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Estimation of Cost and Benefit of Instream Flow

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ESTIMATION OF COSTS AND BENEFITS
OF INSTREAM FLOW

by

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Parvaneh Amirfathi

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ABSTRACT

Estimation of Cost and Benefit

of Instream Flow

by

Parvaneh Amirfathi, Doctor of Philosophy

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Major Professor: Rangesan Narayanan
Department: Economics

Water flowing in streams has value for various types of recreationists and is essential for fish and wildlife. Since water demands for offstream uses in the arid west have been steadily increasing, increasing instream flows to enhance the recreational experience might be in conflict with established withdrawals for uses such as agriculture, industries, and households.

It is the intent of this study to contribute to an economic assessment of the tradeoff between maintaining instream flow for river recreation use and offstream uses; that is, to develop and apply a method to measure costs and benefits of water used for recreation on a river.

Since market prices are not observable for instream flows, the estimation economic value of instream flow would present well known difficulties. The household production function theory was used to build the theoretical model to measure economic value of instream flow.

It was assumed that recreationists were applying the same technology to produce a recreational commodity and other commodities. In order to estimate economic value of water used in the river, it was assumed that individuals were combining goods, services, and time as input to produce recreational services. Based on this procedure, empirical estimates of multisite demands were derived. A representative sample of 500 recreationists at three river sites were interviewed during the summer of 1982, to estimate empirical demand equation for recreational activities. Moreover, the corresponding compensated variation of consumer, from alteration of instream flow, were quantified.

To compute the cost of maintaining instream flow, a general stochastic mathematical programming model was developed. Using a mathematical programming model, three specific strategies for maintaining instream flows under two conditions of water rights transferability were compared. The first strategy was a deterministic model of expected instream flow. The second is a minimum-flow strategy and the third is a critical flow strategy. All three strategies are examined to decide the least cost in terms of expected agricultural output foregone to maintain the desired level of expected instream flow.

Policy implication are discussed with emphasis on application of the information to water management decisions.

(148 pages)

INTRODUCTION

There has been a greatly increased interest in the measurement of the value of outdoor recreation, especially stream related recreation in recent years. One of the major uses of the nation's natural resources is outdoor recreation. Clawson and Knetsch (1966, p. 43) in the book "Economics of Outdoor Recreation" point out that

> ... visits to the national parks increased all through World War I; the Great Depression of the 1930's did hardly more than slow down growth in visits to the national park system and to the national forests. Minor variations in rates of growth occur in other years for some kinds of area, but the whole record is one of surprising uniformity in the persistence of the growth rate. The only major interruption was during World War II, when travel and other restrictions exist.

During the post-war years, the annual rate of participation in outdoor recreation in the United States has grown by an overall average of 10 percent (U.S. Department of the Interior 1971). Also all available evidences indicate that the demand for outdoor recreation will continue to increase over the next 20 years. The demand for recreation use of water resources is projected to grow 25 percent greater than other recreation activities to the year 2000 (Walsh 1980). The major factors behind the steady and rapid rise in use of outdoor recreation are: 1) increased disposable income, 2) increased leisure time, 3) increased mobility of recreationists, and 4) a general desire for a physical outdoor activity such as outdoor recreation. As Wennergren and Fullerton (1972) argued, demand for this form of recreation is expected to almost double by the year 2000 even if individual participation does not increase above present level.

The number of participants in freshwater fishing increased by an average of 3 percent from 21.7 million in 1960 to 29.4 million in 1970 (Walsh 1980). According to the U.S. Department of Commerce, Bureau of the Census (1982-1983), fishing license sales have increased from 23.3 million in 1960 to 35.2 million in 1980 and hunting license sales have increased from 18.4 million in 1960 to 27.0 million in 1980, and visits to national parks from 79.2 million in 1960 to 329.7 million in 1981. Also according to a home telephone survey, from June 1976 to June 1977, 53 percent of population, persons 12 years old and over, were fishing, 48 percent boating and 72 percent were picnicking (U.S. Department of Commerce, Bureau of the Census 1982-1983). As recreational use of outdoor resources continues to increase, it becomes more acute that recreation must be accurately considered in decision process of allocating resources to various uses.

Competition Between Instream and Offstream Flows

As the demand for offstream water uses increase, the competition for water between instream and offstream uses for available supplies intensifies through the political process. The quantity and quality of water left in streams might decrease if recreational values are not adequately incorporated in the resource allocation. Therefore, particularly where water is relatively scarce such as in the western states, this could result in a great damage to the recreational and aesthetic uses of the streams (U.S. Department of the Interior 1980). At the same time more and more people are discovering and seeking recreational opportunities offered in and along rivers. Thus, it is not safe to assume that left over water will be adequate to serve recreational demands. The amount of streamflow that is "necessary" to "maintain instream values" is referred to as the instream flow requirement in the literature (Narayanan et al. 1983).

Activities for which instream flows are valuable include outdoor recreation, hydropower, navigation, waste transport and assimilation, fish and wildlife maintenance and preservation of riverine ecosystems. The legal framework to govern the use of water in the western states is the prior appropriation doctrine (Hutchins 1971). According to prior appropriation doctrines, a water right could be granted to a person for "beneficial uses" of unused water. Priorities for use, then, are on a "first-in-time is first-in-right" basis. The doctrine's evolution, however, has not been hospitable to instream values with the exception of hydroelectricity generation (the actual required flow to drive the turbines). Appropriation doctrine made it virtually impossible to preserve instream values in most western states.

Historically, the lack of institutional provision of rights for instream uses could be the result of relatively abundant instream flows compared to the demand for water for offstream activities. However, with the cumulative effects of offstream development, continued availability of this abundant flow for instream values cannot be taken for granted. Furthermore, realizing benefits of instream flows make it a legitimate use of the resource. But there are two main obstacles in integrating instream uses within the appropriative system. The first one is the difficulties of satisfying the appropriation requirements which are: 1) a notice of intent to appropriate, 2) an actual diversion, and 3) an application to a beneficial use (Tarlock 1978). However, there is evidence that this obstacle can be overcome. Many states have statutory provisions which protect instream flow: Colorado, Montana, Oregon, and Washington (Bagley et al. 1983). Although this has achieved some desired results in protecting instream uses, it is still difficult to secure instream flows on heavily appropriated streams and it does not provide a balanced view of the resources, as it does not integrate instream with offstream uses. A typical provision was enacted by Montana in 1973, authorizing the Board of Natural Resources and Conservation to reserve minimum streamflow (U.S. Department of the Interior 1971).

The second problem is the method for determining instream flow needs which have not been tied to the economic viewpoint that permeates the appropriative system, making more difficult the allocation of water between instream and offstream uses according to relative values. The management of water resources has always been a complicated problem and instream flows add more complexity. The National Conference on Water held in Washington, D.C., in 1975 recommended that state water law should recognize a water right for maintenance of the stream for fish and wildlife, recreation uses and scenic beauty (U.S. Water Resources Council 1978). The State of Utah also has a statute which requires that an application for unappropriated water be rejected when it would unreasonably affect public recreation or the natural stream environment (Utah Code Ann. §73-3-8). Thus, a decision maker needs information and data about instream flow and its value before approving or denying the new application for unappropriated water.

After some recognition was given to instream flows, scientists sought a reliable and practical method to determine stream flow requirements for aquatic environments. An easy and quick method, known as the "Montana Method," was developed for both warm water and cold water streams. The Montana Method assures consistency from stream to stream or state to state. This method recommends an instream flow equal to at least 10 percent of the average flow with an appropriate temperature and quality for protecting aquatic environment.

James A. Morris (1976) argued that a flow which is sufficient to support fish life may not be adequate for recreation. He further points out that water requirements will differ considerably for each activity. For example, more water is required to give a satisfying experience to a white water boater than for fish within the same river segment. Therefore, instream use allocations must be integrated with allocation of offstream uses. Whether instream values are exclusively protected by the state, or state protection and private appropriation are combined, rational allocation decisions require information on the relative benefits of instream flows and the costs of various proposed methods for obtaining needed flows.

Cost and Benefit

For historical reasons as well as legal mechanisms for regulating water use in the western states, the supply of instream flows on the average have been decreasing over time. The competition for water resources for all major uses is increasing. Since the volume of water is essentially fixed on the average, the measurement of the economic or monetary gain and costs of each use of water becomes important. Recently, recreation has begun to be legally recognized as a legal competing use of water. Therefore, it is essential to develop an acceptable procedure for evaluating the benefits of instream flows for recreation. Allocation of water between instream and offstream uses requires estimation of cost and benefit to enhance maximizing overall social benefits of available water resources. Instream uses and the benefits obtained for instream flows must be compared to the opportunity cost of maintaining the flow of water in terms of foregone offstream benefits.

Economic analysis is largely a study of human reaction and choices. Economic comparisons deal with physical and other characteristics of goods and services only to the extent that these affect human decisions. The most important and productive tool of economic analysis is the notion of demand (Stigler 1966). The growing demand for recreation is the cause of increasing value of the natural resources. Therefore, these changes will call for continuing adjustments in resource allocations to better satisfy wants and preferences of consumers. Land and water resources are constantly being reevaluated for their services. These results could be used, e.g., in justification of establishment of national recreation areas and in questions of justification, location, and operation of water development projects.

An economic value of water for outdoor recreation could provide a means for comparing the importance of instream flows with that of other uses. This value would provide a ceiling to any fees that might be charged for stream-related recreation use. Therefore, estimation of benefit and cost provides a means of making efficient decisions about allocation of water for outdoor recreation. For a project to be economically worthwhile, its total benefit must exceed the cost. In the literature of benefit-cost analysis, the ratio test has been frequently mentioned. This is another means of expressing benefits must exceed cost, as the ratio of value of benefits to the value of the cost must be greater than one. Thus, to determine which investment or project should be undertaken, information on benefits and costs is necessary.

In almost all the literature about economic value of water in stream recreation, benefit is measured under assumption of perfect certainty. Under this deterministic assumption, the appropriate measure of benefit for a publicly provided good or service is the aggregate willingness to pay. By ignoring supply uncertainty, the measured economic value of water may either overstate or understate the true value or benefit. This study will take the uncertain nature of streamflow into account in estimating both the cost and recreation value of instream flow. This analysis includes a consideration of seniority of water right according to the prior appropriation doctrine.

In order to provide the needed information for determining the level of instream flow, methodologies are needed for evaluating benefits of both instream flows and offstream water uses. In the first part of this study, a methodology is developed to estimate the potential foregone benefits to offstream uses as a result of increasing instream flow level taking into account the randomness in streamflow. In the second part, instream flow benefits are derived to provide recommendations for the supply of instream flows.

ECONOMIC APPROACH

Instream flow, in economic terms, has a public good characteristic. This implies that for a given level of instream flow, different instream uses can take place without competing or without any one use excluding other uses. But there is a direct competition between instream uses and offstream uses, on the other hand, for the total available water supply. Aggregate demand for instream flow uses can be derived by vertical summation of the derived demands for each user, since it is considered as a public good. However, aggregate demand for all available water supply is the horizontal sum of demands for off-stream uses and instream uses, since the same water cannot satisfy both uses.

In Figure 1a, the curves X_1 and X_2 are the demand curves for two instream uses. The aggregate demand curve X_0 for instream uses is the vertical summation of X_1 and X_2. In Figure 1b, $\hat{X}$ represents the demand for offstream uses of water supply. The horizontal sum of X_0 and $\hat{X}$ is the total demand X for water. The supply curve S which represents the minimum cost of providing various quantities of water, intersects the demand curve X at E. This intersection E represents the benefit maximizing allocation at q_e level of instream flow. The optimal level of instream flow is $q_1 = q_2$ as shown in Figures 1a and 1c. The optimal offstream water use q_0 is shown in Figure 1b. In Figure 1c, another way of approaching this allocation is shown. The optimal instream flows at E_0 can be determined by the intersection of the demand curve X_0 and S' which expresses the marginal opportunity cost of water taken from offstream uses. The marginal opportunity cost

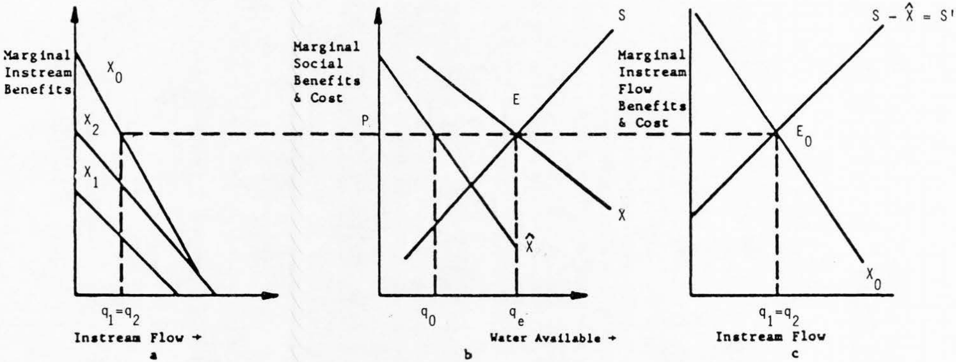

Figure 1. Optimal allocation of water.

curve, S', is obtained from horizontal differences between S and $\hat{X}$. Therefore, the benefit maximizing condition is satisfied when the sum of marginal benefits for instream uses is equal to the marginal benefit of each offstream use, which in turn is equal to the marginal cost of water.

Another way of determining the flow level at any point on a stream is by considering and evaluating marginal trade-offs between upstream and downstream uses. The marginal benefits of downstream uses for various amounts of water are shown by X_d (from 0 to the right in Figure 2). The total quantity of water available is fixed (00'), and X_u indicates the marginal benefits for upstream uses (from point 0' to the left). The intersection of these two curves at F_0 (Figure 2)

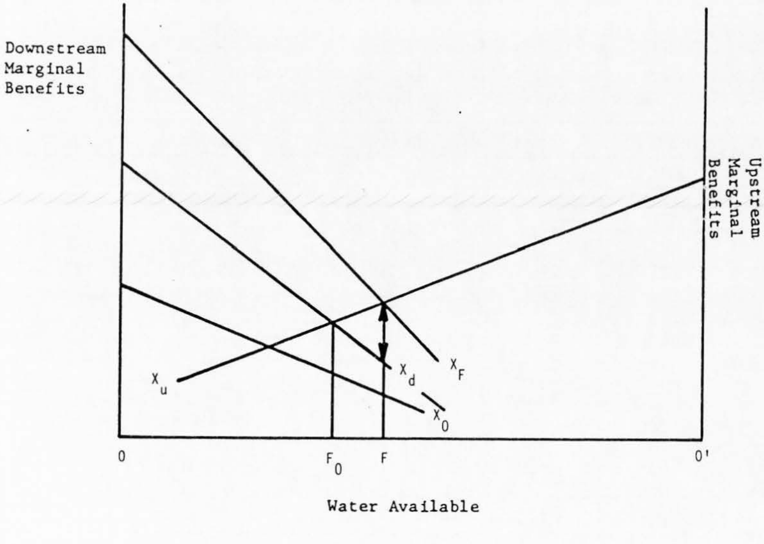

Figure 2. Optimal instream flow determination.

represents the benefit maximizing point, if water rights are freely transferable. Otherwise, intersection of combined marginal benefits of instream and downstream, $X_0 + X_d = X_F$, and upstream marginal benefits at F will represent the benefit maximizing point. Therefore OF is the optimal instream flow, and it should be increased by F_0F to maximize the benefits to society. In practice, determining an optimal level of instream flow, OF or OF_0 is difficult. For several reasons, such as introduction of uncertainty in cost and benefit analysis due to variation in the availability of water from year to year, or theoretical controversies and computational difficulty of estimating instream flow demands and benefits. The high cost and difficulty of obtaining site specific data are barriers to estimating the demand function. Besides, there is no accepted empirical framework in estimating benefits. Even though, the consideration of stochastic nature of water availability in cost and benefit estimation is very important, without quantitative information on instream flow benefits it cannot be incorporated satisfactorily within a cost-benefit framework.

In the deterministic case, if the streamflow is constant every year, the marginal cost of maintaining a base level instream flow is the opportunity cost of that water in the offstream use. Moreover, there is no need to distinquish between junior and senior rights. However, when the streamflow is considered as a random variable, there should be a distinction made between junior and senior rights. In addition, the "instream flow requirement" criterion used in the deterministic approach must be replaced. In this study, the desired level of "expected instream flow requirement" is proposed to be substituted for a desired level of "instream flow requirement." The expected instream flow is the statistical average of instream flows over a long period. Information on the expected cost of offstream benefits foregone to meet various desired expected instream flows could be useful for planning purposes. Therefore, in this study a general stochastic linear programming model was developed to estimate the expected costs of alternative methods to maintain instream flows from foregone value of agricultural products. In this estimation a direct conflict between offstream agricultural use and the maintenance of instream flows is assumed, which could be expanded to include conflicts with other water uses as well.

Demand function for outdoor recreation is used to make inferences about the consumer's surplus (Anderson 1981, Burt and Bremer 1971, Cicchetti and Freman 1971), and implicitly about the social welfare derived from particular sites. The best estimate of recreation benefits, or the total worth of increased supply of recreation services, may be measured directly from the demand curves, since it indicates what consumers would pay for the various units of recreation output, rather than go without them. Total area under demand curves measures the total economic worth to society of the provided recreation services. Therefore, to estimate instream flow benefits, the estimated demand function is needed.

The basic demand equation may be derived by maximizing the quasi-concave utility function for a given outlay or available income. The solution to this problem is a set of Marshallian demand functions. Alternatively, a dual approach may be used to derive the demand function. In this approach total cost or outlay necessary to reach utility

U is minimized. The solution is a set of new cost-minimizing demand functions, which is known as Hicksian or compensated demand functions.

Proper ways of measuring the benefit is discussed by Bishop (1982), Russell and Vaughan (1982), Schmalensee (1972), and Schulze et al. (1981). A preferred measure of welfare change or recreation benefit is the compensating variation CV, (Houthakfer 1952). This CV can be simply defined as how much compensation is needed to make the consumer as well off as before (i.e., to hold utility at U^o). Obviously, it is an amount equal to the change in the cost of securing U^o: i.e.,

$$CV = C(f_g{}', P^o, U^o) - C(f_g{}^o, P^o, U^o)$$

$$= \int_{f_g \text{ (100\% level)}}^{f_g \text{ (at any min level)}} \frac{\partial C}{\partial f_1} (f_1, P^o, U^o) df_1$$

Therefore, the compensated demand curve and CV are directly linked.

As discussed before, instream flows have a public good characteristic. Given the absence of markets in public goods, nonmarket approaches for benefit estimation are needed. One of the easiest approaches is to ask individuals their willingness to pay for stated level of a public good (Walsh et al. 1980b, Walsh 1980, Walsh et al. 1981, Walsh et al. 1980a, and Vaughan and Russell 1982). In this study, for example, questions about recreationists' willingness to pay to avert a defined reduction in streamflow are appropriate. This method ranging from simple interviews to sophisticated multiple questionnaires is used to determine an individual's willingness to pay (Daubert and Young 1979, Daubert and Young 1981). The serious problem with this approach lies in the response of the individual, since individual consumers have strong incentives not to show their true preferences (Maler 1974). Recently, there has been an effort to overcome this problem by structuring complicated survey method to get the true individual preferences based on the assumption of individual's rationality and perfect information. But still there is some doubt about the result.

The second important method to mention is the travel cost method (Clawson 1959, Clawson and Knetsch 1966, and Cesario and Knetsch 1976). This method which is called the Clawson-Knetch travel cost method is one of the traditional techniques for measuring the benefits of a recreation facility. Freeman (1979) argued that there are difficulties in extending this technique to the analysis of demand, such as analysis of demand with changing quality.

The third approach is the Household Production Function method. In this method the demand for recreation at several sites can be estimated by using cross-sectional household data. Unexplained differences in estimated demand among sites could be explained by site quality differences, e.g., differences in instream flow or water quality (Saxonhouse 1977). The household production function method has been a useful approach particularly when the purpose is to evaluate benefit accruing from a change in the natural environment (Barnett 1977, Pollak and Wachter 1975, Pollak and Wachter 1977). In this study, the third approach is used to estimate the multiple-site demands for instream flow recreation at three sites.

A General Model of Household Behavior

The household production framework was first developed by Becker (1965), and has been expanded in a variety of ways in the recent literature (Huffman and Lange 1982, Becker and Lewiss 1973). Valuing a resource whose services contribute to the production of a final good on the basis of the value of the good is not new to economics. What is new is the application of this approach to the final good or service which is not produced or exchanged in the market (Pajooyan 1978, Bockstael and McConnell 1981, Deyak 1978). In this approach, consumption activities are viewed as the outcome of individual or household production process, combining market goods and time.

According to conventional consumer theory, households maximize utility function subject to resource constraints:

$$\text{Max } U = U(X_1, X_2 \ldots X_n)$$

$$\text{S.t. } \sum_{i=1}^{n} P_i X_i = WT_w + N = I$$

where

X_i = goods purchased on the market at price P_i

I = money income

T_w = time spent working

WT_w = earnings

N = other income

Household production approaches assume that the household purchases goods on the market and combines them with time in a household production function to produce commodities which are consumed. Goods and services purchased by consumer are not final products and will not be consumed directly. In other words market goods and time are not desired for their own sake, but only as inputs into the production of consumption commodities. As Becker (1965) mentioned, the advantage of this approach is the systematic incorporation of nonworking time. The consumption commodities, rather than goods, are the arguments of the household utility function. For this study, it is sufficient to consider a rather simple variant of this model. Also we shall assume the household maximizes a utility function expressed in terms of final service flows:

$$\text{Max} \quad U = U(Z_1, Z_2, \ldots Z_n)$$

$$\text{S.t.} \quad \sum_{i=1}^{n} P_i X_i = WT_w + N = I$$

$$T = t_1 + t_2 + \ldots + t_n + T_w$$

where

$Z_i = Z^i (X_i, t_i)$

U = utility

X_i = goods and services

P_i = market price of X

W = wage rate

Z_i = consumption commodities

t_i = time spent to produce Z_i

N = nonwage income

I = money income

T_w = working time

T = total time available to the individual

and

$$\frac{\partial Z_1}{\partial X_1} \geq 0 \quad , \quad \frac{\partial Z_1}{\partial t_1} \geq 0$$

This approach is easily adopted to the study of nonmarket commodities. The analysis focuses on demand for consumption commodities as a function of "commodity prices" which, in turn, depend on prices of goods, wage rate, and the household's technology.

In this study the household production function theory is used to obtain demand function for instream flow's recreation. In this formulation households are both producing units and utility maximizers. Household is assumed to combine time and market goods to produce commodities that directly enter their utility function. These commodities will be called $Z_i{}^j$ and written as

$$Z_i = f(X_i{}^k, T_i) \tag{1}$$

where $X_i{}^k$ is a vector of market goods and T_i a vector of time inputs used in producing the commodities.

The most direct approach is to maximize the utility function subject to separate constraints on the expenditures on market goods, time, and the production functions. Since time can be converted into market goods by using less time at consumption and more at work, we could have a single constraint as:

$$\sum_i \sum_k P_k X_i{}^k + WT_i = I \tag{2}$$

where

I = full income

$X_i{}^k = \sum_j a_{kj}{}^i Z_i{}^j$

$T_i = \sum_j t_j{}^i Z_i{}^j$

$t_j{}^i$ is a vector giving the input of time per unit of $Z_i{}^j$

$a_{kj}{}^i$ is a vector giving the input of k market goods per unit of $Z_i{}^j$

By using the above definitions, Equation 2 can be written as

$$\sum_j \sum_k \sum_i P_k \, a_{kj}{}^i \, Z_i{}^j + W \sum_j \sum_i t_j{}^i \, Z_j{}^i = I \tag{3}$$

with

$$\text{full price of } Z_i = P_i{}^F = \sum_k P_k \, a_{kj}{}^i + Wt_j{}^i \tag{4}$$

$$\text{full income} \quad \bar{I} = N + WT_w$$

The full price of a unit of commodity is the sum of the price of the time and goods used per unit of commodity. In other words the full price is the sum of direct and indirect prices. As Becker (1965) pointed out, since these direct and indirect prices are symmetrical determinants of total price, there is no analytical reason to stress one rather than the other. Therefore, the utility function can be maximized subject to full income constraint (Equation 3). In this study, it is assumed that the recreationist maximizes his total utility and has perfect knowledge. It is further assumed that the recreation experience generates a total utility function which at some point encounters diminishing marginal utility (i.e., is concave).

DATA COLLECTION PROCEDURES

A specific problem area, appropriate sample selection, suitable survey formulation, and proper statistical models are essential and necessary for any kind of econometric study, especially for estimating a direct consumer surplus. Even though the study area chosen may be too small to permit generalization of the results to the rivers in the eastern parts of the country, but it is an ideal location to illustrate western water allocation problems. The recreation possibilities in the Blacksmith Fork, Little Bear and Logan Rivers could create economic allocation problems, such as diverting river waters by water right holders without considering instream flow needs. Therefore, to overcome the existing problems a correct economic theory plus a well constructed sample survey is necessary.

The Study Area

The study area includes the Blacksmith Fork and Little Bear River drainages located in the southwest portion of Cache County in northern Utah plus Logan River which is located in northern Utah and southern Idaho (Figure 3). The Little Bear, draining an area of 339 square miles, flows roughly south to northwest to its confluence with the Bear River. The Blacksmith Fork, draining 268 square miles, flows roughly east to west to joint the Logan River which later flows into the Bear River. The Logan River drains an area of about 223 square miles (Haws 1965), flows roughly northeast to southwest to join the Bear River. The headwaters of all three, Blacksmith, Logan, and Little Bear Rivers, originate in the Wasatch Mountains. Streamflows of the Little Bear,

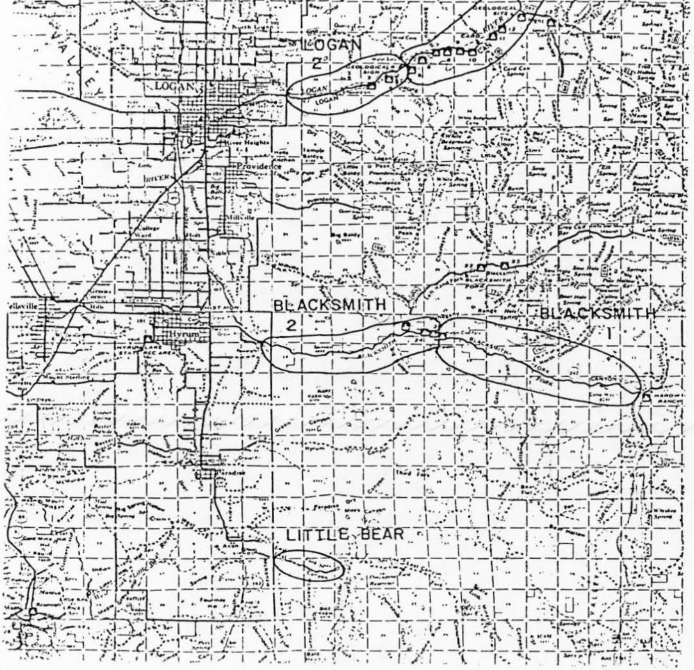

Figure 3. Map of the study area.

Blacksmith Fork and Logan Rivers with the canyon areas are primarily governed by runoff from the winter snowpack as the air temperatures increase from mid-April to mid-July.

The Logan River in the northern part of the drainage area which opens into a wide valley with gently undulating hills is not deeply entrenched. But the river near the center of the drainage basin as the valley converges into a narrow steep canyon is deeply entrenched. This canyon which is unquestionably beautiful (and some of it is privately owned) continues until the stream emerges from the mountains onto the level floor of Cache Valley. The Logan River meanders across Cache Valley, is joined by the Blacksmith Fork River and the Little Bear River and finally joins Bear River, which is the major stream flowing through Cache Valley and into the Great Salt Lake. About 15 percent of the Little Bear drainage and 63 percent of the Blacksmith Fork drainage are in the Cache National Forest or state lands. Approximately 32,000 acres in the Little Bear drainage, and 2,000 acres in the Blacksmith Fork drainage, are irrigated. The Logan River drainage has approximately 15,000 irrigated acres in the downstream reaches. Irrigation, especially on the Blacksmith Fork and Little Bear Rivers, constitutes by far the heaviest use made of the water. Other uses include municipal, culinary, and hydroelectric water.

Farmers in the area have diverted all three rivers' streamflows for irrigation for over 50 years to irrigate corn, peas, potatoes, sugar beets, silage, hay, small grains, pasture, and orchards by the Logan River irrigation system and alfalfa full, alfalfa partial, barley, corn grain, beets, nurse crop by the Blacksmith and Little Bear Rivers irrigation systems. The principal fish that exists in the Blacksmith Fork, Little Bear and Logan Rivers are the brown trout and mountain whitefish. In addition, cutthroat trout, rainbow trout, and speckled dace are found in the Logan and Blacksmith Fork Rivers (Fish and Wildlife Service, U.S. Department of the Interior 1980). The Logan River canyon, the Blacksmith River canyon, and the Little Bear River canyon are popular recreation areas, used for fishing, camping, kayaking, etc. The Logan River, the Blacksmith Fork River and canyons, with high, wooded mountains, form a picturesque mountain setting. In fact, many visitors come to these areas to enjoy the scenery at one of the camp or picnic grounds.

The Logan River between second dam and Bridger Campground is usually dewatered during late summer, even in higher than normal flow years. In 1983, an agreement was reached between the Utah Fish and Wildlife Service and Logan City to let some minimum water flow in this stretch of river, which is an important area for recreationists. Instead, the lower part of the river will be dewatered. The Blacksmith Fork is also dewatered over part of its lower reaches during the middle and late summer in years with below normal flows. Such dewatering occurred in the summer of 1981, resulting in loss of a large number of fish. A proposal by the City of Hyrum to rehabilitate its power plant on the Blacksmith could dewater another stretch above the canyon mouth by diverting the flow into a pipe for conveyance to the downstream generation site. For this study to derive flow data the Logan River has been divided into five homogeneous reaches and the Blacksmith Fork River has been divided into three uniform river reaches. These divisions were determined by considering points where the amount or time distribution of streamflow changes significantly The division points for the Logan River are:

Reach 1, between 1st dam and Smithfield Canal diversion or Logan-Hyde Park

Reach 2, between Smithfield Canal diversion and 2nd dam

Reach 3, between 2nd and 3rd dams

Reach 4, between 3rd dam and Right Fork tributary

Reach 5, the rest of Logan River study area which lies between Right Fork tributary upstream and end of the study area at Woodcamp Campground

Blacksmith Fork River, as mentioned above, is divided into 3 reaches. These reaches are:

Reach 1, from the mouth of the canyon to the existing reservoir structure

Reach 2, between reservoir structure point and the mouth of the left hand fork tributary

Reach 3, located from the left hand fork tributary to the end of the study area at Hardware Ranch

East Fork River or Little Bear River has only one single uniform river reach which is the whole Little Bear study area.

Streamside Recreation Sampling Procedure

To have a complete measure of instream flow value, ideally all individuals who participate in instream recreation activities should be interviewed. Interviewing all participants is an expensive and time consuming task. Therefore, randomly selected recreationists are interviewed and inferences are made about all recreationists from that sample (Earl 1982).

The interviews were conducted for streamside recreation survey in the summer of 1982 in three river sites. A group of six well qualified and trained students and faculty with field interview background helped with the interviewing. Interviews were made at recreation sites. Although, it was a labor-intensive procedure and increased the survey cost, it increased the response rate and, therefore, reduced the possibility of bias. Usually very few people refused to respond when confronted in person. In this study, only 2 percent of the people refused to fill out the survey forms. A copy of the survey questionnaire is shown in Appendix A. The questions were first tested by staff members at Utah State University for timing and ease of understanding of the question. Then, the questionnaire was tested among a couple of ordinary recreationists in each site. The shortcomings of the questionnaire were corrected before the actual survey began.

Any household visiting the Logan, Blacksmith, and Little Bear Rivers during the summer of 1982 was a potential member of the recreation sample population. In this study the actual sample for all three sites included 500 households who participated in fishing, camping or any shoreline and white water activities such as swimming, hiking, tubing, etc. To achieve randomness, such that each household would have the same chance of being selected, a random number of days were selected to interview over a period of six weeks, beginning in August. The interview period was chosen to ensure variations in streamflow would be observed. The higher than normal flows of 1982 required a later starting date than would have been the case in an average year.

Interviews were made at recreation sites on four weekends and four weekdays. Sampling sites for the survey which were defined by streams were divided into five reaches (Figure 3). Logan River had two reaches. From the First Dam to Second Dam was called Logan 2 and from Second Dam to Woodcamp Campground was called Logan 1. Blacksmith Fork River also was divided in two reaches. Blacksmith 1 extended from the mouth of Blacksmith Fork Canyon upstream to Hyrum City park and Blacksmith 2 extended from the park to Rock Creek below Hardware Ranch. The last site was East Fork or Little Bear River, below Porcupine Reservoir.

The interview process, on any given sample day, attempted to eliminate time, selection, or location bias. The interviewers were divided into four groups of two for almost each site. All four groups started interviewing, at the same time at each given day, given a number of randomly selected households. The sampling procedure consisted of setting a quota for sites for each day of interviewing. The quota for each site and for each day was determined according to estimated site capacity, weekend or weekday, and whether it was earlier or later in the season. Relatively higher quotas were assigned for weekends, as recreation use is higher and there is more time for interviewing on weekends. As recreation use comparatively declined later in the season, relatively lower quotas were assigned. Interviewers for each site were given the quota for each day, and were instructed to determine the sampling uniform rule by first counting all cars and campers in the site, dividing the number of vehicles by the given quota for that day, and then interviewing at every nth vehicle. One sampling bias may occur. Individuals fishing on stream will frequently walk too far from their cars to be accessible for interviews, so that the sample might undercount small parties who come primarily to fish. So the site interview procedure has one inherent bias, which is those who stay longer and are more available and have higher probability of being chosen for the interview.

The average interview lasted between 20 and 35 minutes and a few lasted over 35 minutes. The rate of acceptance was over 95 percent. Shoreline participants had the highest response rate and fishermen were also very receptive to the survey, as they had the most to gain from instream flow management. The study especially focused on recreationists evaluation of particular streams as flows varied. This dictated that the questionnaires be administered at the recreation sites, rather than by phone, mail, or at residences. As the household was the basic sample unit, the interviewer was advised to make sure that the spokesman gave answers that represented the family.

The most difficult sample construction decision was to choose an appropriate sample size considering time, cost, and all other constraints. It is known that an increase in sample size will increase the probability that sample estimates accurately represent the true population parameters. But the researcher must tradeoff between increase in statistical accuracy with collection costs. In this study some variables such as number of sites, number of income groups, and the number of travel distance zones plus costs of information collection were considered to set the sample size. Therefore, the decided sample size was 500 interviews and it was hoped to be enough observation for 3 sites in 4 distance zones, and 3 income groups. Table 1 shows the distribution of sample sizes.

Table 1. Distribution of sample sizes.

	Site														
	Logan 1			Logan 2			Blacksmith 1			Blacksmith 2			Little Bear		
	Income Groups														
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Zone 1															
D_1	11	16	10	24	9	4	7	10	1	8	7	4	0	1	0
D_2	2	5	1	6	3	3	1	2	0	5	2	1	0	1	0
Zone 2															
D_1	6	7	5	2	3	3	2	13	3	8	10	5	5	2	2
D_2	2	2	0	3	0	1	2	7	1	2	0	1	3	2	1
Zone 3															
D_1	2	8	4	2	2	8	2	12	9	0	3	2	2	3	0
D_2	2	4	4	1	2	1	0	5	1	2	1	0	0	0	2
Zone 4															
D_1	2	5	6	3	4	3	1	8	4	2	0	4	5	4	2
D_2	2	4	2	1	1	4	0	1	0	1	0	2	2	5	1
Above 365 miles		23			25			3			4			2	
Total		135			118			95			73			45	

D_1 indicates weekend
D_2 indicates weekday

Survey Results

The survey questionnaire is the most important factor determining the success or failure of attempt to estimate objective of survey. The length of survey and the number of questions in each section of survey is important to get accurate answers. In particular, questions should not ask the individual to respond to alternatives beyond the range of his experience. In this study, the questionnaire requested information on three general topics with enough number of questions in each group to get as accurate answers as possible without making the respondents tired. These three categories were: 1) socio-economic, 2) recreation activities, and 3) site evaluations.

Socio-economic

Respondents were asked about composition of party, education completed, household income, and residence (Appendix A). Average sizes of groups were almost similar in 5 reaches and particularly between the 3 sites. They were 4.00 for both Logan River and Blacksmith Fork River and 3.9 for Little Bear River (Table A-1, Appendix A). Group size distribution did not follow a uniform pattern, however, a group of size 2 had the highest frequency. Table A-2 indicates that there were more male recreationists than female. This conclusion is not true in every age group. The largest portion of the recreation population is under 30 years of age. At over 49 years the differences in number between male and female recreationists decrease.

Table A-3 indicates that the median educational attainment of respondents was high school completion. The number of recreationists with college level of education in Logan 1, Logan 2, and Blacksmith 2 was higher than with high school level of education. Also, on the average, recreationists in Logan 1, Logan 2, and Blacksmith 2 reaches have higher level of education than Little Bear and Blacksmith 1 reaches. This noticeably higher level of education in those three samples could be explained by the relatively shorter distance of the sites to the university community centered in Logan, as higher level of education will indicate higher opportunity cost for recreationists.

There is a weak relationship between education level and household annual income (Table A-4). The high number of college students as recreationists in our sample did affect the relationship between education and income. Since these students do not earn as much as they would if they were in the work market, the expected result, which is a relative increase in income earned as education level increases, is not shown in Table A-4. Distribution of household income (Table A-5 and Figure 4) is not significantly different in Logan and Blacksmith sites. The median income for the Logan and Blacksmith sites is in the 20,000-24,999 range, and for Little Bear it is in the 10,000-14,999 range. If ranges above 20,000 are considered upper brackets, then almost 60 percent of the sample from Logan and Blacksmith sites are in the upper brackets and for Little Bear, the upper bracket percentage is 40.

Distance traveled from home is classified in 13 groups from less than 2 miles to almost 1000 miles (Table A-6). According to our samples two groups of people mostly ended up in Logan, those living within 40 miles especially within less than 10 miles and those passing through Utah. But for Blacksmith and Little Bear the opposite is true. Although, one would generally expect that most of the visitors to a site would live in the nearest zone, as in Logan site, the survey sample for

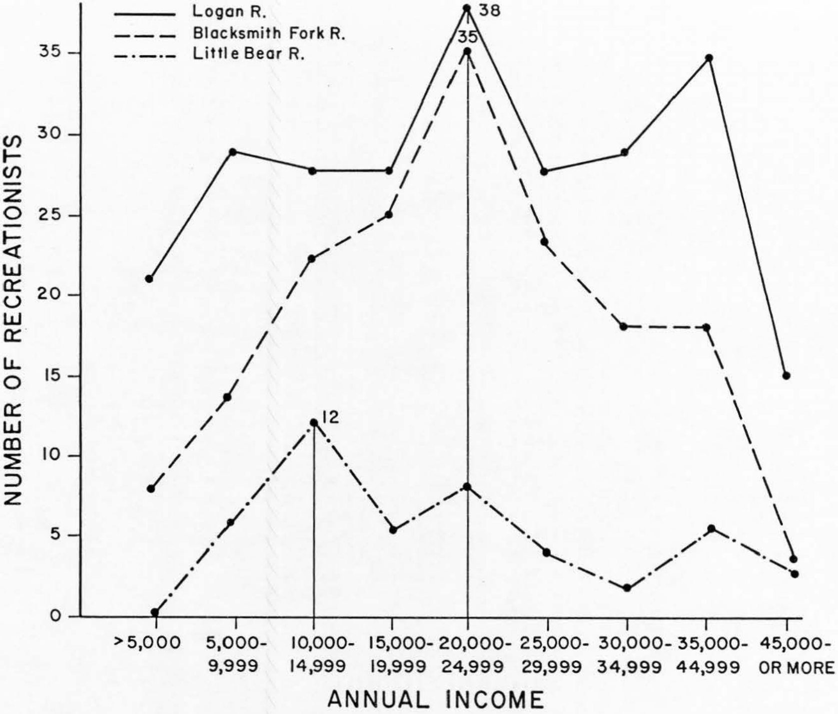

Figure 4. Distribution of annual income by sampling site.

the latter two sites departs from this pattern. This could partly be explained by distribution pattern of population around the sites, as very few people live within 10 miles of the Little Bear and Blacksmith sites especially Blacksmith 1. Other factors such as proximity of the site to major highways and distance between home and the nearest alternative site offering a similar recreation experience, could be mentioned to justify the results in Table A-6. By adjusting the number of visits from distance zones by the differences in population part of the above problem may be overcome and a pattern closer to the expected one could be produced.

Recreation activities

Table A-7 presents the mean or average length of stay for each site. Logan 2 has lowest mean because of proximity of this site to the largest city in northern Utah, and average length of stay for Logan 1, Blacksmith 1, and Blacksmith 2 are exactly the same. Also Table 2 shows that the length of visit was kind of shorter for shorter travel distance. Tables 3 and 4 give us a general idea of average cost of food, recreation equipment cost and cost of durable recreation equipment for each site.

Table 5 could help us to rank the different kinds of activities for each site. As it was expected, fishing was the dominant recreation activity for all five sites. For Logan site water play has second rank, but for Blacksmith and Little Bear sleeping has second place. The result of this table might be used in deriving demand function for each recreation activity from overall recreation demand.

Table 2. Length of visit by travel distance.

Distance Traveled	Hours at Site							Total
	< 1	1-4	5-8	9-15	16-30	31-55	56 or more	
0-10	0	59	16	5	7	9	6	102
11-20	0	15	12	1	6	8	7	49
21-30	0	14	6	0	4	6	7	37
31-40	0	9	8	3	12	18	17	67
41-50	0	1	3	2	0	6	2	14
51-60	0	5	13	4	12	12	26	72
61-70	0	0	1	0	12	6	5	24
71-80	0	2	1	1	2	3	3	12
81-90	1	2	2	0	1	4	2	12
91-100	0	0	1	1	1	3	1	7
101-130	0	2	0	1	4	8	1	16
131-365	0	2	0	0	3	2	2	9
365 or more	0	16	5	5	11	9	10	56
Total	1	127	68	23	75	94	89	477

Table 3. Average expenditure by site.

Average Expenditure	Site					All Sites
	Logan 1	Logan 2	Blacksmith 1	Blacksmith 2	Little Bear	
Food	$30.21	$24.31	$29.61	$24.85	$32.53	$141.51
Equipment	8.50	8.69	13.86	5.01	19.93	49.99
Total $	38.71	33.00	42.47	29.86	46.46	190.50

Table 4. Average cost of durable recreation equipment by site.

Equipment Type	Site: Logan 1 ($)	Logan 2 ($)	Blacksmith 1 ($)	Blacksmith 2 ($)	Little Bear ($)	All Sites
RV, camper, trailer	3,539.22	2,715.68	1,790	1,044	1,923	
Tents and awnings	178.16	155.86	50	169	44	
Sleeping bags, etc.	114.22	85.42	51	70	67	
Food preparation and amenities	154.48	162.78	38	76	92	
Fishing equipment	75.18	60.02	63	64	88	
Licenses	15.00	19.80	16	10	16	
Other	104.50	206.67	0	9	35	
Average Total	4,180.76	3,406.23	2,009	1,442	2,266	

Table 5. Average percentage of time allocated to different activities.

Activity	Site: Logan	Blacksmith	Little Bear
Fishing	28.2	26.45	21.2
Eating	7.6	8.6	11.0
Sleeping	10.8	9.05	14.2
Water play	12.3	4.55	5.4
Hiking	8.4	3.05	2.6
Games	1.9	2.1	2.2
Other	4.4	4.0	6.5

Site evaluation

Recreationists were asked to rate their recreation site on a scale of 1 to 10 over several site characteristics; where a rating of 10 would indicate an ideal site and a rating of 1 would indicate a least desirable site (Table 6). This table shows that 3 reaches, Logan 1, Logan 2 and Blacksmith 2, are close alternative sites, according to the composite site characteristic evaluation of about 7.2. The two remaining reaches have an evaluation of about 6.5

The survey year, 1982, had an unusually high instream flow. As the survey was conducted in that year (Table A-8), the present level of instream flow in the summer of 1982 was rated as an accepted flow level in all three sites. Table 6 shows that site characteristic evaluations by recreationists are above average for all five reaches. Nevertheless, the reaction of recreationists to no water situations is unacceptably low (Table A-8). Furthermore, Table 7 indicates that the mean levels of minimum acceptable flow in all five reaches are above 55 percent of current flow even in summer of 1982. The amount recreationist

Table 6. Site characteristics evaluation by site (10 = perfect, 1 = extremely poor).

Chacteristic	Site Logan 1	Logan 2	Blacksmith 1	Blacksmith 2	Little Bear
Distance	7.73	7.91	7.7	8.1	7.3
Privacy	7.43	7.04	7.9	7.3	7.5
Facilities	6.97	6.74	4.2	5.9	3.0
Landscape	8.37	8.67	8.5	8.3	7.3
Inspects	4.58	6.03	4.0	5.5	4.9
Water	8.78	8.33	8.7	8.1	8.4
Fishing Suitability	6.71	6.54	5.8	6.9	6.8
Composite	7.22	7.32	6.7	7.2	6.5

Table 7. Minimum acceptable flow as a percent of current flow, by site.

Flow Level	Site Logan 1	Logan 2	Blacksmith 1	Blacksmith 2	Little Bear	All Sites
10	1	5	1	3	0	10
25	19	1	6	4	0	30
33	15	5	11	9	1	41
50	45	27	30	19	17	138
67	10	19	29	10	6	74
75	17	38	11	12	14	92
99	24	18	7	16	7	72
Mean level	57	66	58	62	67	62

are willing to pay to maintain acceptable flow levels is shown in Table 8. These results are a strong indication of importance of required flow level for recreationists.

Tables A-9 and A-10 present the results of respondents answers about question of maximum number of other recreationists who would be acceptable at the site before it became too crowded (respondents were asked to use their own definition of site boundaries). Most recreationists were satisfied with the number of others at the site (shown in Table A-9). In summary the result of site evaluation part of the survey was as expected, that is, a high weight is given to the flow level.

Table 8. Willingness to pay to maintain acceptable flow levels, by site.

Dollars Willing to Pay	Site					All Sites
	Logan 1	Logan 2	Blacksmith 1	Blacksmith 2	Little Bear	
0	32	33	15	21	5	106
1-2	40	44	60	22	22	188
3-4	35	18	14	19	11	97
5-6	17	9	2	7	3	38
7-10	9	9	3	3	3	27
11-19	1	2	0	1	0	4
>20	1	0	1	0	1	3

COST ESTIMATION OF MAINTAINING INSTREAM FLOW

The economic cost of any activity could be interpreted as the alternative opportunities foregone. Since in this study the assumption is only a direct conflict between maintenance of instream flow and offstream agricultural use, the foregone value of agricultural products is considered as the expected cost of desired expected instream flow.

Since farmers in semi-arid environments are unable to depend on rainfall, they recognize that their production possibilities would substantially increase by diverting water away from the natural stream channel. Although diverted water is used in production of goods and services, the belief is that instream water uses for recreation and environmental quality have an economic value large enough to warrant instream flow management strategies. Therefore, a stochastic linear programming model (Wagner 1975, Hadley 1963) was developed to estimate the expected costs of alternative methods to maintain instream flows; thus providing additional necessary information for society to make proper judgments on resource allocation. For application of the model developed in this chapter, the Blacksmith Fork and Little Bear Rivers are the study area. Since the selected study area is already experiencing conflicts between water use for irrigated-agriculture and instream flow for fish habitat, this presents a good situation for demonstrating model application in this chapter.

Model Application

Cost of maintaining desired expected instream flow is defined as foregone value of agricultural products. The model developed in this chapter assumes a direct conflict only between agricultural use and the required instream flow. This assumption can be relaxed easily, and the source of water for instream flow which generates the smallest marginal benefit would be the appropriate cost measure.

To analyze alternative instream flow strategies in this model, the stochastic nature of streamflow is considered. Therefore, annual water availability is assumed to be a discrete random variable that can take any one of eight independent levels. These eight levels are assumed to be an independent event with an associated probability, . Under the assumption of perfect correlation between monthly flows and seasonal total flow, the monthly flows are calculated as fixed portions of the annual total. For this calculation, the ratio of the sum of monthly gaged flows for all sample points (34 years) to the sum of the total for all months over the same 34 year period is calculated. Then a histogram of sample points is constructed to determine a discrete density for the 5 months (May-September) flow period. Eight flow events beginning with 10,000 acre feet up to 170,000 acre feet at an interval of 20,000 acre feet are used and the respective probabilities are estimated (Table 9).

The alternative instream flow strategies for which costs are determined in this study include three basic strategies under two conditions of water rights transferability:

1. The expected instream flow strategy (EIF) which determines the combination of junior and senior water rights needed to maintain the desired level of expected instream flow at least cost in terms of expected agricultural products foregone.

Table 9. Streamflow volumes at different probabilities of occurrence in acre feet.

State k	Probability of Occurrence	Months (t) May	June	July	August	September	Seasonal Total
1	0.029	9,000	4,200	2,600	2,200	2,000	20,000
2	0.1176	18,000	8,400	5,200	4,400	4,000	40,000
3	0.1764	27,000	12,600	7,800	6,600	6,000	60,000
4	0.3235	36,000	16,800	10,400	8,800	8,000	80,000
5	0.1470	45,000	21,000	13,000	11,000	10,000	100,000
6	0.1470	54,000	25,200	15,600	13,200	12,000	120,000
7	0.029	63,000	29,400	18,200	15,400	14,000	140,000
8	0.029	72,000	33,600	20,800	17,600	16,000	160,000

2. The minimum flow strategy (IF) which meets the desired level of expected flows by reserving the required amount of the most senior rights.

3. The critical flow strategy (CF). The CF combines the previous two basic strategies, using IF to guarantee a base flow to prevent any irreversible damages (attain maximum protection up to a critical flow level), and EIF to obtain the remainder of the desired expected instream flow.

All three basic strategies defined above are evaluated under two water rights conditions. Under condition 1, transfers from agriculture to instream uses are restricted to permanent conversions, but under condition 2, temporary or short term transfers are freely permitted. This transferability is not applicable to IF. Therefore, three methods and two conditions would combine into five alternatives (EIF 1, EIF 2, IF, CF 1, CF 2).

In formulating the model, let P_{jr} represent the net per acre revenue for jth crop produced on the rth class of land. This irrigated land on the basis of productivity levels is classified into r or three classes. ${Z_{jr}}^k$ is the number of acres of rth class of land devoted to growing jth crop when water availability K occurs with an associated probability π^k. Table 10 shows the value of P_{jr} for six major crops. The expected returns to irrigated agriculture are;

$$\sum_k \sum_j \sum_r P_{jr} \, \pi^k \, {Z_{jr}}^k \tag{5}$$

Therefore, the problem is to maximize these expected returns to irrigated agriculture subject to the following constraints:

Table 10. Net revenues per acre for different crops and land classes (P_{jr}).

Land Class	Crop					
	Alfalfa Full	Alfalfa Partial	Barley	Corn Grain	Beets	Nurse Crop
Class 1	107.49	82.13	106.68	156.63	72.44	64.21
Class 2	86.83	68.29	89.75	120.22	48.47	50.98
Class 3	67.81	62.38	74.96	77.32	43.85	39.98

a. The amount of irrigated land ($\Sigma Z_{jr}{}^{k}$) is restricted to be less than the available acres $L_r{}^*$ in each land class for every event k.

$$\sum_j Z_{jr}{}^{k} \leq L_r{}^* \qquad r = 1, 2, 3 \qquad k = 1, 2, \ldots 8 \qquad (6)$$

b. The $A_t{}^k$ which is total water requirements in month t and probability state k for irrigation is defined by the equation:

$$\sum_r \sum_j W_{jt}\, Z_{jr}{}^{k} - A_t{}^k = 0 \qquad t = 1, 2, \ldots 5 \qquad (7)$$

where W_{jt} represents the consumptive use requirement for crop j in month t (Table 11).

c. A general representation of crop rotational constraints used in the model (Keith et al. 1978) is given by:

$$\sum_r \sum_j V_{jr}{}^{i}\, Z_{jr}{}^{k} \gtrless 0 \qquad i = 1, 2, \ldots 6 \qquad (8)$$

where the $V_{jr}{}^{i}$ represents the portions of various crop acreages required for good crop rotation.

d. The quantity of water available in month t and in kth state ($Q_t{}^k$) should be equal to the sum of the amounts of water used in irrigated agriculture in month t and state k, $A_t{}^k$ and the corresponding instream flow ($I_t{}^k$).

$$I_t{}^k + A_t{}^k = Q_t{}^k \qquad (9)$$

Table 1 shows the distribution of value of $Q_t{}^k$ for five months (May-September), and eight flow events.

e. The expected instream flow requirements constraint is:

$$\sum_k \pi^k\, I_t{}^k \geq \bar{I}_t{}^* \qquad t = 1, 2, \ldots 5 \qquad (10)$$

Table 11. Water requirement for crops per acre in acre-inch (W_{jt}).

Month	Crop					
	Alfalfa Full	Alfalfa Partial	Barley	Corn Grain	Beets	Nurse Crop
May	3.828	3.190	1.772	1.311	1.240	1.772
June	5.727	4.713	7.805	3.801	3.345	7.805
July	7.597	6.228	7.665	7.392	7.528	7.665
August	6.416	5.508	1.513	6.235	7.566	1.513
September	3.644	3.197	0.930	2.417	4.239	0.930
Total	27.212	22.836	19.685	21.156	23.918	19.685

where I_t^* is the desired expected instream flow level (Table 12). The value of desired expected instream flow examined in this analysis corresponds to 40 percent, 50 percent, 60 percent, and 70 percent of average flows (Table 12, first column).

f. Following constraints were restricted water right transfers between irrigation and instream flows.

$$A_t^{k+1} - A_t^k \geq 0 \qquad k = 1, 2, \ldots 7$$
$$I_t^{k+1} - I_t^k \geq 0 \qquad t = 1, 2, \ldots 5 \qquad (11)$$

where A_t^{k+1} is the irrigation water use corresponding to event Q_t^{k+1}. Water rights are grouped into eight levels of seniority, corresponding to eight flow events Q_t^k selected for analysis. Therefore, the differences between A_t^{k+1} and A_t^k can be interpreted as the water right of (k+1)th seniority. The assumption in these constraints is that water rights of different seniorities are maintained as nonnegative. Therefore, in the absence of Equation 11, $A_t^{k+1} - A_t^k$ could be negative. This means that if Q_t^{k+1} is observed to be the streamflow, then A_t^{k+1} is the optimally required agricultural water use. This will require selling some water rights, since A_t^1 is the amount of the most senior water right and $A_t^8 - A_t^7$ represents the most junior water right in the stream. Thus, without constraint (11), sale or purchase of water rights would be required on an annual basis.

The model is solved with and without imposing constraint (11) for various levels of expected instream flow requirements. In this case, the model with constraint (11) results in strategy EIF 1. The model does not allow transfer of water rights between irrigated agriculture and instream flow, because the constraint fixes the allocation between them for any flow event. The variables in constraint (11) could be regarded

Table 12. Minimum instream flow requirements in acre feet (I_t^*).

Expected Instream Flow (Percent of Average)	Time				
	May	June	July	August	September
40% (4,667)	4,667	4,681	4,729	4,790	4,852
50% (5,834)	5,834	5,882	6,034	6,158	6,283
60% (7,000)	7,000	7,084	7,401	7,773	8,003
70% (8,167)	8,167	8,285	9,029	10,127	12,851

as first stage decision variables in a two stage stochastic linear programming model with the cropping pattern regarded as the second stage decision variable. Moreover, the model without constraint (11) results in strategy EIF 2 where water rights can be transferred between agriculture and instream flows after observing the event Q_t^k.

g. Minimum flow requirements are imposed by stipulating

$$I_t^k \geq \bar{I}_t^k \qquad t = 1, 2, \ldots 5$$

$$k = 1, 2, \ldots 8 \qquad (12)$$

Constraints (12) are used in two ways:

1. Implicitly to find $\bar{I}_t k$ such that the expected value of Min $(Q_t^k, \bar{I}_t^k) = \bar{I}_t^*$, the minimum instream flow reservation consistent with the expected instream flow requirements can be determined. Table 12, columns 2-6, shows these minimum requirements by month. Therefore, by imposing constraint (12), $I_t^k \geq$ Min (Q_t^k, I_t^k). This will result in a decrease in the objective function which corresponds to minimum instream flow strategy (IF).

2. Critical flow is required to prevent irreversible damages, since simple EIF requirements could allow zero flows. In this study critical flows $I_t{}^c$ were set at 20 percent of average flows (Montana Method) by stipulating in Equation 12. Therefore, in this case $I_t{}^k \geq$ Min $(Q_t{}^k, I_t{}^c)$. Critical flow strategy with constraints 11 (CF 1) and without constraints 11 (CF 2) is used (Appendix D).

In the model, the net revenue per acre for jth crop produced on rth class of land, P_{jr} is calculated as:

$$P_{jr} = (R_{jr} \cdot P_{Dj}) - C_{jr}$$

where

R_{jr} = productivity per acre for jth crop produced on rth class of land

P_{Dj} = price in dollars per acre of jth crop.

C_{jr} = cost of cultivation of jth crop produced on rth class of land in dollars per acre

The data necessary for this calculation are obtained from Keith et al. (1978). Also data needed for crop rotational constraints (8) are collected from the same publication.

In areas for which no measurements of consumptive use are available, the Blaney-Criddle method with some modification can be used to estimate consumptive use of crops from climatological data. Blaney and Criddle found that the consumptive use of crops closely correlated with mean monthly temperatures and daylight hours. Temperature and precipitation records are more readily available than most other climatic data. Records of actual sunshine are not generally available, but the effect of sunshine can be estimated by using the length of days during the crop-growing season at various latitudes. Therefore in this study the W_{jr} are estimated using the Blaney-Criddle equation which is:

$$ET = 25.4\ (K_c\ K_t)\ \frac{T_a \cdot P}{100} \tag{13}$$

where

ET = consumptive use of crop; millimeters for a given month

T_a = mean temperature during the period in degrees Fahrenheit (State Climatologist)

P = percentage of daytime hours of the year, occurring during the period (USDA SCS TR21)

K_c = monthly crop coefficient (USDA SCS TR21)

K_t = a climatic coefficient calculated by:

$K_t = 0.0173\ T_a - 0.314$

Analysis of Results

The models described before are used to obtain net benefit maximizing solutions for the five strategies for providing instream flows equal to 40 percent, 50 percent, 60 percent, and 70 percent of the average flows. Besides, a base solution with deleting constraints 11 and 12 and $\bar{I}_t^* = 0$ (no required instream flows) is obtained. This base solution is used for comparison purposes and also the result indicates how the available water could be allocated among various agricultural activities to obtain maximum value of agricultural returns. Therefore, the cost of instream flow maintenance for the five strategies can be calculated by subtracting the value of the objective function of each strategy (Table 13) from the base solution value. These costs are shown in Table 14. Tables 15 to 19 show the corresponding water allocations at each strategy.

Table 13. Maximum farmer's income with respect to instream flow management (in dollars).

Strategies	Expected Instream Flow 40%	50%	60%	70%
EIF 1	886,183	725,077	550,978	92,038
EIF 2	886,188	725,081	550,981	92,040
IF	864,665	660,588	385,870	65,420
CF 1	884,486	723,379	549,281	92,038
CF 2	884,491	723,383	549,283	92,040

Table 14. Expected costs of instream flow maintenance (in dollars).

Strategies	Expected Instream Flow 40%	50%	60%	70%
EIF 1	603,653	764,760	938,858	1,397,799
EIF 2	603,648	764,755	938,856	1,397,796
IF	625,171	829,248	1,103,966	1,424,417
CF 1	605,351	766,458	940,556	1,397,799
CF 2	605,346	766,454	940,553	1,397,796

Table 15. Water allocations for expected instream flow (EIF I).

Expected Flow Requirement		40% Flow		50% Flow		60% Flow		70% Flow	
State	Proba-bility	Instream Flow	Agricul-ture	Instream Flow	Agricul-ture	Instream Flow	Agricul-ture	Instream Flow	Agricul-ture
1	0.029	11551	8448	11837	8163	11837	8162	20000	0
2	0.1176	27252	12747	31695	8304	31837	8162	37573	2426
3	0.1764	38804	21195	43255	16744	47871	12128	57573	2426
4	0.3235	58804	21195	62616	17383	67864	12134	77573	2426
5	0.1470	78791	21208	82603	17396	87857	12142	97573	2426
6	0.1470	98789	21210	102601	17398	107855	12144	117573	2426
7	0.029	118789	21210	122601	17398	127855	12144	137573	2426
8	0.029	138789	21210	142601	17398	147855	12144	157573	2426

Table 16. Water allocations for expected instream flow (EIF IIAF).

Expected Flow Requirement		40% Flow		50% Flow		60% Flow		70% Flow	
State	Proba-bility	Instream Flow	Agricul-ture	Instream Flow	Agricul-ture	Instream Flow	Agricul-ture	Instream Flow	Agricul-ture
1	0.029	14211	5788	11837	8162	11837	8162	20000	0
2	0.1176	34211	5788	34211	5788	34211	5788	35380	4619
3	0.1764	34655	25344	48501	11498	36756	23243	58217	1782
4	0.3235	46207	33792	46207	33792	66146	13853	75380	4619
5	0.1470	94213	5786	94213	5786	94213	5786	100000	0
6	0.1470	103891	16108	114211	5788	114211	5788	120000	0
7	0.029	134211	5788	134211	5788	134211	5788	140000	0
8	0.029	154211	5788	154211	5788	154211	5788	160000	0

Table 17. Water allocation for minimum flow (IF) in acre-feet.

Expected Flow Requirement		40% Flow		50% Flow		60% Flow		70% Flow	
State	Probability	Instream Flow	Agriculture	Instream Flow	Agriculture	Instream Flow	Agriculture	Instream Flow	Agriculture
1	0.029	20000	0	20000	0	20000	0	20000	0
2	0.1176	40000	0	40000	0	40000	0	40000	0
3	0.1764	50441	9558	60000	0	60000	0	60000	0
4	0.3235	61572	18427	66303	13696	80000	0	80000	0
5	0.1470	73126	26873	77367	22632	82689	17310	100000	0
6	0.1470	84676	35323	88917	31082	93550	26449	120000	0
7	0.029	96216	43783	100466	39533	104911	35088	116518	23481
8	0.029	107752	52247	112001	47998	116451	43548	126498	33501

Table 18. Water allocation for expected flow with critical flow (CFI) in acre-feet.

Expected Flow Requirement		40% Flow		50% Flow		60% Flow		70% Flow	
State	Probability	Instream Flow	Agriculture	Instream Flow	Agriculture	Instream Flow	Agriculture	Instream Flow	Agriculture
1	0.029	20000	0	20000	0	20000	0	20000	0
2	0.1176	31551	8448	31837	8162	34211	5788	37573	2426
3	0.1764	43103	16896	43472	16527	47304	12695	57573	2426
4	0.3235	56570	23429	62184	17815	67249	12750	77573	2426
5	0.1470	76557	23442	82171	17828	87241	12758	97573	2426
6	0.1470	96555	23444	102169	17830	107239	12760	117573	2426
7	0.029	116555	23444	122169	17830	127239	12760	137573	2426
8	0.029	136555	23444	142169	17830	147239	12760	157573	2426

Table 19. Water allocation for expected flow with critical flow (CF II) in acre-feet.

Expected Flow Requirement		40% Flow		50% Flow		60% Flow		70% Flow	
State	Proba-bility	Instream Flow	Agricul-ture	Instream Flow	Agricul-ture	Instream Flow	Agricul-ture	Instream Flow	Agricul-ture
1	0.029	20000	0	20000	0	20000	0	20000	0
2	0.1176	34211	5758	34211	5788	34211	5788	35380	4619
3	0.1764	34655	25344	47159	12840	36756	23243	58217	1782
4	0.3235	46207	33792	50382	29617	65414	14585	75380	4619
5	0.1470	82751	17248	94213	5786	94213	5786	100000	0
6	0.1470	114241	5758	114211	5788	114211	5788	120000	0
7	0.029	134241	5758	134211	5788	134211	5788	140000	0
8	0.029	154241	5758	154211	5788	154211	5788	160000	0

With application of the five strategies discussed previously, the following results were obtained in the study area. The differences in cost with (EIF 1 and CF 1) and without (EIF 2 and CF 2) the transferability constraint (11) are negligible (Table 14). However, Tables 15 and 19 show that the patterns of water allocation for the corresponding two conditions (EIF 1 and CF 2) are quite different. However, the objective function values between expected instream flow strategies and the critical flow strategies are not significantly different. Moreover, the cost of minimum strategy is substantially higher than other strategies. Therefore, this implies that the instantaneous selected critical flow can be provided with minimum impacts on agriculture. As instream flow requirements are increased from 40 percent to 70 percent of the average flow, the costs increase in an increasing rate because more water is withheld from irrigation use and more senior rights are held for instream flows. Therefore, the minimum flow strategy and the expected flow strategies tend to become similar at higher expected instream flow requirements.

The areas of farm land under irrigation are shown in Figure 5. These areas correspond to the levels of water availability under each of the three alternative strategies for maintaining instream flows at 40 percent, 50 percent, and 60 percent of their average flow levels. Over a wide range of flow levels, EIF and CF strategies give almost flat curves, which indicate a stable situation for maintaining irrigated acreages. On the contrary, minimum flow strategy gives sloping upward curves which shows more land is irrigated at higher streamflows. This is because at lower streamflows a relatively more certain water

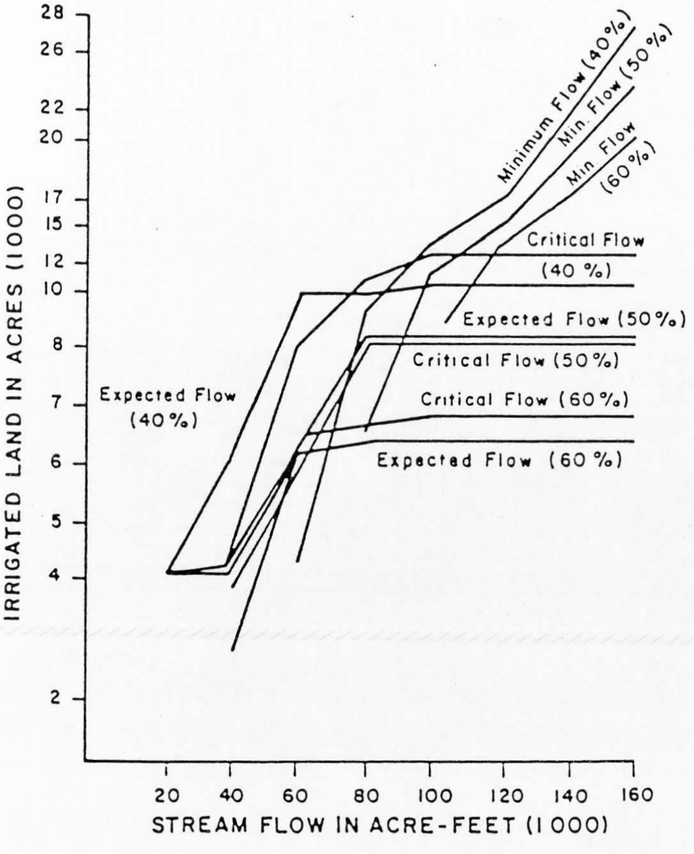

Figure 5. Irrigated land under various strategies.

is reserved for instream purposes and more uncertain water is available at higher flows for irrigation purposes.

Figure 6 shows instream flows under each of the three alternative strategies (EIF 1, CF 1, IF) for 80 percent and 30 percent of the average flow for the irrigation season. The curve of minimum flow strategy, positioned comparatively at a higher level, indicates that this approach requires a larger amount of senior water rights. Therefore, under this assumption much less water is available for agriculture especially during critical periods.

The result of the stochastic linear programming model is that EIF strategy produces a consistently lower cost compared to IF strategy, although this difference in cost narrows at higher level of expected instream flow requirements. However, the EIF strategy has one disadvantage over the CF strategy. Expected instream flow strategy can result in zero instream flows during certain water short periods, which can be prevented by stipulating a crtical instantaneous flow of 20 percent of average flows. This modification causes no appreciable change in the cost of maintaining expected instream flows. Besides, in both strategies (EIF, CF) the irrigated acreage is found to be fairly stable over most ranges of water availability. Therefore, the above discussed results indicate that the critical flow strategy appears to be a promising criterion for providing instream flow.

The decision of selecting the desired level of expected instream flow should be made for any study area after determining the cost of alternative expected instream flow requirement levels. This decision could be more efficiently made if an estimate of expected instream flow benefits is also determined. In the following chapters, a methodology for evaluating demand and benefit function for instream flow recreation is developed.

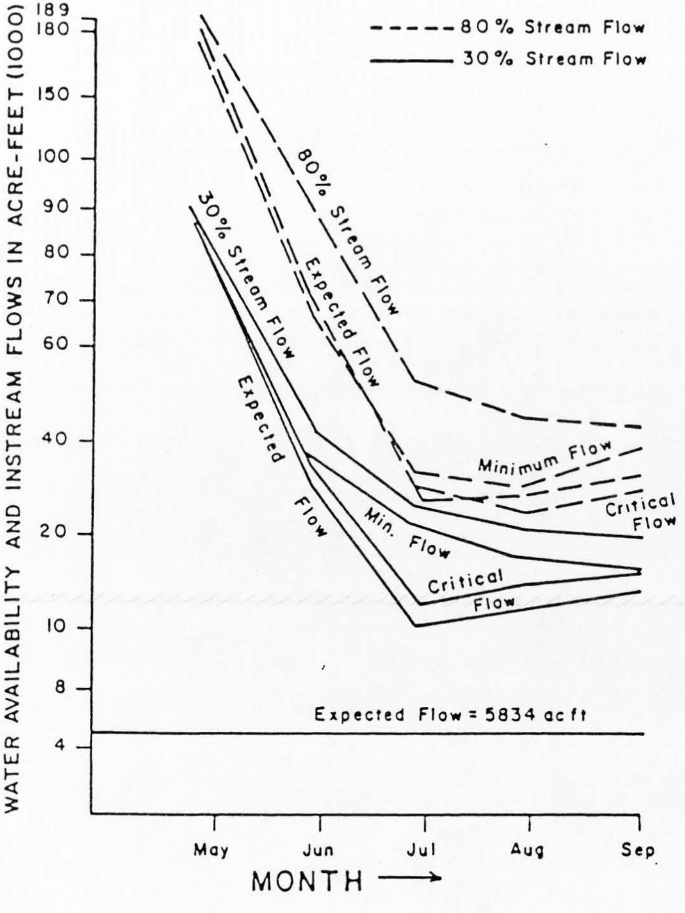

Figure 6. Instream flows under alternative strategies.

ESTIMATION OF INSTREAM FLOW BENEFITS FOR RECREATIONISTS

Several benefit components, such as benefits from stream side and instream recreation, power generation, navigation, waste transport, aesthetics, and the aquatic ecosystem are associated with instream flow. Some of these benefits are extremely difficult to estimate. For instance, to estimate the benefits accruing to nonusers who might be willing to pay to maintain a specific level of streamflow or to estimate aesthetic benefits of those driving along a stream is very difficult. This study attempts to measure the instream flow benefits from recreators data obtained from a streamside survey. Recreation activities of the Logan River, the Blacksmith Fork River, and the Little Bear River are mainly camping, hiking, picnicking, and fishing. According to the stream evaluation map of Utah-1978, these three rivers are considered as high-valued fishery resources.

The area under the appropriate Hicks-compensated demand curve is used to measure the compensated variation, CV, or equivalent variation, EV, definition of benefits of a price change (Layard and Walters 1978). But in practice the area under an ordinary demand curve can be used to approximate these benefits (Cicchetti et al. 1976). In general, the ordinary demand curve can be more easily generated for public or nonmarket goods such as recreation. The demand for water of each instream use can be obtained as a derived demand for each activity. Similarly, the aggregate demand will be the vertical summation of derived demand for instream uses.

Demand Model and Data Compilation

Clawson and Knetsch (1966) define demand for recreation activities as total attendance or use made of the facilities, which refers to the quantities taken at the prevailing recreation opportunity conditions. They also mentioned that raw attendance figures reflect demand, to be sure, but also reflect opportunity or supply as well. In practice, people use outdoor recreation opportunities to the extent to which they believe their satisfactions are exactly equal to the total costs involved. As it was mentioned before, recreationists are assumed to maximize their utility function subject to conventional linear budget constraint:

$$\text{Maximize} \quad U = V(q)$$

$$\text{S.t.} \quad p \cdot q = I$$

The solution to utility maximization is the set of Marshallian demands:

$$q_i = f_i\,(P,\ I)$$

This solution can be substituted back into utility function to get maximum attainable utility. The function is known as the indirect utility function. Since the expenditure and indirect utility functions are inverse, the cost or expenditure function can be solved. Therefore, the derivative of the expenditure function with respect to any price gives the Hicks-compensated demand function for that good (Deaton and Muellhauer 1982).

In much of the recent study, the starting point on system of demand equation has been the specification of a function which is general enough to be a second-order approximation to any arbitrary indirect utility or a cost function. Alternatively, in Rotterdam model a first-order approximation to the demand functions themselves are used. Deaton and Muellhauer (1980) also followed these approaches in terms of generality, but they didn't start from an arbitrary preference ordering. They start their system of demand equation from specific class of preferences which can have an exact aggregation over consumers. These preferences, known as the PIGLOG class, are represented in a cost or expenditure function. The cost function defines the minimum expenditure necessary to have a specific utility level at a given price*. Therefore, it is a function of utility and price vector as:

$$\text{Log } C\ (U,P) = \alpha_0 + \sum_k \alpha_k \log P_k + 1/2 \sum_k \sum_j \gamma_{kj}^* \log P_k \log P_j$$

$$+ U\beta_0\ \pi_k\ P_k^{\beta_k} \qquad (14)$$

where α_i, β_i and γ_{ij}^* are parameters.

In this study the Almost Ideal Demand System (AIDS) is chosen to derive the demand equation. The demand function can be derived directly from Equation 14 which is called AIDS cost function. As mentioned above, the price derivatives of the cost function will be the quantities demanded:

$$W_i = \alpha_i + \sum_j \gamma_{ij} \log P_j + \beta_i\ U\beta_0\ \pi P_k^{\beta_k} \qquad (15)$$

or

$$W_i = f(U, P)$$

---

*For more detail see Appendix of Deaton and Muellhauer (1980).

where

$\gamma_{ij} = 1/2\ (\gamma_{ij}^* + \gamma_{ji}^*)$

After substituting U into Equation 15 by its value, the budget shares W_i will be as a function of price and expenditure:

$$W_i = \alpha_i + \sum_j \gamma_{ij} \log P_j + \beta_i \log (I/P^*) + \varepsilon_i \qquad (16)$$

where P^* is a price index defined as:

$$\log P^* = \alpha_0 + \sum_k \alpha_k \log P_k + 1/2 \sum_j \sum_k \gamma_{kj} \log P_k \log P_j \qquad (17)$$

ε_i = disturbance term related to the demand function

Equation 16 is the AIDS demand function in budget share form. Price, P_j, is defined and calculated like the full price definition, and expenditure, I, is the same as the full income definition in Equation 4. The parameter, β, determines whether goods are luxuries or necessities. With $\beta_i > 0$, W_i will increase as I does, so that good i is luxury. Similarly, if $\beta_i < 0$, good i is a necessity. Parameter γ_{ij} measures the change in the ith budget share following a 1 proportional change in P_j with (I/P^*) constant.

To obtain necessary data for statistical estimation of demand equation, a direct interview of households is about the only feasible way. Before a demand schedule can be constructed an expression is needed of price or money outlay per unit of recreation consumed. The cost of the whole recreation experience can be used for this purpose. These costs will be made up of many items, such as cost of transportation, food for that recreation experience, entrance fees, recreation equipment, and recreationists opportunity cost. These are the added expenditures which the individual or family must make in order to take part in the whole recreation experience. These are the prices per unit of recreation experience.

The site interviews conducted in three instream recreation sites provided the following information required for estimating demand equation (see Appendix A for the sample questionnaire):

1. Number of days the household spent at recreation site (part I questions #2 and #3).
2. Expenditure or the cost of recreation experience incurred that were specific to that trip (parts III and IV).
3. Family income (part V questions #2 and #3).
4. Mileage driven for that specific trip (part I question #1).

Item 1 forms the basis of quantity measures for estimating the demand equation. Data obtained from these items are used to calculate budget share of good (W_i) in the demand equation (Table 20):

$$W_{ij} = \frac{P_{ij} X_{ij}}{I_{ij}}$$

where

i = 1, 2, 3 (site)

j = 1, 2, ..., 12 (group)

P_{ij} = money outlay per unit of recreation consumed which is 24 hours or a day of recreation in this study

I_{ij} = family full income of group j at site i

$X_{ij} = \overset{*}{X}_{ij} D_L$ = estimated total number of days recreationists of group j spent at site i per capita (Table 21)

$\overset{*}{X}_{ij}$ = number of days recreationists spent at site i

Table 20. Calculated budget share of good for each group by site.

Group	Site		
	Logan, W_1	Blacksmith, W_2	Little Bear, W_3
1	W_{11} = 0.000242	W_{21} = 0.000080	W_{31} = 0
2	W_{12} = 0.000128	W_{22} = 0.000052	W_{32} = 0.000010
3	W_{13} = 0.000026	W_{23} = 0.000009	W_{33} = 0.000001
4	W_{14} = 0.000007	W_{24} = 0.000001	W_{34} = 0.000001
5	W_{15} = 0.00012	W_{25} = 0.000029	W_{35} = 0.000005
6	W_{16} = 0.000096	W_{26} = 0.000062	W_{36} = 0.000007
7	W_{17} = 0.000032	W_{27} = 0.000017	W_{37} = 0.000011
8	W_{18} = 0.000005	W_{28} = 0.000001	W_{38} = 0.000002
9	W_{19} = 0.000069	W_{29} = 0.00001	W_{39} = 0
10	W_{110} = 0.000038	W_{210} = 0.000051	W_{310} = 0.000007
11	W_{111} = 0.000037	W_{211} = 0.000009	W_{311} = 0.000007
12	W_{112} = 0.000014	W_{212} = 0.000007	W_{312} = 0.0000003

$$W_1 = \frac{(X_{Lo_1} + X_{Lo_2})[(P_{Lo_1} + P_{Lo_2})/2]}{[(I_{Lo_1} + I_{Lo_2})/2]}$$

$$W_2 = \frac{(X_{BL_1} + X_{BL_2})[(P_{BL_1} + P_{BL_2})/2]}{[(I_{BL_1} + I_{BL_2})/2]}$$

$$W_3 = \frac{X_{LB} \cdot P_{LB}}{I_{LB}}$$

Lo_1 = Logan 1

Lo_2 = Logan 2

BL_1 = Blacksmith 1

BL_2 = Blacksmith 2

LB = Little Bear

Lo_1, Lo_2 = Site 1 as i = 1

BL_1, BL_2 = Site 2 as i = 2

LB = Site 3 as i = 3

Table 21. Number of days of recreation per capita by sites.

Group	Site: Logan, X_1	Blacksmith, X_2	Little Bear, X_3
1	$X_{11} = 0.043$	$X_{21} = 0.0092$	$X_{31} = 0$
2	$X_{12} = 0.033$	$X_{22} = 0.0123$	$X_{32} = 0.003$
3	$X_{13} = 0.0042$	$X_{23} = 0.0022$	$X_{33} = 0.0003$
4	$X_{14} = 0.0008$	$X_{24} = 0.00008$	$X_{34} = 0.0002$
5	$X_{15} = 0.0326$	$X_{25} = 0.0095$	$X_{35} = 0.0017$
6	$X_{16} = 0.0323$	$X_{26} = 0.0215$	$X_{36} = 0.0037$
7	$X_{17} = 0.0122$	$X_{27} = 0.0042$	$X_{37} = 0.0037$
8	$X_{18} = 0.0015$	$X_{28} = 0.0002$	$X_{38} = 0.0006$
9	$X_{19} = 0.029$	$X_{29} = 0.00204$	$X_{39} = 0$
10	$X_{110} = 0.015$	$X_{210} = 0.0169$	$X_{310} = 0.0038$
11	$X_{111} = 0.015$	$X_{211} = 0.0039$	$X_{311} = 0.0030$
12	$X_{112} = 0.0051$	$X_{212} = 0.00029$	$X_{312} = 0.00009$

$X_1 = Lo_1 + Lo_2$

$X_2 = BL_1 + BL_2$

$X_3 = LB$

$$D_L = \hat{X}_{1j} + \hat{X}_{2j}$$

$$\hat{X}_{1j} = \frac{(G_{1j})\ (\text{total number of weekends of season})}{\text{total number of weekends of survey}}$$

$$\hat{X}_{2j} = \frac{(G_{2j})\ (\text{total number of weekdays of season})}{\text{number of weekdays of survey}}$$

$$G_{1j} = \frac{C_k \cdot S_k^{\ ij}}{S_k^{\ i}}$$

$$G_{2j} = \frac{C_D \cdot S_D^{\ ij}}{S_D^{\ i}}$$

$C_k^{\ i}$ = total number of cars in weekend in each site

$C_D^{\ i}$ = total number of cars in weekday in each site

S_k^{ij} = total number of surveys in weekend in each site for each group

S_D^{ij} = total number of surveys in weekday in each site for each group

S_k^{i} = total number of survey in weekend in each site

S_D^{i} = total number of survey in weekday in each site*

The next step is to calculate full price for each site using data obtained from items 2, 3, and 4. The full price as defined before is (Table 22)

$$P_{ij} = \sum_k P_k a_{kji} + Wt_{ij} = (PA + Wt)_{ij} \tag{18}$$

where

$$Wt_{ij} = \{[(R03/168)(1/3)]\ (U_2)\}_{ij}$$

R03 = monthly household salary

U_2 = V_2 - hours of nighttime at recreation site

V_2 = number of hours at recreation site

$$PA = PD + [(V_1 \cdot 2)/W06]\ (1.20)$$

V_1 = distance from home to site in miles

W06 = vehicle gas consumption (miles per gallon)

$$PD = [W08 + (W07)(0.3)] + (\sum_{e=1}^{12} (PE_e/t_e))(1/V6) + (W09)(F)$$

W08 = cost of recreation equipment for that trip (dollars)

W07 = cost of food in dollars

PE_e = cost of durable equipment used in dollars

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*For all of the data explained in this part refer to Appendix B.

Table 22. Full price of each group per day by site.

Group	Site: Logan P_1	$\ln P_1$	Blacksmith Fork P_2	$\ln P_2$	Little Bear P_3	$\ln P_3$
1	42.7	3.75	51.5	3.94	0	0
2	44.4	3.79	42.0	3.74	37.0	3.81
3	55.3	4.01	30.2	3.41	38.4	3.65
4	70.7	4.26	76.5	4.34	62.4	4.14
5	80.2	4.39	64.9	4.17	71.8	4.27
6	57.9	4.06	65.7	4.19	39.8	3.68
7	57.3	4.05	83.8	4.43	55.9	4.02
8	75.0	4.32	81.4	4.40	72.3	4.28
9	91.5	4.52	190.7	5.25	0	0
10	93.0	4.53	104.6	4.65	80.5	4.39
11	89.9	4.50	89.1	4.49	91.8	4.52
12	103.1	4.64	98.2	4.59	113.4	4.73

$P_1 = (P_{Lo_1} + P_{Lo_2})/2$

$P_2 = (P_{BL_1} + P_{BL_2})/2$

$P_3 = P_{LB}$

t_e = life span of equipment e (data were obtained from Outdoor Recreation Center of Utah State University)

W09 = fee for use of that site per day in dollars

F = number of days at recreation site

V_6 = number of times the trip was taken

Based on this information, the full price was calculated for each sample and it was averaged for the group from each zone. The last variable to calculate is full income which was defined as $I = N + WT_w$ and necessary data for this calculation for each site were obtained by item 3 (Table 23).

There are two issues over the role of time cost in estimation of recreation benefit. The first one is, how much of the time involved

Table 23. Full income of each group by site.

Group	Site		
	Logan, I_1	Blacksmith Fork, I_2	Little Bear, I_3
1	7,574.32	9,399.04	0
2	11,406.25	10,000.0	10,625.0
3	8,854.17	7,524.75	10,000.0
4	8,131.25	8,750.0	11,666.67
5	22,648.81	21,388.89	22,500.0
6	19,444.45	22,625.0	20,833.33
7	22,083.33	20,274.51	19,166.67
8	23,833.33	20,833.33	23,611.11
9	38,538.96	39,000.0	0
10	36,250.0	35,000.0	43,333.33
11	36,770.83	40,000.0	40,000.0
12	38,080.36	36,937.50	39,166.67

$I_1 = (I_{Lo_1} + I_{Lo_2})/2$

$I_2 = (I_{BL_1} + I_{BL_2})/2$

$I_3 = I_{LB}$

is costly and should be included in calculation of full price, and second issue is, what is the appropriate value of time spent in the recreation site. Wilman (1980) and Becker (1965) pointed out that the total time spent in an activity is costly and the appropriate value of this time is its opportunity cost; in other words the value of time in its best alternative use. Cesario (1976), after reviewing several studies, concludes that the appropriate value of recreation time is approximately one-third the average wage rate.

As McConnell (1975) mentioned in his discussion of the value of time, understanding and selecting appropriate opportunity cost of total time is important for accurate measurement of the economic value of outdoor recreation. In this study, after carefully considering all all possible recommendations, the value of recreation time or its opportunity cost was decided to be approximately one-third of the average wage rate for the recreationist, and only day time hours of each day was considered as recreation time.

Demand curve derivation or specifically full price estimation requires determination of the fraction of the total travel distance from home to the recreation site. For the visitor living nearby (less than 120 miles), this fraction of total travel distance is actually equal to total distance between home and recreation site. For the visitor living several hundred miles away (above 120 miles) only small fraction of total travel distance was considered in calculation.

A large number of people, unlike a single individual, will have a predictable and measurable reaction to an outdoor recreation opportunity. If we can measure the demand curve for a large group of people, then it is probable that another large group, chosen with more or less similar characteristics to the first group, will respond in a similar fashion to costs and other characteristics of the recreation experience. This assumption is basic to demand curve analysis in this study. Since one single individual cannot be observed at the same time in different sites, therefore, a group of recreationists with similar characteristics were interviewed at different sites, at the same time in estimating multisite demand function. The data used in this evaluation were gathered by the survey which was conducted on site for 12 days in summer of 1982. These 12 days included four weekdays and eight weekend days. The total recreation season was estimated to be 93 days of which 67 days were weekdays and 26 days were weekends. The number of groups surveyed on the four weekdays and on the eight weekends for each reach were recorded (Table B-2, Appendix B). This information plus number of cars at each site were used to estimate total visits for the season adjusted for weekdays, weekends and unsampled visitors on survey days (Tables B-3, B-4, B-5, and B-6, Appendix B). The samples were grouped using four zones and three income classifications. The four zones classification based on average distances of 20, 40, 60 and over 60 miles from the site were defined in such a way that population could be estimated using census district maps. A statistical computer package (SPSS) was used to analyze the data obtained from survey for developing a recreation multi-site demand function. The demand estimation procedure is discussed in the next section.

Econometric Estimation and Model Results

In this section recreationists demand equation which was developed before is estimated. The objective is to estimate the structural demand for three recreation sites (Morey 1981) from the cross-sectional household data. The next step will be to estimate consumer surplus corresponding to various levels of instream flow. The AIDS cost function is used to derive a demand function which is in the semilog form. Selection of an appropriate functional form is very important. As Ziemer et al. (1980) pointed out that, different functional form can produce dramatically different consumer surplus estimates. He also carefully tested the specification problem involving the selection of an appropriate functional form. He compared three kinds of functional forms namely, linear, quadratic, and semilog. The conclusion was that semilog specification is the appropriate functional form for warm-water fishing in Georgia. Even though this conclusion might be different for Utah recreation sites, the semilog form was considered as an appropriate functional form in this study too. Deaton and Muellhauer (1982) discussed different models of demand function and their specifications in a whole chapter of their "Economics and Consumer Behavior" book. They identified a new model of demand as Almost Ideal Demand System (AIDS) which preserves the generality of both Rotterdam and Translog models. Also, they added that an important feature of this function from an econometric viewpoint is that it is close to being linear. These models can be estimated equation by equation using ordinary least squares, since P^* is defined as a linearly homogeneous function of the individual prices. Thus P^* would be approximately proportional to appropriately defined price index, such as the one used by Stone, the logarithm of which is given by $\sum_k W_k \log P_k$ (Deaton and Muellhauer 1980). This index was calculated directly before estimation, so that Equation 16 becomes straightforward to estimate. Estimation procedure started by applying ordinary least square (OLS) to each equation of the form:

$$W_i = \alpha_i + \sum_j \gamma_{ij} \log P_j + \beta_i \log M + \varepsilon_i \qquad (19)$$

where

$M = I/P^*$ (Table 24) and ε_i are disturbances with usual properties. Applying OLS method to estimate multiple-side demand parameter (Equation 19) might encounter some econometric problems since assumptions of nonautocorrelation might be violated. To avoid these econometric problems, the three demand equations were estimated using Generalized Least Square (GLS) method. Since variance-covariance matrix of disturbances are not known, the estimation is done in a two-stage procedure based on Zellner's SUR technique.

Table 24. Estimated M_i for each group by site.

Group	Site		
	Logan, M_1	Blacksmith Fork, M_2	Little Bear, M_3
1	7,565	9,387	0
2	11,397	9,992	10,617
3	8,852	7,523	9,998
4	8,130	8,749	11,666
5	22,633	21,374	22,484
6	19,431	22,609	20,819
7	22,077	20,269	19,161
8	23,832	20,832	23,610
9	38,524	38,985	0
10	36,234	34,984	43,314
11	36,762	39,990	39,990
12	38,077	36,934	39,163

$M_i = I_i/P^*$

First stage: In order to define the variance-covariance matrix of disturbances, estimated value of the disturbance terms were obtained by applying OLS on Equation 16. The estimated form of this equation is:

$$\hat{W}_i = \hat{\alpha}_i + \sum_j \hat{\gamma}_{ij} \log P_j + \hat{\beta}_i \log M \qquad (20)$$

where

$i = 1, 2, 3$

The empirical form of above equations are:

$$\hat{W}_1 = 38.83 - 9.13 \log P_1 - 6.57 \log P_2 - 2.85 \log P_3 + 4.52 \log M_1 \qquad (21)$$

$$(1.32) \quad (0.82) \qquad (0.90) \qquad (2.12)^* \qquad (0.91)$$

$R^2 = 0.639$

F-statistic = 3.10

*Indicates that the estimated parameters are significant at 10 percent level of significance.

$$\hat{W}_2 = 12.18 - 8.08 \log P_1 - 2.23 \log P_2 - 0.47 \log P_3 + 3.64 \log M_2 \quad (22)$$

(0.93) (1.66)* (0.67) (0.81) (1.62)*

$R^2 = 0.55$

F-statistic = 2.16

$$\hat{W}_3 = 1.59 - 1.22 \log P_1 - 0.75 \log P_2 - 0.61 \log P_3 + 0.35 \log M_3 \quad (23)$$

(0.99) (1.96)* (2.21)* (1.20) (1.69)*

$R^2 = 0.703$

F-statistic = 4.14**

The numbers inside the parentheses indicate t-statistic for the relevant parameters.

The residuals can be estimated for each observation group as:

$$W_i - \hat{W}_i = \hat{\varepsilon}_i$$

A Fortran program was developed for estimating the contemporaneous variance-covariance matrix of the disturbance terms across equations based on Zellner's SUR technique.

Stage two: The next step is to apply ordinary least-squares on Equation 24 with premultiplied observation matrix. Equation 16 in matrix notation with transformed observation would be written as:

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*Indicates that the estimated parameters are significant at 10 percent level of significance.

**Indicates that the estimated vector of the parameters are significant at 5 percent level of significance.

$$PW_i = P X \beta + P\varepsilon \tag{24}$$

where

$$X = [1 \ \log P \ \log M]$$

The three estimated demand equations with GLS estimators are:

$$\hat{W}_1 = 1.62 - 21.17 \log P_1 - 2.41 \log P_2 - 0.92 \log P_3 + 10.89 \log M \tag{25}$$

(0.81) (3.86)* (0.79) (1.31) (3.85)*

$R^2 = 0.87$

F-statistic = 11.31**

$$\hat{W}_2 = 0.73 - 12.92 \log P_1 - 3.93 \log P_2 - 0.38 \log P_3 + 7.56 \log M \tag{26}$$

(0.81) (6.72)* (2.58)* (1.12) (6.95)*

$R^2 = 0.91$

F-statistic = 18.42**

$$\hat{W}_3 = 0.12 - 0.54 \log P_1 - 0.45 \log P_2 - 0.75 \log P_3 + 0.38 \log M_3 \tag{27}$$

(1.26) (3.9)* (3.82)* (6.42)* (7.86)*

$R^2 = 0.93$

F-statistic = 24.27**

The numbers in parentheses indicate t-statistic for the relevant parameters. The resulting vector of estimated parameters from three different econometric methods of demand estimation is shown in Table 25. Column 2 in this table shows the value of parameters when OLS is

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*Indicates that the estimated parameters are significant at 10 percent level of significance.

**Indicates that the estimated vector of the parameters are significant at 5 percent level of significance.

Table 25. Comparison of the estimated parameters using different estimation methods.

Parameters	Estimated Parameters Using OLS 1	Estimated Parameters Using GLS Unrestricted 2	Estimated Parameters Using GLS Restricted 3
α_1	38.83	1.62	1.54
α_2	12.18	0.73	0.22
α_3	1.59	0.12	0.62
γ_{11}	-9.13	-21.17*	-21.93*
γ_{12}	-6.57	-2.41	-4.06*
γ_{13}	-2.85*	-0.92	-0.96*
γ_{21}	-8.08*	-12.92*	-4.06*
γ_{22}	-2.23	-3.93*	-0.52
γ_{23}	-0.47	-0.38	0.62*
γ_{31}	-1.22*	-0.54*	-0.96*
γ_{32}	0.75*	0.45*	0.62*
γ_{33}	-0.61	-0.75*	-0.62
β_1	4.53	10.89*	11.97*
β_2	3.64*	7.56*	1.52*
β_3	0.35*	0.38*	0.42*

*Indicates that the estimated parameters are significant at 10 percent level of significance.

applied. The result of using Zellner's procedure without restriction on seemingly unrelated regression equations is shown in column 3 and the 4th column shows the parameters when Zellner's SUR technique with imposing symmetric condition was used. In the case of applying Zellner's SUR technique with imposing symmetric condition the value of $R^2 = 0.83$ and F-statistic = 9.95.

As it was discussed before if $\beta_i > 0$ good i is a luxury good. Since in all three methods $\beta_1 > 0$, $\beta_2 > 0$, $\beta_3 > 0$ the implication is that recreation is a luxury good. Since $\gamma_{12} < 0$ and $\gamma_{13} < 0$ in all three methods of estimation (Table 25), sites 2 and 3 (Blacksmith Fork and Little Bear) are not good alternate sites for Logan or site 1. On the contrary, Blacksmith Fork and Little Bear (sites 2 and 3) are good alternate sites for each other, because $\gamma_{32} > 0$ and in the third method of estimation γ_{23} is also positive.

To check differences in estimated demand due to site quality or characteristic such as water quality, which are not explained by the model or by the estimators, Table 26 was arranged using the data obtained from the survey. According to Table 26, site characteristic evaluations are not significantly different in three sites in this study area. Composite of site characteristics (Table 26) range from 6.5 to 7.28, and the only item in the table which makes this small difference is the evaluation of facilities. The site characteristics on demand function can be balanced by considering the entrance fee paid by users. In other words, the argument is that as Little Bear has lower evaluation score for facilities than Logan site, it has lower fee or no fee to use the site. Therefore, in summary, higher fee with higher evaluation of facilities score is as attractive as lower fee

Table 26. Site characteristic evaluation.

Characteristic	Site		
	Logan	Blacksmith Fork	Little Bear
Distance	7.82	7.90	7.3
Privacy	7.24	7.60	7.5
Facilities	6.86	5.05	3.0
Landscape	8.52	8.40	7.3
Insects	5.31	4.75	4.9
Water	8.56	8.40	8.4
Fishing Suitability	6.63	6.35	6.8
Composite	7.28	6.92	6.5

10 = perfect

1 = poor

with lower evaluation score. Thus, except for flow level (in summer 1982, higher flow level makes no difference in flow level) there was no significant site characteristic differences between the three sites in the study area.

Theoretical and Empirical Estimates of Recreation-Instream Flow Benefits

In the previous section, the demand function for recreation activity at current flow levels in three sites was estimated. Any change in flow level affects visitation rate and consequently the demand function (Sutherland 1982). Table 7 indicates the change of visitation as a function of flow level variation. For instance, this table shows the number of recreationists who will not visit the sites when the flow levels drop to less than 50 percent of flows in the summer of 1982. This information was used to derive the modified estimated demand functions at each flow level, by quality parameter f_i, as a function of flow and, therefore, incorporating the effect of site quality changes in terms of flow levels.

An improvement in water quality or quantity produces an outward shift in the demand curve or visa-versa (Vaughan et al. 1982). The area between the initial and new curve represents the benefits of improved water quantity or quality. Therefore, it is essential to derive the demand curve to measure the benefit of improved instream flow quantity. One way to derive the new modified demand curve q_i^* is to introduce quality parameters f_i directly into the utility function:

$$U = v(f_i q_i) \tag{28}$$

where f_i depends upon the observed specifications of the goods. Corresponding to utility function (Equation 28) is a cost function;

$$X = C(U, Pf) \tag{29}$$

This implies that the demand function $q_i^* = f_i q_i\ (X, P)$ which corresponds to the utility function $U = v(f_i q_i)$.

In this study, quality parameter f_i is a function of the specification variable, flow level (Fg). The cost function would be modified as:

$$\log C^*(U,P) = \alpha_0 + \sum_k \alpha_k^* \log P_k + 1/2 \sum_k \sum_j \gamma_{kj}^* \log P_k \log P_j + \beta_0 U \pi_k P_k^{\beta_k^*} \tag{30}$$

where

$\alpha_k^* = f_k \alpha_k$ or $\alpha_i^* = f_i \alpha_i$

$\gamma_{kj}^* = f_k f_j \gamma_{kj}$

$\beta_k^* = f_k \beta_k$

Accordingly, the modified compensated demand and Marshallian demand function, to include the effect of instream flow change as a quality measure of recreation, would be;

$$\frac{\partial \log C^*}{\partial \log P_i} + W_i^* = \alpha_i f_i + \sum_j \gamma_{ij} f_i f_j \log P_j + f_i \beta_i U \beta_0 \pi_k P_k^{f_k \beta_k} \quad (31)$$

By substituting indirect utility function in compensated demand function (Equation 31), the modified ordinary or Marshallian demand is:

$$W_i^* = \alpha_i f_i + \sum_j \gamma_{ij} f_i f_j \log P_j + f_i \beta_i \log M \quad (32)$$

where

$$W_i^* = W_i f_i$$

The compensated variation or benefit obtained by recreationists from changing instream flow level can be defined as:

$$B_s = C^*(\hat{U}, P^*) - C(\hat{U}, P)$$

To be able to define B_s the following steps are taken. Define cost functions as;

$$\log C = \alpha_0 + Y_1$$

$$\log C^* = \alpha_0 + Y_2$$

where

$\log C$ = cost function at 1982 flow level

$\log C^*$ = modified cost function

then

$$\ln C^* - \ln C = \alpha_0 + Y_2 - \alpha_0 - Y_1$$

$$\ln(C^*/C) = Y_2 - Y_1 \quad (33)$$

taking antilog on both sides:

$$C^*/C = e^{(Y_2 - Y_1)} \quad (34)$$

From Equation 34 B_s can be defined as

$$B_s = I\ (e^{(Y_2-Y_1)} - 1) \tag{35}$$

This equation measures the obtained benefit from changing instream flow level.

Instream Flow Effects on Visitation

In order to measure B_s the quality parameter f_i has to be defined and be estimated. In the process, some specific classification has been made to estimate the instream flow effects on visitation. Define f_i as;

$$\frac{V_g^{\ k}}{V_8^{\ k}} = f(Fg)^k = \frac{1}{1 + e^{-(\xi + \rho F_g)}} \tag{36}$$

where $f(Fg)^k$ is between 0 and 1. Therefore, the function f(Fg) reduces the visitation rate as Fg becomes smaller. Moreover, $f(F_8) = 1$, as F_8 corresponds to 100 percent of 1982 flow for which data were collected. For F_1, the instream flow is zero, and $f(F_1) = 0$ which implies no visitation. In the survey for demand estimation, the visitors were asked to indicate the percent of current flow below which they would not visit the site. These data are used to obtain hypothetical visitation at various Fg's which were compiled for two zones in each site. The plot of these data indicates that the visitation rate increased from Fg = 0 at an increasing rate up to about 50 percent of 1982 flows and it increased at an almost decreasing rate from 50 percent and up. Therefore, a logistic function, Equation 36 appeared to provide the best fit.

The classification of visitation rate at various flow levels specified two zones based on average distances of 40 and over 40 miles from the site. This classification was used to estimate the effect of hypothetical changes in instream flow on visitation rates. In the question of indicating the percentage of current flow below which the visitors would not visit the site, the percentages given as options were 0, 10, 25, 33, 50, 67, 75, and 100. Since 1982 had a much higher flow level than average flows (Table 27), the maximum flow was limited to the present flow level (100 percent). Table 28 shows the estimated number of visitation days for various flow levels as a percentage of the number of visitation days at 100 percent of the flow for the two defined zones.

To estimate the logistic function defined in Equation 36, data from Tables 27, 28, and 29 were used. Moreover, for estimating purposes, this function was rewritten in stochastic form as:

$$\log \frac{f(Fg)}{1 - f(Fg)} = \xi + \rho Fg + \qquad (37)$$

where the stochastic disturbance, is assumed to be random normal with zero mean and constant variance.

$\varepsilon \sim N(0, \quad ^2)$

The three estimated equations for each site are,

$$\log \frac{f_1(Fg)}{1 - f_1(Fg)} = \underset{(9.56)}{-\,2.96} + \underset{(11.16)}{0.03\ Fg} \qquad (38)$$

$R^2 = 0.899 \qquad F = 124.5$

Table 27. Streamflow volumes at different probabilities of occurrence in acre-feet.

State	Logan: Probability of Occurrence	Logan: Seasonal Total	Blacksmith: Probability of Occurrence	Blacksmith: Seasonal Total	Little Bear: Probability of Occurrence	Little Bear: Seasonal Total
1	0.037	100,000	0.037	50,000	0.074	20,000
2	0.259	150,000	0.259	80,000	0.148	30,000
3	0.074	170,000	0.222	100,000	0.148	40,000
4	0.296	190,000	0.259	120,000	0.111	50,000
5	0.074	210,000	0.074	140,000	0.333	70,000
6	0.185	250,000	0.037	160,000	0.111	90,000
7	0.074	300,000	0.074	180,000	0.074	100,000

Table 28. Data for estimating f(Fg) function.

Fg	Logan: Zone 1 (40 miles) f(Fg)x100	Logan: Zone 2 (over 40 miles) f(Fg)x100	Blacksmith: Zone 1 (40 miles) f(Fg)x100	Blacksmith: Zone 2 (over 40 miles) f(Fg)x100	Little Bear: Zone 1 (40 miles) f(Fg)x100	Little Bear: Zone 2 (over 40 miles) f(Fg)x100
0	4.62	0.90	3.06	0.064	0	0
10	14.43	5.80	6.63	3.07	0.05	0
25	35.83	14.4	9.66	8.64	0.05	0
33	55.98	28.9	21.14	16.79	40.71	7.09
50	69.86	61.4	65.55	58.41	60.87	65.2
67	82.78	76.5	80.2	75.91	78.0	84.2
75	87.98	81.7	82.90	80.35	84.6	89.9
100	100.0	100.0	100.0	100.0	100.0	100.0

Table 29. Seasonal average flows in cfs (Fg).

Percent of 1982 Flows	Logan F*	Logan F	Blacksmith F*	Blacksmith F	Little Bear F*	Little Bear F
0 (1)	0	0	0	0	0	0
10	23.06	22.02	13.0	12.67	9.75	8.08
25	57.65	55.05	32.5	31.68	24.38	20.20
33	76.1	72.67	42.9	41.82	32.18	26.66
50	115.3	110.10	65.0	63.36	48.76	40.40
67	149.89	147.53	87.1	84.90	65.33	54.14
75	172.95	165.15	97.5	95.04	73.13	60.6
100 (8)	230.6	220.2	130.0	126.72	97.51	80.8

F* = Flow data for water year of 1982 (from State Engineer's Office).

F = Flow data for 3 months of summer 1982.

$$\log \frac{f_2(Fg)}{1 - f_2(Fg)} = -\underset{(9.21}{4.19} + \underset{(9.05)}{0.06\ Fg} \qquad (39)$$

$R^2 = 0.86$ $\qquad$ $F = 81.9$

$$\log \frac{f_3(Fg)}{1 - f_2(Fg)} = -\underset{(2.7)}{2.91} + \underset{(3.07)}{0.06\ Fg} \qquad (40)$$

$R^2 = 0.40$ $\qquad$ $F = 9.45$

The values in parentheses are the corresponding t values. The F ratio and the R^2 for Equations 38, 39, and 40 are written under each equation.

Estimating Benefits and Analysis of Results

The benefit equation (Equation 35) was used to compute compensating variation, CV, for each site under different conditions. The quality parameters f_i which depends upon the observed specification (flow level) were estimated by Equations 38 to 40. These parameters were used to modify the cost function and the demand functions. The results obtained from estimating multiple-site demand functions were used in Equation 35. The benefit equation was estimated for various instream flows expressed as percentage of 1982 flows, using data from Table 29, and for expected instream flow level with the probability of occurrence from Table 27. The results are shown in Table 30 for different percent of each flow level. In both cases the total benefit of recreationists for 50 percent of flow level were so small that it was virtually equal to zero. Comparison of expected instream flow and current flow for 25 and 20 percent of flow levels, in Table 30, indicate that the higher flow level in 1982 drastically changed the response of visitors. Therefore, the figures under current flow might not be a true indication of the recreationist's benefit.

B_s was also estimated for 10 and 20 percent of expected instream flow, since these two percentages, especially 20 percent, are usually considered as the critical flow level. The result for each individual site is shown in Table 31. This table shows CV values for 10 and 20 percent of instream flow, assuming the reduction of flow occurs only in one site. Since the survey was done only during afternoons and evenings visitors in the morning and night hours and visitors not present during the survey hours were not accounted for in the vehicle count. Moreover, the CV values were estimated for each site, at different flow levels, using limited raw data collected from the survey conducted only in a short period of summer 1982. Therefore, the value of B_s might be underestimated.

Table 30. Estimated total benefits of instream flow at different flow levels (dollars).

Site	Reduced Flow Level					
	50 percent		25 percent		20 percent or less	
	Expected Instream Flow	Current Flow	Expected Instream Flow	Current Flow	Expected Instream Flow	Current Flow
Logan	0	0	869,715	39,395	1,903,884	151,472
Blacksmith Fork	0	0	868,402	41,242	1,899,608	151,138
Little Bear	0	0	773,637	36,506	1,538,451	134,819

Table 31. Estimated B_s by site at expected instream flow (dollars).

Site	Reduced Flow Level at Each Site					
	20 percent			10 percent		
	Lo	BL	LB	Lo	BL	LB
Logan	399,952	-	-	875,496	-	-
Blacksmith Fork	-	196,699	-	-	857,061	-
Little Bear	-	-	123,283	-	-	826,806

In order to do the cost-benefit analysis or to provide information for policy-making with respect to instream flows, benefits of all instream uses as a function of flow are needed. In this study only the benefits resulting from recreation are quantified (Table 32). If information on total benefits could be computed, then the quantitative information for policy-making would be improved. Some of the missing information could be listed as:

1) Changes in the relative land and home values adjacent to the river, as a function of flows.
2) Benefits of preventing irreversible damages to the aquatic ecosystem (Gosse and Helm 1979, Smith 1979).
3) The demand growth for instream flow as a result of increased population and income.
4) Extreme values.

The items listed above do not comprise a comprehensive list. However, the above information plus estimated benefit through the benefit equation are needed for cost-benefit analysis.

Table 32. Total benefits of instream flows.

Strategy	Site: Logan	Blacksmith	Little Bear
1	2,806 (0.29)	-	-
2	-	36,772 (6.97)	-
3	-	-	106,059 (8.9)
4	128,802 (12.9)	-	-
5	-	97,412 (11.5)	-
6	-	-	152,747 (15.98)
7	805,414 (69.27)	-	-
8	-	487,614 (74)	-
9	-	-	242,416 (30.96)

Strategy 1 = 35 percent flow for Logan and 50 percent flow for others.
Strategy 2 = 35 percent flow for Blacksmith River and about 50 percent flow for others.
Strategy 3 = 35 percent flow for Little Bear, 35 percent for Logan, and 50 percent for Blacksmith River.
Strategy 4 = 30 percent flow for Logan and 50 percent flow for others.
Strategy 5 = 30 percent flow for Blacksmith River and the rest as above.
Strategy 6 = 30 percent flow for Little Bear River and the rest as above.
Strategy 7 = 25 percent flow for Logan River and almost 50 percent flow for others.
Strategy 8 = 25 percent flow for Blacksmith River and the rest as above.
Strategy 9 = 25 percent flow for Little Bear River and the rest as above.

Values in parentheses are corresponding marginal benefits.

COST-BENEFIT ANALYSIS

This study provides a methodology for cost-benefit analysis, by estimating cost and only recreationists' benefits from the maintained instream flow. In the first section, the five strategies were evaluated for minimum cost decision rule. Using the benefit function for instream flow B_s, developed in the previous section, the expected benefits can be calculated for any one of the five strategies corresponding to different expected instream flow levels for the purpose of cost-benefit analysis. The expected benefits would be summation of all components of instream flow benefits obtained at different instream flow levels multiplied by corresponding probabilities. Furthermore, the methodology developed in this study can be used to compute the total expected benefits (agricultural benefits and instream flow benefits) for each expected instream flow level and each strategy. Subsequently, the strategy with maximum total expected benefits should be selected as a preferred strategy and the corresponding decision rule such as the one in Tables 15-19 be followed.

In any selected procedure for cost-benefit analysis or for maximizing social benefit of water allocation, all components of costs and benefits as a function of flow are needed. In this study only the foregone value of agricultural output is considered as an expected cost of maintaining instream flow and the foregone value of other water uses such as hydropower and municipal are not included. As some of the missing information listed before indicates, the estimated recreation benefit as a measure of total benefits from alteration of instream flow is underestimated. Collection of all data and information necessary for proper measurement of total costs and benefits, although not impossible in some cases, is prohibitly costly and difficult. However, the methodology developed in this study is capable of computing all the components of benefits and costs of maintaining instream flow.

The social benefits can be maximized by efficient allocation of available water. This is possible when the sum of marginal benefits for instream uses is equal to the marginal benefits of offstream uses. Considering the above discussions, an attempt is made to determine the optimum level of instream flow for Blacksmith Fork River. Table 33 shows the value of marginal benefit for agriculture as the only off-stream use and marginal benefit for recreationists (instream uses) at different percents of flow level for both sectors. To measure marginal benefit for the agriculture sector, the information on maximum farmer's income for EIF strategy with expected flow level is used (Table 13). Marginal benefit for instream use is quantified under two different assumptions. First, the change of instream flow in Blacksmith Fork River is considered with the assumption of only 50 percent of expected flow level in Logan River and Little Bear River (column 2, Table 33). The value of marginal benefit at different instream flows in Blacksmith Fork is measured when Logan River and Little Bear River carry only 50 percent of their expected instream flow. Second, marginal benefit at different instream flow levels in Blacksmith Fork is calculated with the assumption of average instream flow condition on two other sites (column 3, Table 33). The change in average flow level is used in all three marginal benefit estimations. The optimum flow level determination is illustrated in Figure 7. The marginal benefits of agricultural uses (on the right verticial axis) for various percentages of available

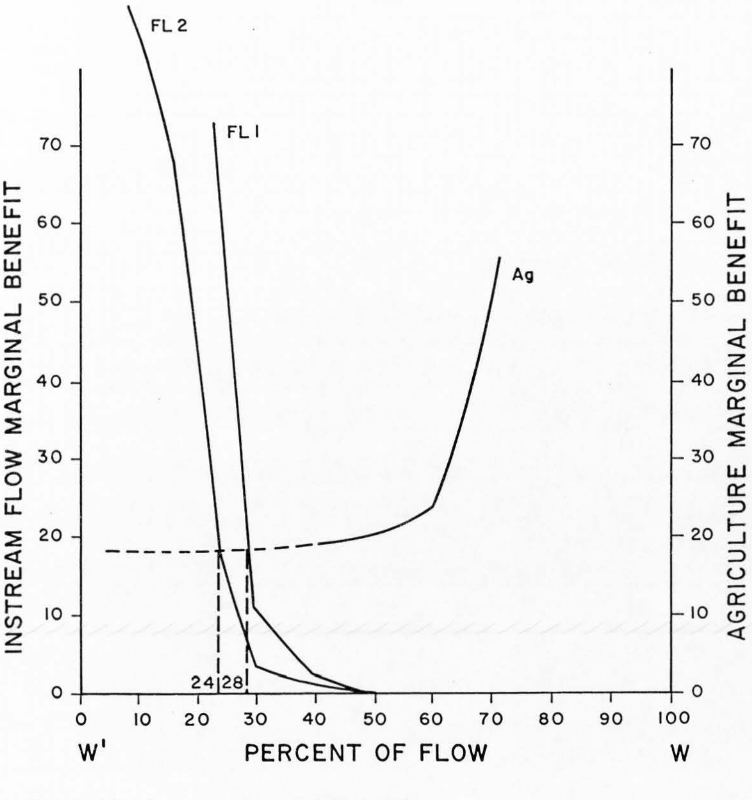

Figure 7. Instream flow determination.

Table 33. Marginal benefit by flow level (in dollars).

Percent of Flow Level	Marginal Benefit: Instream Flow (1)	Instream Flow (2)	Agriculture
10	-	92.7	-
20	-	67.9	-
25	74	18.4	-
30	11.5	4.73	55.43
35	6.97	-	-
40	1.2	0.6	21.03
50	0	0	19.46
60	0	0	17.6
70	0	0	15.25*

(1) Indicates strategy one where marginal benefit of alteration instream flow for Blacksmith Fork River is measured by assuming 50 percent of average flow for sites 1 and 3 (FL_1).

(2) Indicates strategy two where marginal benefit of alteration instream flow for Blacksmith Fork River is measured by assuming average flow for other sites (FL_2).

*An estimated value.

water (measured from W to the left) are shown by Ag. The total quantity of available water is fixed and represented by WW'. FL_1 and FL_2 indicate the corresponding marginal benefits for instream uses (on the left vertical axis) of various percentages of water use (measured from W' to the right). The intersection of Ag and FL_1 at about 28 percent of instream flow represents the benefit maximizing point. This optimum point is determined when only 50 percent of average flow is assumed for two other sites. However, if this assumption is relaxed (FL_2), the optimum point dictates lower instream flow. As intersection of Ag and FL_2 shows, the benefit maximizing point is at about 24 percent of instream flow which is lower than 28 percent. Biological determination

(Montana method) requires the critical flow level at least to be maintained at 20 percent of flow (Gosse and Helm 1979). Therefore, the biological constraint and the optimum flow level under the second assumption require maintaining the instream flow between 20 to 25 percent at Blacksmith Fork. But under the first assumption, almost 30 percent of flow is recommended. It appears that since the first assumption is more realistic, instream flow for Blacksmith Fork River should be maintained at 30 percent of expected flow level to maximize social benefits.

SUMMARY AND CONCLUSIONS

Major economic conflicts are arising between withdrawal and instream flow water use. Until recently, most western government agencies encouraged water diversions and related development projects as a source of new income and economic growth. However, recently increased attention has focused on studies to include instream flow in the water allocation policy. Increases in mobility, leisure time, income and population cause water recreation to assume a greater importance to the general population's welfare. Therefore, properly controlled instream flow can provide direct utility to recreationists, resulting in higher efficiency in economy's productivity and indirect income support to tourist industry and growth of economy. Therefore, water management agencies are interested in estimation of cost and benefits from recreation use of instream flow.

In this study, the expected cost of maintaining a desired level of instream flow for recreation activities and all other instream uses is considered as foregone value of agricultural products. Irrigation, municipal, and recreation activities compete for the existing fixed flows. Water input decisions in each sector influence economic decision making process in other sectors.

In this study a stochastic linear programming model was developed (Appendix D) to estimate the expected costs of alternative strategies to maintain instream flow. The conflict between instream flow uses and water use in agriculture was considered in the model. All other water uses can also be added to the model. The quantity of required water can be determined at least cost to the sectors from which water is is withdrawn to meet instream flow needs. To analyze alternative instream flow strategies, stochastic nature of streamflow with estimated probability of occurrence was considered. The three basic strategies under two conditions of water rights transferability are:

1. The expected instream flow strategy (EIF) which determines the combination of junior and senior water rights needed to maintain the desired level of expected instream flow at least cost in terms of expected agricultural products foregone.

2. The minimum flow strategy (IF) which meets the desired level of expected flows by reserving the required amount of the most senior rights.

3. The critical flow strategy (CF), which combines the previous two basic strategies, using IF to guarantee a base flow to prevent any irreversible damages, and EIF to obtain the remainder of the desired expected instream flow.

These models are used to obtain net benefit maximizing solution for agricultural activities under given water availability. Moreover, by subtracting these values from base solution value, the expected cost of maintaining instream flow can be calculated. The base solution value is maximum agricultural returns with no required instream flow. Therefore, these strategies can be used in two ways. First, to determine minimum cost strategy for maintaining required instream flow. Second, to estimate maximum agricultural return under specific instream flow required. If the economic value of instream flow uses for different flow levels is available, the result of this model will help the decision maker to decide on water allocation on the basis of maximum total benefit of water because water resources are allocated efficiently when the net benefits resulting from all uses are maximized. These models also provide a decision rule for both sectors. For instance, in the case of agriculture, how much of what crop with available water will produce maximum agricultural return. However, application of the stochastic linear programming model in the study areas indicates that the critical flow strategy appears to be a promising criterion for maintaining instream flow. The CF strategy, while guaranteeing 20 percent of average flows, does not involve an appreciably greater cost than EIF strategy which has a lower cost than IF. This method of strategy determination, in some cases, can be considered as cost and benefit evaluation. In each specific site, according to the variety of aquatic and wildlife in the site, a specific predetermined desired expected instream flow level might be required by law. Federal legislation in some states requires that fish and wildlife values be considered in advance of any water project construction. Therefore, the minimum cost determination method would guide the authority to make a correct decision for maximizing social benefit of water allocation.

The allocation decision today may change future consumption benefits. For example, changes in river flow may shift the level of future demand, since it might affect the aquatic life such as fish. But in agriculture sector, water for irrigation use in one period does not deplete the future service flow, nor can the farmer transfer service flows into another period. Therefore, when a desired expected instream flow level for sustaining aquatic life is required, this methodology will provide valuable information. However, the minimum cost strategy of maintaining instream flow would be more beneficial if the economic value of recreation activities in that specific site is also given.

Economists usually rely on the private market system to reveal appropriate economic values. However, most water allocation would occur outside the market place. Therefore, in the absence of market prices, conventional economic observation of consumer behavior cannot be used for instream flow value estimation. The theoretical model developed in this study to estimate recreationists demand function is based on Becker's (1965) new approach to the consumer behavior, since it is the best method to estimate multiple site demand system. In this approach, which is known as the household production function theory, unlike the conventional consumer theory, consumption activities are viewed as the outcome of individual or household production process, combining market goods and time. The most important and productive tool of economic analysis is the notion of demand. Therefore, deriving proper demand function is not only important, it is essential in quantifying economic value. The Almost Ideal Demand System (AIDS) was chosen to derive the multi-site demand equations. The AIDS will lead to a semilog form of demand function which has been shown to be an appropriate functional form for economic evaluation of warm-water recreation activities (Ziemer et al. 1980). The data used in this evaluation were gathered by a survey conducted on 3 sites, Logan River, Blacksmith Fork River, and Little Bear River, during the summer of 1982. The full price and full income are defined and calculated according to household production theory.

The structural demand for three recreation sites are estimated using Zellner's SUR technique. Applying Ordinary Least Square (OLS) method to estimate multiple-site demand parameters might encounter some econometric problems because the assumption of homoskedasticity and nonautocorrelation of random disturbances in OLS may not be met in multiple-site demand estimation. The estimated demand function for all three sites and the results of Table 26 indicate that there is not a significant site characteristic effect on demand functions. The positive sign of coefficients, , leads to the conclusion that recreation is a luxury good. Since $_{12} < 0$ and $_{13} < 0$, sites 2 and 3 are not good alternative sites for site 1, but $_{23} > 0$ means sites 2 and 3 are relatively good alternative sites for each other. According to Table 26, site characteristic evaluations are not significantly different in the three sites in the study area, because composite of site characteristics range from 6.5 (Little Bear) to 7.28 (Logan) in the scale of 1 (poor) to 10 (excellent). This information indicates that, at a given flow level, each of these recreation sites is as attractive as any other. But, the flow level has an important weight on attractiveness of the sites as can be concluded from Table 7. This table indicates how drastically the visitation rate will reduce as flow level decreases.

To test the instream flow effect on visitation rate and estimating compensated variation, CV, of altering instream flow level, the quality parameter f_i (a function of flow) was defined and estimated on the basis of observed values. The necessary data for this estimation were obtained through conducted survey in summer 1982. This quality parameter was used to modify the ordinary demand function and the corresponding cost function. Then, the CV was measured by differences between original cost function and modified cost function at different instream flow levels. The results for 20 percent of average flow in Table 31 indicate that the largest potential recreation benefits exist near the population centers (Logan = 399,952). In contrast, improving instream flow level in sparsely populated agricultural areas will probably not stimulate a substantial increase in recreation demand (Little Bear = 123,283). Strategies 4, 5, and 6 in Table 32, which are considered reasonable strategies in this study, show marginal benefits ranging from 11.5 to 15.98 dollars. According to Tables 30 and 32, the benefit obtained from altering instream flow above 25 or 30 percent of average flow is negligible. On the contrary, reduction of instream flow below 10 or 20 percent of average will cause irreparable damages and loss of benefits to society. This information plus the expected net agricultural return would be beneficial for decision making in allocation of water. This was demonstrated for Blacksmith Fork River.

The following conclusions are drawn from this study:

1. The strategies for maintaining instream flows were compared under 40, 50, 60, and 70 percent of the average annual flow. The result of this comparison indicates that CF is a promising criterion.
2. The obtained result indicates no significant site characteristic effect on demand function.
3. Alteration of flow has a drastic effect on visitation rate.
4. Recreation is a luxury good.
5. Blacksmith Fork and Little Bear Rivers are not good alternative sites for Logan River recreation site. However, Blacksmith Fork and Little Bear Rivers are good alternatives for each other.

6. Increasing instream flow level above 25 or 30 percent of average flow will not singificantly add to economic value of recreation.
7. Reduction of instream flow level below 10 percent of average flow will cause irreparable damages to potential recreation benefits.
8. Thirty percent of average flow is recommended for maintaining instream flow in Logan River and Blacksmith Fork River. For Little Bear, 20 percent (CF) of average flow is recommended.

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APPENDICES

Appendix A

Water-Related Recreation Survey

UTAH WATER RESEARCH LABORATORY
UTAH STATE UNIVERSITY
LOGAN, UTAH

WATER-RELATED RECREATION SURVEY

NUMBER: ____________
DATE: ____________
SITE: ____________
INTERVIEWER: ____________

Introduction

The Utah Water Research Laboratory at Utah State University is conducting a study on the value of water for recreation. In order to determine these values, we need to get some information from people who come to enjoy the streamside recreation opportunities in this area. We would appreciate your helping us to get this information by taking 15 to 20 minutes to answer some questions. In general, the purpose of the questions is to help us estimate the value of the recreation opportunities from the actual expenses that recreationists incur to enjoy those opportunities. You need not answer any questions you would prefer not to, and of course, your answers will be kept confidential.

I. The first 12 questions are designed to give us some background and description of your visit to this site.

1. Where do you live? (Locate on map on last page if home is in map area. Otherwise give place name.)

2. How long have you been at this site? (Locate site on map on last page.)

3. How much longer do you plan to stay?

4. How many people did you come with? (Total in vehicle and group.)

5. What is the age and sex of those in your party? (Place "M" or "F" beside the appropriate age group.)

0 to 9 yrs.	____________	40 to 49 yrs.	____________
10 to 19 yrs.	____________	50 to 59 yrs.	____________
20 to 29 yrs.	____________	60 to 69 yrs.	____________
30 to 39 yrs.	____________	70 yrs or more	____________

6. Circle the highest year of education you have completed.

Elementary 1 2 3 4 5 6 Secondary 7 8 9 10 11 12 College 13

14 15 16+

7. How do you plan to spend your time here? Give approximate time spent in each activity below. (Includes respondent only, not all members in party.)

eating	games
fishing	sleeping
hiking	other (specify) ________
water play	

8. How often do you go on this kind of recreation outing?

1-2 times/yr.	1/wk.
1-2 times/mo.	more than 1/wk.

9. Where do you usually go on such outings? (Indicate percentage of visits at each site. Refer to map on last page.)

Smithfield % ______	Blacksmith 2 % ______
Logan 1 % ______	Little Bear % ______
Logan 2 % ______	Other % (specify)
Blacksmith 1 % ______	______________

10. Compared to your idea of a perfect recreation site, how would you evaluate this site on the characteristics below? (For each characteristic use a scale of 1 to 10, where a "10" means the site is perfect, and a "1" means the site is extremely poor.)

distance ______	fishing suitability
privacy/uncrowded ______	and probable success ______
facilities ______	
vegetation/landscape ______	other important site
insects/pests ______	characteristics ______
water ______	(specify ______________)

11. For your recreation purposes, would you say the number of other recreationists you have seen in the area has been

______ a. more than you would prefer?
______ b. fewer than you prefer?
______ c. about the right number?

12. What is the maximum number of other individuals or parties at this site that you would tolerate before deciding it was too crowded to stay?

______ 1-2	______ 7-8
______ 3-4	______ 9-10
______ 5-6	______ more than 10 (give number range)

II. Now we would like you to imagine what the stream would be like at different flow levels, and indicate how these changes would affect your evaluation of this site for recreation.

1. For each of the alternative stream conditions below indicate the response you feel to be most appropriate.

	So high I would look for another site	Higher than ideal but acceptable	About right (or indifferent)	Lower than ideal but acceptable	So low I would look for another site
a. Present level	______	______	______	______	______
b. Twice the present level	______	______	______	______	______
c. 1 1/2 times the present level	______	______	______	______	______
d. Half the present level	______	______	______	______	______
e. No water	______	______	______	______	______

(Answer 2 only for "so low" responses.)

2. As a percent of the present flow, approximately what is the minimum amount of water acceptable for your purposes?

0 10 25 33 50 67 75 100

One effect of some water resource developments is to deplete stream flow over certain stretches of a river. The next question asks how you might react if a development were proposed that would deplete the flow in this portion of the river.

3. If the flow at this site went below your minimum acceptable level, where would you probably go as an alternative?

4. If the only practical way to preserve the flow was to establish a system of user fees to cover the costs of keeping water in the river, how much would you be willing to pay per visit to maintain the flow level you desire?

   0 $2 $4 $6 $8 $10 $12 $14 $16 $18 $20

5. If you answered "0," was it because

   a. reduced flow levels, or a dry stream, would not adversely affect your use of this site?

   b. user fees on this site are already as high or higher than they should be? (Applicable only on developed sites.)

   c. you think stream flows should be maintained, but do not believe recreation users should have to pay to maintain them?

III. The next four questions concern your expenses <u>for this visit</u>.

1. What mileage does the vehicle you came in get? (Specify vehicle type and mileage whether vehicle belongs to respondent or to another in party.)
2. About how much did you spend for food for this visit?
3. About how much did you spend for recreation equipment (fishing, swimming, etc.) for this visit
4. Did you pay a fee for use of this site? How much?

IV. This group of questions concerns the value of the equipment you are using. The list below is intended as a fairly comprehensive checklist of the kinds of things you might have brought with you. We have three questions we would like you to answer concerning the items on the list. First, we would like you to tell us the cost of those items you have with you. Second, we would like to know how old those items are. Finally, we would like you to tell us how much you plan to spend on new equipment.

Equipment category	1. Cost	2. Age	3. New purchases
RV, camper, trailer	______	______	______
Tents, awnings	______	______	______
Sleeping bags, pads	______	______	______
Stoves, grills, heaters	______	______	______
Cooking utensils	______	______	______
Furniture	______	______	______
Ice chests	______	______	______
Fishing rods & reels	______	______	______
Other fishing equip.	______	______	______
Special apparel	______	______	______
Licenses	______	______	______
Other (specify)	______	______	______
	______	______	______
	______	______	______
	______	______	______
	______	______	______

V. The final set of questions has to do with your occupation and income.

1. What is your occupation?

2. In what interval does your total annual household income fall?

_____ less than $5,000	_____ $20,000 to $24,999
_____ $5,000 to $9,999	_____ $25,000 to $29,999
_____ $10,000 to $14,999	_____ $30,000 to $34,999
_____ $15,000 to $19,999	_____ $35,000 to $44,999
	_____ $45,000 or more

3. In what interval does your monthly household salary or wage income fall?

_____ less than $500	_____ $2,000 to $2,499
_____ $500 to $999	_____ $2,500 to $2,999
_____ $1,000 to $1,499	_____ $3,000 or more
_____ $1,500 to $1,999	

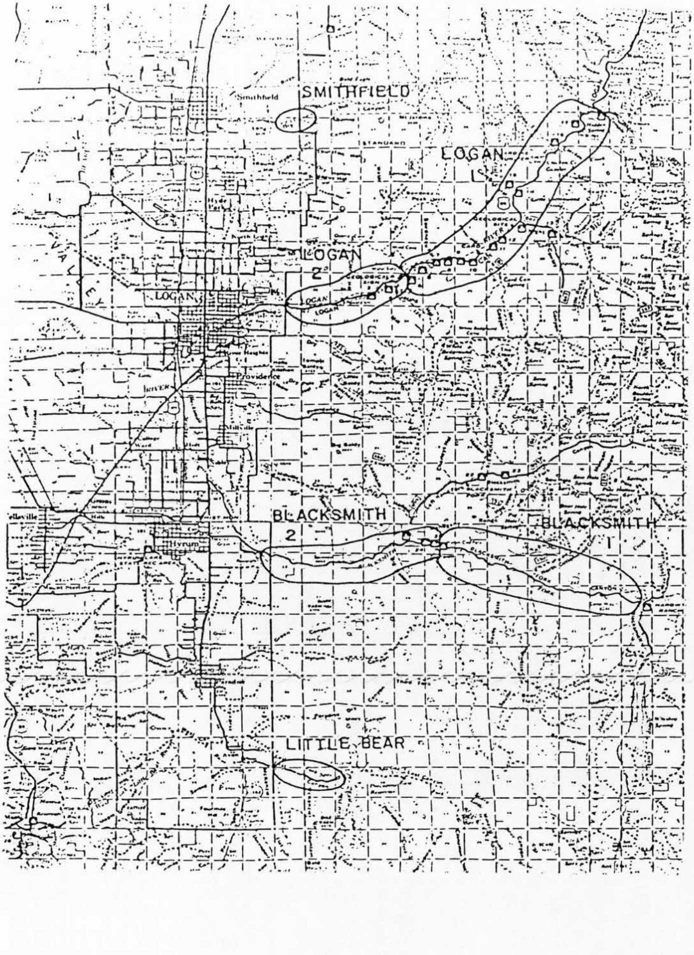
SMITHFIELD
LOGAN
1
LOGAN
2
BLACKSMITH
2
BLACKSMITH
1
LITTLE BEAR

Table A-1. Group size by recreation site.

Number in Group	Site: Logan 1	Logan 2	Blacksmith 1	Blacksmith 2	Little Bear	All Sites
1	11	10	7	9	5	42
2	37	43	23	18	10	131
3	16	22	22	12	8	80
4	22	18	22	11	7	80
5-6	28	11	5	12	10	66
7-10	16	8	11	10	4	49
More than 10	5	6	5	1	1	18
Total	135	118	95	73	45	468
Average group size	4.2	3.8	4.1	3.9	3.9	4.0

Table A-2. Age and sex distribution by site.

Age	Site: Logan 1 Male	Logan 1 Female	Logan 2 Male	Logan 2 Female	Blacksmith 1 Male	Blacksmith 1 Female	Blacksmith 2 Male	Blacksmith 2 Female	Little Bear Male	Little Bear Female	Total Male	Total Female	All Sites
0-9	50	60	30	40	54	34	44	28	25	20	203	182	385
10-19	39	48	48	22	28	27	21	17	13	17	149	131	280
20-29	47	48	69	38	30	36	43	38	24	13	213	173	386
30-39	55	45	33	21	45	32	24	11	16	13	173	122	295
40-49	26	20	24	15	23	22	17	12	4	2	94	71	165
50-59	18	20	18	18	16	15	7	8	7	3	66	64	130
60-69	36	34	18	16	14	10	11	7	8	5	87	72	159
>69	12	9	6	13	4	5	2	0	4	4	28	31	59
Total	283	284	246	183	214	181	169	121	101	77	1013	846	1859

Table A-3. Education level of respondent by site.

Education Level	Site: Logan 1 #	Logan 1 %	Logan 2 #	Logan 2 %	Blacksmith 1 #	Blacksmith 1 %	Blacksmith 2 #	Blacksmith 2 %	Little Bear #	Little Bear %	Total #	Total %
High school	51	10.7	43	9.0	63	13.2	33	6.9	27	5.7	220	46.2
Some college	45	9.5	39	8.2	22	4.6	18	3.8	11	2.3	137	28.8
Bachelors or more	39	8.2	36	7.6	10	2.1	21	4.4	7	1.5	119	25.0
Total	135	28.4	118	24.8	95	20.0	72	15.1	45	9.5	476	100.0

Table A-4. Annual household income by education.

Annual Income	Education							
	High School		Some College		Bachelors or more		Total	
	#	%	#	%	#	%	#	%
Less than 5,000	12	2.6	10	2.1	9	1.9	31	6.6
$ 5,000- 9,999	25	5.0	18	3.9	7	1.4	50	10.3
$10,000-14,999	38	8.2	13	2.6	13	2.6	64	13.4
$15,000-19,999	34	7.3	17	3.7	8	1.7	59	12.7
$20,000-24,999	44	9.3	22	4.5	18	3.7	84	17.5
$25,000-29,999	26	5.6	17	3.7	13	2.8	56	12.1
$30,000-34,999	19	4.1	9	1.9	23	5.0	51	11.0
$35,000-44,999	17	3.5	23	4.8	19	3.9	59	12.1
$45,000 or more	5	0.9	8	1.7	9	1.7	22	4.3
Total	220	46.4	137	28.9	119	24.6	476	100.0

Table A-5. Annual household income by site.

Annual Income	Site					Total
	Logan 1	Logan 2	Blacksmith 1	Blacksmith 2	Little Bear	
Less than 5,000	9	12	3	5	0	31
$ 5,000- 9,999	10	19	5	9	6	50
$10,000-14,999	12	16	9	13	12	64
$15,000-19,999	16	12	12	13	5	59
$20,000-24,999	25	13	27	8	8	84
$25,000-29,999	18	10	19	4	4	56
$30,000-34,999	17	12	12	6	2	51
$35,000-44,999	18	17	7	11	5	59
$45,000 or more	9	7	1	3	3	22
Total	135	118	95	72	45	476

Table A-6. Travel distances by sampling site.

	Site										All Sites Total	
	Logan 1		Logan 2		Blacksmith 1		Blacksmith 2		Little Bear			
Distance*	#	%	#	%	#	%	#	%	#	%	#	%
0-10	36	7.5	46	9.6	1	0.2	13	2.7	2	0.4	102	21.4
11-20	9	1.9	3	0.6	20	4.2	15	3.1	0	0.0	49	10.3
21-30	3	0.6	4	0.8	5	1.0	18	3.8	7	1.5	37	7.8
31-40	20	4.2	7	1.5	24	5.0	8	1.7	7	1.5	67	14.0
41-50	0	0.0	2	0.4	5	1.0	4	0.8	3	0.6	14	2.9
51-60	26	5.5	13	2.7	25	5.2	3	0.6	5	1.0	72	15.1
61-70	6	1.3	0	0.0	4	0.8	2	0.4	11	2.3	24	5.0
71-80	4	0.8	3	0.6	1	0.2	2	0.4	2	0.4	12	2.5
81-90	2	0.4	6	1.3	2	0.4	0	0.0	2	0.4	12	2.5
91-100	3	0.6	1	0.2	0	0.0	2	0.4	0	0.0	7	1.5
101-130	1	0.2	4	0.8	7	1.5	1	0.2	3	0.6	16	3.4
131-365	5	1.0	2	0.4	0	0.0	1	0.2	1	0.2	9	1.9
365-999	20	4.2	27	5.7	1	0.2	4	0.8	2	0.4	56	11.7
Total											476	100.0

*Distance from home in miles.

Table A-7. Length of visit by site.

Hours at Site	Site					Total
	Logan 1	Logan 2	Blacksmith 1	Blacksmith 2	Little Bear	
<1	0	1	0	0	0	1
1-4	24	56	11	25	9	125
5-8	16	12	22	14	3	67
9-15	6	6	7	1	2	22
16-30	25	11	14	9	15	74
31-55	30	13	25	13	10	91
56 or more	34	19	16	11	6	86
Average visit	34.21	21.36	34	34	30	30.71
Total	135	118	95	72	45	466

Table A-8. Average streamflow evaluations, by site (5 = unacceptably low, 1 = unacceptably high).

Flow Level	Site					
	Logan 1	Logan 2	Blacksmith 1	Blacksmith 2	Little Bear	All Sites
2.0 x present level	1.63	1.89	1.6	1.6	1.8	1.70
1.5 x present level	2.02	2.32	1.9	2.0	2.0	2.05
Present level	3.11	3.43	3.1	3.1	3.13	3.17
0.5 x present level	4.18	4.63	4.2	4.3	4.4	4.34
No water	4.95	5.00	4.95	5.0	5.0	4.98

Table A-9. Perceived congestion, by crowding threshold.

Number of Others Seen	Crowding Tolerance					
	1-2	3-4	5-6	7-8	9-10	>10
Fewer than preferred	12	9	7	4	7	11
About right	60	46	57	30	40	80
More than preferred	36	12	16	11	10	21

Table A-10. Crowding tolerance by group size.

Number in Group	Crowding Tolerance					
	1-2	3-4	5-6	7-8	9-10	>10
1	10	11	6	1	3	12
2	30	20	21	13	15	29
3	27	12	13	4	7	18
4	19	12	15	12	7	16
5-6	10	6	13	8	13	17
7-10	9	6	8	5	9	15
>10	4	0	4	2	3	7

Appendix B

Survey Data Used for Derivation of Demand

Table B-1. Number of surveys for each site and group.

Group	Site				
	Lo_1	Lo_2	BL_1	BL_2	LB
1	13	30	0	8	0
2	8	4	8	13	6
3	4	3	5	4	3
4	5	10	2	3	7
5	21	12	3	4	0
6	9	3	15	11	4
7	12	3	16	6	4
8	17	16	24	3	9
9	11	7	0	3	0
10	5	4	1	8	0
11	8	9	7	1	5
12	16	15	12	7	5
Total	129	116	93	71	43

This table does not show transit recreationists (recreationists who are passing through and stop for a short period of time).

Table B-2. Number of surveys for each site, group, and days.

Group	Site									
	Lo_1		Lo_2		BL_1		BL_2		LB	
	D_1*	D_2**	D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2
1	11	2	24	6	7	1	8	5	0	0
2	6	2	1	3	2	2	8	2	5	3
3	2	2	2	1	2	0	0	2	2	0
4	2	2	3	1	1	0	1	1	5	1
5	16	5	9	3	10	2	7	2	1	1
6	7	2	3	0	13	7	10	0	2	1
7	8	4	2	1	12	5	3	0	3	0
8	5	4	4	1	8	1	0	0	4	5
9	10	1	4	3	1	0	4	1	0	0
10	5	0	3	1	3	1	5	1	2	1
11	4	4	8	1	9	1	2	0	0	2
12	6	2	3	4	4	0	4	1	2	1
Total	82	30	66	25	72	20	52	15	26	15

This tables does not show transit recreationists (recreationists who are coming from above 365 miles to sites).

*D_1 indicates weekend
**D_2 indicates weekdays

Table B-3. Number of cars in each site.

Site	Days: Weekend	Days: Weekday	Total
Lo_1	507	115	622
Lo_2	371	100	471
BL_1	90	26	116
BL_2	101	29	130
LB	48	19	67
Total	1,117	289	1,406

Table B-4. Estimated G_1 and G_2 for each group.

Group	Lo_1 G_1	Lo_1 G_2	Lo_2 G_1	Lo_2 G_2	BL_1 G_1	BL_1 G_2	BL_2 G_1	BL_2 G_2	LB G_1	LB G_2
1	67.19	5.0	109.93	17.14	8.63	1.30	14.96	8.53	0	0
2	36.65	5.0	4.58	8.57	2.47	2.60	14.96	3.41	8.57	3.80
3	12.22	5.0	9.16	2.86	2.47	0	0	3.41	3.43	0
4	12.22	5.0	13.74	2.86	1.23	0	1.87	1.71	8.57	1.27
5	97.73	12.50	41.22	8.57	12.33	2.60	13.09	3.41	1.71	1.27
6	42.76	5.0	13.74	0	16.03	9.10	18.70	0	3.43	1.27
7	48.87	10.0	9.16	2.86	14.79	6.50	5.61	0	5.14	0
8	30.54	10.0	18.32	2.86	9.86	1.30	0	0	6.86	6.33
9	61.08	2.50	18.32	8.57	1.23	0	7.48	1.71	0	0
10	30.54	0	13.74	2.86	3.70	1.30	9.35	1.71	3.43	1.27
11	24.43	10.0	36.64	2.86	11.10	1.30	3.74	0	0	2.53
12	36.65	5.0	13.74	11.43	4.93	0	7.48	1.71	3.43	1.27

Lo_1 = Upper Logan River
Lo_2 = Lower Logan River
BL_1 = Upper Blacksmith Fork River
BL_2 = Lower Blacksmith Fork River
LB = Little Bear River

Table B-5. Estimated $\hat{X}_1$ and $\hat{X}_2$ for each group.

	Site									
	Lo_1		Lo_2		BL_1		BL_2		LB	
Group	$\hat{X}_1$	$\hat{X}_2$	$\hat{X}_1$	$\hat{X}_2$	$\hat{X}_1$	$\hat{X}_2$	$\hat{X}_1$	$\hat{X}_2$	$\hat{X}_1$	$\hat{X}_2$
1	218.37	83.75	357.27	287.10	28.05	21.78	48.62	142.88	0	0
2	119.11	83.75	14.89	143.55	8.03	43.55	48.62	57.12	27.85	63.65
3	39.72	83.75	29.77	47.91	8.03	0	0	57.12	11.15	0
4	39.72	83.75	44.66	47.91	4.0	0	6.08	28.64	27.85	21.27
5	317.62	209.38	133.97	143.55	40.07	43.55	42.54	57.12	5.56	21.27
6	138.97	83.75	44.66	0	52.10	152.43	60.78	0	12.58	31.27
7	158.83	167.5	29.77	47.91	48.07	108.88	93.97	0	86.10	0
8	99.26	167.5	59.54	47.91	32.05	21.78	0	0	114.91	106.03
9	198.51	41.88	59.54	143.55	4.0	0	24.31	28.64	0	0
10	99.26	0	103.43	77.91	12.03	21.78	30.39	28.64	11.15	21.27
11	79.40	167.5	119.08	47.91	36.08	21.78	12.16	0	0	42.38
12	119.11	83.75	44.66	191.45	16.02	0	24.31	28.64	11.15	21.27

$\hat{X}_1$ indicates weekends
$\hat{X}_2$ indicates weekdays

Table B-6. Estimated D for each group.

Group	Site: Lo_1	Lo_2	BL_1	BL_2	LB
1	D_{11} = 302.12	D_{21} = 644.37	D_{31} = 49.83	D_{41} = 191.50	D_{51} = 0
2	D_{12} = 202.86	D_{22} = 158.44	D_{32} = 51.58	D_{42} = 105.74	D_{52} = 91.50
3	D_{13} = 123.47	D_{23} = 77.68	D_{33} = 8.03	D_{43} = 57.12	D_{53} = 11.15
4	D_{14} = 123.47	D_{24} = 92.57	D_{34} = 4.0	D_{44} = 34.72	D_{54} = 49.12
5	D_{15} = 527.00	D_{25} = 277.52	D_{35} = 83.62	D_{45} = 99.66	D_{55} = 26.83
6	D_{16} = 222.72	D_{26} = 44.66	D_{36} = 204.53	D_{46} = 60.78	D_{56} = 43.85
7	D_{17} = 326.33	D_{27} = 77.68	D_{37} = 156.95	D_{47} = 93.97	D_{57} = 86.10
8	D_{18} = 266.76	D_{28} = 107.45	D_{38} = 53.83	D_{48} = 0	D_{58} = 220.92
9	D_{19} = 240.39	D_{29} = 203.09	D_{39} = 4.0	D_{49} = 52.95	D_{59} = 0
10	D_{110} = 99.26	D_{210} = 181.34	D_{310} = 33.81	D_{410} = 59.03	D_{510} = 32.42
11	D_{111} = 246.90	D_{211} = 166.99	D_{311} = 57.86	D_{411} = 12.16	D_{511} = 42.38
12	D_{112} = 202.86	D_{212} = 236.11	D_{312} = 16.02	D_{412} = 52.95	D_{512} = 32.42

Table B-7. Distribution of income in Utah.

Income	# of Families	Total	Percentage
0- 2,499	7,731		
2,500- 4,999	11,415		
5,000- 7,499	19,063		
7,500- 9,999	22,584		
10,000-12,499	28,656		
12,500-14,999	27,228		
		116,677.0	32.94
15,000-17,499	31,330		
17,500-19,999	28,774		
20,000-22,499	32,492		
22,500-24,999	25,198		
25,000-27,499	23,935		
27,500-29,999	17,257		
		158,986.0	44.89
30,000-34,999	28,626		
35,000-39,999	17,118		
40,000-49,999	17,563		
50,000-74,999	10,952		
75,000	4,253		
		78,512.0	22.17
		354,175.0	100.00

Table B-8. Population by zone.

Zone	Population 1*	Population 2**
1	46,895	42,864
2	50,225	45,815
3	243,462	156,638
4	1,052,924	1,199,464

*Population for Logan site.
**Population for Blacksmith Fork and Little Bear sites.

Table B-9. Population in each income group and each zone.

Site	Zone	Income Group One 32.94%	Income Group Two 44.89%	Income Group Three 22.17%
Logan	1	15,447.54	21,051.61	10,396.84
	2	16,544.12	22,546.00	11,134.88
	3	80,196.38	109,290.09	53,975.53
	4	346,833.17	472,657.58	233,433.25
Blacksmith Fork and Little Bear	1	14,119.40	19,241.65	9,502.95
	2	15,091.46	20,566.35	10,157.19
	3	51,596.56	70,314.80	34,726.64
	4	395,103.44	538,439.39	265,921.17

Table B-10. Variables for each group, Logan.

Site	Group	Variables			
		X	PA	WT	I
Lo_1	1	X_{11} = 1.6	PA_{11} = 25.0	WT_{11} = 28.2	I_{11} = 7,315.31
Lo_2		X_{21} = 0.3	PA_{21} = 6.42	WT_{21} = 9.41	I_{21} = 7,833.3
Lo_1	2	X_{12} = 2.031	PA_{12} = 39.0	WT_{12} = 41.5	I_{12} = 10,312.5
Lo_2		X_{22} = 1.31	PA_{22} = 24.2	WT_{22} = 40.4	I_{22} = 12,500.0
Lo_1	3	X_{13} = 2.31	PA_{13} = 22.53	WT_{13} = 53.6	I_{13} = 9,375.0
Lo_2		X_{23} = 0.2	PA_{23} = 7.80	WT_{23} = 7.85	I_{23} = 8,333.3
Lo_1	4	X_{14} = 1.42	PA_{14} = 37.1	WT_{14} = 46.1	I_{14} = 8,137.5
Lo_2		X_{24} = 1.31	PA_{24} = 48.2	WT_{24} = 59.7	I_{24} = 8,125.0
Lo_1	5	X_{15} = 1.2	PA_{15} = 30.0	WT_{15} = 47.5	I_{15} = 23,214.3
Lo_2		X_{25} = 0.195	PA_{25} = 7.49	WT_{25} = 11.31	I_{25} = 22,083.3
Lo_1	6	X_{16} = 3.3	PA_{16} = 49.5	WT_{16} = 74.9	I_{16} = 19,722.0
Lo_2		X_{26} = 1.2	PA_{26} = 16.6	WT_{26} = 72.1	I_{26} = 19,166.7
Lo_1	7	X_{17} = 3.1	PA_{17} = 73.3	WT_{17} = 131.2	I_{17} = 23,333.3
Lo_2		X_{27} = 3.1	PA_{27} = 48.8	WT_{27} = 101.2	I_{27} = 20,833.3
Lo_1	8	X_{18} = 1.92	PA_{18} = 51.7	WT_{18} = 87.5	I_{18} = 24,166.7
Lo_2		X_{28} = 2.24	PA_{28} = 80.1	WT_{28} = 94.2	I_{28} = 23,500.0
Lo_1	9	X_{19} = 0.7	PA_{19} = 23.98	WT_{19} = 52.8	I_{19} = 38,863.6
Lo_2		X_{29} = 0.5	PA_{29} = 16.7	WT_{29} = 16.3	I_{29} = 38,214.3
Lo_1	10	X_{110} = 1.35	PA_{110} = 34.38	WT_{110} = 82.1	I_{110} = 35,000.0
Lo_2		X_{210} = 0.31	PA_{210} = 10.61	WT_{210} = 20.0	I_{210} = 37,500.0
Lo_1	11	X_{111} = 1.61	PA_{111} = 33.1	WT_{111} = 106.2	I_{111} = 36,875.0
Lo_2		X_{211} = 2.8	PA_{211} = 82.79	WT_{211} = 178.92	I_{211} = 36,666.7
Lo_1	12	X_{112} = 1.72	PA_{112} = 43.3	WT_{112} = 111.9	I_{112} = 36,875.0
Lo_2		X_{212} = 4.1	PA_{212} = 87.0	WT_{212} = 384.6	I_{212} = 39,285.7

Table B-11. Variables for each group, Blacksmith Fork.

Site	Group	Variables			
		X	PA	WT	I
BL_1	1	X31 = 0.33	PA31 = 6.39	WT31 = 8.7	I31 = 9,375.0
BL_2		X41 = 0.59	PA41 = 18.4	WT41 = 15.6	I41 = 9,423.1
BL_1	2	X32 = 2.42	PA32 = 29.19	WT32 = 53.1	I32 = 11,250.0
BL_2		X42 = 0.650	PA42 = 16.26	WT42 = 16.1	I42 = 8,750.0
BL_1	3	X33 = 1.5	PA33 = 20.8	WT33 = 26.79	I33 = 8,750.0
BL_2		X43 = 1.9	PA43 = 26.91	WT43 = 26.79	I43 = 6,299.50
BL_1	4	X34 = 3.0	PA34 = 35.77	WT34 = 53.57	I34 = 7,500.0
BL_2		X44 = 0.61	PA44 = 54.86	WT44 = 19.59	I44 = 10,000.0
BL_1	5	X35 = 0.81	PA35 = 19.4	WT35 = 28.42	I35 = 22,500.0
BL_2		X45 = 1.083	PA45 = 37.52	WT45 = 38.64	I45 = 20,277.8
BL_1	6	X36 = 1.82	PA36 = 49.1	WT36 = 64.77	I36 = 24,250.0
BL_2		X46 = 1.17	PA46 = 36.31	WT46 = 44.29	I46 = 21,000.0
BL_1	7	X37 = 0.998	PA37 = 56.738	WT37 = 44.26	I37 = 23,382.4
BL_2		X47 = 1.5	PA47 = 32.1	WT47 = 67.46	I47 = 19,166.7
BL_1	8	X38 = 1.74	PA38 = 71.04	WT38 = 70.41	I38 = 20,833.3
BL_2		X48 = -	PA48 = -	WT48 = -	I48 = -
BL_1	9	X39 = 0.104	PA39 = 4.07	WT39 = 13.64	I39 = 40,000.0
BL_2		X49 = 0.321	PA49 = 39.96	WT49 = 27.78	I49 = 38,000.0
BL_1	10	X310 = 0.885	PA310 = 59.88	WT310 = 55.93	I310 = 32,500.0
BL_2		X410 = 2.44	PA410 = 49.9	WT410 = 141.12	I410 = 37,500.0
BL_1	11	X311 = 1.996	PA311 = 45.63	WT311 = 126.74	I311 = 37,500.0
BL_2		X411 = 1.56	PA411 = 36.62	WT411 = 107.14	I411 = 42,500.0
BL_1	12	X312 = 1.44	PA312 = 59.73	WT312 = 55.31	I312 = 34,375.0
BL_2		X412 = 1.008	PA412 = 39.92	WT412 = 77.28	I412 = 39,500.0

Table B-12. Variables for each group, Little Bear.

Group	Variables			
	X	PA	WT	I
1	X_{51} = -	PA_{51} = -	WT_{51} = -	I_{51} = -
2	X_{52} = 1.817	PA_{52} = 51.04	WT_{52} = 16.18	I_{52} = 10,625.0
3	X_{53} = 1.21	PA_{53} = 22.09	WT_{53} = 24.31	I_{53} = 10,000.0
4	X_{54} = 1.33	PA_{54} = 54.025	WT_{54} = 29.1	I_{54} = 11,666.7
5	X_{55} = 1.25	PA_{55} = 21.24	WT_{55} = 68.45	I_{55} = 22,500.0
6	X_{56} = 1.74	PA_{56} = 39.47	WT_{56} = 29.52	I_{56} = 20,833.3
7	X_{57} = 3.06	PA_{57} = 81.54	WT_{57} = 89.29	I_{57} = 19,166.7
8	X_{58} = 1.41	PA_{58} = 42.38	WT_{58} = 59.3	I_{58} = 23,611.1
9	X_{59} = -	PA_{59} = -	WT_{59} = -	I_{59} = -
10	X_{510} = 1.194	PA_{510} = 16.66	WT_{510} = 79.37	I_{510} = 43,333.3
11	X_{511} = 2.5	PA_{511} = 23.95	WT_{511} = 205.36	I_{511} = 40,000.0
12	X_{512} = 0.896	PA_{512} = 38.77	WT_{512} = 62.75	I_{512} = 39,166.67

Table B-13. Number of total days of recreation for season.

Group	Site				
	Lo_1	Lo_2	BL_1	BL_2	LB
1	495.17	192.667	16.593	112.985	0
2	412.01	208.032	124.669	66.781	50.508
3	285.59	15.614	12.045	107.10	13.469
4	174.96	120.804	12.0	20.971	65.477
5	684.16	54.116	67.230	107.932	33.538
6	733.19	50.868	373.063	71.173	76.12
7	1,006.08	241.662	156.636	140.955	263.12
8	513.780	240.903	93.557	0	310.863
9	165.629	93.624	0.416	16.997	0
10	134.001	55.67	29.922	143.915	38.709
11	398.003	498.240	115.489	19.006	105.950
12	349.122	960.023	23.037	53.374	29.048

Table B-14. Number of days of recreation per capita.

Group	Site				
	Lo_1	Lo_2	BL_1	BL_2	LB
1	0.03	0.013	0.0012	0.008	0
2	0.02	0.013	0.0083	0.004	0.003
3	0.004	0.0002	0.0002	0.002	0.0003
4	0.0005	0.0003	0.00003	0.00005	0.0002
5	0.03	0.0026	0.0035	0.006	0.0017
6	0.03	0.0023	0.018	0.0035	0.0037
7	0.01	0.0022	0.0022	0.002	0.0037
8	0.001	0.0005	0.0002	0	0.0006
9	0.02	0.009	0.00004	0.002	0
10	0.01	0.005	0.0029	0.014	0.0038
11	0.007	0.008	0.0033	0.0006	0.0030
12	0.001	0.0041	0.00009	0.0002	0.00009

Table B-15. Full price* of each group per day** by site.

Group	Site				
	Lo_1	Lo_2	BL_1	BL_2	LB
1	32.5	52.8	45.4	57.6	0
2	39.6	49.2	34.1	49.8	36.984
3	32.9	77.6	31.7	28.6	38.4
4	58.7	82.7	29.8	123.3	62.4
5	64.0	96.4	59.5	70.3	71.8
6	37.8	77.9	62.5	68.8	39.8
7	66.4	48.2	101.2	66.4	55.9
8	72.3	77.7	81.4	0	72.3
9	111.5	71.6	170.2	211.2	0
10	86.3	99.7	130.8	78.3	80.5
11	86.4	93.3	86.3	91.9	91.8
12	90.2	116.0	79.97	116.3	113.4

*Full price = PA + WT = P
**Full price per day = P/X

Table B-16. Calculated budget share* of good for each group by site.

Group	Site				
	Lo_1	Lo_2	BL_1	BL_2	LB
1	0.00013	0.000088	0.000006	0.000049	0
2	0.00008	0.000051	0.000025	0.000023	0.00001
3	0.000014	0.000002	0.000001	0.000009	0.000001
4	0.000004	0.000003	0.0000001	0.000001	0.000001
5	0.000083	0.000011	0.000009	0.000021	0.000005
6	0.000057	0.000009	0.000046	0.000011	0.000007
7	0.000028	0.000005	0.00001	0.000007	0.000011
8	0.000003	0.000002	0.000001	0	0.000002
9	0.000057	0.000017	0.000002	0.000011	0
10	0.000025	0.000013	0.000012	0.000029	0.000007
11	0.000016	0.000020	0.000008	0.000001	0.000007
12	0.000002	0.000012	0.0000002	0.000001	0.0000003

$$^*W_i = \frac{P_i X_i}{I_i}$$

Appendix C

Derivation of AIDS Demand Function from the PIGLOG Class of Preferences

These preferences are represented via the cost or expenditure function:

$$\text{Log } C(U, P) = (1-U) \log\{a(P)\} + U \log\{b(P)\} \qquad \text{(C-1)}$$

where a(P) and b(P) are linear homogeneous concave functions, and defined as:

$$\text{Log } a(P) = \alpha_0 + \sum_k \alpha_k \log P_k + 1/2 \sum_k \sum_j \gamma_{kj}^* \log P_k \log P_j \qquad \text{(C-2)}$$

and

$$\text{Log } b(P) = \text{Log } a(P) + \beta_0 \pi_k P_k^{\beta_k}$$

So

$$\text{Log } b(P) = \alpha_0 + \sum_k \alpha_k \log P_k + 1/2 \sum_k \sum_j \gamma_{kj}^* \log P_k \log P_j + \beta_0 \pi_k P_k^{\beta_k}$$

$$\text{(C-3)}$$

Substituting for log a(P) and log b(P) in Equation C-1 will give us the AIDS flexible cost function.

$$\begin{aligned} \text{Log } C(U,P) = {} & (1-U)(\alpha_0 + \sum_k \alpha_k \log P_k + 1/2 \sum_k \sum_j \gamma_{kj}^* \log P_k \log P_j) \\ & + (U)(\alpha_0 + \sum_k \alpha_k \log P_k + 1/2 \sum_k \sum_j \gamma_{kj}^* \log P_k \log P_j \\ & + \beta_0 \pi_k P_k^{\beta_k} \\ = {} & \alpha_0 + \sum_k \alpha_k \log P_k + 1/2 \sum_k \sum_j \gamma_{kj}^* \log P_k \log P_j \\ & - U\alpha_0 - U \sum_k \alpha_k \log P_k - 1/2\, U \sum_k \sum_j \gamma_{kj}^* \log P_k \log P_j \\ & + U\alpha_0 + U \sum_k \alpha_k \log P_k + 1/2\, U \sum_k \sum_j \gamma_{kj}^* \log P_k \log P_j \\ & + \beta_0 U \pi_k P_k^{\beta_k} \end{aligned}$$

Then

$$\log C(U,P) = \alpha_0 + \sum_k \alpha_k \log P_k + 1/2 \sum_k \sum_j \gamma_{kj}^* \log P_k \log P_j + \beta_0 U \pi_k P_k^{\beta_k} \quad (C-4)$$

where α_i, β_i, γ_{ij}^* are parameters

C = cost or expenditure

P = price

U = utility

Hicks-compensated demand function can be derived directly from expenditure function. The price derivatives of cost function will be the quantities demanded:

$$\frac{\partial C(U,P)}{\partial P_i} = q_i \quad (C-5)$$

Multiply both sides of Equation C-5 by $P_i/C(U,P)$:

$$\frac{\partial C(U,P)}{\partial P_i} \cdot \frac{P_i}{C(U,P)} = \frac{q_i \, P_i}{C(U,P)} \quad (C-6)$$

Equation C-6 can be written as:

$$\frac{\partial \log C(U,P)}{\partial \log P_i} = \frac{q_i \, P_i}{C(U,P)} = W_i$$

where W_i = the budget share of good i. Therefore, logarithmic differentiation of Equation C-4 will give us W_i as a function of price and utility.

$$\frac{\partial \log C(U,P)}{\partial \log P_i} = W_i = \alpha_i + \sum_j \gamma_{ij} \log P_j + \beta_i U \beta_0 \pi_k P_k^{\beta_k} \quad (C-7)$$

where

$$\gamma_{ij} = 1/2 \, (\gamma_{ij}^* + \gamma_{ji}^*) \quad (C-8)$$

For a utility maximizing consumer, total expenditure X is equal to cost function. This equality can be inverted to get indirect utility function as a function of price and expenditure as:

$$\log C(U,P) = \log I = \alpha_0 + \sum_k \alpha_k \log P_k + 1/2 \sum_k \sum_j \gamma_{kj}^* \log P_k \log P_j + \beta_0 U \pi_k P_k^{\beta_k}$$

then

$$U = (-\alpha_0 - \sum_k \alpha_k \log P_k - 1/2 \sum_k \sum_j \gamma_{kj}^* \log P_k \log P_j + \log I)/ \beta_0 \pi_k P_k^{\beta_k} \qquad \text{(C-9)}$$

Substituting Equation C-9 in Equation C-7:

$$W_i = \alpha_i + \sum_j \gamma_{ij} \log P_j + \beta_i\beta_0 \pi_k P_k^{\beta_k}(-\alpha_0 - \sum_k \alpha_k \log P_k - 1/2 \sum_k \sum_j \log P_k \log P_j + \log I)/\beta_0 \pi_k P_k^{\beta_k} \qquad \text{(C-10)}$$

Then we have budget shares as a function of price and X.

$$W_i = \alpha_i + \sum_j \gamma_{ij} \log P_j + \beta_i \log\{I/P^*\} \qquad \text{(C-11)}$$

where

P^* is price index which is defined by:

$$\log P = \alpha_0 + \sum_k \alpha_k \log P_k + 1/2 \sum_k \sum_j \gamma_{kj} \log P_k \log P_j \qquad \text{(C-12)}$$

Appendix D

Linear Programming

The five models used to estimate minimum cost of maintaining in-stream flow are described in this appendix.

EIF 1:

$$\text{Max} \sum_k \sum_j \sum_\gamma (P_{j\gamma} \pi^k) Z_{j\gamma}^k$$

Subject to:

$$\sum_j Z_{j\gamma}^k \leq L_\gamma^*$$

$$\sum_\gamma \sum_j W_{jt} Z_{j\gamma}^k - A_t^k = 0$$

$$\sum_j V_{j\gamma} Z_{j\gamma}^k = 0$$

$$I_t^{k+1} - I_t^k \geq 0$$

$$I_t^k + A_t^k = Q_t^k$$

$$\sum_k \pi^k I_t^k - \bar{I}_t = 0$$

$$\bar{I}_t \geq \bar{I}_t^*$$

$$A_t^{k+1} - A_k^t \geq 0$$

EIF 2:

$$\text{Max} \sum_k \sum_j \sum_\gamma (P_{j\gamma} \pi^k) Z_{j\gamma}^k$$

Subject to:

$$\sum_j Z_{j\gamma}^k \leq L_\gamma^*$$

$$\sum_\gamma \sum_j W_{jt} Z_{j\gamma}^k - A_t^k = 0$$

$$\sum_{j} V_{j\gamma} Z_{j\gamma}^{k} = 0$$

$$I_t^k + A_t^k = Q_t^k$$

$$\sum_{k} \pi^k I_t^k - \bar{I}_t = 0$$

$$\bar{I}_t \geq \bar{I}_t^*$$

IF:

$$\text{Max} \sum_{k} \sum_{j} \sum_{\gamma} (P_{j\gamma} \pi^k) Z_{j\gamma}^{k}$$

Subject to:

$$\sum_{j} Z_{j\gamma}^{k} \leq L_\gamma^*$$

$$\sum_{\gamma} \sum_{j} W_{jt} Z_{j\gamma}^{k} - A_t^k = 0$$

$$\sum_{j} V_{j\gamma} Z_{j\gamma}^{k} = 0$$

$$I_t^k + A_t^k = Q_t^*$$

$$\sum_{k} \pi^k I_t^k - \bar{I}_t = 0$$

$$\bar{I}_t \geq \bar{I}_t^*$$

$$A_t^{k+1} - A_t^k \geq 0$$

$$I_t^k \geq B$$

where

$$B = \text{Min}\ (Q_t^k,\ I_t^k)$$

CF 1:

$$\text{Max} \sum_{k}\sum_{j}\sum_{\gamma} (P_{j\gamma}\, \pi^{k})\, Z_{j\gamma}^{k}$$

Subject to:

$$\sum_{j} Z_{j\gamma}^{k} \leq L_{\gamma}^{*}$$

$$\sum_{j}\sum_{\gamma} W_{jt}\, Z_{j\gamma}^{k} - A_{t}^{k} = 0$$

$$\sum_{j} V_{j\gamma}\, Z_{j\gamma}^{k} = 0$$

$$I_{t}^{k+1} - I_{t}^{k} \geq 0$$

$$I_{t}^{k} + A_{t}^{k} = Q_{t}^{k}$$

$$\sum_{k} \pi^{k}\, I_{t}^{k} - \bar{I}_{t} = 0$$

$$\bar{I}_{t} \geq \bar{I}_{t}^{*}$$

$$A_{t}^{k+1} - A_{t}^{k} \geq 0$$

$$I_{t}^{k} \geq C$$

where

$$C = \text{Min}\,(Q_{t}^{k},\, I_{t}^{c})$$

CF 2:

$$\text{Max} \sum_{k}\sum_{j}\sum_{\gamma} (P_{j\gamma}\, \pi^{k})\, Z_{j\gamma}^{k}$$

Subject to:

$$\sum_{j} Z_{j\gamma}^{k} \leq L_{\gamma}^{*}$$

$$\sum_j \sum_\gamma W_{jt} Z_{j\gamma} - A_t^k = 0$$

$$\sum_j V_{j\gamma} Z_{j\gamma}^k = 0$$

$$I_t^k + A_t^k = Q_t^k$$

$$\sum_k \pi^k I_t^k - \bar{I}_t = 0$$

$$\bar{I}_t \geq \bar{I}_t^*$$

$$I_t^k \geq C$$

where

$$C = \text{Min}\ (Q_t^k, I_t^c)$$

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Publications

Amirfathi, P., 1984, "Estimation of Costs and Benefits of Instream Flow," Dissertation Research; in partial fulfillment of requirements of Doctor of Philosophy degree at Utah State University, Logan, Utah.

Narayanan, R., D. Larson, A. B. Bishop, and P. Amirfathi, 1983, "An Economic Evaluation of Alternative Strategies for Maintaining Instream Flows," Proceedings of the Symposium on Aquatic Resources Management of the Colorado River Ecosystem, Nov. 16-18, 1981, Las Vegas, Nevada, Ann Arbor Science Publishers Inc., Ann Arbor, Michigan.

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Work Experience

* Prepared recreation evaluation questionnaires and surveyed the recreationists (in six recreation sites). Used SPSS (a statistical computer package) to analyze the data for developing a recreation demand function, 1982.

* Developed a non-linear programming model for cost benefit analysis of instream flow, Summer 1982.

* Collected crop production and flow level data to measure recreation cost and develop a quantitative decision model to determine the minimum cost method (multiple objective) of providing instream flow requirements, 1982.

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