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Estimating the Value of Water in Alternative Uses**

ABSTRACT

Many public and private decisions regarding water use, allocation, and management require estimation of water's value in alternative uses. This paper discusses economic concepts essential in valuing water, outlines and compares market and nonmarket based approaches used to estimate water values, and reviews the application of these methodologies for valuing water in instream, irrigation, municipal and industrial uses in the western United States.

INTRODUCTION

Information on the value of water in alternative uses is relevant in both public and private decisionmaking. Examples of situations in which estimates of water's value are useful include a farmer deciding whether to sell water rights or to continue to use them for irrigation, a city evaluating whether to buy senior appropriative rights to firm up their supplies, a court assessing the monetary damages associated with impairment of a surface water right and an environmental organization seeking to purchase water rights for instream flow protection. Comparison of water's value in various uses and locations assists public water agencies in making decisions about management and allocation of publicly supplied water, and can contribute to better evaluation of the benefits and costs of water-related projects and policies. Some water uses are competing rather than complementary (instream flow maintenance and irrigation diversions, for instance), and information comparing water's value in these uses can be used to estimate the opportunity costs of allocating water to a particular use. Changing water values are the driving force behind the water marketing phenomena in the West, providing the impetus for transac-

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tions.[1] Estimation of water values assists potential buyers and sellers in negotiating prices and in making well-informed market decisions. Legislatures, courts and public agencies can better formulate and implement water transfer policy if they consider the values that are affected as water moves from one use to another in a market setting.

This discussion of water values is divided into four sections. First, economic concepts essential to estimating values are discussed. Second, different valuation approaches are described. Then applications of various valuation methodologies are reviewed, examining water values in instream, agricultural, municipal and industrial uses.

CONCEPTS AND METHODOLOGIES USEFUL IN VALUING WATER

Economists are often asked to determine the value of a particular set of resources or the costs and benefits associated with changes in resource availability, quality and price. A number of market and nonmarket valuation approaches have been developed. Recent theoretical and empirical developments in nonmarket valuation are a response to policymakers' and the public's desire to consider the value of nonmarketed amenities when making resource management decisions.

Consumer Surplus

For commodities traded routinely in a market setting, a market demand curve can be estimated showing the quantities of the good that would be purchased at various prices. Figure 1 shows a hypothetical market demand curve for water, with P_1 indicating the initial market clearing price and Q_1 showing the quantity demanded at this price. The triangular area above the market price and below the demand curve (area abP_1 in Figure 1) is an estimate of the net benefits generated by Q_1 units of water being purchased at price P_1. It is called consumer surplus and represents the total dollar amount consumers would be willing to pay for Q_1 (area $OabQ_1$ in figure 1) minus what they actually must pay for Q_1 (area OP_1bQ_1). If the market price rose to P_2 and all other factors relevant to demand remained unchanged, then quantity demanded would decline to Q_2. The area representing consumer surplus would then be P_2ac and the loss in benefits due to the price increase would be the decrease in consumer surplus, area P_1P_2cb.

Change in consumer surplus is not an ideal measure of benefits because it does not fully account for the fact that changes in prices involve changes in the real purchasing power of consumers. However, it is a widely used

1. For discussions of water transfer activity in the western states see B. SALIBA & D. BUSH, WATER MARKETS IN THEORY AND PRACTICE (1987); Gardner & Miller, *Price Behavior in the Water Market of Northeastern Colorado*, 19 WATER RESOURCES BULL. 557 (1983).

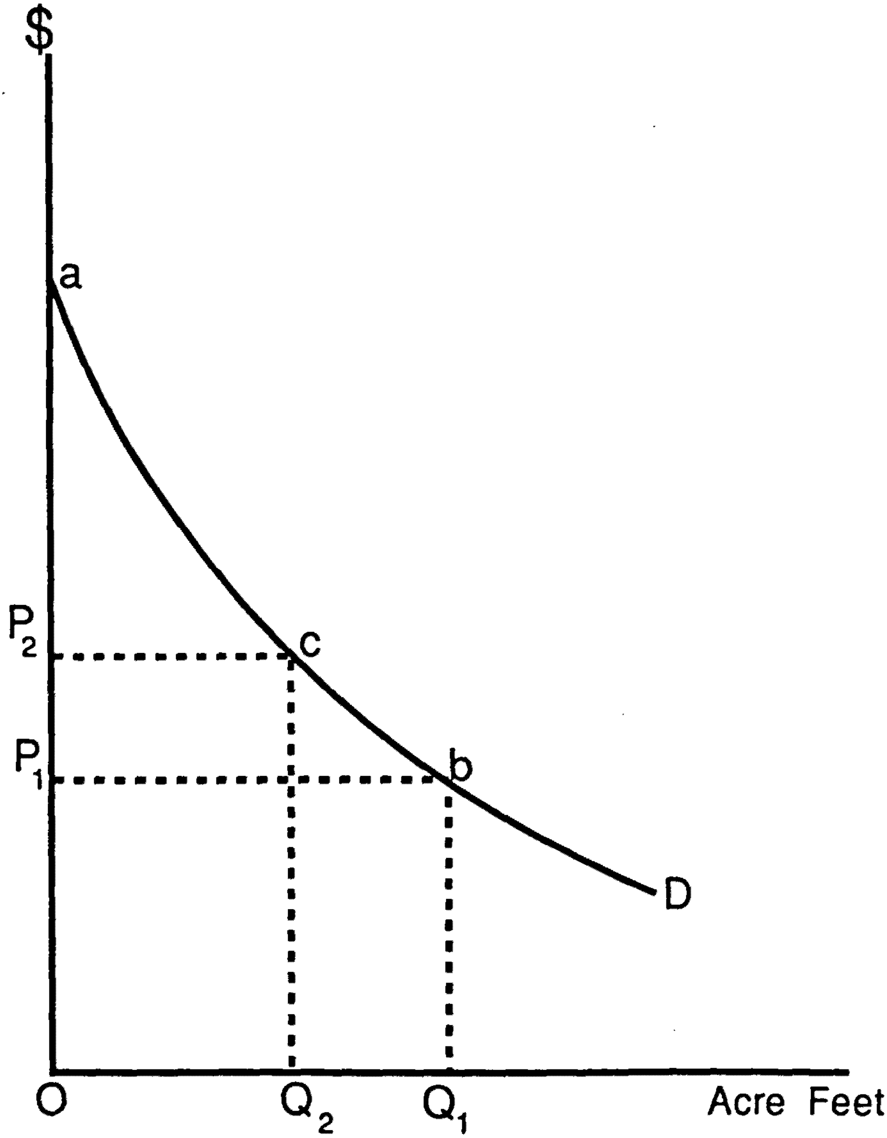

FIGURE 1 Consumer Surplus

measure of the benefits and costs to consumers associated with changes in the price, quantity, or quality of market goods, and guidelines have been developed to adjust consumer surplus estimates to give a more precise measure of change in well-being.[2] The consumer surplus approach is useful in valuing water when a demand curve for water can be estimated. Consumer surplus also provides a conceptual foundation for many of the nonmarket valuation approaches that have been developed.

Nonmarket Valuation

In most regions water is not bought and sold in a competitive market setting, and so there is inadequate data with which to estimate demand curves. Even where there are active water markets, these generally involve water transfers for agricultural, municipal, and industrial uses and rarely incorporate the value of water in non-consumptive uses such as recreation, fish, and wildlife enhancement.[3] Therefore nonmarket valuation is an important means of estimating water values in alternative uses.

Nonmarket valuation approaches can be divided into two categories—inferential valuation and contingent valuation. Inferential approaches use data on actual purchase and consumption of marketed goods and services to infer the value of a nonmarket resource. The travel cost method, for instance, uses data on money and time costs incurred to enjoy a recreation experience in order to infer the value of that recreation experience. This method has been applied widely in valuing outdoor recreation sites and is used routinely in cost-benefit analyses by many public agencies. Another inferential approach, hedonic pricing, analyzes prices for market goods, usually real estate, to infer the value of nonmarket amenities that affect market prices. For instance, statistical analysis of sale prices for similar homes with and without lake front access provides information on the additional amount home buyers are willing to pay for lake front amenities. This information is not only useful to developers and real estate professionals, it can also assist policymakers in evaluating the benefits of preserving lakeside environments.

Inferential approaches can be used only when a defensible case can be made that expenditures for market goods, such as homes and travel-related items, are linked to the value of the nonmarket amenity being valued. Contingent valuation does not require this conceptual linkage between market prices and a nonmarket resource. Instead of drawing on data related to actual market choices that indirectly are related to the good being studied, the researcher elicits information on the value of the amen-

2. Anderson & Bishop, *The Valuation Problem*, in NATURAL RESOURCE ECONOMICS, 89, 89-90 (D. Bromley, ed. 1986).

3. For a discussion of the reasons why non-consumptive water uses are not well represented in market activities, see Colby, *The Economic Value of Instream Flows—Can Instream Values Compete in the Market for Water Rights?*, in INSTREAM FLOW PROTECTION: LAW AND POLICY (L. MacDonnell ed., in publication).

ity directly by creating a hypothetical or experimental situation in which individuals reveal the values they place on the resource. The values reported are contingent upon the situation created by the researcher to elicit values. Contingent valuation techniques usually involve administering questionnaires on values, and may use iterative bidding, creation of temporary experimental markets in which money actually changes hands and other methods of eliciting values from respondents. The theoretical and applied literature on contingent valuation is growing rapidly as new techniques are developed. Contingent valuation has been used to value environmental amenities, including instream recreation opportunities, as described in a later section of this paper.

A thorough discussion of the complexities involved in nonmarket valuation and the advantages and limitations of various approaches is beyond the scope of this article. Readers wanting to learn more are referred to Anderson and Bishop and the extensive list of references they provide.[4]

Methodologies For Estimating Water Values

A number of techniques for estimating the value of water and water rights are being developed and applied in the western states. Methodologies used to value water rights include sales comparisons, income capitalization, analysis of land value differentials between parcels with and without water, and least-cost alternative analyses.

Water rights provide legally recognized access to a specific water source. A water right may be defined in quantitative terms (*e.g.*, the right to pump 100 acre-feet per year) or in terms of priority of access to the water source relative to other water users (*e.g.*, the right to divert up to 500 cfs after a neighboring senior right has been satisfied). Valuation of water rights, as formal property rights, involves special considerations.[5] The characteristics of the right being appraised must be thoroughly identified and described. All characteristics which may affect the value of the right to its current owner and to potential buyers need to be evaluated. These characteristics include long-term average and minimum (firm) yield of the right, quality of the water source and associated treatment costs for various uses, legal issues affecting the security of the right, location of current use, and costs of transferring water for an alternative location and/or use.

In many instances, it is not necessary to value water as a property right. Public policy decisions typically require a comparison of the net benefits a specific quantity of water will generate in one use compared

4. Anderson & Bishop, *supra* note 2.

5. Appraisal of water rights and the application of different methods to value water rights is discussed in Colby, *Alternative Approaches to Valuing Water Rights*, APPRAISAL J. (in publication).

to another. In these cases, value estimates are usually based on net annual benefits attributable to water, estimated using one of the techniques described below.

The sales comparison approach involves comparison of a specific water right with similar water rights which have been sold recently. Prices generated for comparables suggest a range within which the value of the subject water right should fall. Since even similar water rights may differ in financing and other conditions of the sale, location, and other characteristics, dollar adjustments typically are made to the sale price of comparables to reflect differences between comparables and the subject property.

The income capitalization approach involves analysis of the stream of net benefits that a particular water right or quantity of water will generate over time and conversion of this net benefit stream into a value estimate. The income capitalization approach is useful for valuing water used in an activity where annual net returns directly attributable to water can be identified and quantified. However, as water is typically combined with other inputs in most activities, it is often difficult to separate out the contribution of water to net returns. For instance, irrigated crops are produced using not only water but also land, agricultural chemicals, labor, field equipment and management capabilities. In urban real estate development, water rights are combined with land and improvements to produce developed property. In recreation areas, streams and lakes combined with vegetation, fish and wildlife and other environmental amenities provide recreation benefits.

Techniques have been developed to separate out the contribution of water in some uses. The residual method is used to evaluate the contribution of water to net returns in irrigated agriculture.[6] Inferential and contingent valuation techniques are used to focus on the value of water in recreation.

Another approach based on economic returns attributable to water involves land value differentials. This requires comparison of the values of agricultural land (or other income producing property) with and without access to water. Comparison of market data on the price of dry land as combined with irrigated land may be used to establish a price differential that represents the increased productivity attributable to the availability of water. The validity and accuracy of this technique depends on the quantity and reliability of market sales data available.

The least-cost alternative approach estimates the cost of creating a water supply similar to the water right being valued. This approach is

6. *See infra* text accompanying note 22.

based upon the assumption that the costs of alternatives to market acquisition of water rights, such as constructing facilities to create a new water supply or implementing water conservation or recycling, are related to the price an organization seeking new supplies would be willing to pay for an existing right in a market transaction. This is a valid assumption only if there is evidence that water users in the area actually have been paying or would be willing to pay these costs to obtain water supplies. An estimate of value must be based on evidence regarding willingness to pay. In general the least cost alternative approach is considered a technique of last resort for valuing water rights, since it is not necessarily related to willingness to pay for water rights or to net benefits generated by water supplies.[7]

WATER VALUES IN ALTERNATIVE USES

The water values reported in this section are drawn from a variety of sources. In particular, this discussion owes a great deal to Gibbons' work, *The Economic Value of Water,* which reviews a large number of studies on water values in alternative uses.[8] All values in the present work are reported in 1988 dollars using the Gross National Product index and are stated, unless otherwise noted, on a per acre-foot per year basis. In order to compare these annual values to the value of a water right, which provides access to water year after year, the present value of the perpetual stream of annual values must be calculated.[9]

Instream Values

Policymakers' and the public's interest in instream flows has been stimulated by a number of forces over the last several decades. First, the West is rapidly becoming urbanized and urban populations demand boating, fishing, and other outdoor recreation opportunities that rely on adequate stream and lake levels. Second, as diversions of water for offstream irrigation, industrial, and residential deliveries have increased, flow levels on many stream systems have decreased—sometimes to the detriment of instream water uses. Finally, there is increased appreciation by many westerners of the intrinsic and aesthetic value of free flowing water and of its economic value in enhancing recreation and wildlife

7. A. RANDALL, RESOURCE ECONOMICS (2d ed. 1987).

8. D. GIBBONS, THE ECONOMIC VALUE OF WATER (1986).

9. Net returns to water that will be received in some future year can be converted to present values through a process known as "discounting." The formula used for discounting is:

$$PV = NR(t) / [(1 + r)^t]$$

where PV represents the present value of a net return to be received in year t, designated NR(t), discounted using an interest rate r.

habitat, thus contributing to the western tourism industry. Outdoor recreation in the West concentrates around lakes, rivers and streams. Adequate stream flows are essential to boating and fishing and also—because of their importance to wildlife—to hunting, bird watching and other wildlife-related recreation. This section summarizes recent studies on instream flow values in the West. Since there is little direct market evidence on willingness to pay for recreational opportunities and for wildlife preservation, a variety of nonmarket valuation approaches have been applied to estimate the value of water for these purposes.[10]

Daubert and Young examined the contribution of stream flows to recreation benefits on Colorado's Cache la Poudre River.[11] They found the value of an additional acre-foot of flow for fishing to be $22 during low flow periods and the value of an additional acre-foot for shoreline recreation to be $16 during low river flows. Values for an additional unit of flow dropped to zero at higher flow levels suggesting that minimum flow maintenance is of value to recreationists rather than additional increments to already adequate flows. Walsh, Ericson, Arosteguy, and Hansen investigated flow values at nine sites along Colorado mountain streams and found that flow levels of 35 percent of maximum stream flow were optimal for recreation.[12] The value of an additional acre foot of flow beyond the 35 percent flow level was estimated to be $22 per acre-foot for fishing, $5 for kayaking and $4 for rafting. Walsh, Auckerman and Milton estimate that leaving water in high mountain Colorado reservoirs for an additional two weeks in August is worth $51 per acre-foot in additional recreation benefits during that peak recreation period.[13] Amirfathi Narayanan, Bishop, and Larson, analyzing recreation on a river in northern Utah, found that the value of additional flows is zero until flows dropped to 50 percent of peak levels, and that the value of additional flows reached a maximum of $86 per acre-foot when flows were 20-25 percent of peak levels.[14] Ward examined the relationship between stream flow levels, recreation use levels and travel costs incurred by recreationists on New Mexico's

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10. For a current overview of valuation approaches, see the collection of papers in 23 WATER RESOURCES RES. 931-67 (1987).

11. J. DAUBERT & R. YOUNG, ECONOMIC BENEFITS FROM INSTREAM FLOW IN A COLORADO MOUNTAIN STREAM (Colorado Water Resources Research Institute Completion Report No. 91, 1979).

12. R. WALSH, R. ERICSON, D. AROSTEGUY & M. HANSEN, AN EMPIRICAL APPLICATION OF A MODEL FOR ESTIMATING THE RECREATION VALUE OF INSTREAM FLOW (Colorado Water Resources Research Institute Completion Report No. 101, 1980).

13. R. WALSH, R. AUCKERMAN & R. MILTON, MEASURING BENEFITS AND THE ECONOMIC VALUE OF WATER IN RECREATION ON HIGH COUNTRY RESERVOIRS (Colorado Water Resources Research Institute Completion Report No. 103, 1980).

14. P. AMIRFATHI, R. NARAYANAN, B. BISHOP & D. LARSON, A METHODOLOGY FOR ESTIMATING INSTREAM FLOW USES FOR RECREATION (1984).

Rio Chama to infer a value of $17 to $28 per acre-foot of reservoir releases in the summer recreation season, assuming optimal augmentation of streamflows during low flow periods.[15] Consistent with other studies, Ward found that marginal values fall dramatically for high flow periods and when stored water is available to augment natural flow levels. These results suggest a significant economic payoff in augmenting stream flows in low flow years, even though augmentation would reduce water availability for other uses.

Loomis provides an overview of the various methods that have been applied to measure the recreation benefits generated by instream flows, citing studies relying on the travel cost method and on contingent valuation.[16] He argues convincingly, based on the studies cited, that dollar values of instream flows can be measured so as to be comparable to the value of water in offstream uses such as irrigation.

Non-user values—benefits to individuals who do not directly use streamflows for recreation—are of several types. Benefits associated with preserving a riparian area so that one has the option to enjoy it in the future are termed "option values." Option value is relevant when choices must be made between an irreversible alternative (or one that is costly to reverse), such as drying up a stream environment or flooding a canyon, and the alternative of leaving the river system in its current state, which is reversible since new diversions or water development can later be approved. Willingness to pay for preservation so that one's heirs can enjoy the source is termed "bequest value," and benefits generated by simply knowing a unique site will continue to exist are termed "existence values."

Non-user benefits are relevant in valuing instream flows where there are wildlife species whose survival is dependent upon stream flows and also where there are areas whose aesthetic and recreational characteristics are dependent on free-flowing water. Since non-user values are not associated with an actual visit to a site, they are particularly difficult to estimate. However, recent studies indicate that non-user values can be sizable, especially for unique recreation sites and for endangered species.[17] Existence, bequest, and option values ranging from $40-$80 per year per non-user household have been documented for stream systems

15. Ward, *Economics of Water Allocation to Instream Uses in a Fully Appropriated River Basin: Evidence from a New Mexico Wild River*, 23 WATER RESOURCES RES. 381 (1987).

16. Loomis, *The Economic Value of Instream Flow: Methodology and Benefit Estimates for Optimum Flows*, 24 J. ENVTL. MGMT. 169 (1987).

17. Walsh, Loomis & Gilman, *Valuing Option, Existence and Bequest Demands for Wilderness*, 60 LAND ECON. 14 (1984). The different concepts of value that serve as a basis for valuing wildlife and natural environments are discussed in more detail in Madariago & McConnell, *Exploring Existence Value*, 23 WATER RESOURCES RES. 936 (1987).

in Wyoming, Colorado and Alaska.[18] Loomis found that individuals' willingness to pay to preserve the level of California's Mono Lake, while based partly on the enjoyment stemming from an actual site visit, was largely based on the satisfaction of knowing the lake would be preserved (existence value), assuring the opportunity for future visits (option value) and guaranteeing site availability for the next generation (bequest value).[19] These nonuser values accounted for over 80 percent of total willingness to pay. Recognizing that potentially significant but hard-to-measure nonuser values are associated with water in lakes and streams, measurable values for water in recreation uses should be regarded as a lower bound or a minimum estimate of the actual values generated by maintaining instream flows and lake levels.

A few studies have estimated the economic value of improved stream flows for fish and wildlife habitat in the western states. One study places the average value of stream flow in California's Trinity River at $33 per acre-foot for fish hatchery operations.[20] Water to facilitate salmon spawning in California's Trinity River has been valued at $53 per acre-foot.[21]

Irrigated Agriculture

Several approaches have been taken to estimate the value of water in irrigated agriculture. Because the prices that farmers pay for irrigation water typically do not vary significantly in any one region, direct estimation of a water demand function based on quantities of water used at various price levels generally is not possible. Instead, a programming approach based on a representative farm budget often is used to identify annual total crop revenues and input costs. Total revenues generated by irrigated crop production minus all non-water production costs gives a residual that indicates the maximum amount the producer could pay for water and still break even. This amount, divided by the quantity of water applied in production, represents the maximum average willingness to pay per acre-foot per year (the average value product) for the quantity of water currently being applied. The farm budget approach can also be used to identify willingness to pay for additional units of water (marginal value product) by estimating the contribution to total revenues minus all non-water production costs that would be generated by applying one more unit of water.[22]

18. D. GREENLEY, R. WALSH & R. YOUNG, ECONOMIC BENEFITS OF IMPROVED WATER QUALITY (1982).

19. Loomis, *supra* note 16, at 167.

20. Bush, *Is the Trinity River Dying?*, in INSTREAM FLOW NEEDS 12 (1976).

21. F. BOLLMAN, A SIMPLE COMPARISON OF VALUES: SALMON AND LOW VALUE IRRIGATION CROPS (1979).

22. Marginal value product measures the economic returns sacrificed by deleting a unit of water

Young and Gray describe the farm budget residual method for assigning a value to water, and caution that the validity of the estimates depend on how fully the following assumptions are satisfied.[23] All non-water factors must be paid according to their marginal value productivities, as would occur in a perfectly competitive market for agricultural inputs. If there are other inputs that are unpriced, not competitively priced or not employed to the point where their price equals their marginal value product, then the residual method will generate inaccurate estimates of water values. The farm budget and residual approach has been applied widely to impute a value to water in irrigation. A few examples are summarized here.

Kelso, Martin, and Mack applied linear programming to 150 representative farm budget scenarios for various areas in Arizona to develop marginal value functions for irrigation water.[24] The resulting annual values range from $4 per acre-foot for grain sorghum to $236 per acre-foot for cotton.[25] These represent the maximum a farmer could pay for water and still cover all other variable costs of production. A study of the Salt River area of Arizona by Martin and Snider[26] indicates short-run marginal values ranging from $33 per acre-foot for grain sorghum to $157 for lettuce to over $1280 for dry onions.[27] Bush and Martin found that the short-run marginal value product for water in growing cotton, alfalfa and wheat in three central Arizona counties ranged from $38 for alfalfa to $133 for cotton in 1984.[28]

Shumway[29] used the farm budget residual approach with linear programming to derive values for irrigation water on the west side of the San Joaquin Valley ranging from $21 per acre foot for safflower to over $57 for melons.[30] Young suggests that 80 percent of irrigation water values

from the crop production activity in which water generates the lowest returns (the "marginal" crop). Average value product measures the economic returns sacrificed by removing water from the whole farm operation and thus accounts for the returns to water of the various irrigation crops produced. Average value product will exceed marginal value product for farms growing several crops with differing returns to water.

23. Young & Gray, *Input-Output Models, Economic Surplus, and the Evaluation of State or Regional Water Plans*, 21 WATER RESOURCES RES. 1819 (1985).

24. M. KELSO, W. MARTIN & L. MACK, WATER SUPPLIES AND ECONOMIC GROWTH IN AN ARID ENVIRONMENT (1973).

25. D. GIBBONS, *supra* note 8, at 23-44.

26. W. Martin & G. Snider, Valuation of Water and Forage From the Salt-Verde Basin of Arizona (1979) (report to the U.S. Forest Service).

27. D. GIBBONS, *supra* note 8, at 23-24 (citing M. KELSO, W. MARTIN & L. MACK, WATER SUPPLIES AND ECONOMIC GROWTH IN AN ARID ENVIRONMENT (1973)).

28. D. BUSH & W. MARTIN, POTENTIAL COSTS AND BENEFITS TO ARIZONA AGRICULTURE OF THE CENTRAL ARIZONA PROJECT (University of Arizona College of Agriculture Technical Bulletin No. 254, 1986).

29. Shumway, *Derived Demand for Irrigation Water: The California Aqueduct*, 5 S. J. AGRIC. ECON. 195 (1973).

30. D. GIBBONS, *supra* note 8, at 31-40.

in the West are below $55 per acre foot, with higher-valued uses for specialty crops accounting for less than 20 percent of agricultural water use.[31] Gisser, Lansford, Gorman, Creel, and Evans applied a linear programming model to agricultural production in the Four Corners Area, including the Navajo Irrigation Project, and estimated marginal values for water assuming 10 percent cutbacks in agricultural water availability due to competition for water from electric power plants.[32] Value estimates ranged from $4 to $28 per acre-foot. Gollehon et al. examine the marginal value of irrigation water in eleven Rocky Mountain sub-regions given a 20 percent reduction in irrigation water availability.[33] They found marginal values greater than $21 per acre-foot in two regions, between $11 and $21 per acre-foot for four regions, and values below $11 an acre-foot for the remaining regions.

Another approach applied to estimating water values in irrigation involves estimation of the relationship between water applications and crop yields (the crop-water production function) through controlled experiments in which all other inputs are held constant and varying amounts of water are applied. The marginal physical productivity of water for each incremental application is thus estimated and the marginal value of each increment is simply the marginal physical product times crop price. Studies sponsored by the U.S. Department of Agriculture resulted in crop-water production function estimates for Arizona, New Mexico, California, and other states.[34] Marginal values were calculated at 10 percent reductions from yield-maximizing water levels, at average irrigation efficiencies on medium textured soils, and using 1980 national average crop prices. The marginal values thus derived ranged from less than $21 per acre-foot for grain sorghum in Arizona to $536 for tomatoes in California. Due to lack of experimental data on crop yield responses to incremental water applications, this approach has not been as widely applied as the farm-budget residual method.

Hartman and Anderson and Crouter, in separate studies several decades apart, applied a hedonic pricing approach to infer a value for irrigation water from farmland sales data.[35] Hartman and Anderson's 1962 study

31. Young, *Direct and Indirect Regional Impacts of Competition for Irrigation Water*, in WATER SCARCITY: IMPACTS ON WESTERN AGRICULTURE (E. Engelbert, ed. 1984).

32. Gisser, Lansford, Gorman, Creel & Evans, *Water Tradeoffs Between Electric Energy and Agriculture in the Four Corners Area*, 15 WATER RESOURCES RES. 529 (1979).

33. Gollehon, *Impacts on Irrigated Agriculture For Energy Development in the Rocky Mountain Region*, 1 SW. REV. MGMT. & ECON. 35 (1987).

34. D. Gibbons provides a detailed description of these studies along with a tabular summary of the marginal value estimates with references to the individual studies. *Supra* note 8, at 31-34.

35. Hartman & Anderson, *Estimating the Value of Irrigation Water from Farm Sales Data in Northeast Colorado*, 44 J. FARM ECON. 207 (1962); J. Crouter, An Examination of an Implicit Water Rights Market Using Hedonic Estimation (1982) (unpublished PhD dissertation, University of Illinois).

indicated average values of around $119 an acre-foot in 1988 dollars.[36] Crouter's study did not generate an estimate of value in dollars per acre-foot but did indicate that marginal water values were related to other attributes of the farm property, such as soil quality and location.[37]

As is evident from this brief summary of studies in the Southwest, a variety of approaches have been applied to valuing water in agricultural uses and a wide range of values have been reported. As emphasized by Bush and Martin, crop prices received by farmers are the dominant factor in determining the marginal value of water in irrigation.[38] Changes in energy costs of pumping and pumping lifts also play an important role in determining how much farmers can pay for irrigation water and still break even.[39]

Municipal Uses

City governments, municipal water purveyors and urban developers are major water buyers in the southwestern states even though municipal use of water accounts for less than 10 percent of total consumptive water use in the United States.[40] Municipal water demand for current and future use is a key force in Southwestern water markets. Municipal water values reflect multiple water uses by urban dwellers, with different values associated with different uses. Water used for indoor purposes such as drinking, cooking and bathing is thought to be the most highly valued and to be the least responsive to price changes. Water used outdoors for landscape watering and swimming pools is somewhat less highly valued. Young and Gray suggest that the value urban residents place on water for irrigating lawns is around $184 per acre-foot.[41] This value is above the marginal value of water in irrigating most crops and below Young and Gray's estimate of water's value for indoor uses of $326. Municipal water use also includes nonresidential uses for commercial and industrial establishments, and public buildings and grounds. Residential uses, however, generally account for the largest fraction of municipal water use.[42] Some analyses have differentiated between summer and winter urban water demand. Outdoor uses make up a large proportion of water requirements in the summer and a minimal proportion in the winter so that

36. Hartman & Anderson, *supra* note 35.
37. J. Crouter, *supra* note 35.
38. D. BUSH & W. MARTIN, *supra* note 28.
39. *Id.*
40. D. GIBBONS, *supra* note 8, at 7.
41. R. YOUNG & S. GRAY, ECONOMIC VALUE OF WATER: CONCEPTS AND EMPIRICAL ESTIMATES, (U.S. National Water Commission Technical Report No. PB210356, Mar. 1972). Updated figures are provided in Young, *supra* note 31.
42. D. GIBBONS, *supra* note 8, at 8.

two separate demand relationships are needed to reflect seasonal changes in the nature of water demand and its responsiveness to price changes.

There have been many studies on urban water demand and price elasticity (price elasticity of demand measures the percentage change in quantity of water demanded in response to a one percent change in price). While price elasticity estimates indicate how water consumption patterns will change in response to price changes, they do not provide information on willingness by urban water users to pay for additional units of water. Estimates of willingness to pay require data on quantity demanded over a range of observed prices. In general, water rates to urban residents do not change much in real terms (that is, they rise at about the inflation rate), so the opportunity to observe how quantity demanded changes over a substantial price range is rare. Gibbons suggests, using data on Tucson water consumption, that marginal water values in that city, given a 10 percent reduction in water availability, would be about $117 per acre-foot in the winter and $40 per acre-foot in the summer.[43]

Young notes that values for raw water and values for treated water delivered to residences are not directly comparable since quite different water commodities are involved.[44] Martin and Thomas find that the cost of obtaining raw water accounts for only about 12 percent of the price end users pay for delivered potable water in Tucson.[45] It is the municipal demand for raw water that should be compared to water values in irrigation and other uses, not what urban consumers actually pay or are willing to pay for treated delivered water. The market price of rights to raw water are not comparable to the value of treated water delivered to end users.

To summarize, the vast majority of municipal demand studies have focused on the responsiveness of quantity demanded to changes in price, not on marginal water values. Lack of price variation makes it difficult to reliably estimate urban demand curves that could be used to value additional water supplies. Prices paid for delivered water by urban consumers do not shed much light on how much a city water purveyor might be willing to pay for additional rights to untreated surface or groundwater.

Industrial Uses

Industrial processes require water for many different purposes, although they account for only 9 percent of U.S. water consumption.[46] The largest share of industrial water withdrawals are used for cooling and conden-

43. *Id.* at 18.

44. Young, *supra* note 31.

45. Martin & Thomas, *Policy Relevance in Studies of Urban Residential Water Demand*, 23 WATER RESOURCES RES. 1735 (1987).

46. 3 U.S. WATER RESOURCES COUNCIL, THE NATION'S WATER RESOURCES 1975-2000, at 29 (1978).

sation processes. For instance, up to 74 percent of water withdrawn for petroleum refining is used in cooling.[47] Cooling processes generally consume only a small proportion of water withdrawn. Steam electric generation, for instance, accounted for 26.5 percent of total freshwater withdrawals in the U.S. in 1975, but for only 1.3 percent of total consumptive use.[48] Other industrial processes have a high consumptive use. The minerals industry accounts for 2.1 percent of both total U.S. freshwater withdrawals and consumption.[49] Overall, however, industrial processes have a much lower consumptive use than either irrigation or municipal water uses.[50]

In general, water costs are a small proportion of overall production or processing costs and there is little empirical data with which to estimate industrial water demand functions. The studies which have been done indicate that industrial water demand is quite inelastic. Gibbons notes that, due to lack of better ways to estimate value, industrial values have been equated with the industry's cost of recycling water.[51] This approach is based upon the assumption that an industrial user would pay no more for additional water supplies than what it would cost to treat and reuse water already being used in the industrial process. This least-cost alternative approach, as noted earlier, serves only as an upper bound on the value of additional water.

Young and Gray estimated the cost of shifting from once-through water use to recycling water using evaporative cooling processes at $9-14 per acre-foot of water recycled, for the electric power generating sector.[52] Russell estimated these costs at $7 for the electric power sector and $16 per acre-foot of water recycled for cooling in petroleum refineries.[53] Since many power plants and refineries have already adopted recycling with evaporative cooling methods, further recycling would have to rely on more sophisticated technologies which are very expensive. For instance, demineralization and dry cooling recycling systems would only be economically rational at new water supply costs of $850 to $1800 per acre-foot.[54] Additional water recycling for cotton textile finishing would become economical given costs of $187 per acre-foot for new water supplies

47. Stevens & Kalter, *Forecasting Industrial Water Utilization in the Petroleum Refining Sector: An Overview*, 11 WATER RESOURCES BULL. 156 (1975).
48. 3 U.S. WATER RESOURCES COUNCIL, *supra* note 46, app. II, at 40.
49. *Id.*
50. D. GIBBONS, *supra* note 8, at 45.
51. *Id.* at 47-55.
52. R. YOUNG & S. GRAY, *supra* note 41.
53. C. Russell, Industrial Water Use § 2 (1970) (report to the National Water Commission).
54. K. Kollar, R. Brewer & H. McAulty, An Analysis of Price/Cost Sensitivity of Water Use in Selected Manufacturing Industries 8-18 (1976) (Bureau of Domestic Commerce Staff Study, Water Resources Council).

and demineralization would only be economically rational if the industry faced costs of $836 per acre-foot for new water.[55] A study of water recycling in meat packing operations indicates that existing reuse operations have a marginal cost of from $466 to $658 per acre-foot recycled.[56]

Like industrial water values, the value of water in producing hydroelectric power can be estimated by a least-cost alternative approach. Gibbons examined the cost savings possible with hydroelectric power as compared to the alternatives of coal-fired steam generating plants (the next least costly method) and gas-turbine electric plants (a more costly technology).[57] For the Colorado River hydroelectric system, the shortrun cost savings provided by hydropower compared to coal-fired steam generating plants are $33 per acre-foot and are $81 per acre-foot when compared to gas-turbine electric plants. These are the additional costs of replacing lost hydropower production due to an acre-foot decrease in flow with a more expensive source of electricity. There are reliability, facility longevity, and environmental quality advantages of hydropower compared to other electricity producing methods. These values are not incorporated into the marginal value estimates cited. Federal evaluations of hydropower facilities typically assign a 5-10 percent credit above cost-savings to hydropower generation to account for its other advantages over other methods.[58]

In summary, water costs are a small proportion of industrial production costs and industrial users may be able to absorb substantial price increases without significantly increasing their costs of production. Anderson and Keith found that a $200 per acre-foot increase in the price of water would increase costs of electricity production in coal-fired plants by only 1-2 percent.[59] Many industrial users can begin to recycle, or to increase recycling, of their current water supplies and would compare additional recycling costs to market prices for water rights in order to decide whether to acquire additional water rights or to implement additional recycling. Information on recycling costs provides an upper limit to industry's willingness to pay for additional water.

SUMMARY AND IMPLICATIONS FOR VALUING WATER

Many different public and private decisions require a comparison of water's value in alternative uses. Market-based approaches rely on es-

55. *Id.*

56. Kane & Osantowski, *An Evaluation for Water Reuse Using Advanced Waste Treatment at a Meat Packing Plant*, in PROCEEDINGS OF THE 38TH INDUSTRIAL WASTE CONFERENCE 617 (1981).

57. D. GIBBONS, *supra* note 8, at 94.

58. U.S. DEPT. OF ENERGY, HYDROELECTRIC POWER EVALUATION 3-6 (1979).

59. Anderson & Keith, *Energy and the Colorado River*, 17 NAT. RES. J. 157, 161 (1977).

timation of demand curves for water and on prices paid for water rights in a market setting. In many areas there is inadequate data on water use at various price levels with which to estimate demand curves. Water markets often do not generate reliable measures of value due to sparse and irregular market activity, small numbers of buyers and sellers, and other market imperfections.[60] Non-market based approaches can be used to value water under these circumstances.

Failure to incorporate estimates of value into water management decisions can result in water use patterns that do not maximize the economic benefits that are potentially available from regional water resources. For instance, Daubert and Young's research on instream values in northern Colorado suggests that benefits generated by area stream systems could be enhanced by altering the timing of water storage and releases to increase instream flows during the fall recreation season.[61] Loomis estimates total visitor and non-visitor benefits from preservation of Mono Lake levels to be about $40 per California household, well above the cost of 22 cents per household to preserve lake levels by replacing Los Angeles diversions from streams feeding the lake with water from other sources.[62] These figures indicate that, for these cases, the benefits of instream flow and lake preservation greatly outweigh the costs.

A review of studies that estimate the value of water in alternative uses indicates that a wide variety of valuation approaches are being applied. As the studies cited demonstrate, the economic value of instream flows can be measured so as to be comparable to the value of water in offstream agricultural, municipal, and industrial uses. Comparisons of the value of water in alternative uses will help to identify economically beneficial alterations in water allocation between competing offstream and instream uses. Without information comparing benefits generated by different water uses, federal and state water policy decisions will continue to emphasize diversions for offstream uses such as irrigation, mining, and urban development. Evidence on the economic benefits generated by water instream suggests that instream values can exceed the benefits generated by offstream uses, and that the efficiency of water management in the western states can be enhanced by selective increased allocations for instream flows.

60. See Saliba, Bush, Martin & Brown, *Do Water Market Prices Appropriately Measure Water Values?*, 27 NAT. RES. J. 617 (1987), for a discussion of market prices as indicators of water values.

61. J. DAUBERT & R. YOUNG, *supra* note 11.

62. Loomis, *supra* note 16, at 169.