ECONOMIC IMPACTS OF TRANSFERRING WATER FROM AGRICULTURE TO ALTERNATIVE USES IN COLORADO

by

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Colorado Water Resources Research Institute

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ABSTRACT

In Colorado's semi-arid climate, water plays an important role in the economy. A great majority of the water consumed continues to be in the agricultural sector.

This study is premised on the emergence of two sets of forces which reflect the economics of water allocation in Colorado. The first is the increasingly rapid growth of demands for water in non-agricultural uses. The second premise is that Colorado is passing from the "expansionary" phase to the "mature" phase. In the former phase, the incremental cost of water remains constant over time, so that new supplies are readily obtainable at reasonable cost. The mature phase, brought on by growth and change in the economy, is characterized by rapidly rising incremental costs and greatly increased interdependencies among water uses and users. In a maturing water economy, the high cost of new water brings about a search for water supplies from agricultural uses whose economic value productivity is less than the cost of new water supplies. The study assesses the economic impacts of transferring water from agriculture to urban uses in Colorado.

Two competing hypotheses can be identified regarding the economic impacts of reduced water supplies for irrigation. One viewpoint, reflecting the conventional wisdom, contends that water has been a significant source of economic growth in the West, and that removing water from agriculture will have major negative effects on the economy. The alternative "limited impact" hypothesis contends that the water removed from irrigation is the least valuable (largely from the forage, food and feed grain sectors). Since foreseeable urban growth will account for only a small reduction in irrigation water supplies, relatively minor sacrifices in net productivity are implied.

The study tests these competing hypotheses with data from Colorado and other western states.

Direct economic impacts to the agricultural sector, measured by net economic value foregone, will in the final analysis, be registered on the products in which value productivity is lowest. In those sectors (generally in forage and food and feed grain production) the net economic value foregone for a 10 to 20 percent supply reduction will mostly fall in the range of $5-$30 per acre foot. The gain in net value of product or in willingness to pay in households and industries are seen to be five or ten more times as high.

Indirect impacts are measured by income from primary regional resources ("value added") and by employment per unit of water, including multiplier effects. The evidence indicates that the indirect losses associated with transferring water from agriculture, while not insignificant in terms of either income flows or employment, will also be dwarfed by the gains in the non-agricultural sectors. In particular, the sectors most likely to be affected (forage, feed and food grains) yield relatively small indirect employment and income effects when compared to those for emerging urban sectors.

The economic interests of farmers whose water is transferred to urban uses are generally protected by state water and property right laws. It is anticipated that the rate of loss of irrigation water will be relatively slow (a few percent per year) so that indirectly affected workers and businessmen have time to anticipate and adjust. These problems are the natural consequences of the process of economic growth and change, and are similar but no less severe than those felt by those in other sectors of the changing economy. Little need is seen for special public policies, either in terms of water supply or impact mitigation, to deal with these changes.

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I. INTRODUCTION

In Colorado's semi-arid climate, water plays an important role in the economy. Agricultural crop production is greatly enhanced by the application of irrigation water and urban life is made more pleasant by the watering of lawns and shrubbery.

A great majority of water consumed in Colorado has been and continues to be in the agricultural sector. Crop irrigation began with diversion from streams by the early settlers over a century ago. Subsequent developments brought about canal systems to carry water farther from the rivers, then the use of storage reservoirs to capture spring snowmelt and tapping of ground-water supplies. Most recently, transbasin diversions from west of the Continental Divide have provided important additions to the growing agricultural and metropolitan areas along the Front Range corridor. At present, over 90 percent of water use is in crop irrigation.

This paper is premised on the emergence of two sets of forces which affect the economics of water allocation in Colorado. The first is the increasingly rapid growth of demands for water in non-agricultural uses. Growing industrialization of the Front Range economy requires water directly in manufacturing, processing, and services and for the household uses of the burgeoning population. Energy development on the Western Slope presents a potential for significant new water needs. Also of growing importance are non-diversionary uses, which include recreation, instream flows for fish habitat and hydroelectric power generation.

The second premise is that the water economy of Colorado is passing from the "expansionary" phase to the "mature" phase. In the expansionary era, the incremental cost of water remained relatively constant over time (in real terms). Water development project sites were available to meet growing demands. The mature phase, brought on by growth and change in the economy at large, is characterized by rapidly rising incremental costs and greatly increased interdependencies among water uses and users [Randall, 1982].

In a maturing water economy the high cost of new water brings about a search for supplies from existing uses, usually in agriculture, whose economic productivity is less than the cost of acquiring new supplies. Thus, competition is arising from industrial, energy, and household water diversions and from instream uses, such as power generation, recreation, fish and wildlife habitat, and navigation.

The principal objective of this report is to assess the economic impacts of increased competition for irrigation water on farmers and on the sectors of the state's economy which may be closely intertwined with the agricultural sector. The second task is to consider what are the policy changes which are needed to deal with these anticipated impacts. The report is necessarily limited in scope to economic issues; social, legal, political, and engineering aspects are not considered.

Economic Impacts: Alternative Perspectives

Two competing hypotheses or viewpoints can be identified regarding the economic impacts of reduced water supplies for irrigation.

The "Significant Impact" Hypothesis

One viewpoint, which appears to reflect the conventional wisdom in political and media discussions of the western water problem, contends that irrigation has been a significant source of regional growth in the West. Supporters of this perspective point to the sharply increased crop sales brought about by irrigation, and claim substantial multiplier effects in jobs and spending in the related communities and regional economies. From the "significant impact" hypothesis follows its converse: removing water from the agricultural sector will have major, even intolerable, negative effects on the regional economy.

The conceptual approach of the significant impact perspective is to look at the problem globally. Proponents ask: "What happens if irrigated crop production is completely removed from a given region?"

The significant impact hypothesis draws its evidence from several sources. One is our historic sense of the role of irrigation in developing the West. Another is from the obvious fact, seen all around many western communities, that irrigated lands yield enormously more product than semi-desert ranges or wheat-fallow rotations. Also, they point to the relatively high income and employment associated with fresh vegetable and fruit crops adapted to the areas with milder climates.

The "Limited Impact" Hypothesis

The alternative hypothesis conceptualizes the problem in what economists would call "marginalist" terms. This viewpoint, invoking the law of diminishing marginal returns, posits that the productivity of irrigation water ranges from highly productive down to marginally productive uses. Similarly, the indirect regional employment and impacts will range from significant in some sectors to minimal in others. The marginalist position contends that water removed from irrigation will, in the long run, be the least valuable. Even if the first-round impact is at the expense of high-valued irrigation uses, the subsequent economic adjustments will find the low productivity uses giving way. The limited impact hypothesis is not new, being implicit or explicit in Hirshleifer, et al. [1960]; Bain, et al., [1965]; Kelso, et al., [1972]; and Young and Martin [1967].

The limited impact hypothesis finds evidence for its viewpoint in the large proportion of water diversions in Colorado which are devoted to irrigation (80-90 percent), and the high proportion of irrigation water use which is in relatively low-valued uses (forages, food and feed grains). They also focus on the low absolute numbers of indirect income and employment in the processing and input supply sectors associated with most agricultural water use. This approach asks how much water from agriculture will be needed to fuel expected non-agricultural growth and tries to measure what will be the incremental costs of such reallocations, as compared with the costs of new water supplies.

The evidence, I believe, strongly supports the limited impact hypothesis and this report presents the case for that viewpoint.

Procedures and Scenario for Impact Assessment

The general approach taken here is to compare the economic impacts of potential reallocation of water from irrigation to other direct uses of water. Indirect impacts of removal of irrigation water are similarly compared to indirect effects in growing sectors which might acquire water. The net value foregone (or gained) is taken to be the most suitable measure of direct economic impact. Payments to primary factors of production (value added) and employment are the chosen measures of indirect impacts.

The assumptions of the analysis are as follows. The planning horizon is taken to be the remainder of the century. The economic impacts presented below will be expressed in 1982 price levels. The report adopts a general economic and agricultural economic scenario to the effect that there will be no general wars or political upheavals which disrupt world production and trade in agricultural commodities. The forces of technology dominate demand growth so that agricultural commodity prices are likely to continue the trend which has been observed through most of this century, holding food prices down relative to the cost of production inputs and to real consumer incomes. Hence, current price and production relationships can be used in predicting future agricultural net income.

It seems unlikely that water diversion requirements in non-agricultural sectors will grow so rapidly as to require any enormous reduction in water supplies to agriculture during the remainder of this century. (For example, a 2.5 percent compounded rate of growth in non-agricultural water demands in Colorado would permit agricultural water use in the state to continue to be above 80 percent of consumption, supplies remaining unchanged.) The analysis below posits at most a 20 percent reduction in irrigation water supply, which I regard to be an extreme outside limit of impact in the next two decades.

DIRECT IMPACT MEASUREMENT

Kenneth Boulding [1980] has noted that mankind employs three major mechanisms to reflect human values in the process of organizing human utilization of the earth's natural resource endowment. He labels these the "three P's" - Prices, Policemen, and Preachments. "Prices" represent the market system, operating through free exchange and a relative price structure. "Policemen" - the legitimated threat system, or the political order - establish and enforce property rights and administer public regulations. "Preachments" represent the moral order, the process by which human values are learned, conveyed, modified, and employed in making choices.

Water, as with other resources, has been governed by a combination of these mechanisms. In contrast to many other natural resources, the political and moral modes have had, up to the present time, the dominant role. As Boulding puts it, water "has been the subject of sacred observance from very early times in human history . . . [it] becomes the object of a very complex structure of evaluations, rituals, superstitions, and attitudes" (p. 309). Thus, water has been viewed as too important to be left to the marketplace, so that its administration falls largely in the political realm.

The major purposes of this section of the report are (a) to discuss the potential role and limitations of the economic principles of resource allocation as a technique for coordinating of water resource allocation in arid lands and (b) to review the evidence on the value of water in alternative uses.

The analysis proceeds as follows: First, the general characteristics of the market system are sketched, and some important attributes of the structure of prices in a properly functioning market are noted. Second, the nature of water is described, which helps to show why non-market allocation has been and is likely to continue to be the chosen solution to the problem of water management in the arid and semi-arid West. Then, noting the potential role of the economic principles of resource allocation in making non-market allocation decisions regarding water, the concepts and procedures for estimating surrogate prices or the value of water are described. The section concludes with a review of empirical evidence regarding the value of water in alternative uses and the implications for the economy of Colorado.

The Market System's Role as an Allocator of Resources and an Evaluation Mechanism

The term "market system" is used by economists in two senses. It may refer, in one sense, to an actual functioning system: the set of institutional and cultural arrangements that serves to allocate resources through the the price mechanism. The term may also refer to an intellectual idealization of the system and how it performs. This idealization or "model" has been studied to determine how apparently unrelated sets of activities achieve economic order, such that goods and services are provided to consumers at the place, time, and form desired, and capital, labor, and natural resources are organized through the productive system to provide these requirements.

The Idealized Market System

Any economic system must answer the questions: (a) what goods and services are to be produced? (b) what technologies are used in producing them? and (c) who is to enjoy the use of products? The adoption of the market system to answer these questions is based on the premise that the personal wants of individuals should decide the employment of resources in production, distribution, and exchange, and the individuals themselves are the best judges of their own wants (consumer sovereignty).

An idealized competitive market system (one that has many producers and consumers, who are well informed, motivated by individual self-interest, and individually own and control resources) can be shown to have certain desirable properties. One such desirable attribute is that the system will produce the maximum-valued bundles of goods and services to consumers, given the endowment of resources, the available technology level, the preferences of consumers, and the distribution of purchasing power. Individuals producers and consumers, acting within their own self-interest will, in accordance with Adam Smith's "invisible hand," arrive at an allocation of resources which cannot be improved upon. Firms, encouraged by prospective profit, buy inputs as cheaply as possible, combine them in the most efficient form, and produce those things which have the highest value relative to cost. Consumers' tastes and preferences influence their expenditure patterns, thereby encouraging firms to produce the commodities people want. Prices are bid up for the commodities most desired, and producers allocate resources in the direction of greatest profits. The firms most successful in the process, producing desired goods most efficiently, are rewarded by profit and the unsuccessful are eliminated, so production occurs at least cost.

A second desirable property of the idealized market system is its ability to accommodate change in conditions of production and patterns of consumption. New knowledge and technology are rapidly reflected in the prices which producers are willing to accept for their products. On the consumer side, changes in income and preferences soon show up in expenditure patterns. Hence, a market system yields maximum satisfaction in not only a static but a dynamic context.

The actual market system may not always meet the precise preconditions of the idealized construct. The principal problems arise with public or collective goods (those which are non-rival in consumption), external or spillover costs (uncompensated side effects, such as pollution), and economies of large size (a precondition for monopoly). However, our mixed capitalistic system is based on the presumption that for most goods and services, the allocation resulting from market processes sufficiently approximate the idealized system. Where this is not the case, regulatory processes or public production are provided to allocate resources.

<u>Obstacles to Market Allocation of Water in the Arid and Semi-Arid West</u>

Markets in water, however desirable from a conceptual point of view, as a means to a more productive use of resources, are not yet common in the region. Brown, et al., [1982] characterized them as "rudimentary" and unorganized, in that there is no regularity of procedure, intermediaries, or location. (An important exception is found in the Colorado-Big Thompson project area in northeastern Colorado, where a relatively sophisticated market has evolved.)

Several reasons might be put forth to explain the relative lack of water markets. These are (a) physical (due to the nature of water and how it is used in production and consumption activities), (b) economic (which stems from the fact that, until recently, water has been in relatively plentiful supply), and (c) conflicting social values (in that material well-being is not the only yardstick used by society to measure success in water allocation).

The physical barriers to more extensive markets in water stem from its mobile, flowing nature, the fact that is is seldom fully "used" by the consumer, and the further fact of its potential for absorbing and carrying pollutants. As water changes from solid to liquid to gas throughout the season and the hydrologic cycle, it is relatively difficult to identify specific units of water. Hence, water presents unique problems in the establishment and enforcement of property rights which are the essential foundation of any market allocation system. Second, most users of water only consume a part of it, even within one phase of the hydrologic cycle, the remainder being available to subsequent producers or households. The impediments to measuring portions consumed are a constraint on defining water rights and facilitating exchanges. Finally, the potential for water quality degradation is another problem difficult to deal with in market exchanges of water rights.

What may be labeled "economic" reasons for the heretofore limited development of markets stem from both the varied nature of water "use" and the relative plentitude of water (compared to demands) in the region. Water consumption is most often thought of in terms of the consumptive and diversionary uses such as irrigation, household and industrial uses. An important set of growing demands for water is in the class of instream, non-diversionary, and non-consumptive uses. Recreation demands for flows (including fishing, rafting and kayaking, wildlife habitat, and non-contact streamside uses) constitute an important growth area. Hydroelectric power generation and waste load dilution are also increasingly in demand. A number of these instream uses represent collective consumption demands, which are partially non-rival in consumption. It is well known that such commodities are likely to be undersupplied in a market economy [Haveman, 1976]. Society has therefore chose non-market administrative mechanisms for allocation. The second economic reason for rudimentary development of markets lies in the apparently paradoxical assertion that water has not been particularly scarce, at least in the specific technical economic sense of the term. Even though the climate may be arid, additional supplies from mountain runoff or extensive groundwater supplies have been, until quite recently, relatively inexpensive. New uses did not strongly conflict with the interests of established water consuming groups. This condition is obviously changing, but highly subsidized supplies from federal, and to a lesser extent, state and municipal projects, have obscured the growing scarcity. (North and Neely [1977], for example, show that local interests are likely to bear less than 20 percent of the costs of federal irrigation projects.) The relative plenty implies that formal institutions for managing scarcity are only now becoming important. Water is also a very "bulky" commodity, in that the value per unit weight tends to be relatively low. Therefore, costs of transportation and storage tend to be high relative to economic value at the point of use. Hence, only in limited cases it is economical to transport water, and the extensive rail, truck, and pipeline network that the market system has developed to transport more valuable liquids (e.g., petroleum) is absent for water.

The third major force inhibiting the adoption of market institutions for water allocation can be identified as conflicting social values. This is an example of Boulding's third "P": "Preachments." Even though it is likely that economic improvement would be best served by market allocations, several important conflicting themes emerge in opposition to the directions dictated by pure willingness to pay for water. One theme is, in Boulding's terms, "the sacredness of water as a symbol of ritual purity, exempts it in some degree from the dirty rationality of the market" (p. 302). Later in the same essay, Boulding remarks that water is "so holy and valuable to us as a symbol that we are apt to carry the production and transportation of it far beyond the point of rational economic returns" (p. 309). Brown, et al., [1982] also point out the important social values of environmental preservation and agricultural production. Many citizens judge water institutions in terms of the degree to which the beauty of the natural environment is affected. The prospect of market-induced shifts of water to energy or other uses which would alter flows or even dry up mountain streams is strongly opposed in some quarters. Preserving the social character of the region is also a concern. In many river basins, irrigation accounts for over 90 percent of all water consumed. The well-being of many communities based on a traditional crop-livestock production lifestyle in a family farm-ranch system, which depends on preservation of the water supplies customarily available to those areas. Also, many urbanites value the greenbelt amenities provided by extensive areas of irrigated lands surrounding the growing metropolises of the West.

Where markets are absent, due to any of the above causes, government regulations may be established to provide for regularity of water use and to protect a given use against present and future competing demands. Such protections have been created to preserve, for example, fish and wildlife habitat, inland waterways navigation, water rights for Native Americans, and water quality. This type of protection may preclude economically efficient resource allocation, if demands for alternative uses outweigh the economic value of protected uses. Conversely, institutions designed to preserve a given use may provide an inadequate supply in the face of growing demands, but be economically inappropriate in that they leave the impression that the problem is solved.

The Idealized Market Concept as an Evaluation Mechanism for Non-Market Resource Allocation, With Particular Reference to the Water Resource

The constructs embodied in the idealized market system have been brought to bear on non-market resource allocation decisions in the form of the analytic system commonly known as benefit-cost analysis [Pearce and Nash, 1981]. Water resource planning, in fact, represents one of the initial subjects and perhaps still the topic most widely studied with the benefit-cost evaluation mechanism [Krutilla and Eckstein, 1958].

The benefit-cost framework adopts the same principles as underlie the idealized market system, i.e., consumer sovereignty and acceptance of the existing distribution of purchasing power. The main effort in a benefit-cost analysis is the derivation of surrogate prices (usually called "shadow prices"). These are those that would emerge in the presence of a properly functioning market system, and can be used in guiding resource allocation decisions. The use of techniques to shadow price water is the subject of the remainder of this section.

The process of shadow pricing can properly be understood as an attempt to establish an exchange ratio in monetary terms which would be exactly that which would emerge from a properly functioning exchange market. The basic concept is willingness to pay as an indicator of economic value. Willingness to pay reflects the amount a rational, fully informed consumer would be willing to forego rather than do without the commodity in question. In accordance with the principles of diminishing marginal utility (in consumption) or diminishing marginal productivity (in production), willingness to pay falls as quantities increase. The willingness to pay relation is equivalent to the conventional demand function for a commodity or input, and exact shadow price estimates are points on the marginal willingness to pay relationship. A representative demand curve, labeled "D", is shown in Figure 1. Also shown in Figure 1 is a relationship labeled "MC" (marginal cost) representing the incremental cost of water supply.

The reader will recognize the correspondence of the relationships in Figure 1 to the textbook supply and demand curves of microeconomic theory. While the marginal value of water, depending on supply, may be at any point on D, the locus of most interest is the intersection of the two curves, reflecting q* supply units, and identified on the diagram as P*. Points not

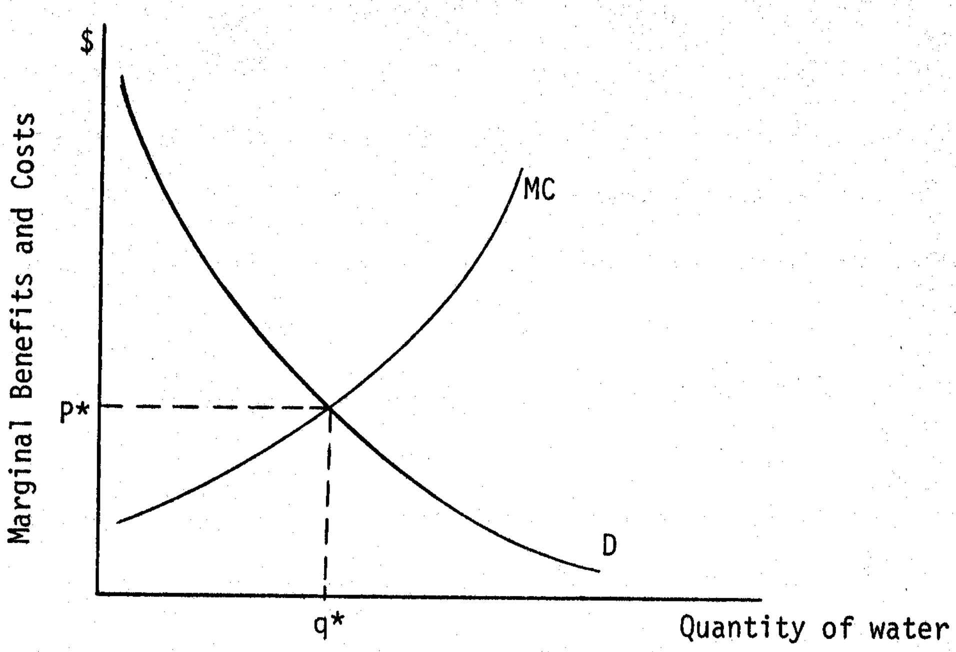

Figure 1. Demand (Marginal Value) and Marginal Cost Curves for Water Supply.

at q* are sub-optimal. To the left of q*, marginal value exceeds marginal cost, so gains can be achieved by adding q. The converse is true to the right of q*. Many synthetic estimates aim to identify P* when specifying a shadow price for water. (Often, however, the analyst is attempting to find what the willingness to pay would be for some specific quantity, usually in order to establish whether or not an added supply increment is valued in excess of its incremental cost, which amounts to determining whether the increment of supply in fact lies to the left or right of the optimal quantity, q*.)

Responsiveness of Demand -- An important attribute of the demand for water is the responsiveness of willingness to pay to varying quantities. This is the inverse of the elasticity of demand. Some types of use exhibit value which is highly responsive to quantity, so that small increases in quantity drive willingness to pay rapidly down. Industrial and household uses fall in this category. The value of agricultural uses tend to be somewhat less responsive, but in all uses, significant increases in supply will negatively affect value at the margin.

Further Methodological and Conceptual Distinctions

The hydrologic system must be considered in terms of it interactions with climate, land, ecosystems, and the human social and economic systems. This intricacy is further complicated by the highly variable nature of moisture supplies, the importance of sequential uses as water flows from upper watersheds to its eventual destinations in sea or sump, and the importance of transportation costs in establishing water value. Concepts of the economic value of water can be relevant only when explicit recognition is given to quantity, location, quality, and time of supply. Put another way, the value of water is highly site-specific, and varies directly with local conditions of supply and demand for the resource.

There are a number of methods and conceptual bases for generating shadow prices for water. Many of these, while perhaps correct in limited contexts of private or regional planning decisions, are inappropriate for valuing water from a long run public policy perspective. Space limits preclude a detailed discussion here; the interested reader is referred to Young and Gray [1972]. Several of the more important issues are touched on briefly below.

Methods of Valuing Water

A brief definition is provided for the several methods deemed acceptable by the writer for deriving water shadow prices in a national policy context.

Observation of Markets -- This approach is straightforward, but due to the limited range of applicable cases, only in a few instances will such estimates be suitable for policy analysis.

Ex-Post Statistical Analysis of Water User Behavior -- Conventional statistical techniques have been applied in various ingenious ways to water consumption data relating to business, agricultural, and household consumers. This approach is, as the above case, highly regarded by specialists since the results reflect actual rather than hypothetical willingness to pay.

Change in Net Income -- This approach derives from the economic theory of the producing firm and when properly applied, credits the value of water as the increment to profits arising from an increment of water supply. As noted below, the approach is often incorrectly performed, thereby biasing the results.

Alternative Cost -- This method values water in terms of the cost savings (labor and capital) which would derive from employing a water-intensive as opposed to alternative production technologies. The alternative technology is required to be economically feasible and the least costly available. Due to the importance of capital costs in most cases where this technique is used, results are particularly sensitive to interest rate and construction cost index assumptions.

Consumer Surveys -- In the case of collective consumption goods (recreation, fish and wildlife habitat, pollution abatement) the potential users may be questioned regarding their valuation of hypothetical changes in water supply or quality. While these techniques are at present experimental, and are viewed with skepticism by many professionals, the writer believes estimates derived in this fashion to be potentially valuable.

Special Problems in Valuing the Water Resource

Marginal versus Total Value -- The correct concept is the incremental worth (value of the last unit) rather than total value or revenue associated with all units of water and other resources. The total value of product can be attributed to water only if all other factors of production (i.e., labor, land, capital) have no known alternative beneficial use (an extremely unlikely event). Therefore, the value of water in crop production is its contribution to output, and as with labor, fertilizer, or other inputs, represents only a portion of the total production revenue.

Long-Run versus Short-Run Value -- Short-run values tend to be higher, as willingness to pay rises the fewer the fixed resources which need to be accounted for. (Consider the case of an unexpected drought -- the farmer might be willing to pay nearly the value of the crop for the water to save it, while ignoring the costs already expended -- but wouldn't have made the initial planting and tillage expenditures had the water supply been initially perceived as being very expensive.)

Comparability in Place, Form, and Time -- As noted above, water is a very bulky commodity, for which transportation costs are often large relative to value at the place of use. Hence, value of water declines rapidly with distances from site of use, and may even be negative at a potential source. Water may also require processing, so there will be differences between value of raw water and that of treated delivered water. Seasonal flows generally don't match seasonal shifts in water demand, so investment in storage facilities may be required to make supplies conform in time to demand.

Measuring Quantity: Diversion versus Consumption -- The quantity of water is obviously an important determinant of marginal value. For off-stream uses, the usual choice is between the amount diverted and the consumptive use (that portion of diversion not returned to the stream or aquifer, and not available for reuse). When consumption is only a fraction of diversion, as is usually the case, large differences in marginal value will result, depending on which measure is used. Although there are no firmly agreed upon conventions, most economists prefer to deal with withdrawals. The discussion below follows that approach.

Annual Value versus Capitalized Value -- A final point concerns the implicit property right to which a price is to be imputed. Is it for an annual rental equivalent (the price of one acre foot in a typical year) or for the right to a certain flow each year into the indefinite future? Clearly, these condepts are related, but not identical. The value of the latter (property right) is conceptually equal to the discounted present value of the stream of annual values. Hence, a time horizon and an interest rate, in addition to annual value, must be specified in order to reconcile the two concepts. The capitalized value will normally be in the range of twelve to fifteen times as large as the annual value.

Value-Added versus Willingness to Pay -- The value-added measure derived from regional input-output models [Wollman, 1963] reflects willingness to pay for not only water, but for all primary resources (land, labor, minerals, water) and thus greatly overstates the correct willingness to pay for water. (The point here is the same as made above regarding total versus marginal value.) Use of this measure indeed of the correct change in net income has provided support for uneconomic water development programs.

In the subsequent discussion, "water values" will refer to the willingness to pay at the margin for one acre foot diverted in a particular year, unless otherwise specified. Diversionary (consumptive) uses are treated first, followed by the non-withdrawal or instream category.

Valuing Water for Diversionary Uses

The Economic Value of Water for Irrigation -- The direct value of water in irrigation should be measured in terms of the increment of profit to the producer with irrigation (or with an increment of water supply) as compared to profits without irrigation. Several methods may be employed. One is an ex-ante approach, which computes the change in net income from assumptions about crop prices and yields, production technology, and production costs. An alternative technique may be labeled ex-post, which relies on statistical analysis of actual production data (from either experimental or survey sources). The ex-ante method is most convenient for planning in specific cases, and is the typical use by the Bureau of Reclamation and other government agencies. The statistical approaches serve to validate the analytic measures, and are regarded by many analysts as more reliable due to their base in "real data". Analytic measures can be abused by over-optimistic assumptions about prices, yields, and/or input requirements, or some cost items may be ignored. Experience has shown, however, that properly performed, the methods yield similar results.

What is the value of irrigation water? The previous discussion implies that the value at the margin will reflect water scarcity and marginal cost of supply. Local production conditions (i.e., rainfall, temperature, and growing season length) and market situations will have an impact, so we would expect considerable variation across the West.

A recent set of estimates has been developed by Beattie and Frank, which involved statistical analysis of 1974 census data on agricultural output, as influenced by resource inputs, including land, labor, machinery, and chemicals, as well as irrigation water. The results yielded values (converted to current 1982 dollars) of $10-$15 per acre foot in the intermountain valleys (Upper Colorado; Snake River Basin), $20-$25 in the desert Southwest and central California, and $40-$45 per acre foot in the Ogallala groundwater region of the High Plains [Beattie, 1980].

Howitt, et al. [1982] recently reported rather similar results, using a much different technique. Their interregional supply-demand model for California yielded prices at the margin of $23-$35 per acre foot in the

Central Valley and southern California and $7 in the Imperial Valley.

Gollehon, et al. [1981] show shadow prices for irrigation water for eleven Rocky Mountain sub-regions, several relevant to Colorado's Western Slope. With a 20 percent reduction in irrigation water supply, two regions were identified with water valued at the margin in excess of $20 per acre foot, while four were between $10 and $20 per acre foot and six were below $10.

The Ogallala-High Plains Study recently completed for the Department of Commerce predicted values of $60-$80 and upwards for the year 2000, based on increasingly favorable crop prices and yields at that future time [Young, et al., 1982].

In the Platte Basin, that most relevant to irrigation-urban conflicts in Colorado, the value of water for corn production has been computed by the author to be in the neighborhood of $25 per acre foot for 1981 crop prices. Forage production (alfalfa, irrigated pasture) probably lie below that figure.

Value estimates obtained for certain specialty crops may be somewhat higher than the figures cited above. However, such uses will account for less than 10 percent of total irrigation water use in the foreseeable future, and are not of much significance for Colorado policy. In other words, 90 percent of the irrigation demand probably lies below $30 per acre foot.

<u>The Value of Water in Industry</u> -- While water is used throughout the industrial sector, the major consumer, particularly in the arid West, is in the energy sector, particularly for cooling steam-electric power plants. Several processes can be used for cooling, depending on water scarcity and price. Young and Gray [1972] show with an alternative cost approach that it is economical to convert from a pass-through system to evaporative cooling towers when water costs rise about $5 per acre foot (1982 price levels).

Methods which conserve much more water are much more expensive. Gold, et al., [1977] in a study for EPA, report that breakeven points for a combination wet-dry system run around $600 per acre foot, while the shift to a completely dry cooling system would be economical only if water was priced above about $1400 per acre foot. Abbey's [1979] comprehensive analysis of the water/energy problems in the Colorado River Basin provides similar estimates. Hence, the large-scale steam plants proposed for several areas in Colorado could, if necessary, be willing to pay an amount many times the price of water in neighboring agricultural uses. Recent experience suggests that even the large water requirements of huge power plants can be met with relatively little loss to the surrounding agriculture.

Leigh [1982] has studied the value of water for coal slurry pipelines, using the cost saving from the alternative of rail transportation as the measure. The value of water in a Colorado to Texas system is estimated to exceed $1600 per acre foot. However, the estimate is extremely sensitive to the level of railroad freight rates. Competitive reductions in railroad rates in response to a slurry project could reduce the imputed value of water, although it is not likely to drive it below willingness to pay in irrigation.

The need for water in recovery of hydrocarbons from oil shale in western Colorado has received considerable attention. Valuing such water could be the alternative cost method or by the change in net income approach. The alternative cost approach suggests that water could substitute for considerable capital and labor in the refining process, and hence be very valuable. The change in net income approach requires that the production process be profitable for any positive residual income to be imputed to water. Under current and anticipated petroleum prices, shale oil extraction is not economically feasible, so the zero or negative value is relevant until such time as petroleum prices rise.

Value of Water in Households -- While willingness to pay for water delivered to households is readily observed and much studied, deriving a marginal value of water to households which is comparable and commensurate with estimates of raw water values in streams is relatively difficult. Household water, which is treated (filtered, chlorinated), stored, and delivered to the user on demand, is a much different economic commodity than the raw river water used in irrigation or in many industries. Hence, a deduction for treatment, storage, and delivery costs must be made to achieve comparability. On the basis of a method suggested by Young and Gray [1972] using data developed by Howe and Lineaweaver [1967] an estimate may be derived. This approach finds that lawn sprinkling is valued at about $150 per acre foot and in-house uses at $250 per acre foot (in 1982 dollars). A weighted average would be about $220 per acre foot.

Howitt, et al., [1982] do not distinguish between industrial and household demand. Their municipal and household sector estimates for 1980 (in 1982 prices) are about $160-$200 per acre foot.

An alternative estimate can be derived from market values of water in the Colorado-Big Thompson project (in northeastern Colorado) transferable to urban uses. Gardner and Miller [1982] report the price of water rights to have averaged $2450 per acre foot in 1981. Converting this figure to an annual acre foot value requires assumptions regarding the appropriate capitalization rate and expectations about future inflation. However, at an interest rate of 8-9 percent (which seems plausible), and a long planning horizon, the figure is practically equivalent to the Young and Gray [1972] and Howitt, et al., [1982] figures given above.

Value of Water in Instream Uses

Instream and non-diversionary uses include electricity generation, recreation, waste load dilution, and navigation.

Hydroelectric Power Generation -- Hydropower plants, once a principal source of electricity, now account for less than one-eighth of the total power generated in the U.S. While recent rises in energy costs have spurred interest in the study of low-head hydro plants, the scarcity of major undeveloped sites suggests this share will continue to decline.

Evaluation of hydroelectric projects has usually proceeded on the assumption that water is a free good, so that recorded efforts to value water in this use are rare. The procedure which has been developed is to value electricity in terms of cost of production by the alternative process of a steam-powered plant (alternative cost method). The value of water is then derived by deducting capital and operating costs of the generation and transmission system. The residual, if any, is attributed to the water resource (change in net income method). Specific value estimates vary according to the differences in head (the distance the water falls before turning the turbines) but also with distance to load centers, energy costs of the steam alternative, and the cost of dam and storage reservoir construction relative to power output. Values also may be expressed for one site only or for several sites on a given river reach. Young and Gray [1972] report single site values, ranging from $3.30 to $10 per acre foot in 1982 prices in the western states, the higher values associated with sites with relatively large head on the Colorado River. Whittlesey and Gibbs [1978] report values in the Columbia Basin of over $30 per acre foot (1982 prices) for water going through all dams below Franklin Reservoir, including Grand Coulee. The higher figure reflects both multiple generating stations and higher relative alternative energy costs as compared with the conditions studied by Young and Gray. While single site values are not large relative to those for diversionary uses, diversions high in a basin can lead to large cumulative benefits foregone.

Valuing Water in Waste Load Dilution -- Water released for dilution of pollutants has value to the extent it reduces damage (in the form of reduced productivity or increased treatment cost) to subsequent users. Precise estimates are difficult to derive, since detrimental effects depend on distance downstream, temperature, rate of flow, and quality of the receiving waters. Most analysts have adopted the concept that the value of a unit of dilution water is equivalent to the cost of treating effluent to achieve an improvement in water quality equivalent to the specified quantity of dilution water.

The results of these studies generally imply that dilution values are, for the most part, relatively insignificant. Merritt and Mar [1969] showed that dilution water in the Willamette Basin (Oregon) to be about $1.30 per acre foot (1982 price levels). Gray and Young [1974] applied this technique for several regions. Their estimates ranged from $.08 per acre foot (Colorado Basin) to $3.25 in the lower Missouri. Employing data from the Colorado River Board of California [1970], Young and Gray [1972], however, derived a value of water in the Colorado Basin for dilution of salinity at about $15 per acre foot.

The Value of Water in Water-Based Recreation -- Water-based recreational services, by tradition and policy, are not often priced by market processes. Hence, the normal problems of valuing water are compounded, since in this case the value of water for recreation must be derived from a prior synthetic imputation of the value of the recreational services themselves. Moreover, recreational uses of water are often complementary to other uses, rather than competing with them. Thus water stored for irrigation or flood control can be enjoyed without diminishing its usefulness in alternative uses. In such cases, it is sufficient to estimate only the value of the recreation.

However, growing recreation demand is creating situations in which these uses are competitive with other classes of instream or offstream use, but few analysts are working on measuring values which are suitable for comparing allocations among alternative uses.

Daubert, Young, and Gray [1979] formulated a direct interview procedure which elicits bids from recreationists on the value of water in flowing streams. Applied to a sample of visitors to the Poudre Canyon in northeastern Colorado, this approach yielded estimates of economic value related to flow in fishing, whitewater kayaking, and non-contact streamside recreation (i.e., picnicking). The resulting marginal values were (at a typical summer flow rate of 200 cfs), converted to dollars per acre foot, $9 per acre foot for fishing, $5 per acre foot for whitewater sports, and $7 per acre foot for the non-contact group. Walsh, et al., [1980] performed similar analyses on western Colorado streams, reporting $13 per acre foot for fishing, $4 per acre foot for kayaking, and $2 per acre foot for rafting, when flows were maintained at 35 percent of maximum.

These findings lend support to the notion that non-consumptive uses, even though they are non-marketed, have economic value to users. While many are skeptical of the validity of benefit estimates based on responses to questions regarding hypothetical consumption situations, a preferable alternative technique to generate quantitative estimates of instream flow values has not been developed. While recognizing that estimates using this technique are subject to more than the usual error, the author believes that they are reasonable reflections of user preferences and should be cautiously incorporated into water management policy decisions.

Fish and Wildlife Habitat -- Efforts to directly value habitat in economic terms are relatively recent. Many suffer from one or more of the potential difficulties noted earlier, particularly valuing total product rather than adopting a marginal stance. For the analyst interested in deriving the value of water from the value of habitat, there remains the problem of relating physical water requirements to habitat productivity, an issue that appears not to have been addressed.

Summary of Direct Impact Analysis

Up to this point, it has been shown that:

a. The direct net economic value foregone from reduced irrigation water supplies in Colorado will mostly fall in the range of \$5-\$35 per acre foot, depending on location and type of use.

b. The gain in net value of product or willingness to pay in industries and households absorbing water previously in agricultural use is five to ten times as high as the losses in the agricultural sector.

These findings are summarized graphically in Figure 2. The horizontal axis represents the fixed supply of developed water in a representative river basin. Agricultural water values are shown in the left vertical scale, and urban-industrial values on the right. The step-function D_a represents the demands (value-quantity) relationships for agriculture. Maximum willingness to pay would be in the \$50-\$100 per acre foot range, but most of the demand is below that range. The step-function D_u, drawn in reverse from the right-hand axis, represents demand in non-agricultural uses. Maximum willingness to pay is much higher than in agriculture. D_u intercepts D_a at a point such that 15 percent (more or less) of the water is most profitably used in non-agricultural

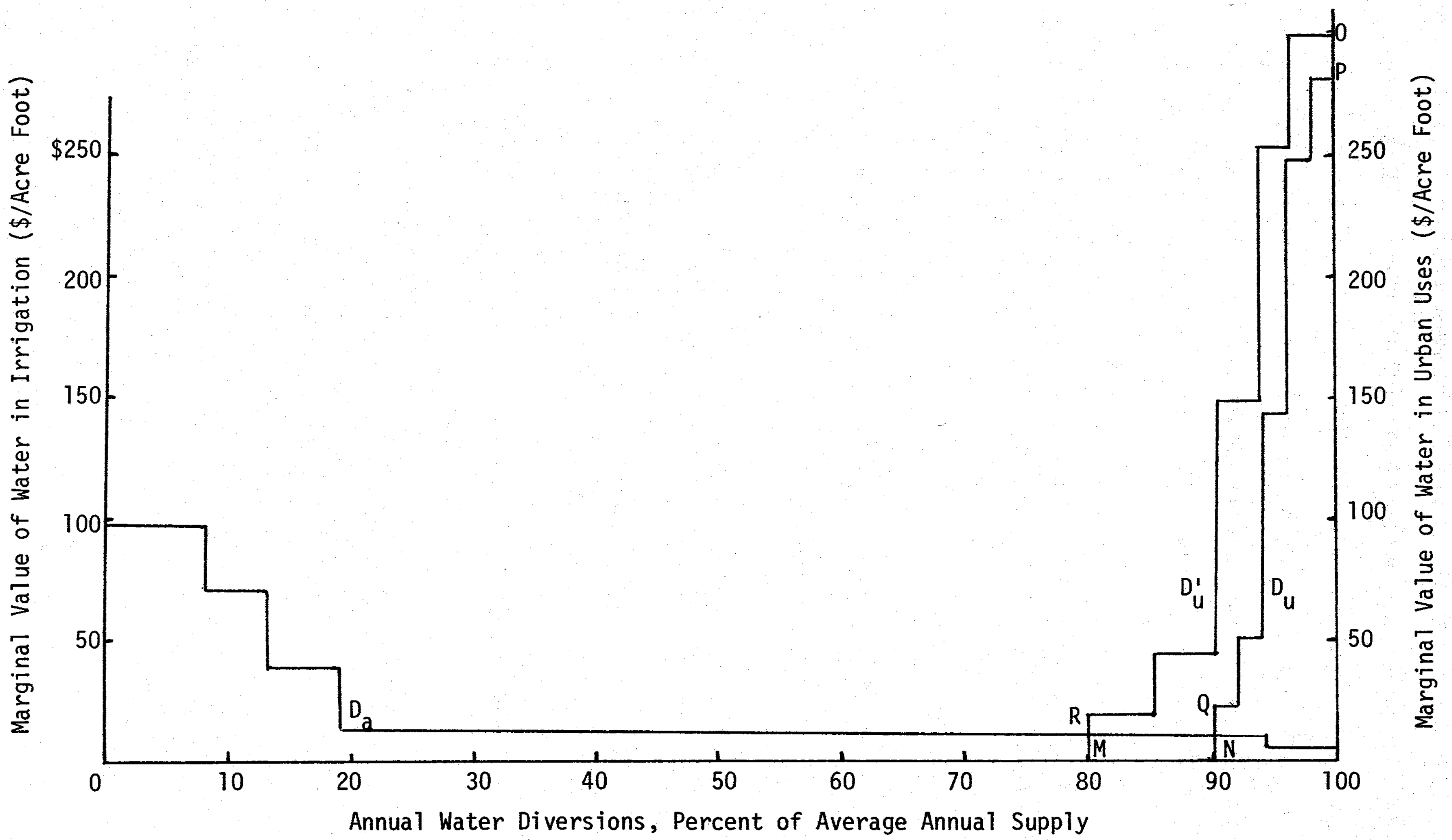

Figure 2. Marginal Willingness to Pay for Water as Related to Percent of Average Annual Supply: Agriculture and Municipal and Industrial Combined (for a Representative Western River Basin).

pursuits, while the balance is profitably employed in irrigation. The function D'_u represents a hypothetical future non-agricultural demand, reflecting growth in those sectors. The gross gains to the regional economy from the shift from D_u to D'_u is shown by the area between the curves, MNOP, while the losses foregone in agriculture are MNQR. The net gain to the economy from the shift is then RQOP, and is likely to be quite large.

III. INDIRECT INCOME IMPACTS FROM REALLOCATION OF WATER

Indirect income effects, often called secondary impacts, are the impacts on related economic sectors which are associated with changes in the level of irrigation. They are conventionally divided into forward-linked activities ("stemming from" effects), those which involve processing, marketing, and transportation of the farm products, and backward-linked activities ("induced" effects) which include supply of inputs (seed, fertilizer, machinery, etc.) to the farm sector.

Indirect impact measures must not be confused with direct impact measures. Indirect income measures usually refer to either gross revenue changes or payments to all primary resources, rather than the net revenue shifts measured in direct impact analysis above. Therefore, direct economic impact measures and indirect economic impact measures, even though both are expressed in dollars, are not strictly commensurate.

The Limited Indirect Impact Hypothesis

For purposes of this report, the main question regarding indirect impacts is the relative magnitudes in losing sectors versus gaining sectors. Concern over the magnitude of potential indirect effects in irrigation-based sub-regions is the basis for public action to avoid loss of the irrigation sector in areas where supply depletion is imminent.

The author's conclusion regarding the importance of irrigation to regional economies has, in some circles, proven to be controversial. Stated simply, the hypothesis is that irrigation developments have had a relatively minor impact on regional economies. The converse proposition, in the context of the theme of decreased irrigation, is that loss of 10 to 20 percent of the irrigation supply in Colorado would not have an appreciable effect on the state's economy.

Evidence of this proposition can be put forward in three classes: casual observation, statisitical analysis of growth impacts on water development, and detailed studies of the structure of regional economies.

Casual Observation -- Consider any of anumber of irrigated areas with no other industry or government installation to bolster the economy, beyond the suppliers and processors linked to agriculture. Many tens of thousands of acres of irrigation, particularly when the products are forages, grains, or cotton, are required to support even a village. The several small communities dotting the Ogallala-High Plains region provide one example, the lower reaches of the Arkansas and South Platte basins are others, the reader's experience may provide other instances.

Econometric Growth Analyses -- More systematic statistical analysis of growth impacts also have not been able to identify significant regional growth impacts from irrigation. Only a few detailed ex-post analyses of regional growth impacts associated with irrigation projects have been published. Cicchetti, et al., [1975] under contract to the Bureau of Reclamation, employed regression analysis to study the effect on various indices of regional economic growth of a number of variables representing Bureau of Reclamation investments. Census data were obtained for numerous "economic sub-regions" in five arid western states, for 1950, 1960, and 1970. Variables representing USBR investments in irrigation facilities were not found to have any significant impact on sub-region income, and only a small and not convincingly significant impact (t-value = 1.62) on the value of farm output.

In a similar study, Fullerton, et al., [1975] used econometric techniques to estimate the quantitative impacts of federal water resource development on economic growth in 246 counties in 7 western states. The authors summed up (p. 22):

> The null hypothesis that regional economic growth is caused by investment in water resources of various types is given virtually no support from these empirical results.

Studies of Regional Economic Structures -- Other detailed regional studies, such as Kelso, et al., [1972] yield similar inferences. Another example is the recent study of the Colorado Ogallala-High Plains region found that the 600,000 acres irrigated in the area directly employed about 1200 workers (one man-year = 2000 hours), while withdrawing 1.1 million acre feet of water annually. Indirect employment in the region associated with irrigation from the Colorado Ogallala accounted for another 1800 workers [Young, et al., 1982; McKean, 1982]. The conclusion was that the 40 percent reduction in irrigation anticipated over the next four decades would have an imperceptible impact on the state economy since the impact would amount to less than one-tenth of one percent of the state's work force.

Gollehon, et al., [1981] studied the effects of reduced irrigation due to energy development on regional employment and income in eleven Rocky Mountain region sub-areas, in Montana, Wyoming, Colorado, and New Mexico. The area studied encompassed nearly one million irrigated acres producing mainly forages and is supplied by 3.1 million acre feet of water. A 20 percent reduction in water supply to this group of sub-regions was forecast to cost the area 450 jobs directly in farming and 900 jobs in the region as a whole.

Indirect effects are often measured by reference to "multipliers" derived from a regional input-output (interindustry) model which indicate the monetary value of income generated elsewhere in the economy in relation to a dollar's worth of increased income in the sector of interest (i.e., irrigated crop production). Applying the multiplier to estimates of increased (or reduced) crop sales yields an estimate of increased (reduced) economic activity in the region represented by the model.

The business multiplier for the irrigated agriculture sector is among the highest of all economic sectors, such that each added dollar's worth of crop output generates more dollars of activity. In Colorado, the irrigated crop sector multiplier has been estimated to be about 2.7 [Gray and McKean, 1975]. To project what would be the net regional effect of reallocation of the water resource, however, the analysis must be carried further. The predicted income effects in Colorado of an additional unit of water in the irrigated agriculture sector and in two other of the rapidly growing sectors in the state's economy, coal mining and electronics, have been computed. These are shown in Table 1 in 1980 dollars. The income projections would probably not differ much in other western states.

Table 1. Direct and Direct Plus Indirect Income per Unit of Water Consumed, Selected Sectors, Colorado[a] (1980 price levels).

Sector	Water Requirement per Dollar Output	Direct Income per Acre Foot	Direct Plus Indirect Income per Acre Foot
	(gallons/$)	($/acre foot)	($/acre foot)
Irrigated Agriculture	1,752.00	184	503
Coal Mining	1.74	186,000	413,000
Electronics	0.14	2,364,000	4,208,000

[a]Source: Calculated from estimates presented in Gray and McKean [1975]. (Adjusted to 1980 price levels.)

The results show that an acre foot of water used in irrigation yields about $184 direct income and $503 in direct plus indirect income. Comparing the other sectors, it is seen that total annual income per acre foot is 800 times as large in coal mining and 8,000 times as large in electronics as in irrigation.

Job creation is another aspect of regional growth policy. The water requirement per worker has also been computed. These are shown in Table 2. Two hundred ten acre feet per year were required to support one worker in irrigated agriculture in Colorado. This compares with 0.39 acre feet per worker in coal mining and 0.031 acre feet per worker in electronics. Considering indirect as well as direct employment shows that 142 acre feet were required to support each worker in irrigation. The corresponding figure for coal mining and electronics are 0.28 acre feet per worker and 0.024 acre feet per worker, respectively.

Table 2. Water Requirements per Direct and per Direct Plus Indirect Worker Employed, Selected Sectors, Colorado,[a] 1980.

Sector	Water Requirements per Worker (af/worker)	Ratio of Direct Plus Indirect Worker Requirements to Direct Worker Requirement	Direct Plus Indirect Water Requirement per Worker (af/worker)
Irrigated Agriculture	210.000	1.48	142.000
Coal Mining	0.390	1.41	0.280
Electronics	0.031	1.27	0.024

[a]Source: Computed from Gray and McKean [1975].

Indirect Impacts: Summing Up

The analysis of indirect regional economic impacts yields similar inferences to those reached concerning on-farm impacts.

a. The indirect losses to a region giving up irrigation water, while not insignificant in terms of either monetary flows or employment, will be dwarfed by the gains in the non-agricultural sectors.

b. As in the direct impact analysis, these are stair-steps of impacts, when analyzed on the basis of returns per acre foot. These steps parallel the steps in the direct analysis, in that forages and food and feed grains, which account for over half of water use in western states, yield relatively small indirect employment and income effects.

IV. POLICY IMPLICATIONS

Colorado has been transformed from an agriculturally-based economy toward more manufacturing and eventually to a primarily service-based structure, the proportion of the irrigation-agriculture sector to the total income and employment has declined. In particular, the proportion of direct and indirect employment and income generated by the marginal 20 percent of water in irrigation represents an imperceptible portion of the economy of the state.

These are the forces which press for the economic change in a mature water economy. However we should recognize that they are among the natural consequence of a changing economy.

Policy Prescriptions Regarding Farmers Facing Losses of Agricultural Water Supplies

In the case of farmers who have a renewable source of supply (usually surface water or aquifers interrelated with streams), the existence of a problem turns on the degree to which property rights in water and land are protected by state and federal law, and hence, whether or not due compensation will be received by the farmers losing the water.

I perceive very little in the way of threat in this instance. Most farmers who have sold water rights (either directly or with associated lands) have not only been amply repaid for foregone productivity of their water, but share liberally the benefits in the alternative uses. Their property values have been greatly bid up in the face of anticipated urban, industrial, and energy demands. The fact is that much land and associated water rights in regions of urban growth is held speculatively (by farmers and others) in anticipation of further asset appreciation. Those who are forced out of farming are "crying all the way to the bank," and to a subsequent reentry to farming where land and water is cheaper, or, if desired, to a more comfortable lifestyle elsewhere.

Policy Prescription Regarding Losses to Indirect Beneficiaries of Irrigation

The property rights protection against loss of assets afforded to primary users of water is not available to the indirect beneficiaries, those who are linked to irrigated agriculture as input suppliers or processors of products. Even so, at the risk of appearing insensitive to these problems, only a limited basis for concern is apparent, but not much need for formal public action in response.

Most losses of irrigation water supply are neither large nor rapid, enabling those indirectly impacted to adapt to new conditions. As seen above, it doesn't take much water from agriculture to fuel a large change in a region's industrial base, so even in rapidly growing metropolitan areas, such as around Denver, irrigation continues and the associated indirect economic activity and employment declines only slowly. In the face of slowly declining demand, workers have time to plan for career change and the business and public sectors can have time to depreciate their investments without suffering severe economic losses.

Finally, it might be observed that while public policy has traditionally protected property rights of direct resource owners in extractive industries (e.g., petroleum, coal, minerals) I can identify relatively few instances outside of irrigated agriculture where secondary impactees are the subject of formal public policy concern. We need to think carefully about the justification for public intervention in this case, unless it is a part of a more general response to the structural changes throughout the economy.

Conclusion

The evidence regarding the role of irrigation in Colorado suggests that under modern conditions of production, irrigation accounts for a relatively minor portion of employment and income. This is particularly true for the half or more of the irrigation water which is used for forage and food and feed grain production. Second, major growth in the non-agricultural sector can occur with relatively small shifts from irrigation. Thus, we can expect only a negligible impact on local economies by the anticipated limited reduction in irrigation water use. The general perception that irrigation has been an engine of economic growth, and conversely that loss of irrigation would have major consequences is more myth than reality. This perception probably arises from a combination of what Boulding terms the mythical role of water in human society and from the interest groups who have a stake in business as usual rather than adjusting to the imperatives of the maturing water economy. Little economic basis for concern over the coming changes is seen and a limited basis for formal public policy to solve what are problems of adjustment similar to those experienced elsewhere as the economy shifts to the post-industrial era.

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