1 Introduction

Why might any of this matter?

By long-standing definition, "economics is 'the study of the allocation of scarce resources'" (Russell and Wilkinson 1979, 1). So it is not astonishing that economics is being applied with rising frequency in water management. One of economics' prime advantages is that it is accustomed to addressing trade-offs among the disparate factors, such as food, lawns, pipe, fish, and electricity, that are constantly encountered during decision making about water. Indeed, economics is actually about such trade-offs.

It is a mistake to confuse economics with accounting, as the uninitiated are prone to do. Although accounting principles are useful for managing the ledgers of water utilities and projects, economics transcends accounting in most decision-making respects while occasionally making use of accounting-based information.

Economics is action oriented, seeking to guide decision making on multiple levels. Water resource economics is strongly prescriptive. It is not content to merely describe water problems from an economic vantage. This is not to say that economics is 100 percent effective in these pursuits, or that it can accomplish them without assistance from the technical and social sciences. So one of the goals of this book is to distinguish the legitimate power of economics in water management. As we demystify the methods of water resource economics, the reader will encounter topics where work remains to be done or economic guidance is weaker than desired.

1.1 An Array of Decision Types

Water-related decision making occurs at various levels, in both governmental and nongovernmental arenas. Properly applied, economics can be of assistance for most of these decisions. For some decisions, the information offered by economics is paramount in framing the selection. In others, it can be helpful without being pivotal.

In some of the most momentous choices faced in water planning, decision makers are trying to refine a property right system or a legal doctrine for guiding the future use of water. These are normally national or state/provincial decisions. Although preexisting legal doctrines tend to be well rooted, ever-mounting scarcity fueled by rising demand has a way of revealing inadequacies in existing rules. So the laws always seem to need incremental improvement and occasionally a complete rewrite. Economics can help us understand the consequences of alternative rules so that better choices can be made.

In other cases, different parties may be voicing conflicting claims to a limited water resource. Regardless of whether the contest is waged in court, in the legislature, or before an agency, its resolution requires a partitioning of the available resources. A key capability of economics is being able to speak to optimal allocation among competing parties. Sometimes this partitioning is indirectly governed by setting a water price and letting water users consume what they wish, as long as they pay their bills. Pricing is an intimately economic undertaking, so the guidance of economics is quite strong here.

Some water-related decision making concerns infrastructure development. Here, we're interested in what kind of infrastructure to undertake. Given limited public funds, which projects should be built, how should they be sized, and who should pay for them? The economic tool called cost-benefit analysis was constructed for the very purpose of analyzing such things. While this tool has been primarily applied to nationally sponsored projects, it is also highly applicable to state and local projects as well as unconventional project proposals. (As a simple example, should the water utility acquire and freely distribute water-conserving showerheads?)

Collectively, these matters of allocation, policy analysis, and project analysis, as well as others, call for an understanding of the behavioral consequences of people and businesses, the determinants of value, and the manners in which alternative decisions shape our future.

1.2 Amid the Noise

A distinguishing feature of water resource decision making is the high degree of public involvement. Whether it is true or not, people think of water resources as public property. They feel entitled to water. They have an opinion about it. Because they drink it and know that life isn't possible without it, they can get emotional about water. They use it in religious ceremonies. Any modification of their access to water generates reactions that can be disproportionate to the modification. Every change proposed in water management has the potential to become a lightning rod for attracting public opinion.

Under these conditions, decision making can be onerous, both in terms of time and costs. Status quo positions can be hard to change. (Why else would there still be communities in the western United States that do not meter water deliveries to residential customers?) Elected officials have lost their seats when they pursue water policy changes before their constituents are ready for it (Martin et al. 1984). To better anticipate and manage public sentiment, it has become standard practice in water management to have public hearings so that "stakeholders" can voice their opinions. Such hearings may guard against postdecision revolt by providing a forum for the public and their leaders to exchange information and opinions.

This high degree of public involvement exposes water managers to forces that can be whimsical and unsettling. Unfortunately, the attitudes of the public can be inaccurate as well as fervent. Water managers can get stuck in their ways too. If we are to make progress under these difficult conditions, it would be helpful to inject clear information about the actual *human* consequences of alternative choices. Translating hydrologic paths into humanly experienced outcomes has clear relevance for this kind of decision making. Economically derived insights can often be of assistance in these situations.

In the water arena, there are plenty of myths and lore to be dispelled, and economics can contribute mightily here. When water consumers contend that the sky will fall if new water supplies are not obtained, it is useful to investigate how much the losses will really be. When someone argues that a proposed change in water rates is too burdensome for large water consumers, it's appropriate to understand how costly these things are, all things considered. If a region's leaders are weighing possible participation in a large water project, public sentiments regarding what should be done will be a mixed bag of emotive appeals for varied and conflicting objectives. Economic procedures offer a means of separating these disparate matters and individually considering each. All such information made available for planning processes can be very helpful.

1.3 Supply Enhancement and Demand Management

Although dichotomies often gloss over noteworthy middle ground, the distinction between ***supply enhancement*** and ***demand management*** is a useful one. Whenever water demand exceeds water supply, there are two general methods for addressing the problem.[1] We may either carry out alternatives designed to enhance water supply or

1. The prevailing economic wisdom is that the quantity of water demanded cannot exceed the quantity of water supplied unless the price is wrong. It is unfortunately true in many water resource situations that the water price is indeed wrong in that it does not equilibrate demand and supply. Often, the water price omits important values and places us into a position of "excess demand," the economic term for demand > supply.

pursue approaches meant to control (manage) demand. The first harnesses another water source in some way, and the second invokes ways to operate within the limits of current supplies. Of course, we can jointly undertake both types of measures, and this is normally best. Examples within each category are listed below:

Supply Enhancement Strategies	Demand Management Strategies
1. Build/enlarge dams	1. Establish water-conserving plumbing codes requiring certain fixture types (such as low-flow toilets and showerheads)
2. Drill/improve wells	2. Establish drought contingency plans
3. Build interbasin water transfer facilities	3. Ration water or constrain water use (e.g., alternate-day watering schedules)
4. Repair leaky infrastructure	4. Buy/lease/sell water rights
5. Build desalinization plants	5. Raise water rates
6. Reprogram reservoir operations (e.g., more storage with less flood protection)	6. Educate water users about conservation options

Supply enhancement has dominated water resource planning in the modern era, but this dominance has been suspended in most of the United States. Traditional forms of supply enhancement have run much of their course, because fresh water supplies are physically limited. New dams and wells generally deprive water from some existing or future use category, even if it is estuary inflows, which have become increasingly valuable due to the great amount of human diversions of water from its natural courses. Moreover, these forms of supply enhancement are much more expensive than they have been in the past. This is not to say that we are through developing water supplies—just that we are unlikely to rely on this approach as we have in the past, and future water developments will tend to be less conventional (e.g., desalinization plants). Some experts will argue that supply enhancement options remain strong, but such assertions may exploit the middle ground of this dichotomy or misclassify demand management approaches.[2]

As the role for supply enhancement has ebbed, the opportunities of demand management have simultaneously increased. While individual demand management options lack the scale of supply enhancement facilities, and they are certainly not viewed as the monuments to human achievement that our dams have become, demand management strategies are powerful tools for balancing demand and supply.

2. As a middle-ground example, is leak repair really a supply enhancement given that leaked water is already part of the supply? Some experts call water marketing a supply enhancement because they are visualizing water transfers as a way of increasing supply for particular user groups. On the other end of such transfers, however, someone is reducing their use, so that there is no net increase in usable supply. So whether a strategy constitutes supply enhancement or demand management may ultimately depend on the accounting stance from which it is viewed.

The rise in the usefulness of economic methods for water planning is partly linked to the rising role of demand management. Competing demands are not strangers in the world of economics, and markets and pricing are inherent concepts to economics. But economics also provides methods for assessing the merits of supply enhancement, and even to compare demand management and supply enhancement options. As a consequence, next-generation water managers can profit from adding economic acumen to their toolkits. Even those water managers who will not practice economic analysis, at least not formally, will benefit from developing their economic intuition. Moreover, noneconomists are likely to find themselves collaborating with economic specialists because of the substantial power that economics brings to water planning. When this occurs, possessing a common language will have obvious rewards.

1.4 Future Forces

While the pivotal water issues lying ahead bear a strong resemblance to those we have been facing in recent decades, some differences promise to emerge. It is useful to keep these in mind as we develop our thinking on foreseeable responses and the types of economic analysis that will be useful.

- A key item is continued population growth and the rising water demand (economically defined) it brings. This continual increase in demand will result in increased water scarcity over time. Some water demands will grow faster than others. The consequences will be a public desire for the reapportionment of available supply, continued interest in new water developments, and the further evolution of water policy. Populations will not rise forever, and the U.S. population will peak within this century, but the force of continued growth will remain strong over the next few decades.
- Economic advance and development will cause added water demand too. When members of a constant population become more affluent due to economic development, their collective water demand rises.
- Environmentally oriented demands for water have risen rapidly in recent decades and may continue to do so. To a large extent, these demands ask that water stay in place, either instream or inground, and that it stay relatively uncontaminated.
- Water supply is not rising; in fact, it is shrinking due to pollution and ground water depletion. The fallout will magnify the consequences of rising water demand. Scarcity will certainly increase.
- A warming global climate promises to raise water demand. Induced shifts in the location of people and agricultural production may have far-reaching implications for the spatial distribution of water demand relative to its current locations (U.S. Global Climate Change Research Program 2000). Because a higher energy climate

is projected to cause more evaporation and precipitation, with more precipitation occurring in large storm events, the demands for reservoir storage and flood control are expected to rise. Spring melting of high-altitude snowpack will be quicker, thereby adding to these demands.

• The best dam sites are occupied. Lesser-quality ones are available, but construction costs are high as is the regulatory burden stemming from ecosystem protection. While additional water development can play a role in managing growing scarcity, development must be shaped differently than it has been in the past. The options of the new era are different.

• Our amassed assets in water infrastructure are depreciating. Most of our large-scale water developments were constructed since 1930. They were not intended to last forever (U.S. Environmental Protection Agency Office of Water 2002). In addition to normal forms of infrastructural aging, sedimentation has progressively claimed reservoir storage capacity. Replacing underground conveyances in urban areas is a huge expense, as older cities in the eastern United States have already discovered. Postponing infrastructure maintenance is a common tactic to avoid unpopular rate increases, but there is an eventual cost to be faced (National Research Council 2002b, 42).

• Public health concerns pertaining to the quality and security of drinking water continues to boost the costs of water and wastewater treatment operations. Unlike the other forces observed here, this one has the capability to lower the quantity of water demanded for certain uses, providing that higher costs are reflected in higher water rates. Rising costs also diminish the net benefits people receive from the water they consume.

• Energy prices will be rising because of the rising scarcity of depletable fossil fuels. Renewable energy options will be induced as prices rise. The demand for hydropower will rise. We should be mindful that water is a heavy commodity relative to its value. The implications for water planning are several. Pumping, conveying, and pressurizing water will become more expensive. Infrastructure construction and replacement are energy intensive, inferring that water supply enhancement strategies will become more costly.

Collectively, these forces will propel social water issues into more serious matters than those we currently experience. This does not mean that water problems will be grave in every region or even in every year. Water scarcity will, however, become a more common condition—it will occur with greater frequency and intensity in regions already familiar with it, and it will emerge in regions where it is foreign. Rising scarcity will increasingly pressure the capacity of our institutions and wisdom.

1.5 Economics, Environment, and Equity

Water is employed for such a great variety of things. We use it in our homes, businesses, and industries. We transport goods on it. We apply it to our crops and serve it to our livestock. We swim in it, fish in it, and recreate on it. We take pleasure in seeing and listening to it flow by. We directly generate power with it and cool our fossil fuel plants with it. We dump our wastes into it, relying on natural forces to transport and assimilate what we discard. Commercial fisheries, even offshore ones, depend on fresh water availability. Water is a vital substance for the maintenance of the environment, and the environment is similarly vital for supporting humankind. Although our knowledge remains incomplete about the extent of humankind's dependence on the environment and water's role in it, we have come to know that much is at stake.

Given the multitude of water demands expressed by people, how should we proceed? Which water demands are we to elevate in planning for the future and which are we to slight? For example, are environmental water demands as important as water directly used by people in production or consumption activities? The stance of economics with respect to such questions is simple: If someone cares about it, it counts. More formally, economics is ***anthropocentric*** or human centered (Tietenberg 2003, 20). Hence, environmental demands for water have equal standing with other demands because they stem from humanly derived wants. On the other hand, only humanly sponsored water demands count in economics.

Box 1.1
The Diamond-Water Paradox

One of the earliest problems to be posed among economists was the so-called diamond-water paradox. Diamonds have been long regarded as an especially valuable commodity, even though their most acknowledged use has been "decorative." Water, fundamental to life on the other hand, has long been exchanged for fairly low prices. Water prices seem especially low relative to the prices of luxury commodities such as diamonds. How can it be that an essential resource like water commands a much lower price per unit weight or volume than diamonds?

The answer to this paradox emerges when we learn that the price of a commodity is determined not by its most important applications but by its most *marginal* uses. The most marginal use is the one that would be rationally eliminated if the supply of the commodity were decreased by one unit. The marginal use of household water is liable to be for an activity like lawn irrigation or sidewalk washing. Hence, the value of water is not normally associated with its essential uses. If scarcity ever advances to a point where the marginal water uses are essential uses, we may witness a reversal of diamond and water prices.

In the late 1700s A. R. J. Turbot, a French economist, came close to pointing out the solution to the paradox (Rothbard n.d.), but he stopped a trifle short of fathering accurate "marginalist" economic principles, perhaps due to a short life focused on public administration (Schumpeter 1954). Final explanation of the paradox is attributed to Alfred Marshall, who developed our most fundamental marginalist principles in the late 1800s (Schmidt 1992). The application of these principles to water will be of the utmost concern in the forthcoming chapter.

If an endangered species requires a certain water flow to guarantee its survival, this is an economic demand for water only to the extent that people assign value to the species' continued existence. In economics, nonhuman species do not, in and of themselves, have standing. That is, economics is not *ecocentric*, but this does not imply that environmental values do not count. Because people derive sustenance and products from the environment, all resources contributing to human welfare have economic value. But that is not all. Because people are caring and exhibit demands for nonhuman welfare, environmental water demands have standing beyond water's "productive" ability. How these demands are compared to direct human water demands in economic methodology will be a subject introduced within the next chapter.

Much of the focus of water resource economics is to identify *efficient* choices. In other words, given the demands, supplies, and scarcities at hand, and given the great number of alternative choices that can be made, what action(s) should be selected to advance our goal(s)? These goals are carefully developed in the next two chapters. While the goals of economic efficiency are not fundamentally concerned with egalitarian objectives such as equality, fairness, intergenerational equity, or sustainability, such objectives are well illuminated by economic investigation. The inherent fuzziness that accompanies these alternative expressions of *equity* can be clarified by purposeful economic study. Hence, even though the main pursuits of water resource economics direct modest attention to equity, it is certainly possible—and often desirable—to examine how alternative choices will affect different people and groups. Because decision makers commonly care about the social distribution of the gains and losses of a new decision, it is worthwhile to prepare this information for general consideration.

1.6 Organization and Conventions

Although this book is constructed to be completely accessible and digestible by noneconomists, it does not sidestep the frontier issues and methods of water resource economics. The overriding goal is to build a practical platform for performing economic analysis, both theoretically and empirically. In the forthcoming chapters, we will progressively

- develop the basic economic theory of resource allocation and customize it for water's peculiarities (chapter 2);
- expand the basic theory to encompass time-defined matters (chapter 3);
- inspect water law as well as the role of economics for critiquing laws and rules (chapter 4);
- establish how economics is employed to investigate proposed policy changes (chapter 5);

• establish how economics is employed to investigate proposed projects (chapter 6);

• analyze the role of water marketing in solving water scarcity problems (chapter 7);

• examine water pricing and the design of efficient water prices (chapter 8);

• develop various methods for empirically specifying water demand functions (chapter 9);

• study how water supply functions can be estimated, and scrutinize the choice between private and public ownership of water supply systems (chapter 10);

• overview methods and studies that combine demand and supply functions into models for specific water settings (chapter 11);

• reassemble, in abridged form, the major contributions available from economics (chapter 12).

Progressing through these topics, both theory and numerical examples will be utilized. As observed in the preface, a feature of this book is the linkage between the theory, graphic portrayals, and empiricism provided here. Complementing this text are the associated Mathematica programs (available at ⟨http://waterecon.tamu.edu⟩) that parallel each chapter containing numerical calculations or graphics.

Wherever possible, end-of-chapter questions are offered as direct applications of the material in each chapter. Many of these questions require no calculations. The exercises that do necessitate computations can ordinarily be accomplished by hand or using a spreadsheet program. Few exercises require unique programming (such as in Fortran or C), or the application of numerical or symbolic programs (such as Mathematica, Matlab, or MathCAD). While the concepts and messages of this book are digestible without performing any of the exercises, future practitioners may wish to undertake these problems as a means of honing insight and skills.

As a matter of standardization, all words appearing in boldface italics in this text are important terms that are redefined in the glossary at the rear of the book.

1.7 Exercises

1. Think of two methods or policies of dealing with water scarcity (not directly listed in this chapter), and then classify them as supply enhancing or demand managing.

2. Download the program MathReader from ⟨http://www.wri.com⟩ and use it to review a program downloadable from ⟨http://waterecon.tamu.edu⟩.

3. Characterize the following sentence as either ecocentric or anthropocentric, and justify your position: "Endangered species have a right to continued existence within the earth's environment, and no water project expected to extinguish a species should ever be constructed."