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This paper discusses some of the issues and methods associated with evaluating the effect of changing water quality on recreation use and economic value. Several different methods can be used to estimate the impact of changes in water quality. An application using probability of participation and visitation models that include water quality variables is presented for river recreation in North Dakota.

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by

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Contents

1.0 INTRODUCTION

Recreation is an important purpose at most U. S. Bureau of Reclamation (Reclamation) water resource projects. Many factors can influence recreation use on reservoirs and streams including reservoir water levels and river stream flows, the range and availability of recreational facilities, the existence and proximity of site substitutes, and the acceptability of water quality levels. Reclamation management activities can have a significant impact on several of these factors. Therefore, measurement of recreation use and economic benefits or values for different management alternatives can help ensure best management practices.

The focus of this paper is on the influence of water quality on recreation use and economic value. Water quality can influence both water based and land based recreational activities. Water contact recreational activities such as swimming, boating and waterskiing, and boat/wade fishing are directly impacted by water quality due to the potential for water ingestion. These activities may not be permitted if water quality levels fall below certain governmentally mandated public health thresholds. Shoreline fishing and other land based water influenced activities, such as hiking, picnicking, and camping can be affected indirectly by changes in water quality. Examples of indirect impacts include the influence of limitations on fish consumption as well as aesthetic influences. Aesthetic influences can include visual effects, such as algae growth or water clarity, as well as impacts due to excessive odors.

In addition to the influence of water quality on recreation use values, changes in water quality can also influence nonuse values. Nonuse values, also referred to as preservation or intrinsic values, refer to an individual's willingness-to-pay (WTP) or benefits from simply knowing a resource exists, even if that individual does not currently use the resource. In early studies, nonuse values were divided into three primary categories - option, existence, and bequest values. Option values relate to WTP for maintaining the resource for possible future recreation use. In recent studies option value has been re-designated as more of a future use value measure. Existence value reflects society's WTP for the knowledge that the resource currently exists whereas bequest values reflect society's WTP for knowing the resource will exist for the enjoyment of future generations. Given the objective of this study is to focus on recreation and water quality, and the state of the art in nonuse valuation emphasizes existence and bequest values which have little recreation orientation, nonuse values are not included in this paper.

This paper includes a brief discussion of recreation demand theory and the theoretical impact of a change in water quality on recreation, a review of the relevant recreation water quality literature, a description of different methods that can be used to measure recreation benefits, and an application that includes water quality variables.

2.0 RECREATION DEMAND THEORY AND ESTIMATION METHODS

The demand for recreational services is based on consumer demand theory, where individuals purchase goods and services in quantities that maximize utility (enjoyment) given their level of available income. The utility obtained from consuming different quantities of recreation and other goods and services can be described using a utility function, where utility is a function of the quantities of various goods and services consumed. The consumption decision can be represented as:

$$Z = U(Q_r, Q_a)$$

subject to:

$$P_rQ_r + P_aQ_a = M$$

where Z is total utility, Q_r is the quantity of recreation, Q_a is the quantity of all other goods and services, P_r is the price of recreation, P_a is the price of all other goods and services, and M is available income. Solving this optimization problem results in first order conditions which require the marginal utility of recreation and other goods to be equal at the quantities purchased:

$$U'_{Qr} = P_r\lambda$$
$$U'_{Qa} = P_a\lambda$$

where U'_{Qr} and U'_{Qa} are measures of the utility an individual receives from purchasing the last unit of the good, or marginal utility. The lambda (λ) represents the marginal utility of income. Therefore, price multiplied by lambda is the opportunity cost of purchasing the good. The first order conditions indicate that an individual will purchase each type of good until the marginal utility of the last unit purchased is equal to the marginal utility given up to purchase the good. The quantity of the different goods are purchased such that the utility associated with each purchase, at the margin, is equal to its price.

Since recreation is not typically exchanged within a market setting, traditional market based valuation approaches cannot be used to estimate recreation benefits. Although a recreator can purchase a recreation trip directly through the market from a commercial guide or outfitter, in most cases, recreators "produce" their recreation activity. As a result, a range of non-market oriented approaches have evolved that can be used to estimate benefits. Two of the most widely used techniques are the travel cost and contingent techniques.

Travel cost approaches attempt to model actual recreation visitation as a function of the cost of access, site quality characteristics including water quality, socioeconomic characteristics, and other relevant explanatory variables. The cost of access includes: the variable cost of transportation (gasoline, oil, tires) and the opportunity costs associated with the time spent to travel to the site. By measuring the cost of gaining access at various distances, a travel cost recreation demand model reflecting the quantity demanded at various prices can be derived which is consistent with consumer demand theory. Contingent valuation approaches involve direct questioning of recreators to determine value and visitation behavior in response to a given scenario. Contingent valuation often requires time consuming and costly survey techniques. Recreator benefits or value per trip are measured in terms of net willingness to pay (WTP), or consumer surplus.

There are several potential problems associated with the estimation of changes in recreation values resulting from changes in water quality. Due to threshold effects and the law of diminishing returns, the value of incremental changes in water quality depends on the initial level of water quality. Threshold effects refer to the possibility that there are important levels of water quality beyond which very noticeable aesthetic or safety effects occur. The law of diminishing returns recognizes that the value of water quality improvements may decrease as the base level of water quality improves. Water quality improvements at a site with poor water quality would probably be highly valued by recreationists, while water quality improvements at a good water quality site would likely be valued at a much lower level. Aggregating marginal values of water quality improvements across the total population of recreators and provide an estimate of the full marginal value of water quality for recreation at that particular level of water quality.

In order to estimate the recreation value for different levels of water quality, an analyst needs measures of the differences in consumer surpluses associated with each level of water quality. The demand curve shifts in or out as site quality characteristics, including water quality, change. Changing water quality can potentially affect the number of trips and the value per trip. Therefore, in order to evaluate the benefits of a change in water quality an analyst needs to know the original number of trips, the original value per trip, the number of trips with a change in water quality, and the value per trip under the new water quality level. Multiplying the original trips by original value provides the original recreation value for an activity and multiplying the revised trips by the new recreation value provides the recreation value for an activity after a change in water quality. The difference between the original value and the revised value reflects the change in value for the activity. Summing the change in value across all activities provides the total recreation value for the water quality change at the site.

A change in water quality could also affect the rate of recreation participation. It is possible, particularly for large increases in water quality, that improved water quality could entice new recreators to visit the site. In such situations, data from a sample of the general population may be needed to evaluate the potential impact on recreation levels. A probability of recreation model can be used to estimate the number of recreators for different levels of water quality.

It should be noted that water quality (WQ) can enter a recreator's utility function either directly or indirectly. For boaters and swimmers, water quality directly influences utility or satisfaction as would any other purchased input (X) and can be represented as:

$$U = f(X_1, X_2, \ldots X_n, WQ).$$

While technically, water would be the input for production of a boating or swimming trip, that water needs to be of satisfactory quality for the site to be open for recreation.

Alternatively, water quality can also enter the utility function indirectly, such as for angling. Water quality can influence fish production or populations. As a result, water quality enters the angler's utility function indirectly through the catch rate variable and can be represented as:

$$U = f(X_1(WQ), X_2, \ldots X_n).$$

That is, as water quality increases the number of fish increase. The increase in fish population leads to an increase in catch rates, which increases utility.

When attempting to evaluate the influence of water quality changes on recreation, one must realize that there may be a difference between actual and perceived water quality. In addition, recreation visitation and value will likely be influenced more by recreator water quality perceptions than actual water quality conditions (Binkley and Hanemann, 1978). Stated differently, benefits accrue to an improvement in water quality only if they are perceived or known by the recreator. In many cases, water quality problems are not perceived by recreators since they involve no obvious visible signs. In such cases, significant changes in visitation many only occur once water quality degrades to the point where the recreation area is closed by the managing body, unless water quality measures are routinely reported to the public. With adequate water quality reporting, the distinction between actual and perceived water quality diminishes. Previous studies have used objective water quality measures, subjective recreator water quality rankings, or a combination of both approaches. For objective water quality measures to be used in a recreation model, there must exist a statistically significant relationship between actual and perceived water quality, unfortunately this relationship does not always exist.

There are many factors that could be used to objectively describe water quality. Binkley and Hanemann (1978) separate these into three general categories: hygenic factors, aesthetic factors, and factors which indirectly influence nuisances. Note that the categories overlap.

Hygenic factors: This category includes health related factors such as bacteria (total bacteria, fecal coliform bacteria, ecoli, enterococci), toxic substances, etc. These are of most concern for water contact activities including swimming and water skiing, but may also be of interest for fishing, boating, and shellfishing. These factors often do not result in a perceived change in water quality, and therefore do not impact visitation until a managing body closes the site.

Aesthetic Factors: This category refers to those factors which are most noticeable to the recreator. They include color, turbidity/suspended solids (algae, oil and grease content), odor, temperature, and acidity (pH and alkalinity levels). These factors may be of interest to both water based and land recreators.

Indirect Factors Contributing to Nuisances: This category refers to those factors which stimulate undesirable aquatic plant growth (e.g., ammonia, phosphorus, and nitrogen levels) or adversely affect fish and shellfish (temperature, toxics, oxygen consuming substances, etc.).

3.0 RECREATION WATER QUALITY LITERATURE

Early recreation economic studies focused on the question of simply valuing a recreation site. Most of the research evaluated variations of using the travel cost and contingent valuation methodologies to address recreation site development. In recent years, there has been a shift in emphasis within Reclamation away from site development towards more efficient use of existing water supplies. As a result, the objective of many current Reclamation studies is to evaluate the effect of changes in system operations on the value of project purposes, including recreation.

Over the last two decades a significant amount of research has been devoted to addressing the effects of management actions on recreation visitation and economic benefits, including the impact of actions affecting water quality. Table 1 provides summary information on the results of past recreation water quality studies. Given the extent of the water quality literature, this list is by no means comprehensive, but includes a series of studies depicting the range of approaches.

Based on the reviewed literature, it is fairly evident that the random utility (RUM) travel cost models have become very popular in recent years. The contingent valuation approach is also quite popular, and is the only approach capable of addressing site quality changes beyond the scope of historical observation. Within the framework of contingent valuation, the dichotomous choice or referendum format has received more emphasis since a panel of Nobel prize winning economists endorsed the approach a decade ago (Arrow, K. et al., 1993).

The range of water quality measures found within this list of studies is quite broad and includes both objective measures (e.g., levels of nitrogen, fecal coliform, clarity, phosphorous, suspended solids) and subjective/perceived measures (e.g., recreator indexes and scales, boatable - fishable - swimmable categories). The water quality changes and valuation estimation approaches also differ considerably across studies resulting in a wide range of value estimates. It is apparent that values depend on the water quality issue, the magnitude of the change in water quality being evaluated, the starting point of the water quality change, and the valuation method.

Table 1: Valuation Results of Recreational Water Quality Studies

Authors, Publishing Date	Location or Site	Recreation Activities	Water Quality Measure	Change in Water Quality	Value Measure	Valuation Approach	Value Measure (Units)	Date of Data	Original Value
Aruna, P. (1998)	North & South Carolina border lakes	None specified	Total Organic Nitrogen	10% drop	Use value	TCM	Loss in value per trip	1992	($.98)
				20% drop			" "		($1.13)
				30% drop			" "		($1.26)
				40% drop			" "		($1.39)
				50% drop			" "		($1.53)
Binkley, C. and M. Hanemann (1978)	Boston, MA area lakes and rivers	Water based and water influenced activities	Composite index on a 1-5 scale (1 = bad, 3 = fair, 5 = good)	fair to bad	Total value (use + nonuse)	CVM	Loss in value per HH per trip	Dec. 1974	($2.08) mean ($1.24) median
				fair to good			Add'l value		$2.03 mean $1.24 median
Bouwes Sr., N. (1983)	Wisconsin lakes	None targeted	Uttormark's Lake Condition Index (0-best to 23-worst)	Shadow/Mirrow Lakes from LCI of 10 to 6 and 20	Use values	Zonal TCM	Add'l value per trip	1978	Ranges from $0.25 to $1.46
				White Clay Lake from LCI of 5 to 14			Loss in value per trip		Ranges from ($0.38) to ($1.76)

Table 1 (Cont'd)

Authors, Publishing Date	Location or Site	Recreation Activities	Water Quality Measure	Change in Water Quality	Value Measure	Valuation Approach	Value Measure (Units)	Date of Data	Original Value
Carson, R. and R. C. Mitchell (1993)	Nationwide U. S.	None targeted	Boatable, fishable, swimmable	Non-boatable to boatable	Use and Nonuse Values	CVM	Add'l Annual HH value	1983	$106
				Boatable to Fishable			" "		$80
				Fishable to Swimmable			" "		$89
Caulkins P., R. Bishop, and N. Bouwes Sr. (1986)	Wisconsin	None targeted	Uttormark & Wall's 1975 Lake Classification Index (LCI)	LCI from 7 to 6	Use value	TCM - RUM and Individual TCM	Add'l value per trip	1978	$1.27 and $2.28

Table 1 (Cont'd)									
Authors, Publishing Date	**Location or Site**	**Recreation Activities**	**Water Quality Measure**	**Change in Water Quality**	**Value Measure**	**Valuation Approach**	**Value Measure (Units)**	**Date of Data**	**Original Value**
Edwards, S. (1984)	Rhode Island	None targeted	100 point water quality scale based on fecal coliform (100 = clean, 90 = no shellfishing, 65= no swimming, 1= no recreation)	3 scenarios: 90 to 0, 90 to 65, and 65 to 0	Use and nonuse values	HPM and CVM	Add'l Annual value per HH	1984	numerous, see paper
Ericson, R. K. (1978)	Rocky Mtn. Nat'l Park, Colorado	None targeted	Recreator water quality perceptions measured on a 100 point scale based on 6 color photos	From 25, 36, 50, 64, 82 to 93 on the 100 point scale	Use value	CVM	Add'l value per trip	1973	Range from $0.19 to $1.51
Feather, P. (1992)	Minnesota	Fishing	Water clarity, total phosphorous		Use value	TCM - conditional RUM linked to Trip Frequency Model		1989	numerous, see paper

Table 1 (Cont'd)

Authors, Publishing Date	Location or Site	Recreation Activities	Water Quality Measure	Change in Water Quality	Value Measure	Valuation Approach	Value Measure (Units)	Date of Data	Original Value
Fishman, K. (2000)	Connecticut lakes	Boating, Fishing, Swimming	Boatable, Fishable, Swimmable	Maintain Swimmable, Swimmable to Fishable, Swimmable to Boatable	Use value	CVM	Add'l annual value per HH	1995	Ranges from $0 to $73
Garifo, S. (1983)	Pacific Northwest lakes	Fishing	Objective water quality data was recoded as good, average, and poor	Improve water quality from average to good at all sites	Use value	Zonal TCM	Add'l value per HH per year	1980	$17.95
Kaoru, Y. (1995)	Albemarle-Pamlico Estuary, N. Carolina	None specified (fishing, boating)	Nitrogen, Suspended Solids	25% reduction	Use value	TCM - nested RUM	Loss in value per trip	1982	Overall average = ($4.98)
Meisner, C. (1997)	Northern Alberta lakes and rivers	Fishing	Water clarity (Secchi depths), % blue-green algae, fish stocks	5% drop in Secchi depth	Use value	TCM - nested RUM	Loss in value per HH per trip	1995	- $2.67
				10% drop in Secchi Depth			" "		- $5.30
				10% increase in blue-green algae			" "		- $3.83
				5% drop in fish stocks			" "		- $2.76
				10% drop in fish stocks					- $5.38
				10% increase in algae & 10% drop in fish stocks			" "		- $9.23

Table 1 (Cont'd)

Authors, Publishing Date	Location or Site	Recreation Activities	Water Quality Measure	Change in Water Quality	Value Meas ure	Valuation Approach	Value Measure (Units)	Date of Data	Original Value
Montgomery, M. and M. Needelman (1997)	New York lakes	Fishing	Toxic fish advisories, pH/acidity	Eliminate toxic contamination at all lakes	Use value	TCM - repeated RUM linked to Logit participation model	Add'l value per trip	1989	$1.51
				avoid toxic lakes closed to fishing			" "		$2.08
				eliminate pH/acidity problems			" "		$0.32
				avoid acid lakes closed to fishing			" "		$0.34
				eliminate toxics and pH/acidity problems at all lakes			" "		$1.89
Murray, C. and B. Sohngen (2001)	Lake Erie, Ohio	Beach use	Number of beach advisories	1 less advisory per year	Use value	TCM - conditional RUM	Add'l value per trip	1998	$1.85
Needelman, M. and M. J. Kealy (1995)	New Hampshire lakes	Swimming	Eutrophication and Bacteria	Eliminate eutrophication at 51 high priority lakes	Use value	TCM - repeated RUM linked to Trip Frequency Model	Add'l value per swimmer per season	1989	$1.40
				Eliminate bacteria			" "		$1.82
				Eliminate both			" "		$4.09

Table 1 (Cont'd)									
Authors, Publishing Date	**Location or Site**	**Recreation Activities**	**Water Quality Measure**	**Change in Water Quality**	**Value Measure**	**Valuation Approach**	**Value Measure (Units)**	**Date of Data**	**Original Value**
Niklitschek, M. and J. Leon (1996)	South American metro area bay beaches	Swimming, fishing, boating	Human and industrial waste	Reduce pollutants to swimmable levels	Use and nonuse values	CVM, Contingent Behavior - TCM, Combined Model	Add'l Value per HH per month	1992	CVM=$8.46, TCM=$11.08, Integrated=$14.75
Parsons, G and M. Kealy (1992)	Wisconsin lakes	Fishing, Boating, Swimming, Viewing	Dissolved oxygen, Clarity	No lakes have periods devoid of oxygen and All lakes have dissolved oxygen >= 5 ppm	Use values	TCM - conditional nested RUM	Add'l value per trip	1978	Ranges from $0.00 to $1.01 depending on activity Ranges from $0.48 to $17.72
Phaneuf, D., C. Kling, and J. Herriges (1998)	Wisconsin Great Lakes	Fishing	Toxin levels in lake trout flesh	20% drop in toxins	Use value	TCM (RUM) - Repeated Nested Logit	Loss in value per angler per season	1990	($29.16)
						TCM (RUM) - Random Parameters Repeated Nested Logit	" "		($8.78)
						Kuhn Tucker	" "		($116.45)

Table 1 (Cont'd)

Authors, Publishing Date	Location or Site	Recreation Activities	Water Quality Measure	Change in Water Quality	Value Measure	Valuation Approach	Value Measure (Units)	Date of Data	Original Value
Tay, R. and P. McCarthy (1994)	Indiana	Fishing	Oil, PCBs, Fecal Coliform, Phosphorus, Copper	1% reduction in each pollutant	Use value	TCM, conditional RUM (site selection only)	Add'l value per trip	1985	Ranged from 3 to 25 cents per trip

4.0 REGIONAL RECREATION MODELS

Multiple site regional recreation models are based on data from a series of recreation sites, which often provide sufficient variation to allow site quality and substitution variables to be included in the same model. The sites included in a regional model are generally limited to those providing similar recreational activities. Excluding dissimilar sites can be justified by assuming participation in one type of recreation is not affected by participation in another unrelated type of recreation (weak separability). As a result, recreation demand functions can be estimated without including all other goods and services competing for an individual's budget.

The development of a multiple site model requires definition of the study region. The region should be based on the geographic distribution of recreational opportunities and users. Statistical tests on individual parameters (Zeimer and Musser, 1979) or an overall recreation equation (Kmenta, 1971) can be used to determine when discarding sites significantly reduces the explanatory power of an estimated equation. Large scale models may be necessary to adequately incorporate substitution and site quality terms within a large study area. However, an appropriately defined small scale model may provide more accurate visitation estimates at a particular site (Loomis et al., 1986).

Two basic types of recreation models are presented in this report, individual and aggregate. Individual models require specific visitation and explanatory variable data from individual recreators and preferably also from non-recreators. Aggregate models require overall site visitation and explanatory variable data by zone of origin (for example, zip code or county). The data requirements and modeling techniques for estimating individual models are much more extensive than for aggregate models. The models presented below are not discussed in great detail. For a more detailed presentation of the recreation models, see the Reclamation Technical Memorandum "Forecasting Changes in Site Specific Recreation Use (Platt, 1996).

4.1 Individual Models

The decision to recreate in an individual choice model involves a sequential decision making process. The first decision reflects whether or not to pursue the recreational activity (participation decision). If the individual participates, decisions must be made about how often to participate (frequency of visitation decision) and where to participate (site selection decision). The individual choice model is designed to use either two or three modeling components. The two-component site specific model analyzes participation and frequency of visitation decisions. The three-component model analyzes participation, frequency of visitation, and site selection decisions.

The use of individual data to estimate a participation decision model creates modeling problems which must be addressed. The participation decision model requires the use of general population survey data because information is needed for users and non-users. The use of general population survey data results in a censored sample because the dependent trip variable is bounded by zero. Statistical estimation using ordinary least squares (OLS) may lead to biased results because the assumption of a normally distributed error term may not hold. The extent of possible bias increases as the number of zero observations increases. Alternative procedures such as Tobit, Heckman, or Cragg can be used to adjust for the non-negativity characteristics within the model (see Madalla, 1983; Bockstael et al., 1990). Without these adjustments, negative trips can be predicted.

Data from on-site surveys used to estimate frequency of visitation models typically result in a truncated sample because information is obtained only from site users. Truncated samples occur when values of the dependent variable are bounded by a value of one. This truncating occurs because all respondents have taken at least 1 trip at the sampled site. Procedures utilizing maximum likelihood truncated normal regressions are required to avoid potential bias problems.

If on-site survey data are collected across several sites, the lower bound for trips would be zero at each site because users would probably not visit all the sites in the region. The sample therefore becomes censored with respect to the frequency of visitation decision. The conditional probability of participation at a given site can be estimated using multinomial logit or probit procedures to reflect the probability of selecting the site conditioned upon one already being a water based recreator (see Madalla, 1983). The frequency model would also require use of the Tobit, Heckman, or Cragg procedures given the censored data.

Another problem associated with on-site recreation surveys is avidity bias. Avidity bias occurs when the probability of being sampled is a function of the number of trips taken to the site. The greater the number of annual trips an individual takes, the higher one's probability of being sampled at the site. Avidity bias is normally corrected by using weighting techniques rather than statistical procedures. General population survey data do not suffer from avidity bias.

The participation and site selection decisions are yes/no in nature (integers) and result in probabilities ranging from 0 to 1. The individual's frequency of visitation decision requires that trips be estimated as an integer while summing over the sample, the visitation for the average individual is not integer constrained and fractional trips may legitimately result. To address the integer issue, count data models have evolved, which are discussed below.

4.1.1 Probability of Participation Model

The probability of participation model uses cross-sectional data and occasionally time series data to estimate an average individual's probability of participation in a given recreational activity or in a given activity at a given site. A probability of participation model can be used to estimate recreation participation by multiplying the average probability of participation by the population within the sampled market area. Projections of probabilities of participation, based on changing site quality characteristics, can be used along with population projections to forecast future participation. The cross-sectional model requires a survey of the general population, where survey respondents include both participants and non-participants.

Estimation of a cross-sectional model requires variation in both dependent and explanatory variables across sites and individuals. The model calculates site participation with values for the explanatory variables relevant to each study site. The time series model may use information from one study site exclusively. To provide the necessary variation in the quality variable, participation information is gathered across individuals over time. When the model relates only to the activity (e.g., participate in activity at any site), site information may still be important, but requires definition. Normally, the site information in this case is based on the closest site or average site across the region.

An extension of this model suggests the use of a simultaneous system of participation models across different recreational activities (Caswell and McConnell, 1980; Hay and McConnell, 1984). Those authors suggest that the models should be estimated simultaneously to account for interrelated participation behavior across activities (e.g., an individual who boats has an increased probability of fishing).

4.1.2 Frequency of Visitation Model

The individual frequency of visitation model is designed to estimate trips per participant for a particular site or across a series of sites within a region. Therefore, this model can be defined by site or region. The model must be linked with a probability of participation model to estimate total visitation.

The individual visitation model is typically designed with trips per participant at the study site as the dependent variable. Other specifications often pool data across sites so the dependent variable becomes either the sum of visits across all sites, the number of visits to the typical site, or the number of visits separated by site (Kling, 1986).

Data for this model are gathered from participants, normally from an on-site survey. A number of econometric/statistical corrections within the modeling process may be appropriate (i.e., integer, truncation, and avidity bias corrections) because of the nature of the dependent variable and the application of on-site sample data. When the model is designed to estimate visitation at multiple sites across a region, the site subscript can refer to the closest site, the average site, the favorite site, or some other designation.

One variation of the frequency of visitation model is the count data model. Count data models are trip frequency models which restrict trip estimates to non-negative integers. The Poisson distribution is a popular non-negative integer distribution which assumes equality of the mean and variance. Should this mean-variance equality assumption prove invalid (e.g., if variance exceeds the mean, called overdispersion), a negative binomial distribution may be appropriate. Overdispersion can result in biased and inconsistent estimators. Tests for overdispersion are fairly simple and could be routinely applied (Gomez and Ozuna, 1993).

If one is using a data set with users only, truncated Poisson or truncated negative binomial distributions can be used (Creel and Loomis, 1990). To account for both truncation and overdispersion, the negative binomial model would be preferred. Count data models have received considerable attention in recent years. They are seen as flexible, strong econometrically, and sound theoretically. As a result, count data models may become the model of choice in recreation analysis (Hellerstein and Mendelsohn, 1993).

Another frequency of visitation model is the on-site time model. This variation of the model attempts to account for the differences between resident and tourist behavior. Tourists, defined as individuals who travel considerable distances to visit a region, behave differently with respect to travel costs. As a result of the substantial travel costs incurred to access the region, tourists have a tendency to spend more time on site per trip as compared to residents. This model may also have some implications for seasonal residents (i.e., "snowbirds").

On-site time models have been developed where annual recreation days as opposed to trips are used as the dependent variable (Bell and Leeworthy, 1990). These models use both travel cost and on-site costs as explanatory variables. For tourists, travel cost is expected to positively influence, whereas on-site costs are expected to negatively influence, the number of recreation days. This positive influence from the travel cost variable is in direct contrast to the conventional travel cost model.

In their study of Florida beach use, Bell and Leeworthy found that the dampening effect of travel cost on number of trips was outweighed by the increase in number of beach days per trip. For tourists, travel costs will have a negative effect on the probability of participation but a positive impact on visitation by those to do decide to participate. For sites where a substantial difference exists in distance traveled between users (e.g., unique natural sites), the on-site model may be appropriate. Conversely, for less unique sites where travel distance variation is less extreme, the traditional travel cost model is more likely to hold.

4.1.3 Site Selection Model (also known as Allocation/Share/Discrete Choice/Random Utility Model)

A site selection model allocates total visits within a region across the various sites. This model may not be necessary depending on how the probability of participation and frequency of visitation models are designed. If these models are designed to be site specific (i.e., estimates trips to a particular site in the region), a site

selection model would be unnecessary. However, if these models are not site specific (i.e., estimates an individual's trips in aggregate across all sites), then a site selection model would be appropriate.

The site selection model estimates the probability that an individual will visit a particular site on any given choice occasion. The number of choice occasions (trips, days, etc.) for the individual is generally obtained from the frequency of visitation model. Multiplying the number of annual choice occasions for the individual by the estimated probabilities of visiting each site, provides an estimate of the individual's annual visitation across sites.

Using individual averages for the explanatory variables or averaging the resulting probabilities across individuals allows for estimation of the trip distribution between sites for the average individual (average probability of visiting each site times the average number of choice occasions). Applying trips by site for the average individual by the number of participants in the region provides an estimate of total visitation by site.

It is assumed in the model that trips within the relevant time period (e.g., year, season) are taken independently of each other. This assumption may or may not be realistic depending on the type of trips. Day trips may be more independent than longer duration trips. Trip decisions are assumed to be made one at a time as opposed to all at once at the beginning of the season and the decision to visit a site is assumed to be based on utility (satisfaction) maximizing behavior.

Individual socioeconomic characteristics are not included in the model. For a given individual, socioeconomic characteristics do not vary and therefore do not help explain an individual's site choice. However, socioeconomic characteristics are often used to segment the data so separate models can be estimated for distinct population groups (Stynes and Peterson, 1984). A specific site substitution variable is not included in the model. The model accounts for substitution by comparing the desirability between sites.

A recent extension of this model incorporates prior trips to the various sites as an explanatory variable. A prior trips variable with a positive sign indicates habit forming behavior. A prior trips variable with a negative sign indicates variety seeking behavior. This dynamic aspect has been shown to improve the predictive power of the model, an ongoing problem with recreation demand models (Adamowicz, 1994). However, inclusion of the prior trips variable creates some econometric and specification problems which are difficult to remedy (McConnell et al., 1990). Habit forming behavior can also be modeled using such variables as the number of years using the site and equipment purchases (e.g., boats).

Because variables included in the probability function include both travel costs and site quality, two variables used to help define site substitution, these models have proven especially attractive when attempting to estimate complicated substitution effects.

The site selection model provides a good format for handling substitution as well as both zero trip and positive trip situations. The site selection model is very data intensive and assumes independent trip occasions.

4.1.4 Individual Model Application: North Dakota Model

The North Dakota regional model is based on survey data obtained from a sample of the general North Dakota population. Therefore, several different types of information are available to model recreational behavior. The households included in the survey are compared to the households that actually responded to the survey to determine if there are characteristics which effect the probability of returning a survey. Those that returned surveys included both river recreation participants and non-participants. These data are used to estimate a probability of participation model. Finally, the data obtained from river recreators is used to estimate a frequency of visitation model which can be used to estimate the benefit from North Dakota river recreation.

North Dakota Data

The source of recreation visitation data for this analysis is a mail survey of North Dakota households implemented in early 1997 by the North Dakota Parks and Recreation Department. The survey was a general population survey of North Dakota residents aimed at estimating recreational use of North Dakota rivers and expenditures associated with that use. Since the survey represented a sample of the general North Dakota population, river recreation users and non-users were included in the data. There were 2,248 deliverable surveys mailed (i.e., surveys with correct addresses), and 1,193 surveys returned for a response rate of 53.1 percent. There were two survey mailings to allow questionnaire recipients a second chance to respond if they had discarded the first questionnaire.

Supplementary data were obtained from the U.S. Bureau of the Census and the U.S. Geological Survey. The Census data were combined with the North Dakota survey data to estimate the values of some variables associated with non-respondents. U.S. Geological survey data are used to estimate water quality in each of the six rivers considered in this analysis.

Six North Dakota rivers are considered in this analysis: the Missouri, Red, Little Missouri, James, Sheyenne, and Souris. Individuals participate in many different types of recreation in these rivers. However, the dominant types of recreation include: fishing, sightseeing, boating, and swimming. The rivers included in this analysis cover essentially the entire state and a wide variety of site characteristics. The Missouri River is the most visited river in the state, although the other rivers provide important regional recreation sites. Only North Dakota residents are included in the travel costs analysis of recreation benefits. However, it is recognized that recreational benefits also accrue to non-North Dakota residents.

North Dakota Model Estimation

As mentioned above, three separate North Dakota models were estimated in order to represent the data collection and recreation decision processes. These models are: a survey response model, a probability of participation model, and a frequency of visitation model.

Survey Response Model

A probit model is estimated and the results are used to account for non-response bias in the mail survey. This step is required because some factors which influence the likelihood of an individual returning a survey may also influence recreation decisions. If this occurs, then using the responses from river recreation users without adjustment will result in biased travel cost estimates. Those that responded to the survey apparently have certain characteristics which influence both the likelihood and value of their response and, therefore, the unadjusted sample would not be representative of the entire North Dakota population. Modeling the survey response decision is important because intuitively non-respondents would be expected to have a lower level of visitation than respondents.

The procedure used to correct for non-response bias generally followed the procedures used by Callaway et al. (1995) in the report "Columbia River System Operation Review Recreation Impacts: Demand Model and Simulation Results." A probit model of the probability of responding to the river recreation survey was estimated and inverse mills ratios were calculated. The inverse mills ratios (IMR's) were then included in the participation and travel cost regressions as explanatory variables. These IMR's (which have unique values for each observation) represent the probabilities associated with providing North Dakota river recreation behavior information (i.e., returning the survey), and provide a statistical correction in the recreation demand equations for any systematic response bias.

The estimated North Dakota survey response model is as follows:

PROBABILITY OF RESPONDING = f (INC, AGE, MILES)

where:

Dependent Variable: PROBABILITY OF RESPONDING (0 if no response, 1 if response)

Explanatory Variables:

INC	= annual household income,
AGE	= age of the respondent,
MILES	= miles to the nearest river recreation site.

Income and age are socio-economic variables that indicate overall wealth and possibly the health of the respondents as well as general attitudes about requests for household information. Since income is positively associated with visitation (i.e., as income increases, so typically does visitation), and visitation is positively related to the probability of survey response, the expected sign for income is positive. The expected sign for age is more difficult to gauge, therefore no expectation was made (although some research has suggested a positive relationship between age and income, implying a possible positive expected sign for age). The miles to the nearest river recreation is an indication of the familiarity and importance of river recreation on the questionnaire recipient. It is expected that the greater the number of miles to river recreation, the less likely the recipient will return the questionnaire.

Identification numbers from the survey responses were matched with the address database to determine who returned or did not return a questionnaire. The response/nonresponse data were used to estimate a survey response model. The only information available for the non-respondents was their location (mailing address and zip code), which is not useful in itself for determining factors influencing the decision to return a survey. However, the location data can be combined with secondary data from the U.S. Bureau of the Census to derive average values for socio-economic variables which influence the probability of returning a survey. Income and age were hypothesized to influence the probability of returning a survey and were based on U.S. Bureau of the Census averages at the most detailed level possible. For example, if the address was a city or place for which detailed data area available (such as Bismarck or Fargo) then city or place data were used. If detailed data were not available, then county level data were used.

Distance to a river which supports recreational activities was also hypothesized to influence the probability of returning a survey. The distance from the home area to the nearest river which supports recreation was included as a variable in the survey response model.

There were 2,298 addresses included in the mailing data file. Three South Dakota addresses were removed and 71 addresses which were for post office boxes or for locations that could not be determined with certainty were discarded. The survey response model was estimated with 2,224 observations.

River Recreation Participation Model

The second model is a recreation participation model which estimates the factors that effect the decision of an individual to participate in river recreation. This model represents the number of people who would participate in recreation at different North Dakota river sites. Factors which could influence the decision to recreate or not recreate include: site quality of nearby rivers (e.g., water quality at the home site and nearby adjacent sites), whether or not the individual lives in a urban or rural setting, and socio-economic characteristics. As mentioned above, the IMR's from the first model were included as an independent variable in the participation model.

The estimated North Dakota river recreation participation model is:

PROBABILITY OF PARTICIPATION = f (HTKN, HTP, ATKN, ATP, URBAN, SEX, AGE, INC, IMR)

where:

Dependent Variable: PROBABILITY OF PARTICIPATION (0 if nonparticipant, 1 if participant)

Explanatory Variables:

HTKN	= total Kieldhal Nitrogen of nearest river recreation area,
HTP	= total phosphorous of nearest river recreation area,
ATKN	= total Kieldhal Nitrogen of second nearest river recreation area,
ATP	= total phosphorous of second nearest river recreation area,
URBAN	= does the respondent live in an urban area (1=yes, 0=no),
SEX	= sex of the respondent (1=male, 0=female),
AGE	= age of the respondent,
INC	= annual household income,
IMR	= inverse mills ratios from the survey response model.

The water quality data were obtained from U.S. Geological Survey NASQUAN data for the six rivers included in this analysis over the 1973 to 1995 period. Total Kjeldhal Nitrogen and total phosphorus are used as measures of river water quality. The urban variable was included to account for the desire of urban residents to get away from crowds that rural residents do not experience. Sex, age, and income are included a general demographic variables. The IMR variable is included to account for non-response bias.

Data from 852 of the 1,193 returned questionnaires included all of the visitation and socio-economic information needed to estimate a participation model.

River Recreation Visitation Model

The third model is a travel cost model which estimates the factors affecting the number of trips an individual will take to a river recreation area. The primary factor is the cost of traveling from the origination point of the trip to the stream site. Other important factors which typically influence visitation to a particular site include: the availability of substitute recreation sites, water quality at the site visited, and income. This model can be used to estimate a demand function and the benefits from recreation. The third model can be represented as:

VISITS = f (COST, URBAN, GOODSUB, TKN, INC, AGE, IMR)

where:

Dependent Variable: VISITS = number of visits by each respondent,

Explanatory Variables:

COST	= estimated travel cost per visitor,
URBAN	= does the respondent live in an urban area (1=yes, 0=no),
GOODSUB	= existence of a substitute closer than study site,
TKN	= water quality measured by total Kjeldhal nitrogen,
INC	= annual household income,
AGE	= age of the respondent,
IMR	= inverse mills ratios from the survey response model.

Of the 852 observations used in the probability of river recreation model, 381 individuals indicated that they participated in North Dakota river recreation. A total of 29 observations were discarded because of missing trip information, leaving 352 observations for estimating the final travel cost model.

Travel costs were estimated using a variable cost of 10.5 cents per mile (American Automobile Manufacturers Association Inc., 1996) and the household income estimates from the survey. Hourly income rates were estimated by dividing household income by the number of household members and dividing per capita income by 2,080 hours (52 weeks multiplied by 40 hours per week). The income rates were then divided by three to estimate the time cost of travel. The rate used for determining the cost of time is generally between 1/4 and 1/2 the income rate. The 1/3 rate was used as a compromise value for time spent traveling.

The travel cost model requires an estimate of the number of trips taken by each recreation participant. However, the questionnaire from which the data was gathered asked for visitation estimates in terms of total days spent recreating at North Dakota rivers. Estimates of the number of recreation days per trip in the northern region of the United States were used to convert river recreation days into trips (U.S. Forest Service, 1990). The number of trips will be overestimated using this method if a significant number of trips are multiple purpose. Approximately 30 percent of the respondents participating in river recreation participated in only one type of activity. Approximately 70 percent of the respondents spent one-half or more of their recreation days on one type of activity.

North Dakota Modeling Results

A probit model was run for the survey response model to enable the calculation of Inverse Mills Ratios for use in the other two regressions. A probit model was also estimated for the probability of participation model. The visitation model was initially estimated using ordinary least squares. The estimated travel cost model was tested for normality of the residuals using a Lagrange Multiplier test and heteroskedasticity was tested using the Park-Glejser test.

The Lagrange Multiplier test for normality is a goodness of fit test where measures of skewness (lack of symmetry) and kurtosis (how peaked or flat a frequency distribution is near the mean compared to a normal distribution) are calculated and compared to expected values if the residuals are normally distributed. The test statistic for comparison of the observed frequencies with expected values for a normal distribution is a chi-square statistic. The Park-Glejser test includes three steps: obtaining the residuals from the estimated regression equation, using these residuals as the dependent variable in a second regression, and testing the significance of the variable suspected of causing heteroskedasticity using a t-test and assuming a specific variance of the error term.

Both of these tests indicated ordinary least squares was not an appropriate estimation technique for the visitation model. The model was re-estimated using the tobit model, which accounts for a large number of observations at a given limit, zero visits in this case (Maddala, 1983). The Park-Glejser test is not appropriate for testing heteroskedasticity in a tobit model. Therefore, a moment based test was used to test for heteroskedasticity in the tobit travel cost model. Moments represent unique characterisitcs of a probability distribution. A moment based test compares these characteristics to determine if the error terms are distributed differently than would be expected with a constant variance of the error term. Heteroskedasticity could not be rejected for the tobit model. Therefore, a weighted tobit model was estimated using the square root of travel cost as a weight. Modeling results are presented in Table 2.

Table 2 - North Dakota Modeling Results

I. Survey Response Probit Model

Variable	Coefficient	t-Statistic	Expected sign
INC	-0.0000073	-0.68	NO
AGE	0.0153630	3.13 *	?
MILES	-0.0036480	-2.45 *	YES
CONSTANT	-1.0863	-	-

Likelihood ratio test = 39.52*

II. River Recreation Participation Probit Model

	Coefficient	t-Statistic	Expected sign
HTKN	-0.33224	-2.71*	YES
HTP	-0.43863	-2.52 *	YES
ATKN	-0.16649	-0.97	YES
ATP	-0.61966	-2.01 *	YES
URBAN	0.20975	1.58	YES
SEX	0.30667	3.38 *	?
AGE	-0.01736	-6.12 *	?
INC	.00000716	3.13 *	YES
IMR	-0.00283	-0.01	?
CONSTANT	1.1809	-	-

Likelihood ratio test = 110.3*

III. River Recreation Travel Cost Weighted Tobit Model

	Coefficient	t-Statistic	Expected sign
URBAN	1.65380	0.61	YES
COST	-0.29780	-4.39 *	YES
GOODSUB	-7.12770	-3.00 *	YES
TKN	-2.90930	-2.47 *	YES
INC	.0002310	3.69 *	YES
AGE	-0.21990	-2.41 *	?
IMR	15.9330	1.36	?
CONSTANT	9.2313	-	-

Likelihood ratio test = 58.12*

Statistical Significance: * 5% level
** 10% level

? Indicates sign uncertainty

All of the variables had the expected sign except income in the survey response model, and the income variable was not significant at the five percent level. The likelihood ratio test for each model is a chi-square based test which indicates the overall significance of the estimated equation. The likelihood ratio tests combined with the individual t-ratios indicate the modeling results were generally good.

North Dakota Benefit Estimation

The river participation model, adjusted for survey response bias, indicates a participation rate of approximately 41.3 percent. This is a fairly high rate but was expected given results from previous recreation surveys (North Dakota Parks and Recreation Department, undated). Based on a July 1996 North Dakota population of 643,539 people, this translates into 265,780 North Dakota river recreation participants in 1996. The travel cost model estimates about 13 visits per participant annually based on mean values for each of the model variables. This results in an estimated 3.45 million visits per year.

The travel cost model can be used to estimate a recreation demand curve, where price varies from zero to the price where visits equal zero (choke price) and average values are used for the non-price variables. Average river recreation benefits per visit can be estimated by taking the area under the curve and dividing by the number of visits per participant. The benefits are estimated to equal about $31.40 per visit.

5.0 CONCLUSIONS

This paper discusses the influence of water quality changes on recreation visitation and value. A theoretical discussion of how water quality could affect recreation from an economic perspective is presented along with information from a range of pertinent articles obtained from literature reviews. Two of the more commonly applied approaches to estimate changes in recreation economic visitation and value as a result of water quality changes are the travel cost method and the contingent valuation method.

While it is possible that water quality could affect both water dependent recreational activities (e.g., swimming, boating, fishing) and water influenced recreational activities (e.g., picnicking, hiking, camping, sightseeing), all the studies reviewed for this report focused on water dependent activities. Furthermore, all of the studies found a statistically significant relationship between water quality measures and recreation visitation and value. This is not to say that water quality changes would typically affect recreation since the selected sites were often chosen because of known water quality problems. However, for sites with water quality problems, it is not surprising to see the water quality changes do affect recreation and especially water dependent recreation.

Recent travel cost models have emphasized econometric requirements associated with specific characteristics of the underlying data (e.g., count data, tobit, and truncation models). As a result, the analyst has a variety of modeling options from which to choose. Decisions as to choice of model depend not only on time and budget considerations, but also on the nature of the question being addressed and type of data likely to be available.

One of the many challenges in estimating recreation impacts stemming from changes in water quality using either the travel cost or contingent valuation approaches centers on the water quality measure to be included in the model. The controversy surrounds the use of either objective or subjective/perceived water quality measures. Some analysts suggest that perceived water quality measures must be used since recreators only react to water quality changes that are noticeable. Conversely, other analysts suggest that objective measures of water quality (such as levels of nitrogen, fecal coliform, E. coli, phosphorous, suspended solids) must be included in the models since these are the measures that site managers monitor and are comparable across different sites. However, changes in many objective measures are not noticeable to recreators unless they manifest themselves in other ways such as through algae blooms or unpleasant odors. Ideally, one would hope to find objective water quality measures that are either readily apparent or well known to recreators.

Finally, an application of the travel cost model is presented for river recreation in North Dakota. This model includes a probability of participation model and a visitation model, from which recreation benefits can be estimated.

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