COMPARING BENEFITS AND COSTS OF WATER RESOURCE ALLOCATION POLICIES FOR CALIFORNIA'S MONO BASIN

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ABSTRACT

This chapter presents the results of a benefit-cost analysis of alternative water allocation policies for California's Mono basin. Using an expanded benefit-cost framework that incorporates the public's willingness to pay (WTP) for protecting Mono Lake, the authors determined that three of the seven lake level alternatives had positive net economic benefits. The 6,390-ft lake level alternative, which would raise the lake by 15 feet above its current level, was found to maximize net economic benefits. This conclusion was found to be relatively insensitive to the discounting of future ecosystem protection benefits.

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INTRODUCTION

Meeting California's thirst for water has never been more challenging for water resource agencies and utilities. Recent court decisions affecting water rights under the public trust doctrine, the enactment of new public laws that affect how developed state and federal water is allocated, and new water quality standards proposed for the Sacramento/San Joaquin River Delta are dramatically changing time-honored procedures for allocating water resources in the state. These changes cast great uncertainty on the future availability of water supplies.

Environmental values have moved to the forefront of these water policies, and economists are grappling with appropriate ways to incorporate these values into traditional forms of economic analysis. This chapter presents the results of an economic analysis of alternative allocation policies for water resources in California's Mono basin. The issue of amending water rights held by the City of Los Angeles in California's Mono basin has been at the center of water rights law in California for more than 10 years.

The primary objectives of the economic analysis were to identify the lake level alternatives that would generate positive net economic benefits (benefits > costs) and to determine the lake level alternative that would maximize net economic benefits. These findings, combined with information on environmental impacts of the alternatives, assisted the state in selecting a policy that balances public trust resources at Mono Lake.

BACKGROUND

In 1940, the City of Los Angeles (City) was granted permits by the State of California allowing the appropriation of flows from four major tributary streams to Mono Lake, which lies in an interior-drained basin east of the Sierra Nevada in Mono County (Figure 1). The lake, because of its great geologic age, is hypersaline and supports a unique and very productive invertebrate (alkali fly and shrimp) population which in turn supports annual migration and the nesting of millions of birds.

For more than 50 years, the City has been diverting an increasing portion of the flows of the tributary streams, which flow from the snowy east side of the Sierra Nevada. By 1970, stream diversions were nearly total. Since the mid-1970s, diversions have averaged about 83,000 acre-feet per year (af/yr), which augmented threefold the flows of the upper Owens River.

The City's exports have caused a 40-foot decline in lake surface elevation and a 25% reduction in lake surface area. As a result, the salinity and alkalinity of the lake waters have increased. In addition, falling lake levels have exposed land that connects the shore to former islands. As a result, birds nesting on the islands have lost their security from mainland predators. Also, riparian and freshwater habitats along the tributary streams have been irreversibly lost through erosion, and occasional massive dust storms have been induced from salt efflorescence on exposed lakebeds. Despite the environmental harm associated with lower lake levels, visitors to the lake have enjoyed one result of the drop in lake surface elevation: the increasing exposure of the lake's fascinating complex of tufa formations, formed underwater during periods of higher lake levels.

Figure 1. Mono Basin and Los Angeles Aqueduct Conveyance System

In 1983, in response to a suit filed by the National Audubon Society, the California Supreme Court held that the public trust mandated reconsideration of the City's water rights in Mono basin. The court found that the City's water rights were granted without consideration of impacts on these resources and therefore that the state or the court should reconsider the City's water rights. The court noted that before continued stream diversions could be approved, the effect of such diversion on interests protected by the public trust should be considered and that harm to those interests should be minimized or avoided if feasible.

The state identified a full range of water rights alternatives for evaluation in an environmental impact report (Jones & Stokes Associates 1993a). Each alternative represented a lake level target and a projected volume of water export based on assumed stream diversion rules. The alternatives ranged from imposing no new restrictions on diversions to ending all diversions. A numerical monthly model of the aqueduct system (LAAMP) was developed that specified relationships between available water exports from Mono basin and the City's water demand, other supplies available to the aqueduct, and water conveyance and storage constraints throughout the system and affected groundwater basins.

ANALYTICAL FRAMEWORK

Benefit-cost analysis was selected as the appropriate framework for the economic analysis. We used a framework that focused on monetary values, which complemented an analysis of environmental effects being presented in the environmental impact report. The analytical framework was expanded to include estimates of nonuse (or passive) values to the nonvisiting public associated with different levels of environmental protection for Mono Lake.

Two key considerations of the benefit-cost analysis were the accounting stance and planning horizon. The accounting stance (or boundary) used for the study was the State of California. This boundary was selected because it was believed that state residents would incur most costs and benefits, with the possible exception of some nonuse value. We selected a 20-year planning horizon for the study because it allowed for consideration of the effects of variable hydrologic conditions (i.e., different types of water years) on supply conditions of affected uses and the effects of population growth.

COSTS AND BENEFITS ANALYZED

Water diverted from the tributary streams to Mono Lake supports beneficial uses in the City and in the Mono and Inyo basins. Beneficial uses to the City are power generation from hydroelectric facilities along the Los Angeles Aqueduct and consumptive water use. Affected beneficial uses in Mono and Inyo counties include agricultural production and recreation. We determined that economic impacts on agricultural production would be minor and therefore did not address them in the analysis. An additional use of Mono basin water resources for which we estimated value was maintaining the ecosystem of Mono Lake.

Water Supply Costs

Water supply costs include both direct and indirect costs. We defined direct impacts as predicted changes in the supply of water delivered to the City via the Los Angeles Aqueduct. We defined indirect impacts as effects on other water users potentially affected by reductions in the City's use of Mono basin water supplies. These effects focused on potential increases in supply costs resulting from reductions in regional supplies available from the Metropolitan Water District of Southern California (MWD), the City's primary alternative supply.

Direct Costs

The task of identifying direct water supply costs focused on estimating the incremental costs that the City would incur to meet future water demands with reduced water supplies from Mono basin. We analyzed predicted changes in water deliveries over a 20-year analysis period in a cost simulation model that balanced the City's annual supply and demand conditions for the City on a least-cost basis. We constructed the 20-year period by randomly selecting 20 years out of the 50-year historical record (1940–1989) used for the hydrologic analysis. The number of dry, normal, and wet years was selected proportionate to the percentage of occurrences of these water year types in the 50-year period.

The simulation model assumes that increasingly more expensive sources of water will be used to meet demands. It includes water demand in the Los Angeles Department of Water and Power (LADWP) service area for the 20-year period from 1992 to 2011 and expected supply sources available to meet these demands. Water supply sources are brought online on a least-cost basis to meet increasing demand.

The primary components of the simulation model are demand projections, supply and cost projections, and procedures for balancing annual supply with demand.

Demand projections. We used the forecast of water demand from LADWP's urban water management plan, which was considered to represent the best estimate of LADWP's future demand. In the forecast, water use is projected to grow from 697,000 af in 1992 to 759,000 af in 2011, an increase of 9 percent. During the same period, the population served by LADWP is expected to rise by 30 percent. The demand projections are based on historical average temperatures and incorporate the effects of water conservation, population density, commercial and industrial growth, pricing, and other miscellaneous factors that affect water use (Los Angeles Department of Water and Power 1991). These demand projections remained constant for all modeling scenarios.

Supply and cost projections. Supply sources in the simulation model include LADWP's three major historical sources and a fourth source, water reclamation, which will become increasingly important in the future. The historical sources are

Mono basin and Owens River basin water delivered through the Los Angeles Aqueduct; local wells that draw groundwater from the San Fernando, Sylmar, central, and west coast basins; and MWD water, which primarily comes from the Colorado River Aqueduct and the State Water Project.

We used the LAAMP model to estimate the amount of water that would be available to the City from Mono basin and the Owens River basin. The costs associated with obtaining water from the Los Angeles Aqueduct consist primarily of fixed costs ($48 million per year) associated with debt payments and maintenance activities. A variable cost of $20 per acre-foot also was included to account for filtration costs.

Groundwater availability was estimated to increase from 112,000 af in 1992 to up to 134,000 af by 2011. This increase in groundwater availability is attributable to expected increases in the amount of water delivered to the San Fernando Valley for municipal uses and eventually returned by natural percolation to the San Fernando basin.

Groundwater was assumed to cost $90 per acre-foot without treatment, which includes the rebate obtained for participating in MWD's groundwater program. Treatment costs were expected to add $53 per acre-foot in 1992, increasing to $246 per acre-foot by 2011. Treatment costs for intermediate years were derived by interpolation.

The City's demand for MWD water ranged from 280,000 af to 300,000 af during the 20-year period. These estimates represent the upper limit of MWD water assumed to be available to LADWP although LADWP's preferential rights to MWD water exceed this amount. Costs for treated MWD water are expected to increase from $322 per acre-foot in 1992 to $680 per acre-foot in 2000 and $800 per acre-foot by 2010.

We estimated that water available from reclamation projects would increase from 4,900 af in 1992 to 119,000 af by 2011. The costs of 21 separate projects, ranging in cost from $346 per acre-foot to $620 per acre-foot, were used in the analysis.

Balancing procedures. The simulation model sequentially steps through each year of the 20-year analysis period to equate supply and demand (Figure 2). First, we estimated the availability of base resources, which include resources owned by LADWP and those that LADWP proposes to acquire over the next 20 years. These include Los Angeles Aqueduct water, groundwater, and reclamation projects.

Base resources are selected in order of least cost to most cost. After each resource is selected, cumulative resource costs are calculated and total resource supply is compared to demand. If the total supply equals or exceeds demand, the model adds any surplus from the marginal supply source to the future-year groundwater credit before it moves to the next year. After all years have been completed, total costs are summed and the modeling results are calculated.

The model moves to step two if total annual supply is less than total demand after all base resources have been selected. In step two, the model examines whether any groundwater credits are available. If groundwater credit is available for pumping,

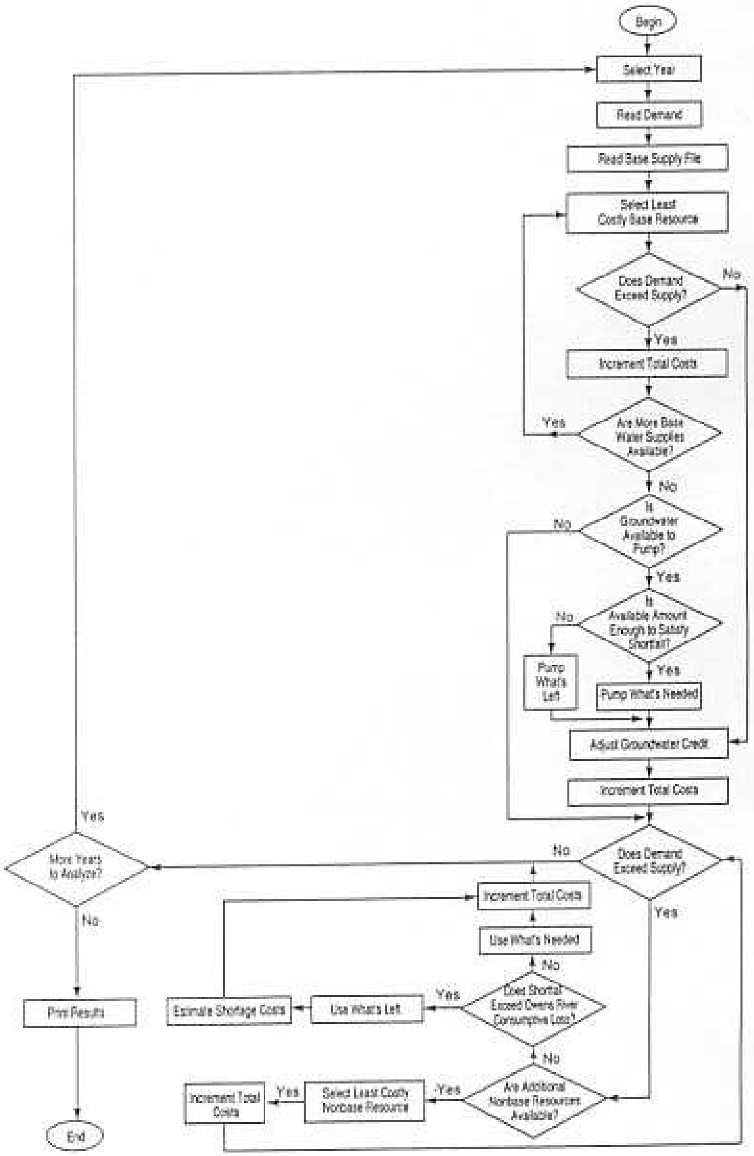

Figure 2. Simulation Model for Estimating Water Supply Costs

then groundwater is pumped until supply equals demand or until the credit limit is reached. The model does not allow a negative credit; that is, LADWP is not allowed to pump more than the credit amount. After the groundwater credit is used up, no additional groundwater can be pumped. After groundwater is pumped, the credit amount is adjusted and the costs of groundwater pumping are estimated.

If supply equals demand after pumping, total costs are estimated, the credit limit is adjusted to account for the credit usage, and the model moves to the next year. If a supply shortfall still exists, the model moves to step three.

In the third step, nonbase resources are selected in order of least cost to most cost until supply equals demand. Nonbase resources are supplied primarily from MWD but also include up to 6,000 af/yr of water that is diverted for irrigation from the upper Owens River and its tributaries under LADWP leases. After each nonbase resource is selected, total supply costs are estimated.

If a supply shortfall still exists after all nonbase resources are selected, the model estimates the costs of that shortfall, using the shortage costs of LADWP water developed by the Mayor's Blue Ribbon Committee on Water Rates (1992). These costs, which were approved by the committee and its technical panel, range from $1,272 to $2,635, depending on the amount of shortage.

Table 1 shows the annualized cost over the 20-year analysis period for the alternative water allocation policies. The costs are relative to a base condition, which represents the estimated cost of water supply to the City if the state took no further action to restrict diversions from Mono basin.

Indirect Costs

We also estimated the indirect costs to other water agencies that would result if the City consumed increased amounts of less expensive regional supplies provided by MWD. These costs (Table 1) were approximated by subtracting the projected 20-year average cost of MWD water ($639) from the estimated average cost of reclaimed water ($800), which was used as the least-cost alternative for water agencies needing replacement of lower cost MWD water supplies.

Power Generation Costs

The City's need for electricity is served by a combination of resources, including the hydroelectric generating facilities located along the Los Angeles Aqueduct. The amount of water diverted through these hydroelectric facilities directly affects the amount of capacity and energy available to the City.

We estimated power generation costs to the City by calculating changes in power output for each hydroelectric plant along the Los Angeles Aqueduct. We applied efficiency values to the amounts of water predicted by LAAMP for each alternative. We then used the ELFIN model, a least-cost production optimization model developed by the Environmental Defense Fund, to estimate incremental fuel costs associated with meeting power demands.

Table 1. Summary of Incremental Annualized Costs and Benefits Relative to Base Condition (in millions of 1992 dollars)

	Costs[a]				*Benefits*[b]			
	Water Supply							
Alternative	*Direct*	*Indirect*	*Power Generation*	*Marginal Costs*[c]	*Recreation*[d]	*Mono Lake Ecosystem Protection*	*Marginal Benefits*[c]	*Net Economic Benefits*
No restriction	(5.1)	(1.2)	(1.3)	—	0.2	(759.7)	—	(751.9)
6,372-ft	10.8	2.7	1.9	23.0	(0.2)	0.0[e]	759.7	(15.6)
6,377-ft	16.5	4.5	2.7	8.3	(0.1)	22.6	22.5	21.3
6,383-ft	26.4	6.8	4.2	13.7	(0.4)	63.0	40.1	25.2
6,390-ft	30.4	7.6	5.0	5.6	(0.5)	85.9	22.8	42.4
6,410-ft	37.9	9.3	6.7	10.9	(0.6)	0.0	(86.0)	(54.5)
No diversion	43.2	10.8	8.2	8.3	(0.1)	0.0[f]	0.5	(62.3)

Notes: [a]Values in parentheses indicate a net savings.

[b]Values in parentheses indicate a net loss in economic welfare.

[c]Calculated as the change in total value from the preceding alternative.

[d]Totals exclude recreation benefits at Mono Lake because they are included in estimates of Mono Lake ecosystem protection benefits.

[e]Interpreted to be equivalent to the base condition.

[f]Assumed equivalent to the 6,410-ft alternative.

✗

The ELFIN model calculates energy production, costs, and emissions associated with serving a given level of electrical load. We first estimated the amount of energy and capacity available from the Los Angeles Aqueduct hydroelectric generating facilities for a given level of assumed water diversions using relationships between water flow, energy, and capacity availability; we developed these relationships from historical information provided by LADWP. Then we used the generation information to develop input data representing the Los Angeles Aqueduct facilities for the ELFIN model. Finally, we performed a series of ELFIN simulations, with each simulation representing a different level of energy production and capacity availability from the aqueduct.

The major inputs to the ELFIN model are the overall level and pattern of energy demands and the operating cost and performance characteristics of generating units (including thermal, hydroelectric, and pumped storage facilities). The model determines the least-cost manner of operating the generating units within any given month, season, or year to maximize overall system reliability. Generating resources are dispatched to serve load in order of increasing incremental operating cost; however, generating units with noneconomic constraints (such as run-of-river hydroelectric generation or unit-minimum generation requirements) are dispatched first.

We estimated the level and pattern of energy demands for LADWP and the operating costs and performance characteristics of LADWP's generating units over a 20-year analysis period. For the 1992–2009 period, we used data files developed by the California Energy Commission for the 1990 Electricity Report; for 2010 and 2011, we estimated data using escalation trends for the 5-year period of 2005–2009.

Table 1 shows estimates of annualized costs associated with replacing low-cost hydroelectric energy from the aqueduct with energy from higher-cost generation sources. The costs are relative to a base condition, which represents the cost of power to meet the City's demand if the state took no further action to restrict diversions from Mono basin.

Recreation Benefits

The key recreation areas affected in the Mono basin are Mono Lake, its four diverted tributary streams, and Grant Lake, which is a reservoir on Rush Creek, one of the diverted streams (Figure 1). Outside the Mono basin, the upper Owens River and Crowley Lake in the Inyo basin are hydrologically connected to the tributaries through the system of water conveyance facilities that make up the Los Angeles Aqueduct system. Because of the hydrologic connections between the basins, reductions in out-of-basin diversions from the Mono Lake tributaries generally mean more water for in-basin resources but less water for upper Owens River and Crowley Lake.

The analysis of recreation benefits focused on estimating the change in net benefits at these recreation areas under the different water allocation policies. We conducted onsite surveys of visitors at all recreation areas except the upper Owens River to obtain data for estimating changes in net benefits. We used the contingent valuation method (CVM) to collect data on visitors' maximum willingness to pay (WTP) for water resource conditions, such as instream flow or reservoir levels, associated with the alternative water allocation policies.

Mono Lake

We conducted surveys of 297 Mono Lake visitors in summer and fall 1992, when the lake level was approximately 6,375 feet above sea level. We asked survey participants whether they would be willing to pay for a Mono Lake protection program in which the funds would be used to purchase water to maintain or increase the lake level. We used photo simulations of the lake at different lake levels (6,372, 6,375, 6,390, and 6,410 feet above sea level) and descriptions of environmental conditions, including abundance of fish and wildlife resources and frequency of severe dust storms, in the surveys.

We selected lake levels for the survey that would encompass the approximate range of lake level alternatives being considered by the state. Although, because of budget constraints, it was impossible to ask participants about all the lake level alternatives, we also asked about two intermediate lake levels. We used results from the survey to estimate values for the other alternatives.

We calculated the benefits of the lake level alternatives identified in the survey by estimating bivariate logit equations from the survey data. The dependent variable in the logit equation is the "yes" or "no" response to the WTP question, and the independent variable is specific dollar amounts (\$A) for a lake level alternative. The estimated logit equation can be specified as follows:

$$\Pr\{\text{response is ``yes''}\} = (1 + \exp\frac{\$A - \mu}{\theta})^{-1} \qquad (1)$$

where \$A is the dollar amount presented to the respondent, μ is the location parameter corresponding to both the mean and the median willingness to pay, and θ is a scale parameter. The parameters μ and θ are estimated by maximum likelihood based on the survey responses, with a separate value of μ for each lake level.

Table 2 shows the resulting parameters estimated from the survey data. Using these estimates, we calculated μ, the annual willingness to pay, which also is shown in Table 2.

We estimated total recreation benefits by multiplying the average WTP per visitor (Table 1) by the estimated number of visitors to Mono Lake in 1992, which was 51,592. These values are shown in Table 3. To estimate the benefits for the 6,377-ft and 6,383-ft alternatives, we interpolated values from the 6,375-ft and 6,390-ft alternatives.

Table 2. Logit Equations and Median Willingness-to-Pay Estimates for Recreation Benefits

Resource/Program	μ	θ	*Median WTP*
Mono Lake			
6,375 feet (Program A)	64.57	47.44	$64.57/year
	(14.08)	(3.68)	
6,390 feet (Program B)	69.54	47.44	$69.54/year
	(12.80)	(3.68)	
6,410 feet (Program C)	39.59	47.44	$39.59/year
	(8.09)	(3.68)	
Tributaries			
40-cfs program	17.64	29.48	$17.64/year
	(6.35)	(4.87)	
20- to 85-cfs program	16.47	22.38	$16.47/year
	(3.20)	(2.97)	
Grant Lake			
Program 2	4.67	3.00	$4.67/day
	(0.60)	(0.44)	
Crowley Lake			
Program 2	64.96	30.87	$64.96/year
	(14.15)	(9.79)	

Tributaries

We conducted surveys of 197 visitors to the Mono Lake tributaries during summer and fall 1992. Using a series of graphs that depicted average monthly streamflows, we asked survey participants whether they would be willing to pay into a trust fund that would be used to secure water for increasing streamflows in the tributaries.

Table 3. Annual Recreation Benefits (in thousands of 1992 dollars)

	Lake Level Alternative						
Resource	*No Restriction*	*6,372-ft*	*6,377-ft*	*6,383-ft*	*6,390-ft*	*6,410-ft*	*No Diversion*
Mono Lake	(3,163.0)	537.0	1,253.0	2,506.0	3,325.0	1,992.0	1,992.0
Tributaries	(3.2)	(0.6)	3.2	5.1	5.6	5.6	5.6
Grant Lake	107.5	(85.3)	(99.2)	(111.8)	(124.3)	(136.4)	365.4
Crowley Lake	88.7	(88.7)	0.0	(266.1)	(266.1)	(354.8)	(354.8)
Upper Owens River	22.8	16.3	(42.3)	(105.7)	(130.1)	(175.6)	(177.3)
Net Effect	(2,947.2)	378.7	1,114.7	2,027.5	2,810.1	1,330.8	1,830.9

We asked survey participants about two flow programs. The first program would maintain flows during the spring and summer months (April through September) at an average of about 40 cubic feet per second (cfs). The second program involved more variable flows, ranging from 20 cfs in early summer, increasing to 85 cfs in July, and then decreasing to approximately 40 cfs by October. (The average flow condition maintained in recent years was approximately 20 cfs.) We believed that these two flow programs encompassed the likely range of flows of the water allocation policies.

Using a process similar to the one we used for making estimates at Mono Lake, we estimated the benefits of the two flow programs from bivariate logit equations that were estimated from the survey data. Table 2 shows the estimated parameters in the logit equation and the median WTP per visitor for these two streamflow programs.

To estimate total benefits for each water allocation policy, we first calculated the average benefit of a 1-foot change in cfs. This calculation was necessary because the average flow conditions of the lake level alternatives were substantially higher (76–126 cfs) than those used in the surveys; therefore, an average benefit "multiplier" was needed.

The benefit multiplier was then used to estimate the change in benefits, which resulted from implementing the different water allocation policies. We used the difference in average cfs between the base condition and each of the alternatives to estimate the net change in benefits. For calculating the benefits of changes in cfs between 20 cfs and 60 cfs, we used the average value per change in cfs ($0.88) derived from the 40-cfs program. For changes between 60 cfs and 100 cfs, we used a value that was 50% of the value for changes between 20 and 60 cfs. We used this scaling to be conservative regarding the benefits of changes in streamflows that were higher than those under our survey alternatives. No values were assigned for flows above 100 cfs.

Total WTP for each alternative was then estimated by applying the average value per visitor for the relevant increase in average streamflows to the estimated number of visitors to the lower portion of the tributaries in 1992, which was 227. Table 3 shows the estimated total WTP for each of the alternative water allocation policies.

Grant Lake

We conducted surveys of 99 visitors to Grant Lake during summer 1992. We asked survey participants whether they would be willing to pay higher parking fees or an access fee (most lake access is uncontrolled) for lake levels that would be higher than planned for 1992.

We asked survey participants about their WTP for two reservoir water level programs. The first program would maintain stable reservoir levels throughout the spring and summer months (April through September) with lake levels between 20 feet and 25 feet above the current 1992 plan. The second program involved more variable reservoir levels (similar to the current plan) and lake levels ranging from 12 feet to 25 feet above the current plan. We used a series of graphs in the surveys that depicted the average monthly reservoir levels and descriptions of expected reservoir conditions, including the fishery and marina access conditions.

The benefits of the higher reservoir levels were calculated from bivariate logit equations estimated from the survey data. Table 2 shows the estimated parameters in the logit equation and the median WTP calculated from the equation.

To estimate total recreation benefits for each water allocation policy, we first calculated the average benefit per 1-foot change in reservoir level. This calculation was necessary because we needed to extrapolate survey results to the alternative water allocation policies, which did not match the scenarios described in the survey. We then used an estimate of the benefit per acre-foot to calculate the benefits of implementing the alternative water allocation policies, relying on the difference in average reservoir levels between the base condition and each alternative to calculate benefits.

Total WTP for each alternative was then estimated by applying an average value per visitor day to the estimated number of annual visitor days predicted for each alternative water allocation policy. Table 3 shows the estimated total WTP for the alternative water allocation policies.

Crowley Lake

We conducted surveys of 271 visitors to Crowley Lake, located in the Inyo basin, during fall 1991 and summer 1992. We asked survey participants whether they would be willing to pay higher parking fees or an access fee (most lake access is uncontrolled) for lake levels that would be higher than planned for 1992.

We asked survey participants about their WTP for a water level program different from what was planned. We developed three alternative water level programs and used a split sample approach so that each participant was asked about only one program to minimize confusion. The first program would maintain stable reservoir levels throughout the summer months (May through September) with lake levels approximately 8 feet above the current plan. The second program that we asked about was to maintain the current plan instead of letting lake levels drop approximately 10 feet. The third program consisted of generally higher but more variable reservoir levels with levels ranging from 3 feet to 10 feet higher during most of the season but becoming slightly lower in late September. We used a series of graphs that depicted the average monthly reservoir levels and descriptions of reservoir conditions, including fishery, marina access, and waterskiing conditions.

We calculated the benefits of implementing the different reservoir programs from bivariate logit equations estimated from the survey data. Table 2 shows the estimated parameters from the logit equation and the median WTP that was calculated from the equation.

To estimate total recreation benefits for each water allocation policy, we first calculated the average benefit per 1-foot change in reservoir level. This calculation was necessary because we needed to extrapolate results from the survey to the alternative water allocation policies, which did not match the scenarios described in the survey. We then used the benefit per acre-foot to estimate the benefits of implementing the alternative water allocation policies, relying on the difference in average reservoir levels between the base condition and each alternative to calculate benefits.

Total WTP for each alternative was then estimated by applying the average value per visitor to the estimated number of visitors in 1992, which was 10,923. Table 3 shows the estimated total WTP for each water allocation policy.

Upper Owens River

We estimated the net benefits of the alternative water allocation policies for the upper Owens River by applying the average benefit per change in cfs ($0.88) derived from the tributary streams analysis to the difference in average (median) streamflows between the base condition and the alternatives. Total benefits were then estimated by multiplying the per-visitor benefit by the estimated number of visitors in 1992, which was 1,848 (Table 3).

Nonuse Benefits of Ecosystem Protection

Mono Lake's natural environment has been identified as a public trust resource that the state has responsibility to protect for the enjoyment of its citizens. People have different motivations for wanting to protect Mono Lake. Participating in current recreation activities, such as bird watching and sightseeing, is one motivation that was addressed previously. Preserving the area for potential future use is another. A third motivation is associated simply with knowing that the resources at Mono Lake are protected. A fourth motivation is to protect Mono Lake for future generations to enjoy. These use and nonuse values, together with any commercial values, constitute what has been referred to as the "total economic value" of a resource (Randall and Stoll 1983; Loomis, Peterson, and Sorg 1984).

We estimated the nonuse benefits of ecosystem protection using CVM. We surveyed 600 California households in June 1992. The survey involved contacting households initially by telephone to solicit participation; sending survey materials to willing participants, including a pamphlet describing and visually depicting Mono Lake under three alternative lake level conditions (elevations 6,375, 6,390, and 6,410 feet, which are referred to as Programs A, B, and C, respectively); and conducting a follow-up interview by telephone to elicit the respondents' WTP for the different lake level and resource conditions at Mono Lake. The survey questions were structured in the form of a voter referendum. Respondents were asked whether they would pay specified amounts for state-sponsored bonds if the revenues would be used to purchase additional water supplies for Mono Lake.

Following the methodology described in Hanemann (1984) and Hanemann, Loomis, and Kanninen (1991), we analyzed the responses to the discrete-choice contingent valuation data using a statistical model derived from an underlying utility maximization model. For this application, in which we were valuing several lake level programs, we extended the standard discrete-response model to allow for the possibility of a nonzero correlation in the values that respondents place on the various programs. We refer to this model as the correlated discrete-response model.

The correlated discrete-response model was applied to the data for Programs A and B. Similar to the conventional discrete-choice model, the starting point for the correlated discrete-response model is an underlying (indirect) utility function associated with each of the outcomes, which we index with the subscript t: the default no-action level is labeled $t = 0$, the improvement associated with Program A is labeled $t = 1$, and the improvement associated with Program B is labeled $t = 2$. We employ the following Box-Cox formulation for the indirect utility function:

$$U_t = \alpha_t + \beta\left(\frac{y^\lambda - 1}{\lambda}\right) + \varepsilon_t \quad t = 0, 1, 2. \tag{2}$$

where y is the respondents' income; α_t, β, and λ are parameters to be estimated with $\alpha_t > \alpha_0$ ($t = 1, 2$) and $\beta > 0$; and ε_t is a stochastic term reflecting the random component of the respondents' preferences for outcome $t = 0, 1, 2$. This formulation nests other models commonly used in the literature, including the linear model, corresponding to $\lambda = 1$, which generates the response probability formula (1) above. The Box-Cox model also can be regarded as a form of CES utility function in income and lake level.

Define $a_1 \equiv (\alpha_1 - \alpha_2)$, $b \equiv (\beta/\lambda)$, and $\eta_t \equiv (\varepsilon_t - \varepsilon_0)$. Let W_t denote the respondents' WTP for raising the level of Mono Lake from the no-action level to level $t = 1$ or 2. It follows from (2) that the formula for W_t is

$$W_t = y - \left[y^\lambda - \frac{a_t}{b} + \frac{\eta_t}{b}\right]^{\frac{1}{\lambda}} \quad t = 1, 2. \tag{3}$$

Because it depends on η_t, which is a random variable, WTP is itself a random variable. If the median of η_t is zero, then

$$\text{Median}\,(W_t) = y - \left[y^\lambda - \frac{a_t}{b}\right]^{\frac{1}{\lambda}} \quad t = 1, 2 \tag{4}$$

We assume that the random variables (η_1, η_2) are jointly normally distributed with mean zero, variances σ_1^2 and σ_2^2, and correlation ρ. From the CV responses, one obtains maximum likelihood estimates of a_1/σ_1, a_2/σ_2, b/σ_1, b/σ_2, ρ, and λ. These estimates were obtained using a likelihood maximum routine in GAUSS. Further details of the statistical model and the estimation are found in Jones & Stokes Associates (1993b). The coefficient estimates and asymptotic standard errors and t-statistics are shown in Table 4.

Table 4. Model Coefficient Estimates for Analyzing Mono Lake Ecosystem Protection Benefits

Parameter	*Coefficient Estimate*	*Standard Error*	*Estimated t-Statistic*
Programs A and B			
a_1/σ_1	0.965	0.113	8.56
b/σ_1	0.329	0.048	6.89
a_2/σ_2	0.841	0.066	12.71
b/σ_2	0.249	0.025	9.96
λ	0.871	0.010	83.15
ρ	0.853	0.023	36.65
Program C			
a/σ	0.137	0.083	1.66
b/σ	0.135	0.070	1.91
λ	0.897	0.063	14.20

For the purpose of computing the median WTP in (4), one takes ratios to estimate $a_1/b = [(a_1/\sigma_1)/(b/\sigma_1)]$ and $a_2/b = [(a_2/\sigma_2)/(b/\sigma_2)]$. Using an income level of $35,000, which is the median for the sample of respondents (and close to the 1990 census), we estimated the median WTP of the sample to be $96.38 for Program A and $110.68 for Program B. After accounting for sampling biases from excluding non-English-speaking households and nonresponding households, we estimated the median WTP of the population of California residents at $81.90 and $91.16 for Programs A and B, respectively.

Preliminary analysis of the responses to the CVM survey shows that most of the respondents regarded Program C (lake elevation of 6,410 feet above sea level) as inferior to both Program A (lake elevation 6,375 feet) and Program B (lake elevation 6,390 feet). For this reason, we analyzed Program C separately from the other two programs.

For Program C, we employed the conventional, double-bounded (univariate) discrete-response model described in Hanemann, Loomis, and Kanninen (1991). However, instead of the linear-logistic model employed there, we used the Box-Cox formulation combined with normal distribution (i.e., double-bounded probit model). Using maximum likelihood, the coefficient estimates are shown in Table 4.

The median WTP for the sample, estimated using the standard formula and the sample median income, is $26.21. The median WTP for the population, calculated using the formula that accounts for nonresponding households, is zero. This estimate is consistent with the results of the survey. Many respondents regarded a lake level of 6,410 feet as undesirable and therefore were willing to pay little, if anything, to maintain the lake at this level. Survey respondents were informed that establishing this high lake level would submerge or topple most tufa formations and destroy habitat for the snowy plover, a candidate species for state and federal protection.

To estimate the total benefits of the alternative water allocation policies, we used estimates for the three programs described in the survey to estimate benefits for the other policies. We used the WTP estimate for Program A (6,375 feet) to estimate the benefit of maintaining that level and therefore avoiding a fall to substantially lower levels. To estimate the benefits of increasing the lake to levels between 6,375 feet and 6,390 feet, we used the incremental benefit of increasing the lake from 6,375 feet to 6,390 feet ($9.26) to estimate the marginal value of a 1-foot change in lake level. We then applied this incremental value per 1-foot change ($0.62) to the relevant change in elevation to estimate a value for each alternative. Table 1 shows these values.

COMPARING COSTS AND BENEFITS

Table 1 compares estimates of annualized costs and benefits for the seven lake level alternatives. All values reported are relative to the base condition. Three of the lake level alternatives have positive net economic benefits, and four have negative economic benefits. The no-restriction alternative, which would continue diversions as they occurred before 1989, would decrease water and power generation costs but also would reduce recreation benefits and result in a substantial loss in ecosystem protection values. Compared to the base condition, all other alternatives involve higher lake levels that increase water and power supply costs for the City.

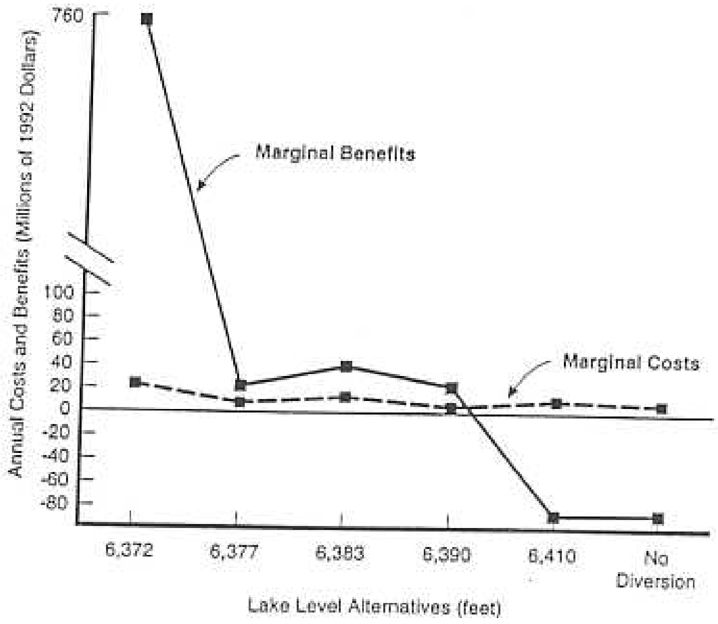

Figure 3. Marginal Economic Costs and Benefits of the Alternatives

The marginal benefits and costs associated with moving from one alternative to another are shown in Figure 3. These marginal values can be used to identify the alternative that maximizes net economic benefits. As shown in Figure 3, marginal benefits exceed the marginal costs for all alternatives up to and including the 6,390-ft alternative; consequently, net economic benefits are maximized by that alternative. Because the marginal benefits for the 6,390-ft alternative are several times greater than its marginal cost, the marginal benefits could be reduced substantially and the alternative would still be optimal from the standpoint of maximizing net economic benefits (i.e., the marginal benefit curve would still lie above the marginal cost curve).

The "robustness" of these results is important because a substantial degree of uncertainty is associated with projecting costs and benefits over a 20-year period. This uncertainty is likely to be especially important for the estimate of Mono Lake ecosystem protection benefits. Although the survey explicitly asks about WTP higher taxes for each year over the next 20 years, respondents often have difficulty projecting their WTP far into the future because preferences can change.

The uncertainty could be addressed by differentially discounting the ecosystem protection values; however, as shown in Table 5, these values could be discounted substantially without affecting the conclusion that the 6,390-ft alternative is preferred from a net economic benefits perspective.

Table 5. Sensitivity of Marginal Benefits of the 6,390-Ft Alternative to Discounting of Ecosystem Protection Benefits (in millions of 1992 dollars)

	Discount Rate			
Lake Level	*0%*	*5%*	*10%*	*15%*
6,383-ft	$63.0	$41.2	$29.5	$22.6
6,390-ft	$85.9	$56.2	$40.2	$30.9
Marginal Benefits	$22.8	$15.0	$10.7	$8.3

Note: For comparison purposes, undiscounted marginal costs are $5.6 million.

CONCLUSIONS

This analysis shows one approach to incorporating market and environmental values of water allocation decisions into economic analysis. An expanded benefit-cost analysis framework was found useful for identifying alternatives with positive net economic benefits and for identifying the alternative that is optimal from a perspective of maximizing net economic benefits. The approach relies on expressing costs and benefits in monetary terms; important other factors, such as equity, legal, and political considerations, are not considered. This type of analysis, however, does lead to decisions consistent with welfare economics theory.

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PART II

DEMAND FORECASTING AND INTEGRATED RESOURCE PLANNING