less than optimal results and even financial ruin.

From the standpoint of national welfare, or society's benefits, a more detailed analysis of income shifts and distribution is possible. In the case presented herein it can be demonstrated that the local region, as well as the farmers involved, are made better off with the project's initiation. The cost involves an income shift from taxpayers outside the area, and from recreationists in the immediate and surrounding areas.

A comprehensive assessment methodology for offsite impacts remains a problem. Despite the large volume of literature on the subject, it is difficult to make generalizations applicable to any particular river basin, and the values generated by the simulation lack credibility. The travel cost and survey methods are generally not cost effective for individual river basin studies. Quite simply, until -- or unless -- a standardized approach to making marginal assessments of impacts with respect to wildlife and land resources is developed, these areas will continue to be ignored. It is hoped that a close relationship between biologists and economists can be nurtured to alleviate some of these major quantification problems.

As a tool for analysis, the simulation model program proved very flexible, easily altered, and easy to use. While the program itself required 29K bytes of memory, its routines did not significantly challenge the limits of the microcomputer. This is encouraging, for it invites the application of more complex decision processes in future models.

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APPENDICES

APPENDIX A

```
100 REM [] Hydrology Model Generator - test model
110 REM []
120 REM [] Generates a series of monthly flows based on the computed
130 REM [] values using the Paris Creek streamflow data. The program
140 REM [] generates its own random values.
200 REM * read data
210 GOSUB 9000
220 REM * generate flows
230 GOSUB 1000
240 REM * compute statistics
250 GOSUB 2000
260 REM * report results
270 GOSUB 3000
280 END
1000 REM [] generate flows
1010 REM []
1020 REM * read distribution data
1030 GOSUB 9500
1040 RANDOMIZE TIMER
1042 REM * print header
1045 PRINT
1050 PRINT "  April       May       June       July        Aug        Sept"
1055 PRINT
1060 FOR Y% = 1 TO YEAR%
1061 PRINT Y%;
1065   REM * get value for April
1070   GOSUB 1500
1080   Q[4,Y%] = QBAR[4] + STD[4] * T
1085 PRINT USING " +#.#      "; T,
1090   FOR MO% = 5 TO 9
1100     REM * get random value
1110     GOSUB 1500
1115 PRINT USING " +#.#      "; T,
1120     Q[MO%,Y%] = QBAR[MO%] + B[MO%-1] * (Q[MO%-1,Y%] - QBAR[MO%-1]) +
                         T * STD[MO%] * (1 - R[MO%-1]^2) ^.5
1130   NEXT MO%
1135 PRINT
1140   REM * transform log data back to standard
1150   FOR I% = 4 TO 9
1160     X[I%,Y%] = EXP (Q[I%,Y%] * 2.302585)
1165     PRINT USING "#,###.#    "; X[I%,Y%],
1170   NEXT I%
1175 PRINT:PRINT
1190 NEXT Y%
1190 RETURN
1500 REM [] generate random values
1510 TEMP = RND - .5
1520 IF (TEMP < 0) THEN SIGN% = -1 ELSE SIGN% = 1
1530 FOR NUM% = 1 TO 35
1540   IF (ABS(TEMP) < DIST [NUM%]) THEN 1560
1550 NEXT NUM%
1560 T = SIGN% * ((NUM% - 1) / 10)
1570 RETURN
2000 REM [] Compute statistics
2010 PRINT "computing statistics..."
2020 FOR MO% = 4 TO 9
2030   T = 0
2040   FOR I% = 1 TO YEAR%
2050     T = T + Q [MO%,I%]
2060   NEXT I%
2070   QBAR [MO%] = T/YEAR%
2080   S = 0 : C2 = 0 : C3 = 0
2090   FOR J% = 1 TO YEAR%
2100     S = S + (Q[MO%,J%] - QBAR[MO%])^2
2110     C2 = C2 + Q[MO%,J%]^2
2120     C3 = C3 + Q[MO%,J%]^3
2130   NEXT J%
```

```
2135    REM * variance, standard deviation, skew
2140    VAR [MO%] = S / (YEAR%-1)
2145    STD [MO%] = (VAR [MO%])^.5
2150    SKEW [MO%] = (YEAR%^2 * C3 - 3*YEAR% * T * C2 + 2 * T^3) /
                 (YEAR% * (YEAR% - 1) * (YEAR% - 2) * (VAR[MO%]^.5)^3)
2160    IF (MO% = 4) THEN 2250     ' first month
2170    COR = 0 : SSE = 0 : SSE2 = 0
2180    FOR K% = 1 TO YEAR%
2190      COR = COR + Q[MO%-1,K%] * Q[MO%,K%]
2200      SSE = SSE + Q[MO%-1,K%]^2
2210      SSE2 = SSE2 + Q[MO%,K%]^2
2220    NEXT K%
2225    REM * regression, correlation coefficients
2230    B [MO%-1] = (COR - YEAR% * QBAR[MO%-1] * QBAR[MO%]) /
                 (SSE - YEAR% * QBAR[MO%-1]^2)
2240    R [MO%-1] = (COR - YEAR% * QBAR[MO%-1] * QBAR[MO%]) /
          ((SSE - YEAR% * QBAR[MO%-1]^2) * (SSE2 - YEAR% * QBAR[MO%]^2))^.5
2250 NEXT MO%
2260 RETURN
3000 REM [] Report statistics
3090 PRINT : PRINT
3100 PRINT "Means, Variances, Standard Deviations, Skews :"
3110 FOR M% = 4 TO 9 : PRINT USING "  #.###    "; QBAR[M%], : NEXT M%
3120 PRINT : PRINT
3130 FOR V% = 4 TO 9 : PRINT USING "  #.####   "; VAR[V%], : NEXT V%
3140 PRINT : PRINT
3150 FOR S% = 4 TO 9 : PRINT USING "  #.####   "; STD[S%], : NEXT S%
3160 PRINT : PRINT
3170 FOR SK% = 4 TO 9 : PRINT USING " +#.###    "; SKEW[SK%], : NEXT SK%
3180 PRINT : PRINT
3190 PRINT : PRINT "Regression, Correlation coefficients :"
3200 FOR B% = 4 TO 8 : PRINT USING "  #.####   "; B[B%], : NEXT B%
3210 PRINT : PRINT
3220 FOR R% = 4 TO 8 : PRINT USING "  #.####   "; R[R%], : NEXT R%
3230 PRINT : PRINT
3240 RETURN
9000 REM [] read data
9010 REM []
9020 REM * matrix sizes
9030 DIM X[10,100], Q[10,100], QBAR[10], VAR[10], STD[10], B[10], R[10]
9040 DIM SKEW[10], FLOW[10], DIST[35]
9050 REM * read statistical data
9055 YEAR% = 100  ' years of record
9060 FOR MO% = 4 TO 9
9070   READ QBAR[MO%], VAR[MO%], STD[MO%], SKEW[MO%], B[MO%], R[MO%]
9080 NEXT MO%
9100 REM * data: mean, variance, st. dev., skew, regres. and corr. coeff.
9110 DATA 2.092,0.0254,0.1593,0.094,0.8472,0.5855
9120 DATA 2.503,0.0532,0.2306,-0.381,0.8412,0.7370
9130 DATA 2.565,0.0692,0.2631,-0.152,0.7138,0.8590
9140 DATA 2.383,0.0479,0.2189,0.339,0.7211,0.9781
9150 DATA 2.239,0.0260,0.1614,-0.148,0.7662,0.9675
9160 DATA 2.134,0.0163,0.1278,-0.418,0,0
9170 RETURN
9500 REM [] normal distribution data
9510 FOR J% = 1 TO 35
9520   READ DIST [J%]
9530 NEXT J%
9540 RETURN
9800 REM * dist data
9810 DATA .0199,.0596,.0987,.1368,.1736,.2088,.2422,.2734,.3023,.3299
9820 DATA .3531,.3749,.3944,.4115,.4265,.4394,.4505,.4599,.4679,.4744
9830 DATA .4798,.4842,.4878,.4906,.4929,.4946,.4960,.4970,.4978,.4984
9840 DATA .4989,.4992,.4994,.4996,.4997
9999 PRINT FLOW[MO%];"=";QBAR[MO%];"+";B[MO%-1];"*";FLOW[MO%-1];"-";QBAR[MO%-1];
"+";T;"*";STD[MO%];"*(1-";R[MO%-1];"^2)^.5"
```

```
100 REM [] Hydrology Model Generator
110 REM []
120 REM [] Reads monthly streamflow levels, calculates monthly means,
130 REM [] variances, correlation coefficients and regression coefficients
140 REM [] for the M-F model.
150 REM * read data
160 GOSUB 9000
1000 FOR MO% = 4 TO 9
1010   T = 0
1020   FOR I% = 1 TO YEAR%
1030     T = T + Q [MO%,I%]
1040   NEXT I%
1050   QBAR [MO%] = T/YEAR%
1060   S = 0 : C2 = 0 : C3 = 0
1070   FOR J% = 1 TO YEAR%
1080     S = S + (Q[MO%,J%] - QBAR[MO%])^2
1090     C2 = C2 + Q[MO%,J%]^2
1095     C3 = C3 + Q[MO%,J%]^3
1100   NEXT J%
1110   VAR [MO%] = S / (YEAR%-1)
1120   SKEW [MO%] = (YEAR%^2 * C3 - 3*YEAR% * T * C2 + 2 * T^3) /
                  (YEAR% * (YEAR% - 1) * (YEAR% - 2) * (VAR[MO%]^.5)^3)
1130.  IF (MO% = 4) THEN 1300     ' first month
1135   COR = 0 : SSE = 0 : SSE2 = 0
1140   FOR K% = 1 TO YEAR%
1150     COR = COR + Q[MO%-1,K%] * Q[MO%,K%]
1160     SSE = SSE + Q[MO%-1,K%]^2
1170     SSE2 = SSE2 + Q[MO%,K%]^2
1180   NEXT K%
1190   B [MO%-1] = (COR - YEAR% * QBAR[MO%-1] * QBAR[MO%]) /
                  (SSE - YEAR% * QBAR[MO%-1]^2)
1200   R [MO%-1] = (COR - YEAR% * QBAR[MO%-1] * QBAR[MO%]) /
     ((SSE - YEAR% * QBAR[MO%-1]^2) * (SSE2 - YEAR% * QBAR[MO%]^2))^.5
1300 NEXT MO%
2000 REM * print results
2010 PRINT "april", "may", "june", "july", "august", "september"
2020 PRINT
2030 FOR Y% = 1 TO YEAR%
2040   FOR M% = 4 TO 9
2050     PRINT Q[M%,Y%],
2060   NEXT M%
2065   PRINT
2070 NEXT Y%
2080 PRINT : PRINT
2090 PRINT "Means, Variances, Standard Deviations, Skews :"
2100 FOR M% = 4 TO 9 : PRINT QBAR[M%], : NEXT M%
2120 PRINT : PRINT
2130 FOR V% = 4 TO 9 : PRINT VAR[V%], : NEXT V%
2140 PRINT : PRINT
2150 FOR S% = 4 TO 9 : PRINT (VAR[S%])^.5, : NEXT S%
2160 PRINT : PRINT
2165 FOR SK% = 4 TO 9 : PRINT SKEW[SK%], : NEXT SK%
2167 PRINT : PRINT
2170 PRINT : PRINT "Regression, Correlation coefficients :"
2180 FOR B% = 4 TO 8 : PRINT B[B%], : NEXT B%
2190 PRINT : PRINT
2200 FOR R% = 4 TO 8 : PRINT R[R%], : NEXT R%
2210 PRINT : PRINT
2300 END
9000 REM * matrix sizes
9005 DIM Q[10,70], QBAR[10], VAR[10], B[10], R[10], SKEW[10]
9010 REM * read data
9015 YEAR% = 69    ' years of data
9020 FOR MO% = 4 TO 9
9030   FOR YR% = 1 TO YEAR%
9040     READ Q[MO%,YR%]
9050   NEXT YR%
9060 NEXT MO%
```

```
9090 REM • monthly data -- july through october
9100 REM - april
9110 DATA 153.7,153.6,205.9,174.5,136.0,112.2,138.2,113.1,139.1,130.0
9120 DATA 147.7,193.7,191.5,75.0,100.0,81.1,144.1,60.9,68.5,81.1
9130 DATA 89.0,90.4,126.6,179.6,114.4,166.9,178.4,66.8,241.2,155.6
9140 DATA 147.8,148.6,179.8,109.7,234.0,255.2,216.8,221.9,153.4,86.0
9150 DATA 97.2,79.5,258.1,113.3,173.4,92.1,111.6,64.8,122.4,89.4
9160 DATA 77.7,117.8,102.4,66.5,75.6,140.8,140.4,104.0,184.9,90.7
9170 DATA 108.3,75.9,97.5,79.3,114.7,120.5,141.8,114.3,170.8
9200 REM - may
9210 DATA 211.6,259.6,479.2,408.9,524.5,450.0,343.6,716.6,613.9,594.2
9220 DATA 262.4,394.4,292.7,260.2,746.2,264.5,292.0,99.4,273.4,273.1
9230 DATA 103.1,256.6,290.8,382.2,350.1,200.8,416.2,106.2,475.8,368.9
9240 DATA 232.6,302.0,443.5,230.6,415.0,384.5,690.6,392.4,368.0,173.7
9250 DATA 232.9,184.0,735.5,224.5,673.4,189.8,224.9,110.7,381.2,150.1
9260 DATA 346.7,471.7,185.8,419.2,220.8,544.3,619.3,193.6,739.3,228.8
9270 DATA 495.2,229.3,448.8,89.6,268.8,590.3,652.8,180.1,627.7
9300 REM - june
9310 DATA 505.0,213.9,600.2,2022.2,584.1,254.2,509.3,1198.1,1114.6,552.3
9320 DATA 234.6,270.2,173.0,625.8,406.5,484.7,226.1,88.7,494.5,455.8
9330 DATA 83.0,270.8,503.8,315.1,421.4,164.0,211.7,139.8,360.9,479.0
9340 DATA 236.3,356.6,389.0,370.7,461.4,299.6,754.4,446.0,456.4,208.1
9350 DATA 220.3,279.1,456.5,285.0,513.0,206.9,198.0,141.9,354.4,235.2
9360 DATA 430.5,781.4,218.5,541.6,381.6,308.5,610.5,350.2,704.2,360.9
9370 DATA 815.3,585.5,479.3,85.6,517.1,392.4,718.7,177.9,932.5
9400 REM - july
9410 DATA 371.9,161.3,464.5,851.6,290.8,175.1,290.6,426.7,385.0,336.3
9420 DATA 165.7,189.7,129.8,298.1,239.4,266.6,156.3,78.0,293.6,130.9
9430 DATA 77.7,216.6,309.2,203.1,223.6,135.8,120.6,128.7,161.1,396.8
9440 DATA 192.1,242.5,296.7,277.4,248.2,203.1,418.8,321.3,298.1,231.0
9450 DATA 153.2,207.6,253.8,278.2,244.1,175.2,151.2,113.9,229.4,208.9
9460 DATA 276.9,407.9,156.8,305.8,212.0,208.1,294.0,487.2,384.3,217.1
9470 DATA 313.9,378.2,274.2,81.5,1256.4,222.6,353.7,154.0,665.7
9500 REM - august
9510 DATA 284.0,143.4,280.1,377.3,206.4,144.5,214.7,291.4,264.4,240.9
9520 DATA 134.5,150.5,112.3,216.1,182.7,182.2,117.6,73.7,198.6,122.7
9530 DATA 72.5,149.7,209.6,151.4,171.6,112.5,109.7,106.0,121.0,248.7
9540 DATA 132.0,181.0,208.0,180.5,184.8,142.4,270.4,232.5,199.3,155.1
9550 DATA 131.2,130.8,195.6,202.5,178.2,133.2,120.7,88.5,179.6,148.3
9560 DATA 192.5,259.6,132.8,199.3,151.9,157.5,175.7,314.3,254.9,163.2
9570 DATA 207.3,239.0,198.4,70.8,398.6,166.8,226.8,118.2,373.0
9600 REM - september
9610 DATA 204.8,123.9,209.4,259.0,169.1,119.4,159.0,200.8,181.8,170.8
9620 DATA 108.0,125.3,97.8,162.3,150.3,143.1,95.9,64.8,154.1,118.5
9630 DATA 67.9,110.6,165.3,120.7,141.5,96.3,93.7,94.9,102.5,192.3
9640 DATA 107.4,139.5,146.7,144.7,139.1,116.3,191.7,173.6,160.8,130.0
9650 DATA 106.7,111.0,149.8,165.0,130.2,113.6,100.2,74.9,153.5,129.3
9660 DATA 148.5,191.6,112.5,148.5,124.8,124.1,135.3,226.4,203.1,131.7
9670 DATA 166.0,176.8,165.1,68.1,166.1,130.4,180.6,90.6,209.4
9700 RETURN
```

APPENDIX B

```
100 REM *  Impact Simulation Model
110 REM *
120 REM *  Purpose:  This program performs an economic analysis of the
130 REM *    offsite impacts associated with a proposed irrigation project
140 REM *
150 REM *  Discussion:  The program takes as input various precalculated data
160 REM *    on the hydrologic characteristics of the region and present and
170 REM *    proposed system.  The changes in stream regime are computed and
180 REM *    applied to analysis of issues of concern.  Based on further econ-
190 REM *    omic relationships, the valuation of each aspect takes place: com-
200 REM *    bining these aspects becomes the net economic impacts of the plan.
210 REM *
220 REM *    A Monte Carlo technique of simulation is used, providing a dist-
230 REM *    ribution of streamflow and net physical impacts.  These values be-
240 REM *    come the basis for a distribution of net economic impacts.
250 REM *
260 REM *  Programmer:  Michael Taylor      Date:  June 1985
270 REM *
500 REM [] initialize
510 GOSUB 8000
520 INPUT "Enter the number of years to simulate:   ", YEARS%
530 IF (YEARS% < 0) GOTO 520
532 INPUT "Trace level (0-3) : ", TRACE%
533 IF (TRACE% < 0) OR (TRACE% > 3) THEN 532
535 REM * Output hydrologic parameters
536 GOSUB 700
538 RANDOMIZE TIMER
540 FOR YEAR% = 1 TO YEARS%
545   REM [] reset accumulation variables
546   GOSUB 800
550   REM []  hydrology
560   GOSUB 1000
570   REM []  physical impacts
580   GOSUB 3000
590   REM []  economic impacts
600   GOSUB 5000
610   REM []  net impact assessment and output
620   GOSUB 6000
630 NEXT YEAR%
640 REM []  statistics
650 GOSUB 7000
660 END
700 REM [] output hydrologic parameters
705 REM * Model heading
710 LPRINT "River Basin Economic Impacts Simulation Model"
715 LPRINT "Paris Creek, Bear Lake County, Idaho"
720 LPRINT TIME$, DATE$
725 LPRINT : LPRINT
730 REM * parameters
735 LPRINT "***   Hydrologic Parameters   ***"
740 LPRINT : LPRINT TAB(27); "Stream     Delivery    Sprinkler    Surface"
745 PR$ = "- Present       .##         .##         .##         .##"
750 FU$ = "- Future        .##         .##         .##         .##"
751 SPA$ = "              "
755 LPRINT USING "Evaporation " + PR$;STMEVAP,DELEVAP(0),SPREVAP(0),0
760 LPRINT USING SPA$ + FU$; STMEVAP, DELEVAP(1), SPREVAP(1),0
765 LPRINT USING "Seepage     " + PR$;STMSEEP,DELSEEP(0),SPROP(0),SUROP(0)
770 LPRINT USING SPA$ + FU$; STMSEEP, DELSEEP(1), SPROP(1), SUROP(1)
775 LPRINT USING "Return Flow " + PR$: 0, 0, 0, SURRET(0)
780 LPRINT USING SPA$ + FU$: 0, 0, 0, SURRET(1)
785 LPRINT
790 RETURN
800 REM -
810 REM - Reset accumulation parameters
820 REM -
830 FOR I% = 1 TO 8
840   FOR J% = 1 TO 6
850     NYP[I%,J%] = 0  :  SYP[I%,J%] = 0
860   NEXT J%
870 NEXT I%
```

```
880 FOR I% = 0 TO 1
890   STREAM [0,I%] = 0  :  WETLAND [0,I%] = 0
900   NTOTYLD [0,I%] = 0  :  STOTYLD [0,I%] = 0
910   NREV [0,I%] = 0  :  SREV [0,I%] = 0
920   NCOST [0,I%] = 0  :  SCOST [0,I%] = 0
930   NNETREV [0,I%] = 0  :  SNETREV [0,I%] = 0
940 NEXT I%
950 RETURN
1000 REM []
1010 REM []  Hydrology section
1020 REM []
1030 HYO$ = "   ##..##          ###.##"
1035 HYO2$ = "             ###.##"
1040 FOR MO% = 4 TO 9
1045   IF (TRACE% > 1) THEN LPRINT "Month #":MO%
1050   REM * generate month's stream flow level
1060   GOSUB 1500
1062   X1[MO%] = X[MO%] - CITY   'Municipal water supply
1065   IF (TRACE% > 1) THEN LPRINT USING "   Paris City municipal right"
         + SPACE$(7) + HYO2$; CITY
1070   REM * North group retains rights on 49.94% of flow
1080   NORTH = X1[MO%] * .4994
1085   SOUTH = X1[MO%] - NORTH
1087   IF (TRACE% > 1) THEN LPRINT USING "   North / South water right:        "
           + HYO$; NORTH,SOUTH
1090   FOR CONO% = 0 TO 1
1095     IF (TRACE% > 1) THEN IF (CONO% = 0) THEN LPRINT "* Present condition"
                                  ELSE LPRINT "* Future condition"
1100     REM * allocate water to crops
1105     SHORTAGE[CONO%] = 0
1110     WATERAVAIL = NORTH  :  N% = -1
1115     IF (TRACE% > 1) THEN LPRINT "North system"
1120     GOSUB 2000   'north section
1121     IF (TRACE% > 2) THEN LPRINT USING"   Return flow:"+SPACE$(21) + HYO2$;
           RETFLOW
1123     IF (TRACE% > 1) THEN LPRINT USING"North total diversions:
"              + HYO$; SPRDIV,SURDIV
1125     NETFLOW = NORTH - (SPRDIV + SURDIV) + RETFLOW
1130     WATERAVAIL = SOUTH  :  N% = 0
1135     IF (TRACE% > 1) THEN LPRINT "South system"
1140     GOSUB 2000   'south section
1141     IF (TRACE% > 2) THEN LPRINT USING"   Return flow:"+SPACE$(21) + HYO2$;
           RETFLOW
1143     IF (TRACE% > 1) THEN LPRINT USING"South total diversions:
"              + HYO$; SPRDIV,SURDIV
1150     NETFLOW = NETFLOW + SOUTH - (SPRDIV + SURDIV) + RETFLOW
1160     STREAM [MO%,CONO%] = NETFLOW * (1 - (STMEVAP + STMSEEP))
1170     DELAY [MO%,CONO%] = DP + NETFLOW * STMSEEP
1180     WETLAND [MO%,CONO%] = STREAM [MO%,CONO%] +
                        DELAY [CINT(MO%-DELAYTIME),CONO%]
1185     IF (TRACE% > 1) THEN LPRINT USING"Resultant flow (incl. return flow): "
          + HYO2$;            NETFLOW
1186     IF (TRACE% < 2) THEN 1190
1187     LPRINT USING"Stream, delay, wetland:  ###.##      " + HYO$;
        STREAM[MO%,CONO%], DELAY[MO%,CONO%], WETLAND[MO%,CONO%]
1190   NEXT CONO%
1191   IF (TRACE% < 1) THEN 1205
1195   REM * Monthly report
1200   GOSUB 2800
1205 NEXT MO%
1210 RETURN
1500 REM --
1510 REM -- Generate random flow values
1520 REM --
1530 REM * get t-value
1540 TEMP = RND - .5
1550 IF (TEMP < 0) THEN SIGN% = -1 ELSE SIGN% = 1
1560 FOR NUM% = 1 TO 35
1570   IF (ABS(TEMP) < DIST[NUM%]) THEN 1590
1580 NEXT NUM%
1590 Z = SIGN% * ((NUM% - 1) / 10)
1595 IF (TRACE% > 2) THEN LPRINT "   Z-value: ", Z
```

```
1600 REM * month's flow
1610 IF (MO% > 4) THEN 1640
1620 Q[MO%] = QBAR[MO%] + STO[MO%] * Z
1630 GOTO 1650
1640 Q[MO%] = QBAR[MO%] + B[MO%-1] * (Q[MO%-1] - QBAR[MO%-1])
            + Z * STO[MO%] * (1 - R[MO%-1]^2) ^.5
1650 REM * convert back to standard from log form
1660 X[MO%] = EXP(Q[MO%] * 2.302585)
1665 IF (TRACE% > 1) THEN LPRINT USING "   Flow level:            (mean = ###.##)
       ###.##"; EXP(QBAR[MO%]*2.302585), X[MO%]
1670 RETURN
2010 REM -- Allocate water to crops
2020 REM --
2030 SPRDIV = 0 : SURDIV = 0 : DP = 0 : RETFLOW = 0
2040 IF (MO% = 4) OR (MO% = 9) THEN RETURN   'No irrigation in May, Sept
2050 DEL% = COND% * 4    'offset for future
2055 MON% = MO% - 4   'monthly offset  (May = 1, ... , Aug = 4)
2056 REM * set south parameters to present condition only
2060 IF N% THEN CO% = COND% ELSE CO% = 0
2065 DELEFFIC = (1 - (DELEVAP[CO%] + DELSEEP[CO%]))
2070 SPREFFIC = DELEFFIC * (1 - (SPREVAP[CO%] + SPROP[CO%]))
2075 SUREFFIC = DELEFFIC * (1 - (SURRET[CO%] + SUROP[CO%]))
2080 FOR CROP% = 1 TO 3
2085   IF NOT N% THEN 2110
2090   SPRNEED = (NAC[MON%+DEL%,CROP%] * INCH[CROP%,COND%]) / DELEFFIC
2100   SURNEED = (NAC[MON%+DEL%,CROP%+3] * INCH[CROP%+3,COND%]) / DELEFFIC
2101   IF (TRACE% > 2) THEN LPRINT USING "   Sprink. & surface needs: \      \ :
"            + HYD$; CNAME$[CROP%], SPRNEED, SURNEED
2105   GOTO 2130
2110   SPRNEED = (SAC[MON%+DEL%,CROP%] * INCH[CROP%,COND%]) / DELEFFIC
2120   SURNEED = (SAC[MON%+DEL%,CROP%+3] * INCH[CROP%+3,COND%]) / DELEFFIC
2121   IF (TRACE% > 2) THEN LPRINT USING "   Sprink. & surface needs: \      \ :
"            + HYD$; CNAME$[CROP%], SPRNEED, SURNEED
2130   IF (WATERAVAIL < (SPRNEED + SURNEED)) THEN 2200
2140   IF N% THEN NYP[MON%+DEL%,CROP%] = 1! ELSE SYP[MON%+DEL%,CROP%] = 1!
2145   IF N% THEN NYP[MON%+DEL%,CROP%+3] = 1! ELSE SYP[MON%+DEL%,CROP%+3] = 1!
2150   WATERAVAIL = WATERAVAIL - SPRNEED - SURNEED
2160   REM * apply water to this crop
2170   GOSUB 2500
2175   IF (TRACE% > 2) THEN LPRINT USING "      Remaining water available:     "
              + HYD2$; WATERAVAIL
2180 NEXT CROP%
2190 RETURN
2200 REM * partial supply of water
2203 PARTIAL = WATERAVAIL / (SPRNEED + SURNEED)
2204 IF (TRACE% > 1) THEN LPRINT"      SHORTAGE: portion of need satisfied:     "
;              PARTIAL * 100; "%"
2205 IF N% THEN NYP[MON%+DEL%,CROP%] = PARTIAL
          ELSE SYP[MON%+DEL%,CROP%] = PARTIAL
2206 IF N% THEN NYP[MON%+DEL%,CROP%+3] = PARTIAL
          ELSE SYP[MON%+DEL%,CROP%+3] = PARTIAL
2210 SPRNEED = SPRNEED * PARTIAL
2220 SURNEED = WATERAVAIL - SPRNEED
2230 WATERAVAIL = 0
2240 REM * apply water to crop
2250 GOSUB 2500
2255 SHORTAGE[COND%] = 1
2260 RETURN
2500 REM -
2510 REM - apply water to crop
2520 REM -
2530 SPRDIV = SPRDIV + SPRNEED
2540 SURDIV = SURDIV + SURNEED
2550 DP = DP + DELSEEP[CO%] * (SPRNEED + SURNEED)
2560 FARMSPR = SPRNEED * (1 - DELSEEP[CO%] - DELEVAP[CO%])
2570 FARMSUR = SURNEED * (1 - DELSEEP[CO%] - DELEVAP[CO%])
2571 IF (TRACE% > 2) THEN LPRINT USING "      Farm gate levels:              "
          + HYD$; FARMSPR, FARMSUR
2575 IF NOT N% THEN 2600
```

```
2580 AUX1 = (FARMSPR * (1 - SPREVAP[CONO%]))
          - (NAC[MON%+DEL%,CROP%] * CON[MON%,CROP%])
2590 AUX2 = FARMSUR - (NAC[MON%+DEL%,CROP%] * CON[MON%,CROP%])
2595 GOTO 2620
2600 AUX1 = (FARMSPR * (1 - SPREVAP[CO%]))
        - (SAC[MON%+DEL%,CROP%] * CON[MON%,CROP%])
2610 AUX2 = FARMSUR - (SAC[MON%+DEL%,CROP%] * CON[MON%,CROP%])
2620 IF (AUX1 < 0) THEN AUX1 = 0
2630 IF (AUX2 < 0) THEN AUX2 = 0
2640 RETFLOW = RETFLOW + SURRET[CO%] * AUX2
2650 OP = OP + AUX1 + (AUX2 * (1 - SURRET[CO%]))
2660 RETURN
2800 REM -
2805 REM - Output monthly report
2807 REM -
2809 LPRINT
2810 LPRINT USING "Month  #                 Base Flow: ####,.# ac. ft.";MO%,X[MO%]

*10
2820 IF SHORTAGE[0] THEN LPRINT TAB(38); "SHORTAGE";
2830 IF SHORTAGE[1] THEN LPRINT TAB(58); "SHORTAGE" ELSE LPRINT
2840 FORM$ = ":        #####,.# ac. ft.    #####,.# ac. ft."
2850 LPRINT USING SPACE$(10)+"Stream flow    " + FORM$;
          STREAM[MO%,0]*10, STREAM[MO%,1]*10
2860 LPRINT USING SPACE$(10)+"Delayed flow   " + FORM$;
          DELAY[MO%,0]*10, DELAY[MO%,1]*10
2870 LPRINT USING SPACE$(10)+"Wetlands flow  " + FORM$;
          WETLAND[MO%,0]*10, WETLAND[MO%,1]*10
2880 LPRINT
2890 RETURN
3000 REM []
3010 REM []  Physical impacts
3020 REM []
3030 REM * trout impacts
3035 GOSUB 3100
3040 REM * pheasant impacts
3050 GOSUB 3800
3060 REM * waterfowl impacts
3070 GOSUB 4000
3090 RETURN
3100 REM -
3105 REM - trout impacts
3107 REM -
3108 IF (TRACE% > 1) THEN LPRINT "Trout impacts"
3110 FOR CONO% = 0 TO 1
3120 REM * x1 - late summer flow; apr-sep = 72.2% of water year
3130 CPF = (STREAM[8,CONO%] + STREAM[9,CONO%]/2)   46
3150 FL = 0
3160 FOR I% = 4 TO 9
3170   FL = FL + (X[I%] * (STMEVAP+STMSEEP))
3180 NEXT I%
3190 ADF =FFL / (.72 * 30)
3210 IF ((CPF/ADF) <= .1) THEN X1% = 0 : GOTO 3260
3220 IF ((CPF/ADF) <= .15) THEN X1% = 1 : GOTO 3260
3230 IF ((CPF/ADF) <= .25) THEN X1% = 2 :: GOTO 3260
3240 IF ((CPF/ADF) <= .55) THEN X1% = 3 : GOTO 3260
3250 X1% = 4
3260 IF (TRACE% > 2) THEN LPRINT "   Late summer flow rating (X1):", X1%
3265 REM * x2 - annual stream variation
3270 JUNDF = STREAM[6,CONO%]/30 : JULDF = STREAM[7,CONO%]/31 : AUGDF = STREAM[8,
CONO%]/31
3290 IF (JUNDF<.01*ADF)OR(JULDF<.01*ADF)OR(AUGDF<.01*ADF) THEN X2%=0 : GOTO 3340

3300 IF (JUNDF<.1*ADF)OR(JULDF<.1*ADF)OR(AUGDF<.1*ADF) THEN X2%=1 : GOTO 3340
3310 IF (JUNDF<.5*ADF)OR(JULDF<.5*ADF)OR(AUGDF<.5*ADF) THEN X2%=2 : GOTO 3340
3315 IF (TRACE% > 2) THEN PRINT "   Nitrate nitogen (X4):", X4%
3320 IF (JUNDF<.9*ADF)OR(JULDF<.9*ADF)OR(AUGDF<.9*ADF) THEN X2%=3 : GOTO 3340
3330 X2% = 4
3340 IF (TRACE% > 2) THEN LPRINT "   Annual stream variation rating (x2):", X2%
```

```
3345 REM * x3 - max summer temperature - estimated
3350 IF (X1% = 0) OR (X2% = 0) THEN X3% = 0 : GOTO 3400
3360 IF (X1% < 3) AND (X2% = 1) THEN X3% = 1 : GOTO 3400
3370 IF (X1% < 3) AND (X2% = 2) THEN X3% = 2 : GOTO 3400
3380 IF (X1% < 4) AND (X2% = 3) THEN X3% = 3 : GOTO 3400
3390 IF (X2% = 4) THEN X3% = 4 ELSE X3% = 3
3400 IF (TRACE% > 2) THEN LPRINT "   Max summer temperature rating (X3):",X3%
3405 REM * x4 - nitrate nitrogen
3410 X4% = TROUT [1]
3415 IF (TRACE% > 2) THEN LPRINT "   Nitrate nitrogen (X4):"; X4%
3420 REM * x7 - cover (%)
3430 IF (FL > (1360 * 1.5)) THEN X7% = 1 ELSE X7% = 2   '50% above ave flow
3435 IF (TRACE% > 2) THEN LPRINT "   Amount of cover (X7):", X7%
3440 REM * x8 - eroding banks (%)
3450 IF (STREAM[5,CONO%]+STREAM[6,CONO%]) > 1200 THEN X8% = 1 ELSE X8% = 2
3453 IF (STREAM[7,CONO%]+STREAM[8,CONO%]) <  50 THEN X8% = 3
3455 IF (TRACE% > 2) THEN LPRINT "   Streambank erosion (X8):", X8%
3460 REM * x9 - substrate
3470 X9% = TROUT [2]
3475 IF (TRACE% > 2) THEN LPRINT "   Substrate (X9):", X9%
3480 REM * x10 - water velocity
3490 X10% = TROUT [3]
3495 IF (TRACE% > 2) THEN LPRINT "   Water velocity (X10):", X10%
3500 REM * x11 - stream width
3510 X11% = TROUT [4]
3515 IF (TRACE% > 2) THEN LPRINT "   Stream width (X11):", X11%
3520 REM * Food and shelter indecies
3530 F% = X3% * X4% * X9% * X10%
3540 S% = X7% * X8% * X11%
3541 IF (TRACE% > 2) THEN LPRINT "   Food index (X3*X4*X9*X10):", F%
3542 IF (TRACE% > 2) THEN LPRINT "   Shelter index (X7*X8*X11):", S%
3545 IF (TRACE% < 3) THEN 3570
3570 REM * calculate standing crop
3580 LOGX1 = LOG(X1%+1)/2.302585  :  LOGX2 = LOG(X2%+1)/2.302585
3590 LOGX3 = LOG(X3%+1)/2.302585  :  LOGF = LOG(F%+1)/2.302585
3600 LOGS = LOG(S%+1)/2.302585
3610 FACTOR = (-.903 + .807 * LOGX1 + .877 * LOGX2 + 1.233 * LOGX3
              + .631 * LOGF + .182 * LOGS) * 1.12085
3620 STNDCROP[CONO%] = EXP(FACTOR * 2.30259) - 1
3625 IF (STNDCROP[CONO%] < 0) THEN STNDCROP[CONO%] = 0
3630 IF (TRACE% > 1) THEN LPRINT "Trout standing crop: ", STNDCROP[CONO%]
3640 NEXT CONO%
3650 RETURN
3800 REM -
3805 REM - pheasant population impacts
3810 REM -
3820 REM * based on conversion of surface to sprinkler acreage
3830 AP% = 0  :  AF% = 0
3840 FOR AC% = 4 TO 6
3850   AP% = AP% + NSYS [AC%,0]
3860   AF% = AF% + NSYS [AC%,1]
3870 NEXT AC%
3880 BIRDS = PHEASANT [1] * (AP% - AF%)
3881 IF (TRACE% < 2) THEN 3890
3882 LPRINT "Pheasant impacts"
3885 LPRINT "   Present, future surface acres:",AP%,AF%
3887 LPRINT "   Birds lost/acre, total birds lost:", PHEASANT [1], BIRDS
3890 RETURN
4000 REM -
4005 REM - waterfowl impacts
4010 REM -
4015 REM * based on pairs per acre of water lost
4017 LAND [0] = 0  :  LAND [1] = 0
4020 FOR MO% = 4 TO 9
4025   FOR CONO% = 0 TO 1
4030     LAND [CONO%] = LAND [CONO%] + WETLAND [MO%,CONO%]
4035   NEXT CONO%
4040 NEXT MO%
```

```
4050 ACLOST = (LANO[0] - LANO [1]) * (FOWL[1] / 120)
4060 WFOWL = ACLOST * FOWL [2]
4065 IF (TRACE% < 2) THEN 4070
4066 LPRINT "Waterfowl impacts"
4067 LPRINT "   Reduced water, acres lost:", LANO[0] - LANO[1], ACLOST
4068 LPRINT "   Birds lost/acre, total birds lost:", FOWL[2], WFOWL
4070 RETURN
5000 REM []
5010 REM []  Economic impacts
5020 REM []
5030 REM * on-site benefits
5040 GOSUB 5200
5050 REM * trout fishing damages
5060 GOSUB 5500
5070 REM * pheasant damages
5080 GOSUB 5700
5090 REM * waterfowl damages
5100 GOSUB 5800
5130 RETURN
5200 REM -
5205 REM - net on-site benefits
5210 REM -
5220 IF (TRACE% > 1) THEN LPRINT "Net On-site benefits"
5240 FOR CONO% = 0 TO 1
5245   IF (TRACE% > 1) THEN IF (CONO% = 0) THEN LPRINT "Present condition - nort
h yields and costs" ELSE LPRINT "Future condition - north yields and costs"
5250   OEL% = CONO% * 4    'note: South group remains the same
5260   FOR CROP% = 1 TO 6
5270     NTOTYLD [CROP%,CONO%] = YIELD [0,CROP%] * NSYS [CROP%,CONO%]
5275     STOTYLD [CROP%,CONO%] = YIELD [0,CROP%] * SSYS [CROP%,CONO%]
5280     NCOST [CROP%,CONO%] = COST [0,CROP%] * NSYS [CROP%,CONO%]
5282     IF (TRACE% < 3) THEN 5290
5285 LPRINT "Initial yield:";YIELD(0,CROP%);"*";NSYS[CROP%,CONO%];"=";NTOTYLD[CR
OP%,CONO%];TAB(40);"Initial cost:";COST[0,CROP%];"*";NSYS [CROP%,CONO%];"=";NCOS
T[COST%,CONO%]
5290     SCOST [CROP%,CONO%] = COST [0,CROP%] * SSYS [CROP%,CONO%]
5300     YP1 = 1  :  YP2 = 1
5310     FOR MO% = 1 TO 4
5315       REM * set yield prod. fcn. parameters by crop
5317       IF (CROP% <> 2) AND (CROP% <> 5) THEN YP1 = 1 : YP2 = 1   'barley
5320       YP1 = YP1 * NYP[MO%+OEL%,CROP%]
5330       YP2 = YP2 * SYP[MO%+OEL%,CROP%]
5340       NTOTYLD[CROP%,CONO%] = NTOTYLD[CROP%,CONO%] + YIELD[MO%+OEL%,CROP%]
                                * NAC[MO%+OEL%,CROP%]*YP1
5350       STOTYLD[CROP%,CONO%] = STOTYLD[CROP%,CONO%] + YIELD[MO%,CROP%]
                                * SAC[MO%+OEL%,CROP%]*YP2
5360       NCOST[CROP%,CONO%] = NCOST[CROP%,CONO%] + COST[MO%+OEL%,CROP%]
                              * NAC[MO%+OEL%,CROP%]
5365       SCOST[CROP%,CONO%] = SCOST[CROP%,CONO%] + COST[MO%,CROP%]
                              * SAC[MO%+OEL%,CROP%]
5366       IF (TRACE% < 3) THEN 5370
5368 LPRINT "Plus:";YIELD[MO%+OEL%,CROP%];"*";NAC[MO%+OEL%,CROP%];"*";YP1;"=";NT
OTYLD[CROP%,CONO%];TAB(40);"Plus:";COST[MO%+OEL%,CROP%];"*";NAC[MO%+OEL%,CROP%];
"=";NCOST[CROP%,CONO%]
5370     NEXT MO%
5375     NREV [CROP%,CONO%] = NTOTYLD [CROP%,CONO%] * PRICE [CROP%]
5377     SREV [CROP%,CONO%] = STOTYLD [CROP%,CONO%] * PRICE [CROP%]
5380     NNETREV[CROP%,CONO%] = NREV [CROP%,CONO%] - NCOST [CROP%,CONO%]
5390     SNETREV[CROP%,CONO%] = SREV [CROP%,CONO%] - SCOST [CROP%,CONO%]
5400     IF (TRACE% < 2) THEN 5430
5410 LPRINT"    Net revenue, North ";CNAME$[CROP%];":";NNETREV[CROP%,CONO%]
5420 LPRINT"    Net revenue, South ";CNAME$[CROP%];":";SNETREV[CROP%,CONO%]
5430   NEXT CROP%
5440 NEXT CONO%
5450 RETURN
5500 REM -
5505 REM - trout fishing damages
5510 REM -
5520 TROUTDAM = (STNOCROP[0] - STNOCROP[1]) * 10!   'fixed value per hectare
```

```
5700 REM -
5705 REM - pheasant damages
5710 REM -
5720 PHEASOAM = PHEASANT [2] * BIROS
5730 RETURN
5800 REM -
5805 REM - waterfowl damagas
5810 REM -
5820 FOWLOAM = WFOWL * 20!    'fixed value, $10 / bird
5830 RETURN
6000 REM []
6010 REM []  Net impact assassment
6020 REM []
6030 REM * gathar sum totals
6040 GOSUB 6100
6050 REM * send output
6060 GOSUB 6300
6065 REM * accumulata results
6067 GOSUB 6800
6070 RETURN
6100 REM -
6105 REM - sum totals
6107 REM -
6108 X[0] = 0
6110 FOR MO% = 4 TO 9
6120   X[0] = X[0] + X[MO%]
6130   FOR CONO% = 0 TO 1
6140     STREAM[0,CONO%] = STREAM[0,CONO%] + STREAM[MO%,CONO%]
6150     WETLANO[0,CONO%] = WETLANO[0,CONO%] + WETLANO[MO%,CONO%]
6153   NEXT CONO%
6155 NEXT MO%
6160 FOR CONO% = 0 TO 1
6170   FOR CROP% = 1 TO 6
6180     NTOTYLO[0,CONO%] = NTOTYLO[0,CONO%] + NTOTYLO[CROP%,CONO%]
6190     STOTYLO[0,CONO%] = STOTYLO[0,CONO%] + STOTYLO[CROP%,CONO%]
6200     NREV[0,CONO%] = NREV[0,CONO%] + NREV[CROP%,CONO%]
6210     SREV[0,CONO%] = SREV[0,CONO%] + SREV[CROP%,CONO%]
6215     NCOST[0,CONO%] = NCOST[0,CONO%] + NCOST[CROP%,CONO%]
6218     SCOST[0,CONO%] = SCOST[0,CONO%] + SCOST[CROP%,CONO%]
6220     NNETREV[0,CONO%] = NNETREV[0,CONO%] + NNETREV[CROP%,CONO%]
6230     SNETREV[0,CONO%] = SNETREV[0,CONO%] + SNETREV[CROP%,CONO%]
6240   NEXT CROP%
6250 NEXT CONO%
6255 OFFSITE = TROUTOAM + PHEASOAM + FOWLOAM
6260 NSB# [0] = NNETREV[0,0] + SNETREV[0.0]
6270 NSB# [1] = NNETREV[0,1] + SNETREV[0,1] - OFFSITE - PUBCOST# - PRIVCOST#
6280 RETURN
6300 REM -
6305 REM - annual raport
6307 REM -
6309 LPRINT
6310 LPRINT "*** ANNUAL SUMMARY  :  YEAR "; YEAR%
6320 LPRINT : LPRINT "Hydrologic summary"
6330 LPRINT USING "     April - September basa flows:            ######,.# ac. f
t.";X[0] * 10
6340 LPRINT USING "     Net saasonal stream flow  : ######,.# ac. ft.    ######,
.# ac. ft."; STREAM[0,0] * 10, STREAM[0,1] * 10
6350 LPRINT USING "     Watland seasonal flow     : ######,.# ac. ft.    ######,
.# ac. ft.": WETLANO[0,0] * 10, WETLANO[0,1] * 10
6355 IF (TRACE% = 0) THEN 6670    ' bypass usual summary output
6360 LPRINT : LPRINT "On-Sita Banafits - North"
6370 LPRINT TAB(18);"Yiald  Price     Revenua      Total cost     Nat Revanua
6380 FOR CONO% = 0 TO 1
6390   IF CONO% THEN LPRINT "  Futura" ELSE LPRINT "  Prasant"
6400   FOR CROP% = 1 TO 6
6410     LPRINT USING "     \      \  #####,    ##.##    #######,.##    #######,.
##    #######,.##"; CNAME$[CROP%], NTOTYLO(CROP%,CONO%), PRICE(CROP%), NREV[CROP
%,CONO%],NCOST(CROP%,CONO%), NNETREV(CROP%,CONO%)
6420   NEXT CROP%
```

```
6430   LPRINT
6440   LPRINT USING "     Totel        --       --      ########,.##    ########,.##
   ########,.##"; NREV[0,CONO%],NCOST(0,CONO%), NNETREV(0,CONO%)
6450   LPRINT
6460 NEXT CONO%
6470 LPRINT : LPRINT "On-Site Benefits - South"
6480 FOR CONO% = 0 TO 1
6490   IF CONO% THEN LPRINT "  Future" ELSE LPRINT "  Present"
6500   FOR CROP% = 1 TO 6
6510     LPRINT USING "     \      \   #####,    ##.##    #######,.##    #######,.
##    #######,.##"; CNAME$[CROP%], STOTYLD(CROP%,CONO%), PRICE(CROP%), SREV[CROP
%,CONO%],SCOST(CROP%,CONO%), SNETREV(CROP%,CONO%)
6520   NEXT CROP%
6530   LPRINT
6540   LPRINT USING "     Totel        --       --      ########,.##    ########,.##
   ########,.##"; SREV[0,CONO%],SCOST[0,CONO%], SNETREV[0,CONO%]
6550   LPRINT
6560 NEXT CONO%
6570 LPRINT : LPRINT "Offsite Impects"
6590 DOLLAR$ = "                                        #####;.##"
6610 LPRINT USING "     Trout standing crop - present          ### kg/ha";
             STNDCROP[0]
6615 LPRINT USING "                             - future           ### kg/ha";
             STNDCROP[1]
6618 LPRINT USING "                             - change           ### kg/ha":
             STNDCROP[0] - STNDCROP[1]
6620 LPRINT USING "     Recreational fishing losses" + DOLLAR$; TROUTDAM
6630 LPRINT USING "     Pheasant populetion losses           #### birds"; BIRDS
6640 LPRINT USING "     Restoration cost              " + DOLLAR$; PHEASDAM
6650 LPRINT USING "     Weterfowl losses                     #### pairs"; WFOWL
6660 LPRINT USING "     Demages                       " + DOLLAR$: FOWLDAM
6665 LPRINT : LPRINT USING "     Total demeges              " + DOLLAR$; OFFSITE

6670 LPRINT : LPRINT "ANNUAL TOTALS"
6680 SUM$ = " ########,.##            ########,.##"
6685 LPRINT TAB(40);" Present              Future"
6690 LPRINT USING "     Onsite benefits - North         " + SUM$;
           NNETREV [0,0], NNETREV [0,1]
6693 LPRINT USING "     Project cost - private shere    " + SUM$; 0,-PRIVCOST#
6695 LPRINT USING "     NET PRIVATE BENEFITS - NORTH    " + SUM$;
           NNETREV [0,0], NNETREV [0,1] - PRIVCOST#
6697 LPRINT
6700 LPRINT USING "     NET PRIVATE BENEFITS - SOUTH    " + SUM$:
           SNETREV [0,0], SNETREV [0,1]
6705 LPRINT
6710 LPRINT USING "     Offsite damages                 " + SUM$: 0,-OFFSITE
6720 LPRINT USING "     Project cost - public share     " + SUM$; 0,-PUBCOST#
6730 LPRINT USING "     NET SOCIAL BENEFITS             " + SUM$; NSB#[0], NSB#[1]

6740 LPRINT
6750 RETURN
6800 REM -
6805 REM - eccumulate results
6810 REM -
6820 REM * onsite net benefits (north pres, north futr, south)
6830 ONSITE [YEAR%,0] = ONSITE [YEAR%,0] + NNETREV [0,0]
6840 ONSITE [YEAR%,1] = ONSITE [YEAR%,1] + NNETREV [0,1]
6850 ONSITE [YEAR%,2] = ONSITE [YEAR%,2] + SNETREV [0,0]
6860 REM * offsite dameges (total, fishing, pheesent, waterfowl)
6870 OFFSITE [YEAR%,0] = OFFSITE [YEAR%,0] + OFFSITE
6880 OFFSITE [YEAR%,1] = OFFSITE [YEAR%,1] + TROUTDAM
6890 OFFSITE [YEAR%,2] = OFFSITE [YEAR%,2] + PHEASDAM
6900 OFFSITE [YEAR%,3] = OFFSITE [YEAR%,3] + FOWLDAM
6910 REM * net social benefits (present, future)
6920 SOCIAL# [YEAR%,0] = SOCIAL# [YEAR%,0] + NSB# [0]
6930 SOCIAL# [YEAR%,1] = SOCIAL# [YEAR%,1] + NSB# [1]
6940 RETURN
```

```
7000 REM []
7010 REM []  Statistics
7020 REM []
7030 REM * calculate statistics
7040 GOSUB 7200
7050 REM * output results
7060 GOSUB 7700
7070 RETURN
7200 REM -
7210 REM - calculate statistics
7220 REM -
7230 FOR I% = 1 TO YEARS%
7240   TOTAL[0] = TOTAL[0] + ONSITE[I%,0]
7250   TOTAL[1] = TOTAL[1] + ONSITE[I%,1]
7260   TOTAL[2] = TOTAL[2] + ONSITE[I%,2]
7270   TOTAL[3] = TOTAL[3] + OFFSITE[I%,0]
7280   TOTAL[4] = TOTAL[4] + OFFSITE[I%,1]
7290   TOTAL[5] = TOTAL[5] + OFFSITE[I%,2]
7300   TOTAL[6] = TOTAL[6] + OFFSITE[I%,3]
7310   TOTAL[7] = TOTAL[7] + SOCIAL$[I%,0]
7320   TOTAL[8] = TOTAL[8] + SOCIAL$[I%,1]
7330 NEXT I%
7340 FOR J% = 0 TO 8
7350   TBAR [J%] = TOTAL [J%] / YEARS%
7360 NEXT J%
7370 FOR I% = 1 TO YEARS%
7380   S[0] = S[0] + (TBAR[0] - ONSITE[I%,0]) ^2
7390   S[1] = S[1] + (TBAR[1] - ONSITE[I%,1]) ^2
7400   S[2] = S[2] + (TBAR[2] - ONSITE[I%,2]) ^2
7410   S[3] = S[3] + (TBAR[3] - OFFSITE[I%,0]) ^2
7420   S[4] = S[4] + (TBAR[4] - OFFSITE[I%,1]) ^2
7430   S[5] = S[5] + (TBAR[5] - OFFSITE[I%,2]) ^2
7440   S[6] = S[6] + (TBAR[6] - OFFSITE[I%,3]) ^2
7450   S[7] = S[7] + (TBAR[7] - SOCIAL$[I%,0]) ^2
7460   S[8] = S[8] + (TBAR[8] - SOCIAL$[I%,1]) ^2
7470 NEXT I%
7480 FOR J% = 0 TO 8
7490   TVAR [J%] = S [J%] / (YEARS% - 1)
7500   TSTD [J%] = (TVAR [J%]) ^.5
7510 NEXT J%
7513 FOR J% = 0 TO 8 : LO[J%] = 999999! : NEXT J%   'set upper limit
7520 FOR I% = 1 TO YEARS%
7530   IF (ONSITE[I%,0] > HI[0]) THEN HI[0] = ONSITE[I%,0]
7535   IF (ONSITE[I%,0] < LO[0]) THEN LO[0] = ONSITE[I%,0]
7540   IF (ONSITE[I%,1] > HI[1]) THEN HI[1] = ONSITE[I%,1]
7545   IF (ONSITE[I%,1] < LO[1]) THEN LO[1] = ONSITE[I%,1]
7550   IF (ONSITE[I%,2] > HI[2]) THEN HI[2] = ONSITE[I%,2]
7555   IF (ONSITE[I%,2] < LO[2]) THEN LO[2] = ONSITE[I%,2]
7560   IF (OFFSITE[I%,0] > HI[3]) THEN HI[3] = OFFSITE[I%,0]
7565   IF (OFFSITE[I%,0] < LO[3]) THEN LO[3] = OFFSITE[I%,0]
7570   IF (OFFSITE[I%,1] > HI[4]) THEN HI[4] = OFFSITE[I%,1]
7575   IF (OFFSITE[I%,1] < LO[4]) THEN LO[4] = OFFSITE[I%,1]
7580   IF (OFFSITE[I%,2] > HI[5]) THEN HI[5] = OFFSITE[I%,2]
7585   IF (OFFSITE[I%,2] < LO[5]) THEN LO[5] = OFFSITE[I%,2]
7590   IF (OFFSITE[I%,3] > HI[6]) THEN HI[6] = OFFSITE[I%,3]
7595   IF (OFFSITE[I%,3] < LO[6]) THEN LO[6] = OFFSITE[I%,3]
7600   IF (SOCIAL$[I%,0] > HI[7]) THEN HI[7] = SOCIAL$[I%,0]
7605   IF (SOCIAL$[I%,0] < LO[7]) THEN LO[7] = SOCIAL$[I%,0]
7610   IF (SOCIAL$[I%,1] > HI[8]) THEN HI[8] = SOCIAL$[I%,1]
7615   IF (SOCIAL$[I%,1] < LO[8]) THEN LO[8] = SOCIAL$[I%,1]
7620 NEXT I%
7630 RETURN
7700 REM -
7710 REM - output results
7720 REM -
7730 LPRINT : LPRINT
7740 LPRINT "***  CUMULATIVE RESULTS  :  "; YEARS%; " years  ***" : LPRINT
7750 LPRINT TAB(25);" Mean        Standard Dev.     High            Low"
7760 FORM$ = "  $$$$$$,.$$     $$$$$$,.$$     $$$$$$,.$$    $$$$$$$,.$$"
```

```
7770 LPRINT "Onsite benefits
7780 LPRINT USING " - North, present    " + FORM$; TBAR[0], TSTO[0], HI[0], LO[0]

7790 LPRINT USING " - North, future     " + FORM$; TBAR[1], TSTO[1], HI[1], LO[1]

7800 LPRINT USING " - South             " + FORM$; TBAR[2], TSTO[2], HI[2], LO[2]

7805 LPRINT : LPRINT "Offsite damages"
7810 LPRINT USING " - Total             " + FORM$; TBAR[3], TSTO[3], HI[3], LO[3]

7820 LPRINT USING " - Rec. fishing      " + FORM$; TBAR[4], TSTO[4], HI[4], LO[4]

7830 LPRINT USING " - Pheasant          " + FORM$; TBAR[5], TSTO[5], HI[5], LO[5]

7840 LPRINT USING " - Waterfowl         " + FORM$; TBAR[6], TSTO[6], HI[6], LO[6]

7845 LPRINT : LPRINT "Project costs"
7850 LPRINT USING " - Private           " + FORM$; PRIVCOST#, 0, PRIVCOST#,
      PRIVCOST#
7860 LPRINT USING " - Public            " + FORM$; PUBCOST#, 0, PUBCOST#,
      PUBCOST#
7875 LPRINT : LPRINT "Net benefits"
7880 LPRINT USING " - North, present    " + FORM$; TBAR[0], TSTO[0], HI[0], LO[0]

7890 LPRINT USING " - North, future     " + FORM$; TBAR[1]-PRIVCOST#,
      TSTO[1], HI[1]-PRIVCOST#, LO[1]-PRIVCOST#
7900 LPRINT USING " - South             " + FORM$; TBAR[2], TSTO[2], HI[2], LO[2]

7910 LPRINT USING " - Social, present   " + FORM$; TBAR[7], TSTO[7], HI[7], LO[7]

7920 LPRINT USING " - Social, future    " + FORM$; TBAR[8], TSTO[8], HI[8], LO[8]

7930 RETURN
8000 REM []
8010 REM []  Initializations
8020 REM []
8030 REM * matrix definitions
8040 DIM Q[10], QBAR[10], VAR[10], STO[10], B[10], R[10], FLOW[10], DIST[35]
8050 DIM X[10], NAC[8,6], SAC[8,6], INCH[6,1], CON[4,3], COST[8,6], PRICE[6]
8060 DIM YIELD[8,6], TROUT[5], NYP[8,6], SYP[8,6], NNETREV[6,1], SNETREV[6,1]
8065 DIM NTOTYLD[6,1], STOTYLD[6,1], NCOST[6,1], SCOST[6,1],NSYS[6,1],SSYS[6,1]
8066 DIM ONSITE[100,2], OFFSITE[100,3], SOCIAL#[100,1]
8067 DIM TOTAL[8], TBAR[8], S[8], TVAR[8], TSTD[8]
8070 REM * flow generator statistical data
8080 FOR MO% = 4 TO 9
8090   READ QBAR[MO%], VAR[MO%], STO[MO%], B[MO%], R[MO%]
8100 NEXT MO%
8110 REM * data
8120 DATA 2.092, 0.0254, 0.1593, 0.8472, 0.5855
8130 DATA 2.503, 0.0532, 0.2306, 0.8412, 0.7370
8140 DATA 2.565, 0.0692, 0.2631, 0.7138, 0.8580
8150 DATA 2.383, 0.0479, 0.2189, 0.7211, 0.9781
8160 DATA 2.239, 0.0260, 0.1614, 0.7662, 0.9675
8170 DATA 2.134, 0.0163, 0.1278, 0, 0
8180 REM * on-farm crop data
8182 FOR CROP% = 1 TO 6
8184   READ CNAME$ [CROP%]
8185 NEXT CROP%
8190 FOR CROP% = 1 TO 6    '(1-3 sprinkler, 4-6 surface)
8195   FOR COND% = 0 TO 1
8196     DEL% = COND% * 4
8197     READ NSYS [CROP%,COND%]
8200     FOR MO% = 1 TO 4    '(1-4 present,   5-8 future)
8210       READ NAC [MO%+DEL%, CROP%]    '# of acres - north
8220     NEXT MO%
8225   NEXT COND%
8230 NEXT CROP%
```

```
8240 FOR CROP% = 1 TO 6   '(1-3 sprinkler, 4-6 surface)
8245   FOR CONO% = 0 TO 1
8246     DEL% = CONO% * 4
8247     READ SSYS [CROP%,CONO%]
8250     FOR MO% = 1 TO 4   '(1-4 present,   5-8 future)
8260       READ SAC [MO%+DEL%, CROP%]   '# of acres - south
8270     NEXT MO%
8275   NEXT CONO%
8280 NEXT CROP%
8290 FOR CONO% = 0 TO 1
8300   FOR CROP% = 1 TO 6   '(1-3 sprinkler, 4-6 surface)
8310     READ INCH [CROP%, CONO%]   '# inches applied
8320     INCH [CROP%,CONO%] = INCH [CROP%,CONO%] / 120  'convert to 10's of fee
8330   NEXT CROP%
8340 NEXT CONO%
8350 FOR CROP% = 1 TO 3
8360   FOR MO% = 1 TO 4
8370     READ CON [MO%, CROP%]   '# inches consumptive use by crop
8380     CON [MO%,CROP%] = CON [MO%,CROP%] / 120  'convert to 10's of feet
8390   NEXT MO%
8400 NEXT CROP%
8405 READ CITY   'Paris municipal water right
8410 REM * data
8415 DATA "alfalfa", "barley ", "pasture", "alfalfa", "barley ", "pasture"
8420 REM   north acres
8430 DATA 585,0,585,240,0,   1616,1616,1584,1023,846
8431 DATA 172,0,172,0,0,     808,0,808,642,0
8440 DATA 388,0,388,0,0,     0,0,0,0,0,       603,0,603,216,0,   0,0,0,0,0
8450 DATA 178,0,178,0,0,     0,0,0,0,0,       498,0,498,0,0,     0,0,0,0,0
8460 REM   south acres
8470 DATA 235,0,235,118,0,   235,0,235,118,0,    69,0,69,0,0,   69,0,69,0,0
8480 DATA 143,0,143,0,0,     143,0,143,0,0,    235,0,235,84,0,   235,0,235,84,0
8490 DATA 69,0,69,0,0,       69,0,69,0,0,     342,0,342,0,0,     342,0,342,0,0
8500 DATA 7.0,5.8,6.0,  12.0,10.0,10.0,  7.0,5.8,6.0,   12.0,10.0,10.0
8530 DATA 1.1,3.1,5.7,4.4,   0.8,3.2,4.8,0.3,   1.5,2.3,4.7,3.7,   14.91
8540 REM * hydrologic data
8550 FOR CONO% = 0 TO 1
8560   READ DELEVAP[CONO%], DELSEEP[CONO%], SPREVAP[CONO%], SPROP[CONO%]
8570   READ SURRET[CONO%], SUROP[CONO%]
8580 NEXT CONO%
8590 READ STMEVAP, STMSEEP, DELAYTIME
8600 REM * data
8610 DATA .20,.10,.10,.40,.40,.30,  .00,.00,.10,.25,.30,.20,  .10,.10,1
8620 REM * on-site benefit data
8630 FOR CROP% = 1 TO 6   '1-3 sprinkler, 4-6 future
8640   FOR CONO% = 0 TO 1
8650     FOR IRR% = 0 TO 4   'number of irrigations
8655       IF (IRR% = 0) AND (CONO% = 1) THEN 8670
8660       READ COST [IRR% + 4*CONO%, CROP%]
8670     NEXT IRR%
8680   NEXT CONO%
8690 NEXT CROP%
8700 FOR CROP% = 1 TO 6
8710   READ PRICE [CROP%]
8720 NEXT CROP%
8730 READ PUBCOST#, PRIVCOST#
8740 FOR CROP% = 1 TO 6
8750   FOR CONO% = 0 TO 1
8760     DEL% = CONO% * 4
8770     FOR MO% = 0 TO 4    ' includes dryland yield potential (0)
8780       IF (MO% = 0) AND (CONO% = 1) THEN 8800
8790       READ YIELD [MO%+DEL%, CROP%]       'yield potential for month
8800     NEXT MO%
8880   NEXT CONO%
8890 NEXT CROP%
```

```
8900 REM • data
8910 DATA 128.53,0.00,34.06,34.06,0.00,   34.06,34.06,34.05,18.75
8920 DATA 113.54,0.00, 3.94, 0.00,0.00,    0.00, 3.94, 3.94, 0.00
8930 DATA  60.00,0.00, 5.17, 0.00,0.00,    0.00, 5.17, 0.00, 0.00
8940 DATA  89.62,0.00,41.65,41.65,0.00,    0.00, 0.00, 0.00, 0.00
8950 DATA 100.00,0.00,14.94, 0.00,0.00,    0.00, 0.00, 0.00, 0.00
8960 DATA  70.00,0.00, 3.85, 0.00,0.00,    0.00, 0.00, 0.00, 0.00
8990 DATA 71.15,2.94,50.00,  71.15,2.94,50.00,  42973., 72974.
9000 REM ... data for yields
9010 DATA 1.5,0,2.0,1.0,0,   2.0,1.0,1.0,0.5,   25,0,40,0,0,   0,40,20,0
9020 DATA 1.5,0,0.25,0,0,    0,0.25,0,0,   1.5,0,1.0,0.5,0,   0,1.0,0.5,0
9030 DATA 25,0,25,0,0,     0,25,0,0,     1.5,0,0.25,0,0,   0,0.25,0,0
9040 REM • distribution percentages (z-values)
9050 FOR I% = 1 TO 35
9060   READ DIST [I%]
9070 NEXT I%
9080 REM • data
9090 DATA .0199,.0596,.0987,.1368,.1736,.2088,.2422,.2734,.3023,.3289
9100 DATA .3531,.3749,.3944,.4115,.4265,.4394,.4505,.4599,.4678,.4744
9110 DATA .4798,.4842,.4878,.4906,.4929,.4946,.4960,.4970,.4978,.4984
9120 DATA .4989,.4992,.4994,.4996,.4997
9130 REM • trout habitat indecias
9140 FOR T% = 1 TO 4
9150   READ TROUT [T%]
9160 NEXT T%
9170 REM • data: nitrogen, substrate, velocity, width
9180 DATA 2, 2, 3, 3
9190 REM • pheasant and waterfowl data
9200 READ PHEASANT[1], PHEASANT[2], FOWL[1], FOWL[2]
9210 REM • birds/acre, enhance cost, inches/pond, birds/acre
9220 DATA 1.3, 7.0,     30, 1.5
9230 RETURN
```

APPENDIX C

	North Group						South Group		
	- Present -			- Future -					
run #	Mean	St. Dev.	Low	Mean	St. Dev.	Low	Mean	St. Dev.	Low
1	97,458	36,664	(25,540)	224,428	94,962	(122,180)	48,533	6,635	10,198
2	89,137	40,360	2,602	210,901	90,351	(2,995)	49,002	2,901	34,802
3	83,208	41,715	(24,630)	209,749	99,941	(153,267)	48,146	6,452	14,580
4	85,338	39,612	(15,000)	217,190	87,120	(1,473)	48,708	4,899	18,922
5	89,962	40,533	(15,482)	202,323	92,253	23,119	48,746	4,695	19,057
6	85,084	41,458	(6,732)	214,142	87,239	(44,873)	48,595	4,230	28,930
7	90,032	41,786	(43,515)	217,662	99,279	(78,416)	47,901	8,887	(326)
8	83,654	42,517	(12,701)	207,551	94,494	(85,532)	48,598	4,272	24,830
9	89,706	37,145	(488)	213,465	95,032	(102,279)	49,190	3,001	33,111
10	81,448	43,499	(7,568)	209,925	92,886	(76,331)	48,069	5,091	28,771
11	89,334	37,031	5,343	229,041	74,283	19,910	49,252	2,508	37,786
12	80,024	43,551	(11,440)	191,568	98,846	(45,149)	48,076	5,349	26,296
13	89,324	41,401	(10,712)	215,586	95,070	(46,944)	48,323	5,235	26,947
14	84,478	43,107	(21,937)	197,312	109,998	(108,139)	48,014	6,420	15,734
15	89,334	37,031	5,342	229,041	74,283	19,910	49,252	2,508	37,786
16	89,255	37,951	(11,274)	209,668	98,750	(123,719)	48,940	3,793	31,383
17	89,187	41,102	(17,324)	220,864	85,876	(32,561)	48,346	5,839	19,558
18	89,157	40,676	(26,253)	215,414	98,230	(90,698)	48,278	6,477	12,992
19	82,973	41,333	(44,694)	198,892	97,174	(39,521)	48,042	8,023	794
20	83,076	44,536	(17,384)	208,671	105,618	(108,958)	47,853	6,054	22,503
21	87,587	41,461	(25,059)	210,757	98,130	(107,124)	48,023	7,511	11,039
22	76,267	40,543	(19,064)	191,053	99,122	(52,559)	48,400	4,794	24,225
23	83,095	41,168	(13,789)	210,428	96,526	(118,050)	48,282	5,772	22,179
24	84,757	44,654	(35,548)	195,679	112,224	(137,919)	47,261	9,728	6,300
25	82,813	46,364	(45,620)	202,250	103,769	(125,029)	47,010	10,334	(2,638)
min	76,267	36,664	(45,620)	191,053	74,283	(153,267)	47,010	2,508	(2,638)
max	97,458	46,364	5,343	229,041	112,224	23,119	49,252	10,334	37,786

	Net Social Benefits						Offsite Damages			
	- Present -			- Future -						
run #	Mean	St. Dev.	Low	Mean	St. Dev.	Low	Mean	St. Dev.	High	Low
1	145,991	42,025	(15,342)	216,966	100,049	(166,983)	13,022	528	14,316	12,028
2	138,139	42,706	37,404	204,040	92,570	(23,673)	12,891	505	14,224	12,313
3	131,354	46,353	(10,049)	201,803	104,733	(193,590)	13,119	612	14,345	11,931
4	134,046	42,944	3,922	209,797	90,228	(12,497)	13,128	598	14,357	12,313
5	138,708	43,861	3,575	195,000	94,792	(14,146)	13,096	483	13,802	12,313
6	133,680	44,699	22,198	206,735	90,773	(64,913)	13,030	509	14,309	12,313
7	137,933	48,525	(43,840)	209,711	105,837	(133,949)	12,878	586	14,229	12,235
8	132,252	45,659	12,129	200,041	98,069	(116,661)	13,135	502	14,162	12,313
9	138,896	39,468	34,160	206,565	97,149	(114,186)	13,117	521	13,968	12,103
10	129,517	47,621	21,203	202,010	97,237	(103,603)	13,012	563	14,349	12,313
11	138,586	39,076	43,129	222,207	76,294	10,451	13,112	571	14,313	12,313
12	128,101	47,581	18,620	183,628	102,593	(71,177)	13,043	562	14,138	12,227
13	137,647	45,655	21,171	207,866	99,010	(71,148)	13,072	575	14,338	12,313
14	132,492	48,063	(6,204)	189,308	114,964	(136,764)	13,046	559	14,274	12,238
15	138,586	39,076	43,129	222,208	76,294	10,451	13,112	571	14,313	12,313
16	138,195	40,953	20,189	202,556	101,701	(142,769)	13,099	537	14,006	12,056
17	137,533	45,519	2,234	213,261	90,365	(57,309)	12,978	579	14,357	12,313
18	137,435	45,635	(13,261)	207,776	102,794	(133,683)	12,943	504	13,881	12,275
19	131,016	47,190	(43,900)	190,987	101,902	(69,971)	12,974	523	14,093	12,313
20	130,929	49,357	5,120	200,510	110,527	(140,086)	13,041	530	14,348	12,116
21	135,609	47,213	(13,902)	202,755	103,495	(151,228)	13,051	555	14,211	12,170
22	124,667	44,043	5,161	183,361	102,571	(81,508)	13,119	413	13,795	12,261
23	131,377	45,305	8,390	202,631	100,652	(150,863)	13,106	621	14,345	12,019
24	132,019	52,293	(26,702)	186,991	119,517	(186,581)	12,976	519	13,874	11,989
25	129,084	54,424	(48,258)	193,207	111,827	(182,767)	13,080	615	14,346	12,127
min	124,667	39,076	(48,258)	183,361	76,294	(193,590)	12,878	413	13,795	11,931
max	145,991	54,424	43,129	222,208	119,517	10,451	13,135	621	14,357	12,313