WATER RESOURCES RESEARCH, VOL. 32, NO. 4, PAGES 1075–1081, APRIL 1996

The economic value of water in recreation: Evidence from the California drought

Frank A. Ward
Department of Agricultural Economics and Agricultural Business, New Mexico State University, Las Cruces

Brian A. Roach
Division of Environmental Studies, University of California, Davis

Jim E. Henderson
U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi

Abstract. A significant barrier to economically efficient management of most reservoir systems is lack of reliable information about how recreational values change with reservoir levels. This paper presents evidence on marginal values of water for recreation at Corps of Engineer reservoirs in the Sacramento, California, District. Data on visitors were collected by origin and destination before and during the early part of the 1985–1991 California drought. Because lake levels varied widely during the sample period, water's effect on visits was isolated from price and other effects. An estimated regional travel cost model containing water level as a visit predictor provided information to compute marginal values of water in recreation. For the range of the lake levels seen, annual recreational values per acre-foot (1234 m^3) of water vary from \$6 at Pine Flat Reservoir to more than \$600 at Success Lake. These findings are limited to use values of visitors who travel to the reservoirs and do not reflect passive use values to people who value the reservoirs but never visit them. Analysts could apply similar methods to other river basins in which a public agency controls the management of multiple water uses.

Background

Multiple-use management of reservoir systems occurs throughout the United States. Both single-reservoir management programs and larger, comprehensive basin-wide plans include multiple-use management. Within a river basin, many uses of water complement and compete with each other. These uses include irrigation, hydropower, water quality, flood control, municipal water supply, streamflow regulation, fish and wildlife enhancement, and recreation.

While various congressional acts emphasize the importance of managing reservoir systems to increase their total economic value, several barriers have made this difficult to accomplish in practice. One barrier is the lack of reliable economic information on system gains or losses produced by altered storage and release patterns. Even less information is available on how recreational values change with changes in reservoir levels. Throughout much of the southern and western United States, low water levels in the summer and fall reduce the value of reservoirs for many recreational activities, including boating, sailing, water skiing, swimming, and fishing.

Economic information on water's recreation value lets analysts trade off recreation with flood control, navigation, irrigation, and other water uses for which methods are more widely available to estimate benefits. Without a method to estimate recreational values, water managers cannot economically justify holding water for recreational purposes. The typical river basin contains several uses for water; any one use may affect others through quantity, quality, time, and location dimensions [*Young and Haveman*, 1985, p. 479]. For example, one reason for low water levels in the south and west is the reservoir drawdown in anticipation of fall and winter runoff for flood control benefits. The increase in recreation benefits from holding the water needs to be compared to the benefits produced by the added flood storage space.

Paper number 96WR00076.
0043-1397/96/96WR-00076\$05.00

There have been several studies about water's recreational value. *Boyle et al.* [1993] used contingent valuation methods to estimate effects of changed river flows in the Colorado River on recreational boating benefits. *Young and Gray* [1972] estimated recreation values of \$3 to \$5 per acre-foot (1234 m^3) of water. *Creel and Loomis* [1992] estimated that an acre-foot of water in San Joaquin Valley wetlands is worth about \$300 for waterfowl hunting, fishing, and wildlife viewing. Their travel cost model included a variable for water flow levels into the wetlands. *Ward* [1987] also used travel cost analysis to estimate values from \$20 to \$30 per acre-foot released into New Mexico's Chama River for anglers and rafters. *Hansen and Hallam* [1990] estimated marginal values of water as a recreational fishery resource. *Cordell and Bergstrom* [1993] used contingent valuation methods to estimate the impact of lake level fluctuations on recreation benefits for four North Carolina reservoirs.

Despite these studies, our literature search found little evidence about how recreational values of water vary over a wide range of reservoir management plans. Basin-wide management plans center on the timing, location, and duration of reservoir drawdowns over several reservoirs in the system. Evidence about recreational values gained and lost from these drawdowns is especially important for managers. However, not only

Table 1. Regional Recreation Demand Model for Day Use and Camping for Corps of Engineer Reservoirs in the Sacramento, California, District

			Camping Model			Day Use Model		
Variable	Name	Index	Mean of Variable	Parameter Estimate	*T* Statistic	Mean of Variable	Parameter Estimate	*T* Statistic
INT	Intercept	···	···	−25.34	−2.92		2.01	0.32
P	Travel cost	*i, j, t*	20	−2.54	−17.38*	14	−4.41	−18.46*
OWN_PF	Percent full surface area	*j, t*	90	2.08	4.41*	90	4.38	6.01*
OWN_RP	Recreation pool surface area capacity	*j*	2594	0.15	1.25	2635	0.96	5.11*
CHR	Site characteristic (*k*th)	*j, k, t*						
WILDLIFE	Acres on site wildlife habitat	*j*	1063	0.61	8.92*	1034	0.32	3.17*
VARIABILITY	Coefficient variation in monthly lake levels	*j, t*	17	−0.41	−4.26*	17	−0.69	4.43*
DEM	Demographic factor (*L*th)	*i, L, t*						
POPULATION	Population at zone of origin	*i, t*	395457	0.921	8.84*	25995	1.07	6.83*
OCEAN	Distance from county to nearest ocean	*i*				116	−0.61	−2.15†
SCHOOL	Years education	*i*	13	8.94	2.82*	13	−0.10	−2.51*
DENSITY	Population density/square mile‡	*i*	563	−0.13	−1.50	523	−0.17	−1.09
U18	Percent population younger than 18	*i*				0.26	−1.55	−1.63
SUB_RP	Substitute recreation surface area capacity	*i, j*	3464	−0.15	−1.00	3557	−0.41	−1.34
SUB_PF	Substitute recreation surface area percent full	*i, j, t*	69	−1.72	−4.69*	68	−2.68	−4.24*
		R^2	···	0.57	···	···	0.65	···
		N		462			264	
		F		62.66			46.04	

*Significant at 0.005 level.
†Significant at 0.01 level.
‡One square mile equals 2.59 km^2.

is evidence on these marginal values scarce, but research has seldom examined factors that influence the recreational values of water.

This paper presents an analysis of the marginal value of water for recreation at several U.S. Army Corps of Engineers reservoirs in California's Sacramento district. An estimated regional travel cost model for this district provides information to compute marginal values of water. During the 1983–1985 study period in which on-site visitor use data were collected, most of the study reservoirs and their substitutes experienced wide water level fluctuations, this period being the onset of the 1985–1991 California drought. High agricultural demands for water and other competing uses also contributed to large water level fluctuations.

These large water fluctuations allowed us to estimate a travel cost model (TCM) with enough variation in water level to isolate water's effect on visits from price and demographic effects. Moreover, water level changes during the drought were large enough to allow us to estimate marginal water values over a range of reservoir sizes and lake levels. Data on marginal values produced by the drought widen the range of conditions under which managers could apply our estimated marginal values to situations whose local information is lacking or unreliable.

Empirical Model

The U.S. Army Corps of Engineers manages 12 reservoirs in the Sacramento, California, District. Many of these reservoirs commonly experience drawdowns during the summer. These drawdowns were especially large during the 1985–1991 drought. Drawdowns typically reduce recreational visits for several reasons: Lake level reductions affect aesthetics, expand mud flats, reduce water for fish habitat, and cause facilities such as boat ramps to be inoperative.

Data

Visitor surveys administered by the Corps at 10 of the 12 Sacramento district projects from 1983 to 1985 provided usable data for this study. While most of these reservoir water levels were nearly full in 1983, they had dropped significantly by 1985 because of the drought. The range of water levels within and across these reservoirs combined with the ongoing on-site survey provided an opportunity to analyze the impact of water level changes on visitor use.

We estimated separate TCMs for day users and campers because we expected lake level fluctuations to have different effects on their recreational behavior. The dependent variable was the total reported visitation from county i to site j during year t. Different sampling rates across projects required the use of sample visitation expansion factors that varied by project. For any given reservoir the expansion factor was the ratio of the total reported visits to total sampled visits. We allocated total reported visits to counties based on patterns of sampled visits over counties.

An extensive database of independent variables for explaining visit behavior was assembled using several sources. These included the Corps Natural Resource Management System (NRMS) inventory of site facilities [*U.S. Army Corps of Engineers*, 1991], state fish and game agency records of fish stocking, U.S. Census sources [*U.S. Bureau of the Census*, 1994], and data on substitute non-Corps reservoirs [*Ruddy and Hitt*, 1990].

The following specify the model; the indices are

- i county of visitor origin.
- j Corps reservoir of visitor destination.
- k one of two reservoir characteristic variables shown in Table 1.
- L one of four visitor demographic variables shown in Table 1.

s one of 145 substitute reservoir destinations in the market area.
t 1 of 3 years of visitor sampling (1983, 1984, 1985).

For both the day user and camper models, variables are

V_{ijt} total visits from the ith county to the jth site in the tth year.
P_{ijt} price from the ith county to the jth site in the tth year, equal to round trip miles (1 mile = 1.609 km) multiplied by travel cost/mile, plus any entry fee; travel cost includes an opportunity cost of time valued at one third the county average hourly wage by zone of origin [*U.S. Bureau of the Census*, 1994].
OWN_RP_j recreation pool in surface acres at the "own" site j.
OWN_PF_{jt} average percentage full of OWN_RP_j, weighted by the distribution of monthly visitation over year t.
CHR_{jkt} site j's characteristic variable k in year t (Table 1).
DEM_{iLt} county i's demographic variable L in time t (Table 1).
SUB_RP_{ij} water-based recreational substitute index for county i and site j. It is defined as $\Sigma_{s \neq j}$ $(SUB\_RP_s/MILES_{is})$ [*Knetsch et al.*, 1976], where SUB_RP_s is the recreation pool in surface acres at substitute reservoir s, and $MILES_{is}$ is the round trip miles from county i to substitute site s.
SUB_PF_{ijt} substitute index of percentage full for county i and site j in time t. It is defined as $\Sigma_{s \neq j}$ $(1/SS_t)SUB\_PF_{st}$, where SS_t is number of substitute sites within the market area of county i, and SUB_PF_{st} is average percentage full in surface acres at substitute reservoir s in time t.

In addition, we used two hydrologic variables to assign volumes and surface acres to various levels of a reservoir's OWN_PF_{jt}. We used these variables to allow us to translate values of a surface acre into values per acre-foot (1234 m^3) of water. They are SA_{jt}, average monthly surface acres at site j in the year t; and VOL_{jt}, acre-feet of water volume corresponding to SA_{jt}.

Model Specification

Several criteria were used in selecting an appropriate functional form for the demand model: (1) The algebraic structure should be consistent with the nature of our data; (2) the model should give rise to theoretically acceptable signs, significance, and magnitudes of estimated coefficients; (3) it should predict visits well; (4) it should not predict negative visits even under extreme reservoir operation plans, such as draining a reservoir; (5) the model should allow total benefits of site characteristic improvements to increase at a decreasing rate; and (6) it should let average benefits per visitor day be constant or increase with site quality improvements.

Using the above performance criteria, four models were considered: a linear, log linear, and two semilog models. We rejected the linear model for this study because it predicts negative visits when a project has sufficiently few facilities or price is sufficiently high. Both semilog models also were rejected because they fail to consistently allow for decreasing incremental benefits in the face of improved site characteristics.

The log linear model was selected for estimation. A nice characteristic of a log linear model is that its β coefficients are equal to elasticities. For example, if the price coefficient is estimated at -0.5, then a 1% increase in price decreases visitation by 0.5 times 1%, or 0.5%.

In addition to the functional form described, we tried preliminary experimental model runs for a nonlinear least squares model, a Heckman sample selection model, and a Tobit model. Additional details are given by *Loomis et al.* [1995] and *Ward et al.* [1995]. However, the simpler log linear model performed as well as or better than any of these more sophisticated models in explanatory power, predictive ability, and expected parameter signs.

Nevertheless, the log linear model simplifies reality. Future research can profitably focus on more sophisticated behavioral models. Demand and benefit equation systems should incorporate various dimensions of unpriced site quality while being consistent with choice theory. Where resource managers are responsible for systems of sites, estimates of the benefits of improvements should be consistent with choices and opportunities facing resource users at all sites.

The final demand equation was specified as the log linear model:

$$V_{ijt} = \beta_0 P_{ijt}^{\beta_P} OWN\_PF_{jt}^{\beta_{PF}} OWN\_RP_j^{\beta_{RP}} \cdot \prod_k CHR_{jkt}^{\beta_k} \prod_L DEM_{iLt}^{\beta_L} SUB\_RP_{ij}^{\beta_{SUB1}} SUB\_PF_{ijt}^{\beta_{SUB2}} \quad (1)$$

where all variables are defined above, and the β terms are estimated parameters. Equation (1) has four classes of variables that affect recreation visitation according to economic theory: price, demographic factors, on-site characteristics, and substitutes.

We included price in the model because visits should decrease as origins become more distant, holding other factors constant. Travel distances from county i to site j were calculated using the program PCMiler® [*ALK Associates*, 1995]. It measures road distances and travel times between pairs of zip code locations or cities. The origin point for visitors in any county was defined as the largest city in the county. Both travel distance and travel time are important elements in total travel costs. Failure to include travel time as a visit predictor overstates the price elasticity in absolute terms and therefore understates recreation benefits. Time was valued at one third the average per capita county wage, based on the 1980 census data available at the time of the study. Also, one third the wage rate reflects the median revealed value of travel time in the transportation literature surveyed by *Cesario* [1976] and has been widely used in subsequent travel cost models. Additional details on the specification of the price variable are given by *Ward et al.* [1995].

Although various demographic variables were expected to influence visitation, few consistent hypotheses regarding their influence have been published. Visits should increase with a larger population, but may not increase proportionally. The final decision of which demographic variables to include was based on obtaining an acceptable fit. For the camping model, variables included were county population, $POPULATION_{it}$; mean years county education, $SCHOOL_i$; and county population density per square mile (2.59 km^2), $DENSITY_i$. For the day use model, these same demographic variables were specified in addition to the percent of the population under 18 years old, $U18_i$, and distance from the county to the nearest ocean recreation site, $OCEAN_i$. Ocean distance is viewed as a substitute proxy and was expected to enter with a negative sign.

The designed recreation pool surface area, OWN_RP_j, was specified as a proxy for the project's size and facility level. Its coefficient reflects the effect on visits due to the reservoir's recreation pool design size and that of the facilities correlated with that size, but not the effect of the lake's actual water level. Number of acres of wildlife habitat on site, $WILDLIFE_j$, was specified as a site characteristic, as a proxy for the project's scenic quality. It was expected to have a positive influence on visitation.

Given this paper's focus on the recreational value of water, an important variable is OWN_PF_{jt}, percent full of the Corps reservoir in water surface area. We used surface area instead of volume because it should predict visits better. Increased surface area provides greater shoreline access and more space for boating, while beyond a few feet (a meter or so) added depth does not for steep-banked reservoirs.

Much thought was given to water's correct specification. For "own" site water we focused on two separate ideas. First, more people are expected to visit a larger site than a smaller one. To account for this scale effect OWN_RP_j is specified, for reasons described above. Next, fewer people will visit a given reservoir as it is drained. Actual lake level in surface acres by period seemed like a good variable specification, but it presented a problem. The use of actual lake surface area implies that a full 1500-acre (6.07 km^2) lake produces the same visitation as a half-full, 3000-acre (12.14 km^2) lake. However, the half-full lake typically is less appealing to visitors because of drainage rings, exposed mud flats, lack of vegetation, and unusable facilities such as boat lanes, boat docks, and swimming beaches.

We also wanted to cleanly separate a lake's design size from its actual water level. To that end, we specified the variable OWN_PF_{jt} as a proxy for a lake's fullness. It is defined as the year's actual average lake level in acres, SA_{jt}, divided by its OWN_RP_j, expressed in percentage terms. Lower values of OWN_PF_{jt} reflect less surface water at a lake. Using OWN_PF_{jt} corrects for reservoir design size, but it still represents an actual water quantity. The quantity it represents varies by site according to its design pool, OWN_RP_j. It is also a good choice for policy analysis because it lets us value changes in water levels at a given site.

We used similar ideas to specify substitute reservoirs' characteristics. For a measure of substitute water and related facilities we looked for an index that weighted larger and closer substitutes more heavily than smaller, more distant ones. We defined a substitute index, SUB_RP_{ij}, which is similar to the one used by *Knetsch et al.* [1976]. Like OWN_RP_j, this substitute index only accounts for the full recreation pool size of substitute sites. Other on-site characteristics were excluded, except to the extent that sites with more extensive facilities correlate with a larger recreation pool. All substitute sites for which we could find data on size within the market area were included in the substitute variable (145 in total), including both Corps and non-Corps sites. SUB_RP_{ij} varies by zone, because each zone faces a different substitute opportunity set. Within a given zone it varies slightly by the destination Corps site (the j index) because the substitute opportunity set includes all sites except the destination site.

Unfortunately, the substitute variable SUB_RP_{ij} does not account for actual levels of substitute reservoirs by time. Therefore we defined an additional substitute variable, SUB_PF_{ijt}, based on historical data on surface acres throughout the region. For a given zone of origin, SUB_PF_{ijt} reflects the percentage full of substitutes, while SUB_RP_{ij} accounts for their distance and size. Besides varying by zone and site, SUB_PF_{ijt} varies by year so it can account for actual substitute lake levels for the period of analysis. It is defined mathematically above.

Once the model was estimated, it could be used to analyze the benefits of management actions. Total benefit is defined as consumers' surplus. Consumers' surplus is computed as the definite integral of (1): The integral is evaluated at each county from the observed travel cost, P_{ijt}, up to a travel cost at the outer limit of the market area, $P_{\max}$ [*Smith and Kopp*, 1980]. For camper visitors, $P_{\max}$ was based on a maximum observed market area, equal to 175 miles (282 km) for campers and 125 miles (201 km) for day users. Consumers' surplus is

$$CS_{ijt} = \int_{P_{ijt}}^{P_{\max}} V_{ijt}. \tag{2}$$

Any table of definite integrals will show that for the log linear specification in (1), (2) equals

$$CS_{ijt} = \frac{[Vm_{ijt}P_{\max} - V_{ijt}P_{ijt}]}{1+\beta_p}, \tag{3}$$

where Vm_{ijt} is the number of visits that the model predicts at the threshold travel cost $P_{\max}$. Thus any demographic, site characteristic, travel cost, or substitute variable that affects visitation in (1) also affects total benefits in (3). Average per visit benefit is calculated by dividing (3) by (1). Total benefits in (3) can be thought of as average benefits per visit times visits predicted in (1).

Incremental Value of Added Water

The annual economic value of an additional acre-foot (1234 m^3) of water held at a reservoir to the jth county at the ith site in the tth year is obtained by applying the chain rule to differentiate (3) with respect to water volume:

$$MB_{ijt} = \frac{\partial CS_{ijt}}{\partial Vol_{jt}} = \frac{\partial CS_{ijt}}{\partial OWN\_PF_{jt}} \frac{\partial OWN\_PF_{jt}}{\partial SA_{jt}} \frac{\partial SA_{jt}}{\partial Vol_{jt}}. \tag{4}$$

Considerable algebraic manipulation shows that for the functional forms (1) and (3), the marginal benefits in (4) can be expressed as

$$MB_{ijt} = CS_{ijt} \frac{\beta_{PF}}{OWN\_PF_{jt}} \frac{100}{OWN\_RP_j} \frac{\partial SA_{jt}}{\partial Vol_{jt}}. \tag{5}$$

The first two terms on the right-hand side of (5) come from differentiating (1) with respect to percent full, OWN_PF_{jt}. The third term comes by differentiating OWN_PF_{jt} with respect to SA_{jt}; the fourth term is the change in water surface area with respect to water volume.

Several factors influence this marginal value. First is the existing level of total benefits, CS_{ijt}. From (3), CS_{ijt} increases with a price elasticity closer to 0. It also increases from any site characteristic, substitute, or demographic factor that increases visits, V_{ijt}. One such important site characteristic is percentage full of the reservoir, OWN_PF_{jt}. Equations (1) and (3) show that if β_{PF}, the percent full elasticity, is 1, then CS_{ijt} increases in proportion to the current water level. A doubling of OWN_PF_{jt} doubles total benefits. If β_{PF} is greater (less) than 1,

Table 2. Parameter Estimates of Area-Capacity Regressions That Predict Water Volume by Water Surface Area at Corps Reservoirs in the Sacramento District

Site	β_1*	β_2†	β_3‡	R^2
Black Butte Lake	8.77 (23.72)	0.0049 (28.62)	1.12×10^{-7} (5.98)	0.9996
Eastman Lake	−9.06 (−2.28)	0.0558 (8.87)	-2.02×10^{-6} (−0.87)	0.9994
Englebright Lake	32.41 (10.62)	0.1033 (12.83)	-4.63×10^{-5} (−8.74)	0.9999
Hensley Lake	13.86 (19.90)	0.0129 (7.21)	9.62×10^{-6} (11.74)	0.9970
Lake Isabella	11.60 (22.36)	0.0024 (20.23)	8.27×10^{-8} (12.60)	0.9924
Lake Kaweah	20.02 (9.94)	0.0123 (4.54)	8.33×10^{-6} (9.59)	0.9998
Lake Mendocino	49.58 (11.82)	−0.0724 (−11.73)	4.06×10^{-5} (13.42)	0.9936
New Hogan Lake	1.49 (0.23)	0.0240 (5.35)	-7.75×10^{-6} (−2.38)	0.9991
Pine Flat Lake	−5.72 (−2.64)	0.0371 (35.19)	-1.31×10^{-6} (−10.67)	0.9999
Success Lake	21.82 (10.38)	0.0054 (3.24)	-9.03×10^{-8} (−0.30)	0.9993

T statistics are in parentheses.
*Linear.
†Squared.
‡Cubed.

then total benefits increase in greater (less) proportion than increases in the current water level.

Each of the following factors increases marginal values of water: a higher percent full elasticity, β_{PF}; lower percent full, OWN_PF_{jt}; a smaller reservoir in recreation pool surface area capacity, OWN_RP_j; and shallower banks at the reservoir's current level, that is, higher $\partial SA_{jt}/\partial VOL_{jt}$. The term $\partial SA_{jt}/\partial VOL_{jt}$ provides information about the relationship between added surface area and added volume of water.

All these factors combine to influence the marginal value of water. Suppose the bank slope at a given reservoir is constant; that is, $\partial SA_{jt}/\partial VOL_{jt}$ is independent of the lake level. If $\beta_{PF} = 1$, then the OWN_PF_{jt} variable inside each of the first two terms on the right-hand side of (5) cancels out, and the marginal value of water is independent of lake level. If $\beta_{PF} > 1$, then CS_{ijt} increases faster than the second term decreases in the face of higher lake levels: the marginal value of water increases with increased lake levels. Finally, if $0 < \beta_{PF} < 1$, the marginal value of water falls with increased lake levels.

Area-capacity regressions were estimated for each reservoir using area-capacity data. For these regressions, volume (in acre-feet) was the dependent variable, and surface acres, the independent variable. One common way to fit such regressions is to use higher-order polynomial terms of the independent variable. For our analysis, including both squared and cubic terms produced models with high explanatory power. No constant term was specified because reservoir volume is zero when surface acres are zero. The model used to predict reservoir volume as a function of reservoir area was

$$\text{Volume}_{jt} = \beta_1 SA_{jt} + \beta_2 SA_{jt}^2 + \beta_3 SA_{jt}^3. \tag{6}$$

For each of the 10 reservoirs, tables maintained by the Corps were obtained that contained water volume and surface area data for elevations from full to empty. These area-elevation-capacity tables were used to fit (6). The estimated coefficients by reservoir are presented in Table 2. All models have high explanatory power with percentages of explained variance (R^2) well above 0.99. Most parameter estimates are highly significant.

Surface acres are important to visitors, but values per acre-foot are needed to establish common denominators among competing users of water for policy analysis. Water surface area and water volume both increase as a reservoir is filled. The sensitivity of volume to changes in surface acres is important when translating values per unit surface area into values per unit volume. This sensitivity was calculated by inverting and differentiating (6) with respect to volume:

$$\frac{\partial SA_{jt}}{\partial Vol_{jt}} = \frac{1}{\partial Vol_{jt}/\partial SA_{jt}} = \frac{1}{\beta_1 + 2\beta_2 SA_{jt} + 3\beta_3 SA_{jt}^2}. \tag{7}$$

Equation (7) is related to the shallowness of a reservoir's bank, because shallower bank slopes at the water line produce a larger change in surface area from a given change in volume. Even for a given project, the value of (7) often varies considerably according to the reservoir's level. For bowl-shaped reservoirs, a 1 acre-foot (1234 m^3) drawndown takes away less surface area when full than when nearly empty. Equation (7) was calculated for all reservoir projects for the water levels shown in Table 3.

Equations (1)–(7) allow calculating marginal values of water volume for recreation. Marginal values are calculated for each origin, reservoir destination, and time period for selected water levels by reservoir. Finally, marginal values for each reservoir are summed over all visitor origins and over both recreation user classes.

Results

Table 1 shows results for the day use and camping demand models. The explanatory power of the models is comparable with most other published travel cost analyses, and the estimated coefficients all have the expected signs. Coefficients for OWN_PF_{jt} (4.38 for day use and 2.08 for camping) are highly significant. This means that day use visits fall off faster than camping as any reservoir level drops. Larger reservoirs have higher values of OWN_RP_j and attract more visitors. Reservoir size has more influence on day users (0.96) than on campers (0.15).

The two substitute variables also entered the regression models as expected. The parameter estimate for SUB_PF_{ijt} was −2.68 for day users and −1.72 for campers. Substitute surface area capacity, SUB_RP_{ij}, was entered with a coefficient of −0.41 for day users and −0.15 for campers. Although statistically insignificant, the signs and magnitudes of the estimates were plausible, as expected.

The coefficients of OWN_PF_{jt} in Table 1 are interpreted as the reduction in recreation use at a Corps site resulting from allocating that site's water to other consumptive users, such as

Table 3. Annual Recreational Value of Holding 1 Added Acre-Foot of Water at Corps Reservoirs, Sacramento, California, District

Reservoir Name	Percent Full, US$*										Visits, Thousands		Recreation Pool, Surface Acres	Bank Slope at Recreation Pool, ∂acres/∂acre-feet
	100	90	80	70	60	50	40	30	20	10	Camp	Day		
Black Butte	40.25†	31.90†	24.74†	18.72	13.78	9.85	6.82	4.57	2.90	1.46	34	277	3128	.023
Eastman	39.94†	32.90†	26.90†	21.86†	17.76	14.54	12.20	10.80	10.88	23.73	39	103	1070	.009
Englebright	22.21†	16.94	12.94	9.86	7.54	5.76	4.37	3.29	2.33	1.29	34	104	779	.009
Hensley	52.28†	46.67†	41.52†	36.82†	32.53†	28.54†	24.68	20.56	15.57	8.70	64	39	1300	.010
Isabella	127.43†	102.37	80.49	61.75	46.12	33.46	23.51	15.93	10.09	5.05	346	1385	6520	.018
Kaweah	98.81†	28.82	61.03	45.56	32.49	21.80	13.78	7.99	4.78	1.73	39	748	1065	.013
Mendocino	44.99†	46.73	50.41	57.58	71.62	100.00	144.54	112.55	34.42	7.25	230	121	1785	.006
New Hogan	32.22†	25.48†	20.06†	15.73	12.35	9.73	7.76	6.28	5.16	4.07	86	271	3094	.010
Pine Flat	13.98	10.66†	7.99†	5.86†	4.21	2.95	2.05	1.41	1.02	0.80	108	724	5956	.003
Success	1307.36	969.01	692.91†	473.70†	305.69†	182.92†	98.89†	46.57	18.25	5.47	60	605	2450	.021

Use is measured for 1983. Reported marginal values per acre-foot of water are obtained by applying (5) to each lake level at the column heading. For each lake level, (5) is summed over zones of origin. Results are then summed over the day user and camper models. One acre-foot equals 1234 m^3; 1 acre equals 4047 m^2.

*In 1994 dollars.

†Brackets the range of lake level surface areas recorded during 1983–1985 visitor survey period.

farmers or cities, while holding substitute reservoir levels constant. Interestingly, the coefficients on OWN_PF_{jt} were only about half as large when SUB_PF_{ijt} was excluded in an earlier version of the model. This earlier misspecified model would have led us to understate marginal values of water in recreation.

Table 3 presents the marginal values of water at the 10 reservoirs for various lake levels. It also shows three factors that influence those values: visitor use, reservoir size, and reservoir bank slope. Values vary significantly by both site and lake level. Values noted with a dagger indicate the range of lake levels that occurred during the study period. Over this range, values of water range from $5.86 at Pine Flat Reservoir to about $692 at Success Lake. Despite high visitor use at Pine Flat, its size and shape result in little benefit from holding added water volume. Success Lake illustrates the opposite extreme: high use, a small recreation pool, and shallow banks.

The high coefficient on the percent full variable in both the day use and camping models typically causes marginal values to decrease as lake levels fall. This means it is more economically valuable at the margin to hold water when a lake is nearly full than when it is nearly empty. One exception to this trend occurs at Lake Mendocino, because the slope of its bank changes quickly with falling water; this causes its surface area to fall considerably even with modest decreases in volume. Therefore Mendocino's marginal value of water increases over a wide range of falling lake levels.

Concluding Comments

This study has important implications for water resource management in multiple-use river basins. In droughts or when demands for competing water uses are high, economically efficient basin management will draw down reservoirs that have lowest marginal values for recreation. Pine Flat Reservoir is a good example. Drawdowns at Pine Flat produce small losses in regional recreation benefits because it is isolated and large, and has steep bank slopes.

By contrast, drawing down a reservoir with a high recreational value per acre-foot (1234 m^3) imposes considerable recreation economic losses to the region; these reservoirs typically have few substitutes, are located near population centers, or have shallow bank slopes. During a drought or in times of high water demand, maintaining high lake levels at such sites will increase regional economic efficiency. In this way, tradeoffs between recreation benefits and benefits of competing water users can be identified for water managers and other decisionmakers.

For the range of the lake levels observed in the California Central Valley, annual recreational values per acre-foot of water vary from $6 at Pine Flat Reservoir to more than $600 at Success Lake. These estimated values of reservoir water are comparable with values reported in previous work. They are a plausible updating of the *Young and Gray* [1972] findings. However, they are generally lower than those reported by *Creel and Loomis* [1992].

Water values reported in this paper are competitive with water values for other uses in the western United States, for example, agriculture, as reported on by *Colby* [1989]. While the highest value Colby reported was well over $1000 per acre-foot, eight of the other cases reported irrigation values of less than $50 per acre-foot for crops. Specialty crops such as tomatoes, cotton, and lettuce produced the highest water value. Only three of Colby's reported values showed agricultural values larger than $200 per acre-foot.

More recently, D. Tegelman (personal conversation, 1995) reported marginal agricultural values of water in the California Central Valley that reflect estimates of what the U.S. Bureau of Reclamation would have to pay farmers to fallow currently irrigated land on their least valuable acreage. Values generally increase from north to south. They range from $55 to $80 in the Sacramento Valley to $135 to $200 in the southern San Joaquin Valley [*U.S. Bureau of Reclamation*, 1995].

Finally, recreational values of water reported in this study have important implications for application to other contexts. For managers who wish to estimate marginal values of water at a target reservoir but lack primary data, four terms should be multiplied together. First is the current visitor use multiplied by average benefits per visit. For this study, benefits per visit ranged from $1 to $3 for day users and $4 to $6 for campers. Better local estimates may be available. The second term is the ratio of the elasticity of "percent full" (Table 1) to the reservoir's actual percent full measured in surface area. The third term is 100 divided by the reservoir's recreational capacity in surface area, as 0.02 for a reservoir with a recreational capacity of 5000 surface acres. The last term is the addition to surface acres produced by adding 1 acre-foot of water to the reservoir, available from area-capacity tables. Following these steps will produce a mechanically correct benefits transfer. However, one should be cautioned that without testing these transferred values against results of an original study in the target region, the error is unknown.

Acknowledgments. Without implicating anyone, the authors would like to thank several people for their help in carrying out this study. Joe Holmberg, Sacramento District, U.S. Army Corps of Engineers, helped organize much of the water and visitor use data. Donna Tegelman, U.S. Bureau of Reclamation, Sacramento, provided estimates of agricultural values of water in California's Central Valley. We thank Bruce McCarl and three anonymous referees for suggestions that improved this paper considerably. The U.S. Army Waterways Experiment Station and state agricultural experiment stations at New Mexico State University and the University of California provided financial support. John Meadows organized the cooperative agreements between the Corps, U.S. Department of Agriculture (USDA), and state agricultural experiment stations. Participants of the USDA Regional Project "Benefits and Costs Transfer in Natural Resource Planning" (W-133) made helpful suggestions on earlier drafts. None of these helpful people or organizations is responsible for this paper's analysis and conclusions, which are ours alone.

References

ALK Associates, Inc., *PCMiler® User's Guide Version 9.0*, Princeton, N. J., 1995.

Boyle, K. J., M. P. Welsh, R. C. Bishop, and R. M. Baumgartner, Analyzing the effects of Glen Canyon Dam releases on Colorado River recreation using scenarios of unexpected flow conditions, paper presented at W-133 Western Regional Resource Economics Conference, Santa Fe, N. M., 1993.

Cesario, F. J., Value of time in recreation benefit studies, *Land Econ.*, *52*(1), 32–41, 1976.

Colby, B. G., Estimating the value of water in alternative uses, *Nat. Resour. J.*, *29*(2), 511–527, 1989.

Cordell, H. K., and J. C. Bergstrom, Comparison of recreation use values among alternative reservoir water level management scenarios, *Water Resour. Res.*, *29*(2), 247–258, 1993.

Creel, M., and J. Loomis, Recreation value of water to wetlands in the San Joaquin Valley: Linked multinomial logit and count trip frequency models, *Water Resour. Res.*, *28*(10), 2597–2606, 1992.

Hansen, L. T., and A. J. Hallam, Single-stage and two-stage decision modeling of the recreational demand for water, *J. Agric. Econ. Res.*, *42*(1), 16–26, 1990.

Knetsch, J. L., R. E. Brown, and W. J. Hansen, Estimating expected use and value of recreation sites, in *Planning for Tourism Development*, edited by C. Gearing, W. Swart, and T. Vars, Praeger, New York, 1976.

Loomis, J. B., B. Roach, F. Ward, and R. Ready, Testing transferability of recreation demand models across regions: A study of Corps of Engineer reservoirs, *Water Resour. Res.*, *31*(3), 721–730, 1995.

Ruddy, B. C., and K. J. Hitt, Summary of selected characteristics of large reservoirs in the United States and Puerto Rico, 1988, *U.S. Geol. Surv. Open File Rep. 90-163*, 1990.

Smith, V. K., and R. J. Kopp, The spatial limits of the travel cost recreational demand model, *Land Econ.*, *56*(1), 64–72, 1980.

U.S. Army Corps of Engineers, *Natural Resource Management System*, Washington, D. C., 1991.

U.S. Bureau of Reclamation, *Administrative Least Cost Central Valley Project Yield Increase Plan*, U.S. Bur. of Reclam., Sacramento, Calif., 1995.

U.S. Bureau of the Census, *County and Cities Data Book: 1994*, U.S. Gov. Print. Off., Washington, D. C., 1994.

Ward, F. A., Economics of water allocation to instream uses in a fully appropriated river basin: Evidence from a New Mexico wild river, *Water Resour. Res.*, *23*(3), 381–392, 1987.

Ward, F. A., B. A. Roach, J. B. Loomis, R. C. Ready, and J. Henderson, Regional recreation demand models for large reservoirs: Database development, model estimation, and management applications, Final Rep. to U.S. Army Corps of Eng., Washington, D. C., March 1995.

Young, R. A., and S. L. Gray, *Economic Value of Water: Concepts and Empirical Estimates*, Final Rep. to the Natl. Water Qual. Comm., Contract NWC-70-280, Colo. State Univ., Fort Collins, March 1972.

Young, R. A., and R. H. Haveman, Economics of water resources: A survey, in *Handbook of Natural Resource and Energy Economics*, vol. I, edited by Allen V. Kneese and James L. Sweeney, pp. 465–521, North-Holland, New York, 1985.

J. Henderson, U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS 39180.

B. A. Roach, Division of Environmental Studies, University of California, Davis, CA 95616.

F. A. Ward, Department of Agricultural Economics and Agricultural Business, New Mexico State University, Box 30003, Department 3169, Las Cruces, NM 88003. (e-mail: fward@nmsu.edu)

(Received November 2, 1995; revised December 18, 1995; accepted January 5, 1996.)