Estimating the economic benefits of maintaining residential lake levels at an irrigation reservoir: A contingent valuation study

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[1] The contingent valuation method (CVM) was used to estimate homeowners’ willingness to pay for water leasing to maintain stable lake levels at an irrigation reservoir in a residential neighborhood. A binary logit model was used to analyze households’ voter referendum responses for maintaining the lake level. The median willingness to pay (WTP) was found to be $368 per year for lakefront residents and $59 per year for off-lake residents. The median WTP for lakefront residents was significantly different from off-lake residents at the 90% confidence level. Using the median WTP for lakefront and nonlakefront residents, we found that the increase in homeowner association fees would generate approximately $43,000, enough money to lease sufficient water to reach the target higher lake level in a normal water year.


1. Introduction

[2] Many reservoirs in the western United States were originally developed for irrigated agriculture. However, with economic growth, much of the land around the reservoirs has been developed for houses, owing to the attractiveness of living around lakes in the arid west. Further, as urban areas expanded, much of the land once used for agriculture also became residential areas, shifting the use of the water to nonagricultural uses. With this shift in water use, an issue of valuing the water for maintaining the residential lake amenities arises because there is a potential of upstream diversion of the water to municipal uses that could adversely affect the reservoir levels previously enjoyed by residents.

[3] Irrigation reservoirs in residential areas provide non-market joint benefits. They provide habitat for fish, birds, and other wildlife that live around it, riparian vegetation, and recreational opportunities on the lake and along the shore. In fact, amenities become an important part of how these lakes are valued. However, changes in downstream water uses often result in changes in the timing of water inflows and water releases with a potential to adversely affect the recreational amenity values of a lake.

[4] For many lakes or reservoirs in the western United States, as well as other areas nationwide, nearby residents currently have little influence over how these water bodies are managed. Thus much of the water stored in the lake may be diverted upstream and reallocated to other uses, no longer reaching the lake. This could (1) reduce a lake to a permanently lower level; (2) decrease recreational and visual aesthetics of a lake, as the smaller lake could result in large areas of exposed mudflats along much of the lakeshore; (3) reduce water quality for fish; and (4) reduce habitat for fish and wildlife at the lake due to a lower lake level.

[5] This has led many homeowners’ associations (HOAs) surrounding lakes to take a more active interest in water management at such lakes by purchasing shares of interest in the reservoir itself, purchasing shares of water, and in some years renting water from traditional owners to maintain the residential lake at more desirable levels. In essence, some homeowners’ associations are in a transition from being free riders on these reservoirs to converting these reservoirs into a club good or local public good [Cornes and Sandler, 1996]. Since in many residential areas membership in and payment of fees to the HOAs is mandatory, the reservoir is closer to a local public good than a club good; as Cornes and Sandler [1996, p. 347] indicate, voluntarism is one of the defining characteristics of a club good as compared with a local public good. The decision by the HOAs to buy or rent water, and if so, how much is economically justified, should be based on benefits to homeowners, as they will be forced to pay for the costs. In most states, though, water is not a purely private commodity that HOAs can simply purchase. Obtaining water for lake level maintenance many times requires permission or at least coordination with water resource managers and city officials, due to third party effects that must be considered. In many western states, including our case study in Colorado, water resources managers are reluctant to allow water to be reallocated from traditional uses such as agricultural to amenity uses such as instream flow or lake level maintenance. Nonetheless, water for recreation is considered a beneficial use in Colorado and many other western states, particularly California, where water to maintain lake levels for wildlife has been considered part of the public trust. However, economic analysis is needed first to determine if water acquisition for lake level maintenance is a good economic decision for HOA members, and then for society as a whole, i.e., whether the value
of the water for lake level maintenance exceeds its opportunity cost to society. This second test is needed since in many cases water is not priced at its true opportunity costs by cities or water agencies, and some water managers believe there is some “intangible” value associated with using water in agriculture that is not reflected in the water price.

[6] The objective of this study is to illustrate how a contingent valuation method referendum format survey can be used to estimate how residents living by a residential lake value alternative lake levels. The adaptation of a contingent valuation survey to simulate an HOA referendum will be of interest to irrigation reservoir managers, HOAs, and lake-area residents as a means to quantify the benefits of maintaining lake levels.

2. Nonmarket Valuation and Contingent Valuation Method

[7] The benefits of the lake such as wildlife and recreation are largely nonmarket in nature and may extend beyond the residents that live on the shoreline. While the hedonic property method could be used to estimate the house price differential from living on the lake versus off the lake, estimating the value of a lower lake level than has historically existed often requires a stated preference methodology such as the contingent valuation method (CVM). The contingent valuation method (responses are contingent upon a simulated situation presented in a survey) of valuing a good is an approach in which a direct interview or survey is administered to elicit the households’ willingness to pay for preservation of natural resources [Loomis and Walsh, 1997]. It is used to estimate values of public or quasi-public goods, as well as counterfactual scenarios that do not presently exist but might with different future management.

[8] The CVM survey approach has been widely used to value environmental goods where other valuation methods are difficult to apply [Brookshire et al., 1982]. CVM is a recommended approach by the U.S. Water Resources Council (U.S. WRC) under two different administrations [U.S. WRC, 1979, 1983] and is used today by the U.S. Bureau of Reclamation and U.S. Environmental Protection Agency in their cost-benefit analyses. Although not without controversy [Portney, 1994], CVM has been used to simulate other local voter referenda and has been shown to be reasonably accurate [Vossler and Kerkvliet, 2003] and yield values comparable to revealed preference valuation methods [Brookshire et al., 1982; Carson et al., 1996]. Nonetheless, hypothetical bias has been a found in several CVM studies [Neil et al., 1994; Cummings et al., 1995; Brown et al., 1996]. Our case study has more similarities to the situations studied by Vossler and Kerkvliet [2003], Brookshire et al. [1982], and Carson et al. [1996]. Similar to these three studies, the public good being valued, Sherwood Lake, is well known to the local residents we are surveying. The familiarity is due to the average time lived in the Lake Sherwood area, which is 12 years, and the fact that 83% of the residents have visited the lake. In addition, the payment vehicle of higher HOA fees is quite familiar to residents who pay these fees annually. Thus the conditions that Cummings et al. [1986] suggest are necessary for obtaining a valid estimate of WTP are met in our study.

Nonetheless, short of an actual vote, the possibility of hypothetical bias in our survey remains a legitimate concern.

3. WTP Question Format and Data Analysis Techniques

[9] To realistically simulate a voter referendum for higher lake levels, a dichotomous choice question format is used. In this question format, an individual answers either “yes” if they would vote in favor of paying a higher HOA fee ($X) for a higher lake level or “no” if they would not. The specific amount of the fee increase ($X) varies across the sample. The economic motivation for this type of discrete choice model can be motivated using either the utility difference approach of Hanemann [1984] or the compensation function of Cameron [1988]. In the linear utility difference approach of Hanemann [1984, p. 334] the probability of responding yes or no is independent of income. In the linear utility difference formulation with additive error terms (the unobservable part of utility), income is a characteristic of the respondent and does not vary across the two alternative choices (e.g., current lake level and higher lake levels), and so income does not influence which alternative is chosen. Thus in the resulting linear-bid models, income should not be included as an explanatory variable. The more general Cameron compensation function approach [Haab and McConnell, 2002, p. 54] or the Hanemann indirect utility function approach when the error term enters the utility function nonlinearly, both yield a log-of-bid model [Hanemann and Kanninen, 1999, p. 312] in which income can be included as a separate variable [Haab and McConnell, 2002, p. 55]. In the non-linear utility formulation, income no longer nets out across alternatives. We chose to use the log-of-bid specification so we could include a variable to control for income, since we anticipated that income of lakefront and nonlakefront residents would be quite different due to higher prices of homes on the lake. As is common in dichotomous choice CVM studies, we use a logit model.

[10] Our general specification of the logit willingness to pay model is

\[
L_i = \ln \left( \frac{P_i}{1 - P_i} \right) = \beta_0 + \beta_1 (\ln bid) + \beta_2 income + \beta_3 X + \ldots + \beta_6 income + \mu_i, \tag{1}
\]

where \(P_i\) is the probability of a yes response, \(\beta\) are coefficients, and \(X\) are independent variables. This model is estimated using maximum likelihood estimation because ordinary least squares (OLS) suffers from serious shortcomings such as the resulting estimated probabilities not being constrained to the zero-one interval. To estimate equation (1) using maximum likelihood requires that the equation be rewritten as a log likelihood function (see Kmenta [1986, p. 551] or Haab and McConnell [2002, p. 29] for details).

[11] From the coefficients in equation (1) the mean and median WTP can be calculated using formulas from Hanemann [1984]. Because we cast our WTP question as a voter referendum, and the HOA decision rule is majority rule, we are interested in determining the dollar amount that
a majority of residents would vote in favor of. Thus we calculate the median using

\[
\text{median WTP} = (\exp(\beta_0 + \beta_2 X_2 + \beta_3 X_3 + \cdots + \beta_n X_n/\beta_1)). \tag{2}
\]

In this equation, \(\beta_0\) is the intercept, \(\beta_2 \cdots \beta_n\) represent the nonbid independent variables, and \(\beta_1\) is the absolute value of the bid coefficient. To compute median WTP, the means of all the nonbid independent variables are multiplied by their respective coefficients and added to the constant term. This product is divided by the absolute value of the coefficient on the bid amount. The result is exponentiated using the antilog (to base e) to yield median WTP.

4. Background for Case Study

Our study area is Lake Sherwood, which is located on the southeast side of Fort Collins, Colorado. This lake was originally created as an irrigation reservoir. When the lake is completely full, it has 37 surface acres. The irrigation reservoir is now also a residential body of water that bestows many benefits to the residents that surround it. The lake provides habitat for fish, waterfowl, and other types of wildlife. The lake is frequently used for fishing, wildlife viewing and walking. There are over 430 homes in subdivisions that are within a quarter mile of the lake. Residents living in the Lake Sherwood area are in one of six homeowners’ associations (HOAs). As described to respondents in the survey, most of the water that flows through the reservoir is owned by other entities (e.g., a university, the city) not associated with the six HOAs around Lake Sherwood. The majority of the water in Lake Sherwood has been used downstream by two large farms (one that was owned by the university, as well as the city of Fort Collins. Both of these farms have been converted to subdivisions. The university kept much of the water when selling the land, and the other subdivision acquired a significant portion of the farm water, beyond the need of the subdivision. The university is looking at transferring that water to other uses, upstream from Lake Sherwood. Thus there is a strong possibility that the water that had historically run through the lake could be sold and/or diverted upstream and allocated for other purposes before it reaches Lake Sherwood. Respondents were told that if this happened, it would leave the lake at a permanently low level.

The focus of the study is to find the residents’ willingness to pay to maintain the lake’s water level in the future in the face of possible upstream water diversions. The survey posed the key question of whether a household would vote to increase its HOA fees to rent water to maintain the lake level during the summer months of July and August. If they voted for the increase in HOA fees, they would be told the lake would have a surface area of 35 acres during the summer. If they did not vote in favor, the lake surface would be 28 acres during the summer. This difference in surface area was illustrated with a color map insert showing the two different lake levels (see Figure 1). In the survey the consequences of maintaining the lake level were spelled out as (1) reducing the amount of exposed mud flats along the lakeshore; (2) improving habitat for fish and wildlife; and (c) improving water quality for fishing and boating. Wildlife species such as geese, ducks, herons, and pelicans were also mentioned as specifically benefiting from maintaining the lake level. As noted above, because of the familiarity of the residents with the lake, it was not necessary to provide extremely detailed description of the lake and resources as is typical when asking individuals to value natural resources they are not familiar with.

The dollar amount a household was asked to pay varied across households. There were 15 different dollar amounts randomly but evenly distributed across all 433 households living in the area. The bid amount ranged from $5–300 for off-lake residents and $10–300 for on-lake residents. Pretesting suggested a differential of 2 for lakefront residents. In the returned surveys there was a great deal of overlap of bid amounts, although there were several more high bid amounts in the lakefront surveys. The exact text of the WTP question asked was, “If your household were asked to decide whether to approve the annual homeowner association fee increase stated above to have Lake Sherwood filled to Lake Level #2 on the map in seven out of ten years rather than Lake Level #1, would you decide in favor or against?”

The current HOA fees are fixed by a vote of the respective HOA and do not vary with the value of the house within the HOA.

The use of increased HOA fees as the payment vehicle is quite realistic in this case, as a portion of existing homeowner fees are used to rent a small amount of water in the lake, for watering the greenbelts around the lake, paying for insurance associated with the lake, and security patrols at the lake.

5. Defining the Empirical Logit WTP Model

There are several variables that could explain whether the residents living in the Lake Sherwood area would vote to pay a higher HOA fee to obtain a higher lake level. Monetary factors would seem relevant in deciding whether or not one would pay a fee increase. Of course, the amount the fee would increase, called the bid amount in the model, is used as a variable. Income potentially may be an important variable used in order to explain whether the residents of Lake Sherwood would pay a higher HOA fee for maintaining water levels in the lake, particularly in the pooled model that combines lakefront and nonlakefront households. As noted above, there is a substantial difference in house prices and income between the two housing locations. The current total HOA fee may also be important in explaining the willingness to pay of the Lake Sherwood residents, as the six HOAs have quite different fees. Demographic variables of the respondents may be indicative of differences in tastes and preferences, and therefore utility, and ultimately their willingness to pay for higher lake level. For example, gender has been shown in past studies to influence environmental attitudes [McStay and Dunlap, 1983; Mohai, 1991], especially about local issues [Blocker and Eckberg, 1989], and thus may influence willingness to pay for maintaining a neighborhood lake. Attitudes toward maintaining the lake as a habitat for ducks, geese, and herons may be influenced by whether or not the resident is involved in any sort of environmental organization (envorg). The amount of education that the respondent has may also influence his or her response, as people with higher education levels are often more concerned with the environment.
**Normal Water Year**

**Comparison of Lake Levels in Summer**

![Map insert for Lake Sherwood survey.](image)

**Figure 1.** Map insert for Lake Sherwood survey.
Hypotheses

[18] The level of importance that a resident places on different aspects of the lake may yield additional insight to explain how the residents of the Lake Sherwood area value maintaining a high lake level. One such factor that was evaluated was that of the perceived importance of the existence of the lake in the general neighborhood even if you did not visit it regularly (existimp). The respondents’ perceived importance of Lake Sherwood to their property value may also be important (pvimp). How long a person has lived in the Lake Sherwood area (livesherwood) may influence their willingness to support a fee increase, since long-term residents may have some affinity toward Lake Sherwood. Obviously, whether the respondent lived on the lake or not (lakefront) is likely to be a key determinant of whether they would pay a higher HOA fee for a higher lake level. An individual’s use value of Lake Sherwood would be influenced by whether or not they visit the lake (visit). Relatedly, whether the respondent is an active recreation user such as an angler (fishyear) or bird-watcher (birdwyear) is expected to positively influence their likelihood of voting in favor of a fee increase to maintain lake levels. Thus the following logit model reflects these candidate variables:

\[
\text{vote} = \beta_0 - \beta_1(\text{Inbidamt}) + \beta_2(\text{educ}) + \beta_3(\text{envorg}) + \beta_4(\text{existimp})
+ \beta_5(\text{fishyear}) + \beta_6(\text{gender}) + \beta_7(\text{income}) + \beta_8(\text{lakefront})
+ \beta_9(\text{livesherwood}) + \beta_{10}(\text{pvimp}) + \beta_{11}(\text{visit})
+ \beta_{12}(\text{birdwyear}) - \beta_{13}(\text{totlohafee})
\] (3)

6. Hypotheses

[19] For the purposes of evaluating the willingness to pay of the residents living in the Lake Sherwood area, this study focuses on five hypotheses. The first two hypotheses deal with individual variables, and the other three focus on comparing lakefront and nonlakefront residents. The income variable will be the initial hypothesis that will be examined in this study. The probability that a “yes” vote for an increase in yearly fees to maintain the water level of Lake Sherwood would likely increase as a person’s income increases if lake level is a normal good. Specifically,

**Hypothesis 1**

\[H_0 : \beta(\text{income}) = 0, \quad H_a : \beta(\text{income}) > 0.\]

The influence of the current total homeowner association fee (totlohafee) is the next hypothesis tested. In this case, the probability that a “yes” vote for an increase in yearly fees to keep the water level of Lake Sherwood at a permanently higher level may decrease as a person’s total HOA fee increases due to budget limits. Specifically,

**Hypothesis 2**

\[H_0 : \beta(\text{totlohafee}) = 0, \quad H_a : \beta(\text{totlohafee}) < 0.\]

[20] The three remaining hypotheses will compare the residents that live on and off the lakefront. The logit coefficients in the WTP model will be tested to see if there is a significant difference between lakefront (LF) and nonlakefront residents (NLF):

**Hypothesis 3**

\[H_0 : \beta_{\text{LF}} = \beta_{\text{NLF}} \quad \text{versus} \quad \beta_{\text{LF}} \neq \beta_{\text{NLF}}\]

This will be tested using a likelihood ratio test.

[21] Subsequently, the pattern of refusals to pay will be compared using a test of whether or not there is a significant difference between lakefront and nonlakefront residents regarding protest and nonprotest refusals to pay anything:

**Hypothesis 4**

\[H_0 : \text{refusals to pay}_{\text{LF}} = \text{refusals to pay}_{\text{NLF}}\]

This will be tested using a chi-square test.

[22] Finally, the willingness to pay for the residents living on and off Lake Sherwood will be compared to determine whether there is a significant difference between the two:

**Hypothesis 5**

\[H_0 : \text{WTP}_{\text{LF}} = \text{WTP}_{\text{NLF}}; \quad H_a : \text{WTP}_{\text{LF}} > \text{WTP}_{\text{NLF}}\]

This will be tested using confidence intervals around the two groups mean WTP.

[23] The results of all five of these hypothesis tests will provide valuable information to HOA and water resources managers in evaluating whether a water fee proposal could pass a vote.

7. Survey Pretesting

[24] The survey was pretested on several lakefront and nonlakefront homeowners to make sure that the presentation of information and question ordering was clear, concise, and understandable. After each in-person pretesting session, the input that each respondent gave was taken into consideration and the survey revised. Each subsequent session was conducted using the revised survey booklet.

8. Sample Design and Data Collection Procedures

[25] Since there are less than 500 households living in HOAs around Lake Sherwood, a relatively small sample size, each household was targeted to receive the survey. Since the study area studied is also relatively small, a complete census was utilized.

[26] Furthermore, because of the small target group, the response rate had to be very high. One way to increase this response rate, by creating or reiterating a vested interest to the respondents, is to perform the survey in conjunction with the HOA. Since each home must pay to be a part of an association, the residents would not see the study as such an “outside” affair and might feel that the study has significant relevance to them personally.

[27] Combining in-person survey distribution and mail replies together may increase the response rate as well. Going door to door and personally handing out the survey to each home may contribute to an increase in the response rate. These efforts may lead the respondent to relate at a more personal level with the surveyor. This will also create chances for the resident to inquire directly about the survey
and get a personal explanation of what they will be participating in. However, the advantage of leaving the survey booklet is to allow the respondent to fill out the survey at his or her leisure. In addition, there are certain questions that may seem too personal for a respondent to answer in front of a stranger. Being able to fill out the survey in the privacy of his or her own home may make respondent feel secure in that the responses are confidential and anonymous, which in turn may lead to an increased response rate and reduce social desirability bias.

[28] To ensure that the response rate would be as high as possible, reminder postcards were sent to each household 1 week after they received a copy of the survey. This postcard respectfully thanked the respondent for agreeing to complete the questionnaire and reminded the household to return the finished survey if they have not already done so. If a survey was not returned a week after the reminder postcard was sent out, then the household received a follow-up copy of the questionnaire with a new cover letter and postage-paid return envelope. The new cover letter repeated what was mentioned in the previous mailing, but it also reminded them that their completed survey had not been returned.

9. Descriptive Results

[29] There were 433 surveys handed out and 325 returned, a 75% response rate. The response rate for off-lake residents was slightly lower than average, at 72%. Fifty-six percent of the total residents that responded would vote yes on the HOA fee increase, corresponding to the bid amount that was randomly assigned to their household. There were 80 residents, or 25% of the people that responded, who were not willing to pay anything to keep the level of Lake Sherwood permanently higher. Of the 80 responses, 31% said that they do not get any benefits from the lake and another 31% said that only the residents living on the lake should pay. Twenty-six percent said that they could not afford an increase in fees, and 12% gave other reasons for not wanting to pay an increased fee. An important distinction needs to be noted when explaining the responses that did not agree to a fee increase. Some residents not only disagreed with paying a fee increase at any level devoted to getting more water, but also disagreed with the entire proposal altogether. These responses are often referred to as protest responses [Halstead et al., 1992]. In our logit WTP model we have retained protest responses because in part, these people still have an actual vote in any election on raising HOA fees for the lake.

[30] Table 1 compares lakefront and nonlakefront residents’ reasons for not being willing to pay. Because a resident could give more than one reason why he or she refused to pay the bid amount, the number of responses exceeds the number of households refusing to pay. Furthermore, it was not counted as a protest response if the respondent answered that they could not afford a higher fee at this time. In some ways we were delighted to see people select the “can’t afford” reason, as it indicated they took the dollar amount seriously and acted like they would in a real vote.

10. Discussion for Protest Response Hypothesis

[31] This section presents the results of hypothesis 4, regarding differences in protest refusals to pay and non-protest refusals to pay of lakefront versus nonlakefront residents. As is evident in Table 1, there was only one refusal among the lakefront residents, but 70 among nonlakefront. The $\chi^2$ test is used to test whether these differences are statistically significant. The calculated value for the specific hypothesis for this study is $\chi^2_{calculated} = 9.30$ with a $\chi^2_{critical,0.05} = 6.635$ at the 1% confidence level. From the information above, we reject the null of hypothesis 4 of independence of protest and nonprotest refusals to pay between lakefront and nonlakefront residents. This reveals that the protest responses for the residents living on the lake are significantly different from the protest responses for the residents living off the lake. Consequently, it can be stated that living on or off the lake has an effect on whether a resident gave a protest response or not.

11. Results of Pooled Lakefront and Nonlakefront Logit WTP Model

[32] The results of the model that combined responses from lakefront and nonlakefront residents is presented in Table 2. Overall, this model is highly significant as judged by the likelihood ratio statistic and the reasonable McFadden $R^2$ of 0.39. Two of the main hypotheses could be evaluated using this model.

[33] The first major hypothesis that was tested is whether the income variable was significant in explaining if a resident would vote for a yearly increase in homeowner association fees to lease more water so that Lake Sherwood would be maintained at a permanently higher level (hypothesis 1). From the results in Table 2, it can be stated that the null hypothesis for the income variable can be rejected; therefore there is a positive relationship between income and willingness to pay. The second major hypothesis is the relationship between the total amount of HOA fees paid each year and voting in favor of a yearly fee increase to maintain water levels in Lake Sherwood (hypothesis 2). Table 2 reveals that the tollohafee variable is not statistically different from zero. Therefore it appears that the current level of association fees in the six HOAs does not have a significant relationship with the willingness to pay to maintain Lake Sherwood water levels. The insignificance of tollohafee also occurs in the separately estimated lakefront ($p = 0.2177$) and nonlakefront resident ($p = 0.4798$) model when income is included as a separate variable. These models are presented in the next section. However, HOA fee was significant and negative in the lakefront model without income, indicating those households that currently pay high HOA fees are less likely to vote in favor.
of an increase for purchasing water to maintain high lake levels.

[34] The insignificance of the lakefront variable appears to be due to its high correlation with income ($r = 0.46$). When income is removed from the model, lakefront is statistically significant at the 0.06 level (results available from the first author).

12. Testing Differences Between Lakefront and Nonlakefront Residents WTP

[35] To conduct a likelihood ratio test of coefficient equality between lakefront and nonlakefront residents as well as calculating WTP of each group, separate logit models for each group were estimated. Table 3 displays the results.

[36] Generally, the two individual logit models fit the data well, as judged by the highly significant likelihood ratio statistic, and a good McFadden $R^2$ for the nonlakefront residents (0.35) and a relatively high McFadden $R^2$ for the lakefront residents (0.65).

[37] The first hypothesis focuses on whether there is a difference in behavior, as reflected in the logit coefficients, of the residents living on the lake versus the residents living off the lake (hypothesis 3). If the H0 is rejected, then living on the lake has an effect on how the resident responded to the survey. In order to test the hypothesis, a likelihood ratio (LR) test is performed. The test involves comparing the log-likelihood value of a single pooled model that combines lakefront and nonlakefront responses (i.e., the restricted model) with the sum of the log-likelihoods of the two separately estimated logit models presented in Table 3 (the unrestricted models). Mathematically, the formula and values used to calculate the value to test the LR test are

\[ \chi^2_{calc} = -2(\text{LLF}_{\text{restricted}} - \text{LLF}_{\text{unrestricted}}) \]

\[ \chi^2_{calc} = -2[-109.6797 - (-8.30 - 95.747)] = 11.265 \] (4)

Table 2. Pooled Lakefront and Nonlakefront Residents Logit Model

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>z-Statistic</th>
<th>Probability</th>
<th>Mean–Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-3.0274</td>
<td>-2.3116</td>
<td>0.0208</td>
<td></td>
</tr>
<tr>
<td>(Bidamt)</td>
<td>-1.1108</td>
<td>-4.3662</td>
<td>0.0000</td>
<td>3.75–1.05</td>
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<tr>
<td>Educ</td>
<td>0.0809</td>
<td>1.3665</td>
<td>0.1718</td>
<td>16.59–2.99</td>
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<tr>
<td>Envorg</td>
<td>0.4978</td>
<td>1.0850</td>
<td>0.2779</td>
<td>0.24–0.43</td>
</tr>
<tr>
<td>Exisimp</td>
<td>1.1896</td>
<td>4.5359</td>
<td>0.0000</td>
<td>2.07–0.85</td>
</tr>
<tr>
<td>Fishyear</td>
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<td>0.2742</td>
<td>0.39–0.49</td>
</tr>
<tr>
<td>Gender</td>
<td>-0.2070</td>
<td>-0.8433</td>
<td>0.3990</td>
<td>1.09–0.80</td>
</tr>
<tr>
<td>Income</td>
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<td>3.2368</td>
<td>0.0012</td>
<td>88.6–61.8</td>
</tr>
<tr>
<td>Lakefront</td>
<td>0.0772</td>
<td>0.1221</td>
<td>0.9028</td>
<td>0.14–0.35</td>
</tr>
<tr>
<td>Livesherwood</td>
<td>-0.0456</td>
<td>-2.0523</td>
<td>0.0401</td>
<td>11.7–9.15</td>
</tr>
<tr>
<td>Pvimp</td>
<td>1.4081</td>
<td>4.6539</td>
<td>0.0000</td>
<td>2.36–0.78</td>
</tr>
<tr>
<td>Visit</td>
<td>0.9634</td>
<td>1.7888</td>
<td>0.0736</td>
<td>0.83–0.37</td>
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<tr>
<td>Birdwyear</td>
<td>-0.3023</td>
<td>-1.1787</td>
<td>0.0738</td>
<td>0.63–0.48</td>
</tr>
<tr>
<td>Tolhoafce</td>
<td>2.96 × 10^-6</td>
<td>0.0086</td>
<td>0.9931</td>
<td>676–547</td>
</tr>
</tbody>
</table>

Mean dependent variable: 0.6120
Standard error of regression: 0.3712
Log likelihood: -94.366
Restricted log likelihood: -154.93
LR statistic (13 degrees of freedom): 121.13
Probability (LR statistic): 0.0000
McFadden $R^2$: 0.3512
Sample size: 232

Table 3. Separate Logit Models for Nonlakefront and Lakefront Residents

<table>
<thead>
<tr>
<th>Variable</th>
<th>Nonlakefront Residents</th>
<th>Lakefront Residents</th>
<th>Mean–Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficient</td>
<td>z-Statistic</td>
<td>Probability</td>
<td>Coefficient</td>
</tr>
<tr>
<td>Constant</td>
<td>-1.735</td>
<td>-1.826</td>
<td>0.067</td>
</tr>
<tr>
<td>(Bidamt)</td>
<td>-0.8556</td>
<td>-4.068</td>
<td>0.000</td>
</tr>
<tr>
<td>Educ</td>
<td>0.0096</td>
<td>2.064</td>
<td>0.039</td>
</tr>
<tr>
<td>Envorg</td>
<td>-0.0579</td>
<td>-2.705</td>
<td>0.006</td>
</tr>
<tr>
<td>Exisimp</td>
<td>1.21</td>
<td>4.525</td>
<td>0.000</td>
</tr>
<tr>
<td>Fishyear</td>
<td>-95.747</td>
<td>-31.0792</td>
<td>0.000</td>
</tr>
<tr>
<td>Gender</td>
<td>-147.578</td>
<td>-23.8437</td>
<td>0.000</td>
</tr>
<tr>
<td>Income</td>
<td>103.665</td>
<td>31.0792</td>
<td>0.000</td>
</tr>
<tr>
<td>Lakefront</td>
<td>0.3512</td>
<td>0.6517</td>
<td>0.000</td>
</tr>
<tr>
<td>Livesherwood</td>
<td>217</td>
<td>41</td>
<td>0.000</td>
</tr>
</tbody>
</table>
In equation (4) the pooled restricted logit model imposes coefficient equality of lakefront and nonlakefront responses. The unrestricted model is estimated separately for the two groups, and those logit models are presented in Table 3 (the pooled model is not shown to conserve space). With six degrees of freedom, the corresponding critical value is 12.59 at the 95% confidence level:

\[ \chi^2_{\text{critical}, 0.05} = 12.59, \quad \chi^2_{\text{calculated}} = 11.265 \]  

(5)

[38] Since the \( \chi^2_{\text{calculated}} \) is less than the \( \chi^2_{\text{critical}} \) at the 5% significance level the logit coefficients for the lakefront residents are not statistically different from the coefficients for nonlakefront residents. Thus the results of the likelihood ratio test are consistent with the insignificance of the lakefront variable in Table 2.

### 13. Discussion for the WTP Hypothesis

[39] The final hypothesis that will be discussed deals with willingness to pay (WTP), specifically whether households living on Lake Sherwood have a significantly higher WTP to keep Lake Sherwood at a permanently higher level. If the data support a rejection of the \( H_o \), the willingness to pay for lakefront residents is statistically different from the willingness to pay for nonlakefront residents. Hanemann [1989] presents the formulae used to calculate median WTP:

\[ WTP = \exp(\beta_0 + \beta_2 X_2 + \beta_3 X_3 + \ldots \beta_n X_n / \beta_1) \]  

(6)

where \( \beta_1 \) is the absolute value of the sbid coefficient. In order to investigate the hypothesis, the Krinsky-Robb technique is used to construct a confidence interval around each group’s (lakefront and nonlakefront) median WTP [Park et al., 1991]. If the confidence intervals for the lakefront and nonlakefront residents do not overlap, then the null hypothesis can be rejected.

[40] The median willingness to pay for lakefront residents was found to be $367.91 per year. The 90% confidence intervals associated with lakefront residents are $191 and $2389. The large upper end of the confidence interval for this group is partly due to the relatively small sample size of lakefront residents. The median willingness to pay for the residents living off the lake was found to be $58.75. The 90% confidence intervals of the nonlakefront residents were calculated to be between $42 and $102. The confidence intervals for the lakefront and nonlakefront residents do not overlap, suggesting they are statistically different at the 10% level. As a result, the null hypothesis can be rejected and it can be stated that the willingness to pay for lakefront residents is statistically different from the willingness to pay for nonlakefront residents.

### 14. Application of Values to Lake Water Management

[41] On the basis of previous results, the median willingness to pay is $367.91 for residents living on the lake and $58.75 for residents living off the lake. Therefore, if the HOA fee increase for the two types of Lake Sherwood residents were set at this level and the proposal were voted on by the residents, 50% of the residents are expected to vote for the increase. Given the number of lakefront homeowners and nonlakefront homeowners within the six HOAs, and the median willingness to pay of each group, estimated annual willingness to pay higher HOA fees for maintaining the lake level is $43,357. Table 4 summarizes the total benefits for all six HOAs at the median WTP amount. However, it is worth noting the broader support at lower HOA fee increases. For example, nearly 75% of nonlakefront households would pay $10 a year more, and nearly two thirds (62%) would pay $30 per year. At these two lower payment amounts, 100% of all lakefront households would pay.

[42] During drought periods, renting water has cost $400 an acre foot (1 ac-ft = 1234 m³) in northern Colorado. Using this cost, nearly 108 ac-ft of water can be rented for maintaining the lake level. Using the official state hydrograph for Lake Sherwood indicates that 108 ac-ft of water would translate into maintaining Lake Sherwood at 33 surface acres, close to the higher Lake Level shown in the survey. Of course, during a normal water year, costs of water are closer to historic levels (about $100 an acre foot). Hence the $43,357 would buy more than 400 ac-ft, more than enough to keep Sherwood Lake full throughout the entire summer period. Since much of the water in northern Colorado is imported water from the Colorado Big Thompson project and actively traded and exchanged, these water prices are rental rates from willing sellers. As such, they reflect at least the foregone rates of return in their agricultural uses along the Front Range of Colorado.

[43] As a postscript to this study, it is worth mentioning that the HOA representatives on the Lake Sherwood committee did vote in favor of renting some additional quantities of water during the summer following our survey. They justified their decision and expenditures of HOA money for this, in part, on the results of this survey showing homeowner support for higher lake levels.

### 15. General Implications for Water Resource Management

[44] This study illustrated how a voter referendum contingent valuation study can be used to value residential lake amenities that vary with the lake level. This study quantified how nonlakefront and lakefront homeowners around a residential lake value alternative lake water levels, and what level of increase in homeowner association fees a majority would be willing to vote for to maintain the lake level. The methodology described in this study will aid water public managers and HOAs in designing their own surveys to value residential lake amenities whether the source of drawdown is irrigation, hydropower releases, or flood control. Managing a reservoir primarily for these other uses can adversely affect lake levels if one use is maximized.
while the consequences on lake levels are ignored. Ideally, society would want to maximize total benefits from all the uses of multiple purpose or public reservoirs. Therefore water resources managers may want to adopt our methodology so as to incorporate the benefits of maintaining residential lake levels when timing irrigation or hydropower releases. While the specific results will vary from lake to lake, the general approach has nationwide applicability to irrigation reservoirs that also serve as residential lakes. Whether it is a residential lake in Colorado or anywhere else in the developed world, gaining better knowledge of how people value lake levels will certainly increase the ability to obtain the maximum joint benefits from scarce water resources.

[45] Acknowledgments. We thank the Colorado Agricultural Experiment Station for financial support, and Paul Bell, Department of Psychology, Colorado State University, for suggestions on the survey. We also thank three anonymous reviewers and the associate editor for their suggestions that improved the technical details and clarity of this paper. The usual disclaimer regarding any errors applies.

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