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Recreation Benefits of Instream Flow: Application to Montana's Big Hole and Bitterroot Rivers

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Allocation of water between instream uses such as recreation and consumptive uses such as irrigation is an important public policy issue in the western United States. One basis for identifying appropriate levels of instream flows is maximization of net economic benefits. A general framework for estimating the recreational value of instream flows was developed and applied to Montana's Big Hole and Bitterroot rivers. The paper also provides a synthesis of methods for interpreting covariate effects in dichotomous choice contingent valuation models. Precision of the estimates is examined through a simulation approach. The marginal recreational value of instream flow in these rivers is in the range of \$50 per acre foot (1 acre foot equals 1233.5 m^3) for recreation at low-flow levels plus \$25 per acre foot for downstream hydroelectric generation. These values indicate that at some flow levels, gains may be achieved on the study rivers by reallocating water from consumptive to instream uses.

INTRODUCTION

The allocation of water among competing uses is an increasingly important public policy issue, especially in the western United States. Instream water uses have actively joined the competition, as policies of instream flow reservation have emerged in many states [*McKinney and Taylor*, 1988; *Reiser et al.*, 1989; *Colby*, 1990]. Montana's 1975 Water Use Act, for example, formally recognized instream flow for recreational and other purposes as a beneficial use of water.

Streamflow levels can influence recreation benefits through a variety of mechanisms. Flow levels directly influence the quality of whitewater boating experiences [*Brown et al.*, 1991] as well as stream aesthetics for general shoreline use [*Brown and Daniel*, 1991]. Streamflow at any given time affects fishing via influences on the locations, distribution, and behavior of fish and aquatic insects. Flow levels also directly affect recreation carrying capacity; for example, the number of anglers that can use the same stretch of river at any one time without congestion problems may increase with flow. Over time, streamflows affect fish stock levels and associated angler catch rates [*Johnson and Adams*, 1988], as well as general recreation and aesthetics via effects on streamside vegetation [*Shelby et al.*, 1992].

Instream flow reservation requests to protect fish, wildlife, and recreation resources in Montana to date have been based on a model that relates discharge to the wetted perimeter of the stream cross section [*Leathe and Nelson*, 1986]. As *Ward* [1987] notes, the use of largely hydrological and biological criteria is typical of streamflow studies. An alternative basis for identifying appropriate levels of instream flow is to compare the economic values of instream flow to the values of competing consumptive uses such as irrigation or municipal withdrawals. Consumptive uses are typically marketed commodities or inputs to marketed commodities, so their values are relatively well understood. However, instream uses are generally not marketed, requiring novel approaches for estimating their economic value.

The purpose of this paper is to present and apply a general framework relating alternative streamflow levels to economic net benefits [*U.S. Water Resources Council*, 1983]. We estimate net benefits with contingent valuation but utilize observed behavior where feasible. Our model of the effect of streamflow on recreational participation is based on observed use and actual flow conditions. Similarly, our model of the relationship of willingness to pay and flow conditions is based on responses obtained for experienced environmental conditions.

The specific valuation method used in this study is the dichotomous choice or referendum question format. This relatively new approach [*Bishop and Heberlein*, 1979] appears to overcome some of the potential bias and participation problems of the bidding game and open-ended formats. In order to utilize dichotomous choice we draw on recent work that examines the relationship between the welfare measure and covariates in these types of models [*Cameron*, 1988; *Patterson and Duffield*, 1991]. We provide a synthesis and application of methods for interpreting the effect of covariates in contingent valuation models and show that covariate effects can be defined for a variety of welfare measures. Specifically, we examine the influence of streamflow levels on respondent willingness to pay for the current recreational trip. Transformation of the bid variable in our logistic regression model is investigated using a Box-Cox

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procedure [*Box and Cox*, 1964] and measures of precision for our estimates are computed via a simulation [*Krinsky and Robb*, 1986] approach.

We demonstrate these methods for two Montana rivers, the Big Hole and Bitterroot. Both rivers are "blue ribbon" trout fisheries that are sometimes subject to severe dewatering during the summer irrigation season. While both rivers are important fisheries, there are differences between the two that provide the opportunity for interesting comparisons. The Big Hole is nationally acclaimed for its wild trout fishery; use in the study section is dominated by anglers. The Bitterroot is also a good fishery, but is less well known outside the local area, and receives over half of its use from floaters and general shoreline recreationists.

BACKGROUND

Previous economic studies of instream uses have measured the effect of flows on either the quality of the experience [*Walsh et al.*, 1980; *Daubert and Young*, 1981; *Boyle et al.*, 1988; *Johnson and Adams*, 1988] or on participation [*Narayanan*, 1986; *Ward*, 1987]. Both of the latter studies basically used the travel cost method to establish the value of a given recreational trip, with the effect of flows estimated via a "contingent behavior" question relating participation to flow. In the other studies, which focused on recreation quality, respondents were asked to evaluate scenarios of alternative recreational experiences. For example, *Johnson and Adams* [1988] asked anglers to value increments in catch rates, and *Daubert and Young* [1981] asked anglers, whitewater boaters, and shoreline users to value alternative flow scenarios depicted by color photos. *Walsh et al.* [1980] perhaps came closest to modeling both quality and participation effects of flow when they queried river users with both flow and congestion scenarios; however, participation was not modeled explicitly.

All but one of these studies measured the concurrent relationship of streamflow and recreation benefits. The exception was *Johnson and Adams'* [1988] innovative study which utilized a multiperiod biological model to link the time path of streamflows and the resulting catchable fish stocks.

An empirical focus that ignores one or more aspect of the complete streamflow-benefit relationship may be entirely appropriate. For example, the *Boyle et al.* [1988] study of whitewater boating in the Grand Canyon of the Colorado ignored the effect of flows on participation because use was controlled by permit and essentially fully allocated at all times. Nevertheless, what is absent from the literature is a general model that can measure the full range of possible influences of streamflow on recreation benefits.

We present a general multiperiod framework for estimating the recreation value of instream flows that includes the direct effect of flows on both trip valuation (quality change) and participation. Additionally, the model can incorporate the indirect effects of flows on trip values (for example, congestion effects) as well as multiperiod lagged effects such as the streamflow-angler success relationship.

GENERAL FRAMEWORK FOR VALUING INSTREAM FLOWS

The present net worth (PNW) of the recreational benefits of a given river resource can be represented in a discrete time period model (where time can be in annual, seasonal, or daily units). Recreational benefits are a multiplicative function of participation and the welfare measure for homogeneous units of recreational use. The latter is typically a compensating variation measure [*Hicks*, 1943] of willingness to pay per day of activity. These elements are in turn a function of a variety of environmental and social factors. The model is given by

$$\text{PNW}\ (\bar{Q}) = \sum_{t=0}^{n} R_t(Q_t, \bar{Z})W_t[Q_t, R_t(\cdot), S_t(Q_{t-a}), \bar{X}](1+r)^{-t} \qquad (1)$$

where $\bar{Q}$ is the vector of the Q_t daily or seasonal streamflows, r is the discount rate, R_t is the measure of recreational participation in period t, W_t is a measure of individual net willingness to pay in period t, S_t is a measure of recreational quality such as angler success, a indicates a lag period for biological effects, $\bar{Z}$ is a vector of site environmental conditions in period t, and $\bar{X}$ is a vector of socioeconomic factors such as income and preferences.

The basic structure of this model reflects *Bradford*'s [1970] aggregate bid function. Because this model is limited to direct recreational use, it does not provide a measure of indirect values (such as existence, option, or bequest values [*Krutilla*, 1967]) that may be associated with adequate streamflows. Addressing indirect values would require a sample frame based on households rather than onsite users. For studies of indirect benefits of instream flow, see *Duffield et al.* [1991] and *Sanders et al.* [1990].

The value of a unit change in flows for any time period t is given by the partial total derivative of PNW with respect to Q_t. For example, when t corresponds to the current period:

$$\frac{d\ \text{PNW}}{dQ_t} = \left\{ W_t \frac{\partial R_t}{\partial Q_t} + R_t\left(\frac{\partial W_t}{\partial Q_t} + \frac{\partial W_t}{\partial R_t}\frac{\partial R_t}{\partial Q_t}\right) + R_{t+a}\left(\frac{\partial W_{t+a}}{\partial S_{t+a}}\frac{\partial S_{t+a}}{\partial Q_t}\right)\right\}(1+r)^{-a} \qquad (2)$$

The marginal value of a given unit of flow (e.g., dollars per acre foot (1 acre foot equals 1233.5 m^3)) is the sum of the effect of instream flows on participation, quality of the recreational experience, and lagged effects.

In the context of this model, previous applications have examined any one of the three major possible effects. The applications by *Narayanan* [1986] and *Ward* [1987] measured the participation effect described by the first term in (2), while applications by *Walsh et al.* [1980], *Daubert and Young* [1981], and *Boyle et al.* [1988] correspond to the concurrent effects of instream flow on the quality of the recreational experience (second term in equation (2)). *Johnson and Adams'* [1988] model is an example of a model examining lagged effects, corresponding to the third term in (2). It is possible that only one or two of the three terms may be empirically significant for a given resource. However, it is also possible that all three effects may be important. To the extent that the signs on the partial derivatives are positive in the streamflow range of interest, an implication of this framework is that previous estimates of recreational instream flow values may be conservative.

The specification here is only intended to illustrate the basic types of linkages; additional elements are certainly feasible. For example, one could easily incorporate a lagged effect on participation into the model, perhaps reflecting how previous success could influence current use levels. Similarly, additional quality factors (lagged or unlagged) could be introduced. The model could also be specified for continuous rather than discrete time. The marginal valuation given by (2) is for a change over the time period; one could also compute the present net worth of a change in an annual flow regime, or over several time periods, or for perpetuity.

EMPIRICAL MODEL

The general framework described above is applied to two rivers in a single-period model that integrates both participation and quality effects of streamflow on recreation. Estimation of lagged effects was not feasible with existing data. Accordingly, the estimates in this application may also be conservative.

We estimate a single-period version of (2):

$$\frac{\partial T}{\partial Q} = W(\cdot)\,\frac{\partial R}{\partial Q} + R(\cdot)\,\frac{\partial W}{\partial Q} \tag{3}$$

where T is total value for the period. This model incorporates both participation and quality effects based on actual conditions. In the following two sections we describe our empirical model for estimating the effect of flow level on willingness to pay $W(\cdot)$ and then our model of participation, $R(\cdot)$.

Dichotomous Choice Contingent Valuation

We use a dichotomous choice contingent valuation survey to estimate the value of a recreation trip. The trip is generally considered the logical unit of analysis for recreation behavior [*McConnell*, 1975]. The hypothetical situation posed for valuation of the current trip is an increase in trip expenditures. This is both simple and relatively easily communicated in an interview setting, which should minimize hypothetical bias.

In dichotomous choice, individuals respond "yes" or "no" as to their willingness to pay (WTP) a given cash amount for a specified commodity or service. The advantages of this approach, as compared to open-ended or bidding game questions formats, have been discussed elsewhere [*Boyle and Bishop*, 1988; *Bowker and Stoll*, 1988]. The disadvantage of this approach is that analysis and interpretation are relatively complex, since WTP must be inferred from visitor yes/no responses, rather than elicited directly from each respondent.

Two basic approaches have been used in past studies to incorporate flow level into a valuation model. The first uses what *Boyle et al.* [1988] called "unexperienced scenarios." *Daubert and Young* [1981] used this approach when they asked respondents for their WTP given alternative flow levels depicted by photos, as did Boyle et al. when they asked respondents to value specific flow levels based on descriptions of the recreation experience corresponding to those flows. The second approach is to include actual (i.e., experienced) flow levels as an explanatory variable in the logistic regression estimate. Boyle et al. used this approach to compute welfare estimates conditional on several discrete flow levels. We chose this latter approach, but in contrast to the Boyle et al. study we estimate a continuous relation between value and flow.

Our general strategy is to develop a model with instream flow as a covariate and to identify the relationship of flow and valuation analytically. Accordingly, in the discussion of the empirical valuation model that follows, the choice of specification and welfare measure is influenced by whether covariate effects can be derived. This emphasis is somewhat different from that of most contingent valuation literature where the focus is simply on valuation. Because of model complexity, only recently have investigators begun to explore the influence of covariates on welfare measures in dichotomous choice models [*Seller et al.*, 1986; *Cameron*, 1988]. We derive an empirical model for which derivatives are defined for a variety of welfare measures.

Hanemann [1984] has investigated the theoretical motivation for dichotomous choice models. He provides both a utility difference approach and an alternative derivation based on the relationship of the individual's unobserved true valuation compared to the offered threshold sum (see also *Cameron* [1988]). In the latter, it is assumed that if each individual has a true WTP, then the individual will respond positively to a given bid only if his WTP is greater than the bid. For example, suppose that an individual is confronted with an offered price (t) for access to a given resource or recreational site. The probability of accepting this offer $\pi(t)$, given the individual's true (unobserved) WTP, is then

$$\pi(t) = Pr(\mathrm{WTP} > t) = 1 - F(t) \tag{4}$$

where F is a cumulative distribution function (cdf) of the WTP values in the population. In the logit model, $F(\cdot)$ is the cdf of a logistic variate, and in the probit model, $F(\cdot)$ is the cdf of a normal variate.

The specification of this model can be briefly illustrated for the case where the WTP values are assumed to have a logistic distribution in the population of interest, conditional on the value of covariates. A statistical model is developed that relates the probability of a "yes" response to explanatory variables such as the bid amount, preferences, income, and other standard demand shifter-type variables. The specific model is

$$\pi(t;\,\bar{x}) = [1 + \exp\,(-\alpha t - \bar{\gamma}'\bar{x})]^{-1} \tag{5}$$

where $\pi(t;\,\bar{x})$ is the probability that an individual with covariate vector $\bar{x}$ is willing to pay the bid amount t. The parameters to be estimated are α and $\bar{\gamma}'$ (the constant term is included in $\bar{x}$). The equation to be estimated can be derived as

$$L = \ln\,[p/(1-p)] = \alpha t + \bar{\gamma}'\bar{x} \tag{6}$$

where L is the "logit" or log of the odds of a "yes" and p are observed response proportions. In application, the logit and probit models are so similar that it is difficult to justify one over the other on the basis of goodness of fit. We choose to use the logistic specification here because the probit model does not produce a closed form cumulative density function and our preference is to work with the logit model.

Maximum likelihood estimates (MLEs) of the parameters in (6) can be obtained with a conventional logistic regression program. *Cameron* [1988] has provided an alternative parameterization of this model that emphasizes the threshold motivation and the dependence of individual WTP on covariates. In Cameron's derivation the distribution of WTP conditional on $\bar{x}$ is logistic with mean $\bar{\beta}'\ \bar{x}$ and scale parameter k (standard deviation $\pi k/3^{(1/2)}$ or

$$\pi(t;\ \bar{x}) = 1 - F(t;\ \bar{\beta}'\bar{x},\ k) = [1 + \exp\ (t/k - \bar{\beta}'\bar{x}/k)]^{-1} \qquad (7)$$

where $F(\cdot;\ \mu,\ k)$ is the cumulative distribution function of a logistic random variable with mean μ and scale parameter k. Directly estimating the alternative parameterization requires a general maximum likelihood program. However, because of the MLE invariance property, these parameters can be derived from MLEs for the conventional parameterization [*Cameron*, 1988]. Given the $p + 1$ parameters of the two models, $\bar{\beta}^* = (k,\ \bar{\beta})$ and $\tilde{\gamma}^* = (\alpha,\ \tilde{\gamma})$, there is a one-to-one correspondence between the parameter sets or

$$g(\tilde{\gamma}^*) = (-1/\alpha,\ -\gamma_1/\alpha,\ \cdots,\ -\gamma_p/\alpha) = \beta^* \qquad (8)$$

A recent paper by *Schultz and Lindsay* [1990] reports both forms of the model (for a groundwater valuation study). However, their paper does not report standard errors for the reparameterized estimates. It has been shown that asymptotic standard errors for the MLEs in Cameron's parameterization can be calculated from the estimated asymptotic covariance matrix for the conventional parameterization [*Patterson and Duffield*, 1991]. We provide an application of that procedure. An advantage of the reparameterized model is that the coefficients are more easily interpreted. For example, in a log-log specification the coefficients are elasticity point estimates of the relationship of willingness to pay and a given covariate. For this reason, we report our estimates in the alternative parameterization form of the model.

Hanemann [1984] has shown that the linear specification in (6) is consistent with utility maximization based on his utility difference motivation. However, *Cameron* [1988] argues that from the standpoint of the threshold motivation any of a variety of WTP distributions are theoretically plausible. This implies that the choice of functional form for $F(\cdot)$ should be based on empirical considerations. Many investigators [e.g., *Boyle and Bishop*, 1988; *Bowker and Stoll*, 1988] have found that WTP distributions are skewed to the right. In these cases a better estimate may be obtained with a log-logistic model (replacing t in (6) with log t). We examine a range of Box-Cox transformation parameters [*Box and Cox*, 1964] to see whether the true transformation of the bid variable is close to linear or closer to log (or in between).

The responses to our specific valuation questions (described below) provide a Hicksian compensating variation measure [*Hicks*, 1943] of welfare change for increments of recreational services. However, because the dichotomous choice contingent valuation approach yields a distribution of WTP values, the question remains as to which parameter of the distribution to use as a welfare measure. A variety of welfare measures for dichotomous choice models have been proposed in the literature, including a truncated mean [*Bishop and Heberlein*, 1979], the overall mean [*Johansson et al.*, 1989], and percentiles of the distribution, including the median [*Hanemann*, 1984, 1989]. In all cases the distribution of F is assumed to be continuous and nonnegative.

For the log-logistic model the mean is given by

$$\begin{aligned}\mu(\bar{\mathbf{x}}) &= \exp\ (-\tilde{\gamma}'\bar{x}/\alpha)\Gamma(1 + 1/\alpha)\Gamma(1 - 1/\alpha)\\ &= \exp\ (\bar{\beta}'\bar{x})\Gamma(1 - k)\Gamma(1 + k) \qquad (9)\end{aligned}$$

where $\Gamma(\cdot)$ is the gamma function. We assume that $k < 1$ so that the mean exists (otherwise the mean is infinite). The pth quantile is given by

$$\begin{aligned}\eta_p(\bar{x}) &= \exp\ (-\tilde{\gamma}'\bar{x}/\alpha)[p/(1 - p)]^{1/\alpha}\\ &= \exp\ (\bar{\beta}'\bar{x})[p/(1 - p)]^k \qquad (10)\end{aligned}$$

Of course, when $p = 0.5$, (10) provides an estimate of the median. For the case where WTP values are skewed the median and the mean may differ considerably, as demonstrated in previous studies [e.g., *Bowker and Stoll*, 1988]. As *Hanemann* [1989] has discussed, choice of the welfare measure is a value judgement in that there is an implicit weighing of whose values are to count. Hanemann suggests 75th percentile as an alternative. We report all three measures: the overall mean, the median, and the 75th percentile, with an emphasis on the 75th percentile. The overall mean is the correct measure to use for aggregation [*Johansson et al.*, 1989] but requires extrapolation beyond the range of the data. This is true for both the logit and probit models with the bid variable logged, although at least for the probit the overall means are always defined. The median is generally much smaller than the mean for these types of models. We view the 75th percentile as a compromise measure in the sense that (given the skewness of the estimated distributions) it is conservative compared to the overall mean but less so than the median. The other widely used measure for these models, the truncated mean [*Bishop and Heberlein*, 1979], also has the property of approaching the overall mean in value but staying within the range of the available data (for a recent example, see *Shultz and Lindsay* [1990]). We prefer the percentile measure for this application because derivatives can be defined in closed form.

The partial derivatives of (9) and (10) with respect to a covariate x are

$$\frac{\partial \mu(\bar{\mathbf{x}})}{\partial x_i} = (-\gamma_i/\alpha)\mu(\bar{\mathbf{x}}) = \beta_i\mu(\bar{\mathbf{x}}) \qquad (11)$$

$$\frac{\partial \eta_p(\bar{\mathbf{x}})}{\partial x_i} = (-\gamma_i/\alpha)\eta_p(\bar{\mathbf{x}}) = \beta_i\eta_p(\bar{\mathbf{x}}) \qquad (12)$$

Obviously, these partial derivatives have the same form. The elasticity of either welfare measure with respect to a linear covariate x_i is equal to $-\gamma_i x_i/\alpha = \beta_i x_i$. For log transformed variables, elasticity is given by $-\gamma_i/\alpha = \beta_i$. Thus a proportional change in either of these measures with respect to a fixed change in x_i is constant [*Patterson and Duffield*, 1991]. This interesting result applies to a broad range of welfare measures, including the mean and any percentile of the WTP distribution. Again, it may be noted that the widely used truncated mean welfare measure does not have defined derivatives.

Participation

Another element in our flow valuation model (equation (3)) is $R(Q,\ \bar{Z})$. $R(\cdot)$ is use per period (e.g., day) for a given recreation site. This is modeled as a second- (or higher) order polynomial in the flow variable (Q) plus an assumed linear relationship to a vector of other explanatory variables ($\bar{\mathbf{Z}}$), such as a weekend/weekday dummy variable and a weather variable, that might affect daily use, or

$$R(Q) = b_0 + b_1Q + b_2Q^2 + \sum_{i=3}^{m} b_iZ_i \qquad (13)$$

In contrast to this specification, *Narayanan* [1986] uses a logistic model to measure participation. The limitation of the logistic specification is that use is not necessarily a continuous positive function of flows; rather it will likely turn negative as flows reach very high levels. A second-order or higher polynomial specification (depending on signs of estimated parameters) may permit identification of an optimal flow level in terms of participation. Equation (13) can be estimated using ordinary least squares.

Precision of the Estimates

Previous studies of instream flow values have not examined the precision of welfare estimates. However, recent applications to related nonmarket valuation issues have reported standard errors for dichotomous choice contingent valuation [*Kealy et al.*, 1988; *Duffield and Patterson*, 1989; *Park et al.*, 1989]. Because of model complexity, we utilize the simulation approach described by *Krinsky and Robb* [1986] to estimate standard errors for marginal total instream flow value ($\partial T/\partial Q$) as well as all other terms in (3). It would be very difficult if not impossible to estimate these standard errors through analytical procedures. Using IMSL SFUN/LIBRARY, version 2.1, we drew 1000 repetitions from the asymptotic multivariate normal distributions for the estimated parameters. It should be noted that "bootstrapping" procedures are somewhat different in that one draws from distributions based on the original data [*Duffield and Patterson*, 1991].

APPLICATION TO THE BIG HOLE AND BITTERROOT RIVERS

The Big Hole River starts near Jackson, Montana, in a broad valley bounded by the Bitterroot, Pioneer, and Pintler mountains. It circles around the Pioneers to where it joins the Beaverhead (to form the Jefferson) at Twin Bridges. In the middle section of the river, between Wise River and Melrose, the valley narrows to a canyon, which is world-renowned for its dry fly fishing for browns and rainbows. Particularly during the salmon fly hatch in mid-June, the river attracts anglers from across the nation.

The Bitterroot is also a good fishery but receives the bulk of its use from floaters and general shoreline recreationists. This river flows north from the junction of the East and West Forks south of Darby, Montana, to where it joins the Clark Fork in Missoula. While the Big Hole has a well-defined and generally stable streambed, the Bitterroot is a river on the move, constantly redefining its course through braided channels lined with cottonwoods. The Bitterroot has a major reservoir (Painted Rocks) on its West Fork tributary, from which the Montana Department of Fish, Wildlife, and Parks (DFWP) has in recent years purchased water to supplement summertime flows. The DFWP has monitored the effect of Bitterroot flows on the fishery [*Spoon*, 1987] and has developed specific minimum instream flow recommendations for the entire Upper Missouri River Basin, which includes the Big Hole.

Like most Montana streams, the Big Hole and Bitterroot have pronounced seasonal variation, with snowmelt runoff peaking in June and minimum flows occurring in August or September. Both rivers have extensive historical flow records maintained by the U.S. Geological Survey. Flow at Melrose on the Big Hole has averaged 1153 cfs (32 m^3/s) (based on 65 years of record), with mean June and August flows of 4055 cfs (114 m^3/s) and 479 cfs (13 m^3/s), respectively. Flow on the Bitterroot at Darby has averaged 909 cfs (25 m^3/s) (51 years of record), with mean June and August flows of 3197 cfs (90 m^3/s) and 376 cfs (11 m^3/s), respectively.

Data Collection and Survey Design

Onsite surveys were conducted from May 1 to August 26, 1988. On the Big Hole River the study section was between Wise River and Glen, a 43-mile section of the 129-mile-long river. This section receives about 40% of total Big Hole recreational use. Interviews were conducted at all nine major river access sites in this section. Onsite interviews on the Bitterroot were conducted at four river access sites between Woodside Crossing and the Stevensville bridge. This study section encompasses 18 river miles of the 83-mile-long river and accounted for about 10% of total recreational use on the Bitterroot in 1985 based on *McFarland* [1989].

Interview days were randomly chosen over the May through August summer season and totaled 37 days on the Big Hole and 34 days on the Bitterroot. During a typical 8-hour interview day, 2 hours were spent at each Bitterroot access point, with time of day randomly varied across sites. On the Big Hole, approximately 45 min were spent at each access in the course of a day. There were 319 respondents on the Bitterroot and 590 on the Big Hole. Since the sample frame was similar on both rivers, the larger Big Hole sample reflects the higher use density on this river, particularly in the early season.

The onsite surveys gathered information from respondents on a daily basis that could be correlated to daily river flows measured at U.S. Geological Survey gauges along each river. The interviews identified respondent characteristics, river activity share, trip valuation, and total visitation. The current trip valuation part of the survey obtained the respondent's estimate of the monetary cost of the trip, and then asked if the respondent "would still have visited" the site if his or her "personal expenses were [offer price] more" [*Duffield et al.*, 1991, p. 126]. A limitation of this form of the question is the ambiguity as to whether the "price" is higher for all visits to the site or just for today's visit. If respondents do not assume that all visits have the higher price, there is a conservative bias to the willingness-to-pay values. Details of the survey instruments and interview schedule are provided in the work by *Duffield et al.* [1991].

The selection of the bid range and the distribution of the sample among the offer amounts followed procedures developed to minimize the standard error of welfare estimates in logistic dichotomous choice models [*Duffield and Patterson*, 1991]. A previous contingent valuation study of Montana stream anglers [*Duffield and Allen*, 1988] provided prior estimates of the expected logistic distribution. A general

TABLE 1. Activity Shares and Variable Means by River

Subsample	N	Variable Means					
		Days	Expense	Distance	Income	Triptime	Age
Bitterroot River							
Resident float angler	37	1.03	17.24	18.29	35,294	6.21	37.19
Resident other	193	1.08	23.59	28.97	26,955	3.19	38.31
Nonresident float angler	7	2.71	342.85	818.5	46,071	16.00	32.86
Nonresident other	52	4.50	591.31	1289	46,341	19.12	41.48
Big Hole River							
Resident float angler	182	1.85	72.16	130.7	40,290	20.91	38.65
Resident other	175	1.85	48.43	85.7	27,978	20.48	41.88
Nonresident float angler	75	3.81	894.66	942.5	66,771	30.00	45.07
Nonresident other	121	3.29	717.26	1209	52,824	36.28	46.16

finding from *Duffield and Patterson* [1991] is that more precise estimates of a given percentile welfare measure result from allocation of a higher proportion of the sample at bid levels near the value of the welfare estimate. In this application the bid range used was $1 to $2000 with a higher proportion of the sample allocated at the $250, $350, and $500 bid levels.

Site and Respondent Characteristics

The mix of activity types differed across rivers. Eighty-seven percent of the Big Hole respondents were fishing, compared with only 41% of the Bitterroot respondents. Although about 25% of users on both rivers fished from the shore, there was much more float fishing on the Big Hole (47%) than on the Bitterroot (14%) (Table 1). General shoreline activities (picnicking, swimming, etc.) occupied 53% of Bitterroot users but only 7% of Big Hole users.

The fame of the Big Hole's fishery is reflected in the type of visitor it attracted in 1988. Thirty-six percent of Big Hole users were from out of state, compared with 20% of Bitterroot users. Mean household income of Big Hole visitors was $41,500 compared to $31,000 on the Bitterroot. Eight percent of Big Hole visitors were on guided trips, compared to only 0.3% on the Bitterroot. The typical trip to the Big Hole entailed more time at the site (25.5 hours compared to 6.8 on the Bitterroot), greater expense per person per trip ($329 verses $133), and was less frequently taken. The average Big Hole respondent had already taken 2.8 trips to the river that year, compared to 8.6 trips for the average Bitterroot respondent. Additionally, 20% of Big Hole respondents considered the river to be crowded, while only 7% of Bitterroot visitors thought that river was crowded. There were also substantial differences in income, age, and days per trip between residents and nonresidents on both rivers (Table 1, variable definitions in Table 2).

The summer of 1988 happened to be one of the driest on record, and the Big Hole was particularly hard hit. July flow on the Big Hole averaged only 306 cfs (9 m^3/s) or 23% of the historical July flow as measured at the Melrose gauge (1346 cfs (38 m^3/s)). By August, flows averaged 92 cfs (3 m^3/s). Flow in the Bitterroot also was below normal with August discharge averaging 216 cfs (6 m^3/s). (Bell Crossing gauge and Darby gauge average), or 57% of the historical average flow of 376 cfs (11 m^3/s) at Darby.

On the basis of individuals sampled per day, use peaked in June on the Big Hole and July on the Bitterroot. Nonresident use increased over time on both rivers. On the Bitterroot, only 2% of May users were nonresidents, compared with 29% by August. The absolute change was even more pronounced on the Big Hole, going from 16% nonresident use in May to 63% in August. While visits on the Bitterroot averaged around 7 hours onsite throughout the summer, trip length on the Big Hole changed from 17 hours onsite in May to 50 hours in August.

For the complete sample the majority of users on both rivers reported that the flow was adequate for their purposes at the time of the interview. Only 19% of all Bitterroot respondents and 31% of Big Hole respondents would have preferred higher flows. However, for July-August, 30% of Bitterroot visitors and 59% of Big Hole visitors would have preferred higher flows.

TABLE 2. Variable Definitions

Variable	Definition
BIDT	dollar bid offer for current trip
Income	household annual income in dollars
TRIPTM	hours on site for this trip
Q	daily average flow in CFS on study sections based on USGS gauges at Melrose (Big Hole) and Darby and Bell Crossing (Bitterroot)
Age	age of respondent
RES	dummy variable with 1, Montana Resident; 0, nonresident
BITTER	dummy variable with 1, visitor to Bitterroot River; 0, visitor to Big Hole River
FLOATA	dummy variable with 1, visitor is a floating angler; 0, visitor engages in other activity
*N*sample	number of anglers interviewed on a specific day
Crowded	perception of visitor as to how crowded the river was ranging from 1, not crowded to 9, very crowded
WKEND	dummy variable with 1, interview conducted on weekend day; 0, weekday
Wind	dummy variable with 1, strong winds on river; 0, no strong winds
k	scale parameter for the logistic distribution (standard deviation is $\pi\kappa/3^{1/2}$)
Cold	dummy variable with 1, cold temperature on interview day; 0, not cold
SALDATE	dummy variable with 1, a day when greater than 20% of anglers reported fishing the Salmon fly hatch
Days	days per trip
Expenses	expense per person per trip
DIST	on way travel distance in miles

TABLE 3. Logistic Dichotomous Choice Model for Valuation of Current Trip: Full Model

Variable	Coefficient	Variable Mean	Standard Error	Asymptotic *T* Statistics
Intercept	−3.8982	···	2.52479	−1.5439
k	−0.7808	···	0.05871	−13.299*
ln income	0.0452	11.513	0.14374	3.1496*
RES	−0.1329	0.697	1.50960	−0.0880
ln age	0.9406	3.661	0.36569	2.5720†
ln *Q*	0.1988	6.629	0.27569	0.7214
ln TRIPTM	−0.1701	1.913	0.53574	−0.3182
BITTER	−3.5602	0.344	1.68515	−2.1994†
BITTER*ln*Q*	0.4571	2.204	0.24747	1.8471‡
RES*ln*Q*	−0.1837	4.722	0.22640	−0.8159
TRIPTM*ln*Q*	0.0578	12.752	0.08137	0.7111
FLOATA*ln*Q*	−0.3264	2.607	0.27426	−1.1901
Crowded	0.0629	1.891	0.12803	0.4909
*N*sample	−0.0079	17.546	0.01324	−0.5956
FLOATA	1.8636	0.357	1.92645	0.9674

$N = 732$; −2 (Log likelihood) = 456.43; dependent variable is Log (unobserved willingness to pay).

*Values are significant at 99% level.

†Values are significant at 95% level.

‡Values are significant at 90% level.

A formal use survey was beyond the resources available for this study; we used individuals sampled per day as a proxy for daily use levels. Individuals sampled per day is a good index of daily use on the Bitterroot because it was always possible to sample all individuals observed at the access sites during our selected interview times. On the Big Hole, which was more crowded than the Bitterroot during times of adequate flow levels, it was not always possible to sample all observed individuals. Because our sampling procedure underestimated use at higher flow levels, the participation effect measured by the estimate of (13) for the Big Hole is conservative.

Estimation Procedure

Models of current trip value (equation (6)) and recreation participation (equation (13)) were estimated. For the former, we examined a large subset of the theoretically plausible independent variable combinations using the maximum likelihood logistic regression procedure in the work by *SAS Institute, Inc.* [1988]. Likelihood ratio tests for the incremental contribution of specific variables or sets of variables were used to test the hypothesis that the valuation function is different for different user groups or at different locations. Since a major focus of the model was on derivatives with respect to discharge, interactive terms for residency status, location (river), trip length, and activity type with discharge were specifically tested as detailed below. On the basis of initial comparisons of alternative Box-Cox transformations of the bid variable, we primarily worked with the log transformation. A comparison of alternative transformations for the final reduced model is described below. Ordinary least squares regression results reported here for the relationship of participation to flow levels were computed with the *SAS Institute, Inc.* [1988] stepwise regression procedure. Models reported are based on the step with the last variable included having an estimated coefficient significant at the 90% level, based on a t test. Table 2 provides definitions of independent variables for both the participation and valuation models.

Current Trip Valuation

A logistic regression model that includes a complete set of our theoretically plausible independent variables is summarized in Table 3. Data from both rivers was pooled in order to gain efficiency and to test the hypothesis that analogous coefficients differ across locations. The estimates were made on an equation of the form of (6) and reparameterized as in (8) so that the dependent variable is the log of unobserved willingness to pay. Standard errors are derived following *Patterson and Duffield* [1991]. The model was reestimated several times to test the contribution of sets of variables based on likelihood ratio tests. It was found that the contribution of variables to measure congestion and the interaction of residency status, activity group, and length of trip with discharge did not provide a significant improvement in the likelihood ratio at the 90% level. Note that the finding of no significant congestion effect contrasts with *Walsh et al.* [1980], who found that congestion had a significant effect on recreational trip value for a set of Colorado rivers. However, it appears that on average the Colorado rivers are much more crowded than the Montana study sites. The Colorado sites average approximately 12 users/mile-day over the sample season, compared with about 2 users/mile-day on the Big Hole and Bitterroot.

A reduced model is reported in Table 4. Alternative transformations of the bid variable were examined using a range of 1.0 to −1.0 for the Box-Cox transformation parameter λ (where the transformation is $(t^{\lambda} - 1)/\lambda$) [*Box and Cox*, 1964]. With this parameter at zero the model corresponds to a log specification, and at $\lambda = 1$, a linear transformation. A plot of the log likelihood statistic against λ for the variable set of Table 4 is shown in Figure 1. The log likelihood is maximized at a λ of −0.1 (log likelihood of −229.4), but this transformation results in only a slight improvement over the log transformation (−229.8). Both the −0.1 and log transformations result in large and statistically significant improvements over the linear model (log likelihood of −319.9). For convenience, we use the transformation rounded to $\lambda = 0$. Note that we conducted a line search rather than optimizing the Box-Cox model explicitly.

TABLE 4. Logistic Dichotomous Choice Model for Valuation of Current Trip: Reduced Model

Variable	Coefficient	Variable Mean	Standard Error	Asymptotic *T* Statistics
Intercept	−3.3410	···	1.98459	−1.6835
k	−0.7942	···	0.05824	−13.636*
ln income	0.4412	10.296	0.14413	3.0614*
RES	−1.3864	0.697	0.29178	−4.7513*
ln age	0.9152	3.661	0.36247	2.5249†
ln *Q*	0.1361	6.629	0.14226	0.9568
ln TRIPTM	0.2159	1.913	0.08907	2.4242†
BITTER	−2.9574	0.344	1.41068	−2.0964†
BITTER*ln*Q*	0.3841	2.204	0.20554	1.8685‡
FLOATA	−0.4539	0.357	0.23933	−1.8967‡

$N = 732$; (−2* Log likelihood) = 459.62; dependent variable is Log (unobserved willingness to pay).

*Values are significant at 99% level.

†Values are significant at 95% level.

‡Values are significant at 90% level.

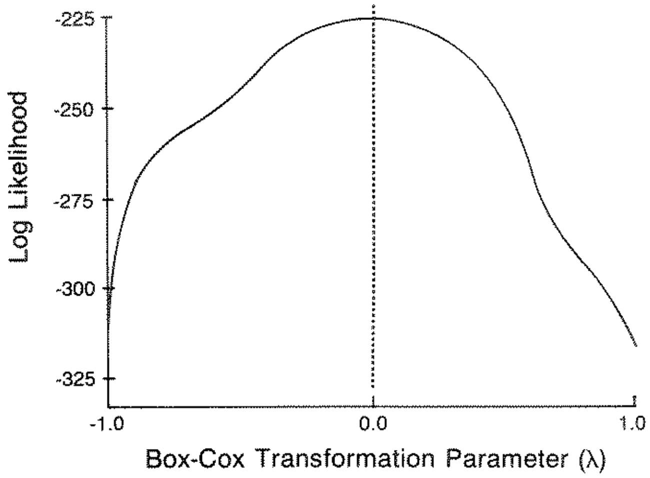

Fig. 1. Log-likelihood statistic for logistic contingent valuation model for a range of Box-Cox transformation parameters.

It was found that the relationship of discharge to WTP varied significantly across rivers based on a likelihood ratio test of the Bitterroot river dummy variable and discharge interaction term. The elasticity of WTP with respect to discharge is 0.14 on the Big Hole River but 0.52 on the Bitterroot. This means, for example, that a 10% increment in streamflow on the Bitterroot leads to a 5.2% increase in trip value, other things equal. The bid variable is negatively correlated with odds of a "yes" response and is highly significant. Income, time on site, and age also have the theoretically expected sign, are highly significant, and have elasticities of 0.44, 0.22, and 0.92, respectively. The large, negative and highly significant coefficient on the Bitterroot dummy variable (location) indicates that trips on the Bitterroot river are less valuable, other things equal. The only coefficient sign that appears counterintuitive is the negative sign on the float angler (activity group) dummy variable, indicating that, other things equal, these types of trips are less valuable.

Recreation Use

The estimated use equation for the Bitterroot has expected signs for discharge, weekends, and strong winds, and all variables are highly significant (Table 5). In addition, discharge squared and cubed are significant at the 99% level. This polynomial fit to discharge indicates that use is initially positively related to discharge, peaks at some optimal flow level (about 1100 foot^3/s (31 m^3/s) for this model), and then declines. There is only one sign change for the derivative of this function in the domain of the actual data on flows. (There is an inflection point at about 4000 cfs (112 m^3/s) and a minimum value at about 6500 foot^3/s (182 m^3/s), well beyond the observed range of 100 cfs (3 m^3/s) to 2000 cfs (56 m^3/s)). This is consistent with the general expectation that use is low at very low flows and at flood levels and is maximized at moderate flows. The equation for the Big Hole shows significant correlations with expected signs for discharge, discharge squared, and dummy variables for cold temperatures and times when the salmon fly hatch is on. Use levels on the Big Hole are maximized at flow levels of around 1800 foot^3/s (50 m^3/s). Other things being equal, when salmon flies were present, use doubled.

Recreation Values of Instream Flows

Estimated net economic benefits for recreational trips to the Big Hole and Bitterroot Rivers are presented in Table 6 for three specific welfare measures: the median, 75th percentile, and the overall mean and for four subsamples defined by residency status and activity. All measures indicate that trips on the Big Hole River are on average more valuable than trips on the Bitterroot River and that trips by nonresidents have much higher WTP than resident trips. The difference across river types and residency status is in part

TABLE 5. Daily Use as a Function of Flow Level: Big Hole and Bitterroot Rivers

	Bitterroot		Big Hole	
Variable/Statistic	Coefficient*	Variable Mean	Coefficient*	Variable Mean
Intercept	6.04334 (4.04)	···	6.3247 (3.696)	···
Q	0.006584 (1.87)	1153	0.010338 (2.241)	931
Q^2	$-3.74E-6$ (−2.11)	4,941,342	$-2.776E-6$ (−1.692)	1,592,122
Q^3	$4.467E-10$ (1.98)	$1.9725E+10$	···	···
WKEND	4.6216 (2.83)	0.294	3.3926 (1.722)	0.432
Wind	−4.7971 (−2.15)	0.088	···	···
Cold	···	···	−7.4475 (−2.783)	0.135
SALDATE	···	···	5.5931 (1.946)	0.162
R^2	0.411	···	0.571	···
Sample size	34	···	37	···
*N*sample (dep)	···	7.50	···	12.892

Read $-3.747E-6$ as -3.74×10^{-6}.
*T statistics are in parentheses.

TABLE 6. Welfare Measures for Willingness to Pay for Recreational Trip (1988 Dollars)

River/Sample	Median (Standard Error)*	75% (Standard Error)*	Overall Mean
	Bitterroot		
Resident, float angler	48 (13)	115 (31)	199
Resident, other user	60 (12)	143 (30)	247
Nonresident, float angler	236 (76)	566 (209)	980
Nonresident, other user	480 (142)	1148 (365)	1988
	Big Hole		
Resident, float angler	87 (18)	207 (42)	359
Resident, other user	125 (29)	298 (65)	516
Nonresident, float angler	540 (115)	1291 (308)	2234
Nonresident, other user	816 (215)	1952 (517)	3377

*Data are based on *Krinsky and Robb* [1986] simulation procedure with 1000 repetitions.

due to differences in user characteristics (Table 1) given the elasticities in Table 4. The values in Table 6 are per trip; values per day can be derived using the days per trip reported in Table 1. On the basis of the median welfare measure the value per day for residents is from about $50 to $70 and the value per day for nonresidents is $90 to $110 on the Bitterroot and $165 to $215 on the Big Hole.

These values can be compared to average values reported in the *Walsh et al.* [1989] literature review of 88 specific nonmarket fishing value estimates. The median values for our resident users are similar to the literature average values reported for cold water, anadromous, and salt water fishing. Our nonresident median per day values are at the upper end of the reported range for these types of fishing ($120 to $220 per day). The 75th percentile estimates in Table 6 for nonresidents on the Bitterroot are also at the upper end of the reported range, while Big Hole nonresident values are from $400 to $500 per day. These findings indicate that computing average values for recreation on a given stream obscures some important differences among user groups. It also appears that the values for nonresident anglers on a major "destination" trout fishery like the Big Hole may be quite high. These values may be plausible given the income level, trip length, and expenses of this group of dedicated anglers (Table 1). This application indicates the importance of user group attributes in explaining average values. These findings have implications for the benefit transfer issue. It may be more appropriate to argue that the fitted valuation function might be transferable than to suggest the same for the fitted point estimates of average value.

Standard errors were computed for the two percentile measures using the procedures of *Krinsky and Robb* [1986]. On the basis of 1000 repetitions, standard errors for the welfare measures are 12% to 14% of the estimate, indicating 95% confidence intervals that are about ±25% of the estimate.

Using the estimated parameters from Tables 4 and 5, marginal recreational values for instream flows, as in (3), were computed for both study sites. Table 7 provides a listing of the marginal values per acre foot for the river study sections at discharge levels ranging from 100 cfs (3 m^3/s) to 2000 cfs (56 m^3/s). Values are weighted averages for a given river based on user group subsample shares (Table 1). Results are presented for the 75th percentile welfare measure; estimates based on the median would vary in direct proportion to the values of this percentile measure, as reported in Table 6.

Marginal values on the Bitterroot range from $10 per acre foot ($7 per $m^3 \times 10^3$) at 100 cfs (3 m^3/s) to zero value at 1900 cfs (53 m^3/s) (Figure 2 and Table 7). This is the value of an additional acre foot of water on any given day through the respective study sections. The effect of flows on quality of the experience (WTP per day) accounts for over two thirds of the marginal value, with the effect of flows on participation comprising the remainder (Table 7). On the Big Hole marginal values range from $25 per acre foot at 100 cfs (3 m^3/s) to zero at about 2200 cfs (62 m^3/s). On this river the marginal value of additional streamflow is about equally due to increased participation and increased WTP per day.

Total recreation values for the two rivers as a function of discharge are also depicted in Figure 2. On the Bitterroot, total WTP reaches a maximum of about $15,500 per day at 1800 cfs (50 m^3/s), while on the Big Hole WTP reaches a maximum of about $53,000 per day at a discharge of 2000 cfs (56 m^3/s). These total WTP values can also easily be scaled up to estimated values for the 153 day (May 1 to September 30) season. The respective seasonal values are about $2.4 million on the Bitterroot study section and $8.1 million on the Big Hole study section.

Precision of these estimates was also derived using the *Krinsky and Robb* [1986] procedure. In this case we drew simultaneously from the two multivariate normal distributions of parameter estimates from our two underlying models: the maximum likelihood logistic model of trip valuation and the OLS model of daily use. At lower flow levels the 95% confidence intervals are from plus or minus 50% to 80% of the estimates.

It is interesting to note that the instream values estimated here are in the range of typical transaction prices for instream flows. Ten instream flow transactions reported in *Water Market Update* between 1988 and 1989 were between

TABLE 7. Marginal Recreational Value as a Function of Instream Flow Levels: Big Hole and Bitterroot Rivers (1988 Dollars per Acre Foot)

	Bitterroot			Big Hole		
Discharge, cfs	Participation Effect	Quality Effect	Marginal Value	Participation Effect	Quality Effect	Marginal Value
			Estimated Values			
100	1.22	9.08	10.31	10.08	15.36	25.45
200	1.53	7.05	8.59	10.45	9.36	19.82
300	1.64	6.19	7.84	10.38	7.21	17.59
400	1.63	5.68	7.31	10.10	6.07	16.17
500	1.52	5.33	6.85	9.70	5.35	15.05
600	1.36	5.05	6.40	9.21	4.84	14.06
700	1.14	4.81	5.95	8.67	4.46	13.13
800	0.89	4.60	5.48	8.07	4.16	12.22
900	0.60	4.40	5.00	7.42	3.90	11.33
1000	0.30	4.21	4.51	6.75	3.69	10.43
1200	−0.36	3.86	3.49	5.31	3.32	8.64
1400	−1.05	3.51	2.46	3.79	3.02	6.81
1600	−1.74	3.18	1.44	2.19	2.76	4.94
1800	−2.40	2.85	0.45	0.53	2.52	3.04
2000	−3.01	2.53	−0.48	−1.19	2.29	1.11
			*Standard Errors of Marginal Value Estimates**			
100			1.67			7.54
500			1.45			3.84
1000			1.36			2.64
1500			1.11			2.21

One acre foot equals 1233.5 m^3.

*Data are based on a simulation with 1000 repetitions using procedure of *Krinsky and Robb* [1986].

$1 and $7, two were in the $15 to $25 range and another was $50. One of these transactions was a purchase by Montana Department of Fish, Wildlife, and Parks of 10,000 acre feet (1.233×10^7 m^3) annually at the administratively set price of $2 per acre foot for release from Painted Rocks Reservoir in the Bitterroot headwaters. Given that these releases were during low summer flow conditions, the purchase of these releases on the Bitterroot appears to be justified by the value generated in the study section alone.

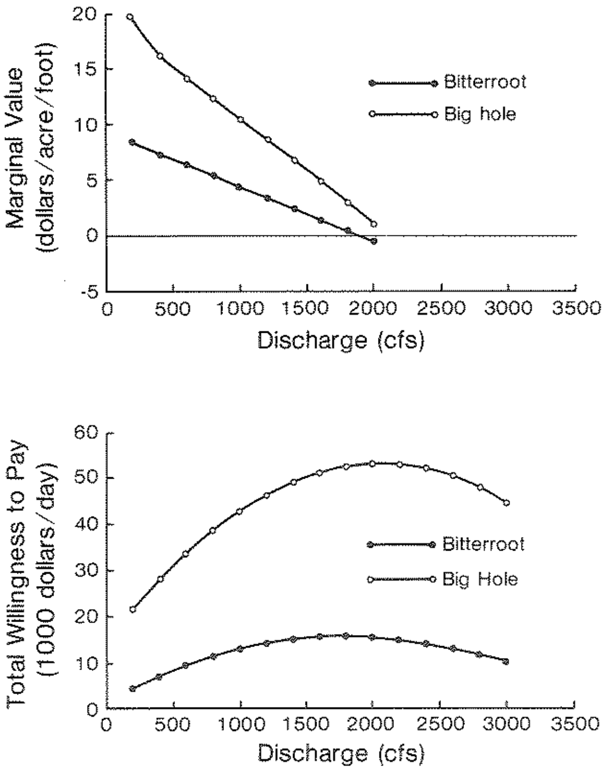

Fig. 2. Marginal and total recreation value for Big Hole and Bitterroot River study sections as a function of instream flow (1988 dollars).

Implications of Incomplete Models

The estimated marginal values presented above can be compared with those from a simplified model, similar to that used by *Daubert and Young* [1981], where only WTP per day varies with flow levels while participation is held constant at average use levels. When participation is held constant, the value change associated with the quality effect is overstated at low flows and high flows and, of course, is similar to the full model estimates at average flows. In a related simplified model, similar to that used by *Narayanan* [1986], value per day is held constant across flow levels but participation varies. Again marginal values for this effect alone are overstated at low flows. For our application, both types of simplified models understate marginal values compared to the complete model results of Table 7. Details of this comparison are provided in the work by *Duffield et al.* [1991]. The results presented here for the Big Hole and Bitterroot are probably also understated compared to true marginal values because lagged effects were not measured.

ALLOCATIVE IMPLICATIONS

A complete evaluation of the tradeoff between withdrawal and instream use would require modeling flow, storage, allocation, and instream uses, with and without the diversion, for the entire affected river basin, and is beyond the scope of this study. However, relatively simple examples for the Bitterroot and Big Hole shed light on the diversion/instream flow allocation issue.

Irrigation accounts for 96% of consumptive water use in Montana [*Gibbons*, 1986], and is also the primary consumptive use in both the Bitterroot and Big Hole Valleys. In Ravalli County, where most of the irrigation water from the Bitterroot River is used, alfalfa and other hays occupy 48% and 38% of the irrigated acreage, respectively. Over 90% of the approximately 16,000 acres (6478 ha) in other hays is irrigated. Because other hays yield less income per acre foot of water applied than alfalfa and other crops and are less sensitive to lack of water than most other crops, we assume it is the main crop on which irrigation would be reduced if water were lacking. The situation is similar in Beaverhead County along the Big Hole.

We estimated the marginal value of irrigation based on the difference in return between irrigated and nonirrigated other hays, which averages 1.1 tons per acre (404 kg/ha) (1.88 minus 0.78 tons) (691 minus 287 kg/ha) in Ravalli County and 0.6 tons per acre (220 kg/ha) (1.45 minus 0.85 tons) (533 minus 313 kg/ha) in Beaverhead County [*Montana Agricultural Statistics Service*, 1990]. Using an average 1987–1989 price for other hays in Montana of \$58 per ton, a short run cost of \$20 per acre for flood irrigation, and a net irrigation requirement of 13 inches (33 cm), yields a value of \$40 per acre foot consumed in irrigating other hays in Ravalli County [*Duffield et al.*, 1990]. In Beaverhead County the net irrigation requirement is 10 inches (25.4 cm) for a value of \$19 per acre foot consumed for flood irrigation.

These values per acre foot may tend to overestimate the short run marginal value of irrigation water in that they are for the average acre, not the least productive acre. Irrigation is most likely to be cut back on less productive fields if water is limited. The estimates also assume that all water not consumed by the crop returns to the stream (delivery and on farm application efficiencies each average about 50%). On the other hand, the example values may tend to underestimate the marginal value of irrigation water because they reflect a year of average water availability, rather than a dry year when water is limited and more valuable.

The value of instream flow in both rivers includes the value of recreation and hydroelectric power generation, plus any existence value (such as of the fishery), for as far downstream as the water remains in the stream. We will ignore existence value. Also, in the well-watered Columbia Basin we can ignore navigation, plus any final consumptive use downstream. We also ignore these values on the Missouri. We have estimated the marginal recreation value in our study sections to range from \$8 per acre foot on the Bitterroot and \$22 on the Big Hole in times of very low flow to \$0 when flow is ample. These values apply to the 22% of the Bitterroot length and 33% of the Big Hole length that were included in our study.

In order to estimate the value of an acre foot of incremental streamflow through the entire river length, it is necessary to estimate marginal recreational values for other river sections. Equation (3) can be aggregated across j river sections as follows by defining river section use (R_j) and discharge levels (Q_j). The relationships of participation and valuation for the study section, $R(\cdot)$ and $W(\cdot)$, are assumed to hold for the other river sections.

$$\frac{\partial T}{\partial Q} = \sum_j \left(\frac{\partial T}{\partial Q}\right)_j = \sum_j R_j(Q_j) \frac{\partial W}{\partial Q}(Q_j) + W(Q_j) \frac{\partial R}{\partial Q}(Q_j) \tag{14}$$

River section specific use estimates for three sections (lower, study, and upper) were derived from *McFarland* [1989]. The relationship of discharge on the upper section to streamflow on the study section was derived from a regression relationship for the respective gauges. Flows on the lower 22 miles (35 km) of the Big Hole were assumed to be the same as those in the study section. Flows on the lower 32 miles (51 km) of the Bitterroot were interpolated from nearby gauges on the Clark Fork River above and below the Bitterroot confluence. Recreation values further downstream for these rivers, on the Clark Fork-Columbia and Missouri, would add to these estimates.

Both the Big Hole and Bitterroot rivers have very substantial instream values associated with hydroelectric power. This is because these streams are in the headwaters (in fact separated by only a few miles at the Continental Divide) of two of the most important hydroelectric resources in the continental United States—the Columbia and the Missouri. Hydroelectricity replaces more expensive power produced at thermal plants. One approach to valuing hydropower is to estimate the short run marginal cost savings: variable costs at thermal plants less variable costs at hydroelectric plants. *Gibbons* [1986] uses a value of 20 mills per kilowatt hour based on replacing coal as the thermal plant fuel. If the hydroelectric energy were assumed to replace energy produced at gas turbine plants or if the long run cost of capital replacement were included, the value would be considerably higher.

Gibbons [1986] reports a cumulative 1025-kW hours per acre foot for the dams on the mainstem of the Columbia River. Adding the additional 571-kW hours for the Clark Fork of the Columbia and the Spokane River yields a total of 1596-kW hours per acre foot. At the conservative cost savings estimate of 20 mills per kilowatt hour this yields a value of \$32 per acre foot (ignoring evaporative losses). Downstream from the Big Hole there are 1303-kW hours of generation per acre foot on the Missouri, indicating a short run value of \$26 per acre foot.

Adding the recreation and hydropower values yields an instream value of from \$95 per acre foot at low flows to \$34 at flows of 2000 cfs (56 m^3/s) on the Big Hole and values of from \$110 to \$0 on the Bitterroot (Figure 3). Ignoring the lost instream use of water between the diversion and return flow points, the instream flow values should be compared with the marginal value of water consumed in agriculture, which as reported above is about \$20 per acre foot on the Big Hole and \$40 on the Bitterroot. Applying the usual equimarginal allocation principle, these findings suggest that when the Bitterroot river is discharging under 1400 cfs (39 m^3/s), instream flows provide a more valuable use of the water than agriculture. When instream flow is ample, agricultural diversion remains a wise procedure at the margin. On the Big Hole, hydropower values alone exceed irrigation values at all flow levels modeled. Obviously, the assumption of constant marginal values for either of these uses is untenable for very large changes in flow. These findings are, of course, premised on our assumption that our valuation and participation models can be applied to other river sections. Given the potential allocative importance of instream uses, a more complete empirical study of these resources may be justified.

SUMMARY AND CONCLUSIONS

This paper introduces a general framework for estimating the recreational value of instream flow. The theoretical

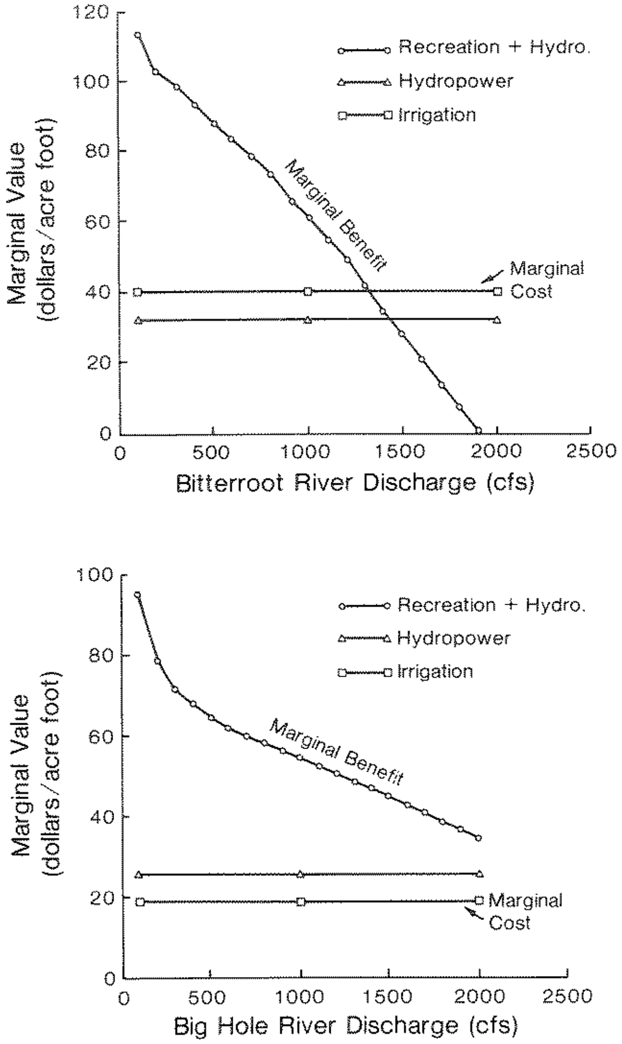

Fig. 3. Comparison of marginal instream flow values for recreation and hydroelectricity versus opportunity cost of irrigation withdrawals for mainstem of Big Hole and Bitterroot rivers (1988 dollars per acre foot).

model incorporates the influence of instream flow on both the quality of the recreational experience and on the participation level. The model can be used to value an increment to flow over a season or alternative flow regimes. Methods for interpreting covariate effects in dichotomous choice contingent valuation are presented, and procedures for estimating standard errors for welfare estimates and the marginal value of water are demonstrated.

The recreation value model is demonstrated in applications to the Big Hole and Bitterroot Rivers in Montana. Valuation was based on experienced flow levels using a dichotomous choice current trip valuation model, while use was actual observed. A broad range of flows was experienced during the May to August sample season, as the summer of 1988 happened to be one of the driest on record. Valuation varied by residency status, user group, and across rivers.

Marginal recreation values per acre foot for the river study sections were found to be in the $10 to $20 range at low flow levels. These estimates were less precise than the estimated value of a recreational trip because of the additional variability introduced by the model of recreational use.

The instream flow valuation framework provides a convenient structure for comparing results of previous instream flow research. Marginal instream flow values were computed using the full model specification as well as incomplete models where either participation or willingness to pay is assumed invariant with river discharge. In general, the incomplete models result in underestimates of marginal values of instream flows at most discharge levels.

Estimated instream flow values on the Bitterroot and Big Hole rivers (including the benefits of downstream hydroelectric generation) were compared to consumptive withdrawals for irrigation. This study indicates that at many flow levels, allocative gains may be achieved by reallocating water from consumptive to instream uses.

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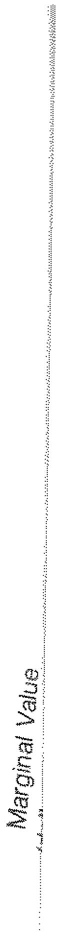

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