THE ECONOMIC VALUE OF WATER

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TABLE OF CONTENTS

ABOUT THIS REPORT

This report is Working Paper No. 7 in a series of eight. The reports are being prepared as background technical studies for the preparation of a long-term water supply plan for the Metropolitan Area. The long-term plan preparation was required by the 1989 legislature and must be presented to the legislature on February 1, 1992.

The other technical reports in the series are:

- No. 1. Alternative Sources of Water in the Twin Cities Metropolitan Area. Metropolitan Council Report No. 590-91-011.
- No. 2. Water Demand in the Twin Cities Metropolitan Area. Metropolitan Council Report No. 590-91-009.
- No. 3. Water Availability in the Twin Cities Metropolitan Area: The Water Balance. Council Report No. 590-91-008.
- No. 4. The Public Water Supply System: Inventory and the Possibility of Subregional Interconnection. Council Report No. 590-91-010.
- No. 5. Water Conservation in the Twin Cities Metropolitan Area. Council Report No. 590-91-020.
- No. 6. The Effects of Low Flow on Water Quality in the Metropolitan Area. Council Report No. 590-91-054.
- No. 8. The Institutional Framework for Water Supply Management. Council Report No. 590-91-064.

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THE ECONOMIC VALUE OF WATER

Minnesota is blessed with an abundant supply of fresh water. It has been called the state's most important natural resource. This paper focuses on the value of water. It is one of a series of background reports as part of the work to develop the Long-Term Water Supply Plan for the Twin Cities Metropolitan Area.

Two primary objectives of public policy regarding natural resources are to maintain the quality of the resources and to ensure their long-range productivity. Changes in the cost of water or in the availability of high quality water affect the value of water to individual users. For example, economic growth can be limited by an inadequate supply of quality water. State and local government actions can support these objectives through regulation, providing incentives (for example, funding and pricing policy), or direct programs to manage, conserve and protect resources.

In many parts of the country, the price of water, its value in exchange, does not reflect the costs of providing a given level of supply. The expansion of water supplies has been subsidized by state and federal governments. Consequently, consumers have used water without much regard for conserving supplies. Uses have developed that would not have if users were charged the full costs. For example, in California, agriculture accounts for more than 80 percent of the state's water use. Low-value crops such as alfalfa and cotton are grown along with more valuable fruits, nuts and vegetables. Today these areas are facing escalating costs of dealing with water problems. Water shortages are perceived as a serious threat to their economic well-being and reliability of water supply is a serious issue. For example, a semiconductor firm that recently located in Minnesota cited the availability of water as a key advantage of this area over the Silicon Valley in California.[1]

In Minnesota, the recent drought focused attention on the availability of water. If water becomes scarce, value increases as some users are willing to pay more than others to get it. Ideally, an analysis of the value of water would pinpoint a precise dollar estimate of water to the state. Two difficulties in developing this estimate are that water has not been valued highly historically because of its abundance, and that water is often shared by different users. This paper will discuss different concepts of value as they apply to water resources. For some uses of water, other studies will be referenced that have estimated actual values.

WATER--THE RESOURCE

Water has some characteristics that distinguish it from other natural resources. It can be used in many ways, sometimes simultaneously. It is used in homes for drinking and bathing. Industry uses water for heating, cooling, and cleaning. Farmers have increased the use of irrigation to boost land productivity. Households and industry alike depend on water for waste assimilation. Rivers remain important for commercial navigation. Finally, surface waters are the basis of recreational swimming, fishing and boating. They support other resources such as forests, fish/wildlife and agriculture. The variety of activities linked to water hint at its economic importance. However, its economic value tends to go unnoticed, partly because of its abundance and partly because water is not priced and marketed like other resources.

Water is a renewable resource. It can be purified and reused. Most ground water supplies recharge naturally over a period of years. Users tap into two general sources of water: surface streams and ground water reservoirs. Water uses of surface streams are often separated into instream use (occurring right on the body of water) from offstream use (at a site some distance away).

It is important to distinguish two aspects of water: quantity and quality. In cases where water is available in large quantities, quality determines its suitability for particular uses and gives it value. The quality of water is an increasingly important dimension of water issues. Pollution from people, industry and agriculture has increased to the point where aesthetic and recreational values, and even human health are threatened. In addition, the demand placed on our water resources continue to grow. The large potential increase in use suggests that quality water will become more scarce even in Minnesota. We know that ground water levels are lower than they were five years ago (Working Paper No. 3). We are becoming aware that water, like any valuable resource, must be safeguarded and managed intelligently to optimize the benefits for the present and the future.

Like many other natural resource problems, the problems of water management extend beyond local concerns about water supply and specific instances of point pollution. The scope of the problem has extended to multi-state regions and even international scale, particularly regarding problems involving contaminants and toxic substances. It is not certain that our institutions, public policies and our ability to respond to problems have kept up with the scope of the problems.

As use increases, potential conflicts develop within and among these uses. For example, intensive use in waste assimilation reduces the value of water in recreational use. In addition, it increases the costs of treatment of water to make it fit for many residential, commercial and industrial uses. Use of water for industrial cooling raises its temperature, and may thus affect the capacity as wildlife habitat and as a medium for wastewater assimilation.

Economic analysis can contribute to understanding these issues and evaluating proposals to deal with problems. Few resource-related decisions are truly private. Estimates of the value of water in different uses provide a basis for analyzing the effects of resource decisions and for "pricing" the use of water in a way that protects these resources and encourages uses that are more in tune with its true worth.

THE VALUE OF WATER

How do we put a value on water? Value is simply what something is worth, its relative importance. The economic value of water can be thought of as what users are willing to pay for it, or the demand for it. If demand exceeds available supply, water is "scarce" and it is necessary to develop a mechanism to allocate supplies among uses. In an economic sense, the most efficient allocation results when the extra benefit a user gets from one more unit of water is the same for all consumers. There is no one way to make any user happier (better off). One way to achieve this is by establishing a competitive market for the resource with prices used to balance supply and demand.

One difficulty is that some water "uses" do not consume water directly. In addition to its utility, water may have recreational value or aesthetic value (as in its natural state or in a wilderness setting). Despite the difficulties of measuring value, people readily acknowledge that water is valuable. For example, water for drinking is obviously highly valued. People respond quickly if their water supply is curtailed or if water quality deteriorates significantly. For other uses, it is difficult to measure in conventional economic terms. While there is agreement that water has value in these uses, differences of opinion exist as to the relative amount of value. Economists are gradually improving the measurement of value, but considerable imprecision still exists.

Why bother to put a value on water in different types of uses? Several reasons come readily to mind. One is that, if we want to save this resource, we need to know what it is worth and thus how much we should spend to save it. Another is that this is useful if it becomes necessary to choose one use or mix of uses over another. For example, do recreationists have a more legitimate claim (higher value) on a river than the barge industry? Third, it provides a basis for deciding who should pay the public costs of managing and protecting water resources. Fourth, value by use can assist in determining the potential effects of water changes in terms of economic gains and losses (economic impacts). Finally, the quality aspect of the resource suggest that value will change with quality. Water of higher quality is perceived as more valuable. Similarly, if water resources are contaminated, this creates costs for suppliers and users.

Some Useful Economic Concepts

Allocating water among alternative uses is the focus of economic analysis. Value in economics is related to scarcity. As commodities become more scarce (demand exceeds supply), they become more valuable. As prices change, different supply and demand options come into play. For example, conservation can offset the need for additional supplies.

Economics is concerned with the relative scarcity of resources. Value reflects what users are willing to pay for a resource. Competitive markets are the preferred mechanism for establishing value and using prices to allocate resources among alternative uses. Presumably they direct them into uses that generate the largest return. Economists have developed a number of measures of value in instances where competitive markets do not exist or which may go beyond the notion of value in exchange.

Two other economic concepts that are useful in making valuations are opportunity costs and externalities. Opportunity costs recognize that use of a resource for one purpose forecloses other options, and that the value of these other options is viewed as a cost or missed opportunity. The cost, in fact, equals what the resource could produce if used in the best alternative. The concept allows for considering alternative uses of a resource and their potential value in alternative uses.

Externalities relate to situations where one use of a resource affects its use by others. Some of the costs or benefits of an action affect others who are not part of the decision to act. A common example is pollution, a negative externality. Clean water is a scarce resource with alternative uses. The contamination of water by one use may preclude other uses or impose significant costs on other users to purify the water. Externalities may also enhance value and provide benefits for other users.

Water provides goods and services that directly and indirectly generate economic benefits. For example, water is used to produce paper, as a medium to dispose of wastes, and as an amenity contributing to the attractiveness of a wilderness area. Economists refer to "common property resources" in describing the environmental services from water and other environmental resources.

Two characteristics of common property resources are 1) unrestricted access to the resource, and 2) the creation of externalities. One potential problem is damage to the resource from overuse. Numerous "owners" with equal rights of use means that all will most likely maximize their own benefit without regard to what others are doing. Examples of problems include pollution and congestion (for example, barges versus recreational boats on rivers).

How to Value Water

For a variety of reasons, competitive markets in the United States are not used to allocate water supplies among users. Water is viewed as too vital to be left to economic forces to determine who gets it. In addition, some of the characteristics of water and its use are quite similar to such "public goods"--goods and services that are shared or consumed jointly.

The institutional system that has evolved to control water supplies depends more on legal structures than on the use of markets. In part, this reflects the availability of water across the country. Historically, water was plentiful in the eastern U.S. and it was treated as a free commodity, available to all users. In the arid sections of the western U.S. water became an instrument of power, and laws were established to protect this aspect of water. This system implicitly sets priorities and favors some users over others, generally those who are first in line. As times have changed, uses, and consequently, demand has changed and increased. Unfortunately, the system for allocating water supplies has not responded to the changes in water use.

Economists have developed several approaches to estimate the value of natural resources in situations where a market for the resource doesn't exist, but it is being used and thus valued. "Nonmarket value" is particularly important in alternative uses of water such as recreation. In addition, economists recognize a value in water completely apart from use ("non-use value").

Nonmarket Value

It is important to realize that economic value is not limited to instances where cash is actually transferred. "Social value" may exist and can be estimated. In the absence of competitive markets, prices that will appropriately allocate resources are not available. One way to get around this is to estimate an implicit price, one that might be inferred from related information. In general, the approaches used to estimate nonmarket values are either indirect or direct. The indirect approach uses data on purchases and consumption of goods and services that are related to the resource. The direct approach is to actually ask users what they would be willing to pay.

Two examples of the indirect approach are the travel cost method and the hedonic price method. The travel cost method is often used to value recreation sites. It infers a value from the amount of expenses and time costs of traveling to the site. The idea is that as costs increase, use will decrease. By examining the relationship between distance and cost, a value is inferred.

The hedonic approach uses characteristics that affect market price and infer value to the characteristics as prices change. For example, values are inferred for a lake by comparing changes in the prices of lakeshore property from nonlakeshore property.

The direct approach, typified by the contingent value method, surveys users and asks them questions about their willingness to pay contingent on changes in the resource that is being valued. In other words, by creating a hypothetical situation, one develops information on the value of the nonmarketed resource or amenity.

Much of the economic analysis of water issues deals with situations in the arid western states. In addition to the techniques mentioned, the existence of water rights as part of land ownership in the West allows the use of additional techniques that are often used in analyzing land values. These include the analysis of land value differentials and least-cost alternatives. The first allows for the use of various methods of estimating land values. The second involves estimating a maximum value based on what it would cost for a feasible alternative. For example, existing water supply might be valued in terms of what it would cost to replace it. A variation of this is discussed in the industrial use section below.

Underlying the new approaches is the recognition that there are valuable uses of water resources that are not reflected in the prices charged to users. Typically, the discussion of water issues is limited to water withdrawn and consumed. Economic value broadens the discussion to activities that are affected by the availability of water and its quality, whether or not water is withdrawn. Recognizing the non-consumptive uses of water and their value is important in deciding how to protect and manage available supplies and quality.

Nonuse Value

Studies indicate a public willingness to pay for the preservation of environmental quality when this quality is threatened. This nonuse or intrinsic value assumes that some people value a resource for itself or on the possibility they might use it in the future. The term used to describe this added value ("option value") reflects the idea of protecting opportunities for current and future generations to use water resources. While economists agree that nonuse benefits exist, controversy remains on precisely how to define and measure such value. However, recognition of nonuse value is important in any policy discussions regarding environmental quality.

Economists are also examining the issue of uncertainty and the importance of reliable water supplies. Reliability has become an important issue in areas where water shortages are relatively common. The issue is really the cost of reliability. Higher levels of reliability mean higher costs in terms of facilities, distribution systems, environmental effects, secondary effects on other users and, in the western United States, water rights. In other words, there is a value associated with water reliability.

Value in this context includes consideration of damages that result from shortages and the value of insuring against such damages. A recent study found that California residents place a substantial insurance value on the reliability of water supplies.[2] This study estimated that the median California household was willing to pay an extra $83 annually to avoid a water shortage, given a scenario of a 10-to-15-percent reduction in supplies occurring once in a five-year period. They were willing to pay more for other scenarios with more severe shortages.

The following sections of the paper look at specific uses of water. In some instances, water is sold to users. While this may represent a starting place for the discussion of value, it may not reflect value in terms of the willingness-to-pay concept mentioned earlier. In other cases, we will use standard economic concepts to discuss value and how it might be measured.

ALTERNATIVE USES OF WATER

Water is used in a number of ways. Obviously, it is difficult to measure value in these different users (such as industry, navigation, recreation). In addition, particularly in the case of surface water, the resource is shared by users. As supplies shrink relative to growing demand, uses compete with each other. Furthermore, one use may affect other uses (pollution).

The discussion of various uses that follows does not examine these interrelationships among uses, but treats each use separately. No attempts are made to develop new measures of value. We depend upon other estimates that might be available. Because water historically has been readily available (low value), these values understate what will happen if quality water becomes scarce. Similarly, estimates developed for other areas may not be strictly parallel to the Twin Cities area. Nevertheless, the estimates do illustrate the concepts involved and suggest how they might be measured.

Residential Use

The most important use of water is generally perceived to be for domestic purposes, what people need to survive. Residential use includes essential uses (such as drinking, waste assimilation, bathing) and nonessential use (such as watering lawns/gardens, swimming pools, car washing). In fact, water for human consumption is a relatively small share of total water use. Working Paper No. 2, Water Demand in the Twin Cities Metropolitan Area, describes how water is used in the Twin Cities, including projections of water use to the year 2010. Residential use currently accounts for approximately 17 percent of overall water use.

The primary supplier of residential water is municipal water utilities. Municipal water use represents the amounts supplied by these utilities and would include use by businesses and public uses (such as fire fighting) as well as residential consumption. Municipal water is typically supplied through a centralized distribution system that resembles a market system. Water prices are not set by market forces, but by the local water authority ("administered"). Typically they are set to cover the costs of operations and maintenance and do not vary with the amount of water used. Also, they do not usually include any replacement funding for facilities. Many uses of water and water-related activities, however, do not involve organized economic markets. Consequently, the only way to find out how the consumer values water would be to estimate a demand function, indicating the quantity demanded at different prices.

A number of studies have been done in other parts of the country on the household demand for water. Most of these show fairly weak relationships on average between changes in price and changes in demand. These relationships (economists call this "price elasticity") are in the range of -0.3 to -0.7 (a price increase of 1% results in a decline in use of 0.3% to 0.7%).

Looking at the demand for water in essential uses versus nonessential uses gives a much different picture. Studies that analyzed different types of use indicate that essential uses are relatively insensitive to price changes, while nonessential uses are relatively responsive to price changes. Similarly, winter demand is relatively insensitive while summer demand is more responsive.[3] This suggests an opportunity to use water rates to encourage increased conservation. For example, the relatively low elasticities indicate that higher prices for nonessential uses--or for use during the summer--wlll stimulate a reduction in water use. If rates are carefully structured, the reduction in use volume does not have to mean a drop in revenues for the utility.

From the information on price elasticity, we can infer several things about the relative value of water in the different types of residential use. As might be expected, essential uses are valued more highly. Similarly, the value for winter use (less price-sensitive) will be greater than the value for summer use (more price-sensitive). Finally, as supply shrinks, the marginal value increases sharply, more sharply for essential uses than nonessential.

Commercial/Industrial Use

The primary commercial/industrial use of water is for cooling and condensation, primarily in the electrical power plants. However, most of this water is discharged back into the surface water system, meaning that a relatively small amount is actually consumed on-site. Other industries use water in a variety of ways. It may be used to clean components or as part of the final product. Electric utilities accounted for 69 percent of total surface water withdrawals in the Twin Cities Metropolitan Area, and only 0.3 percent of ground water withdrawals. Manufacturing water use in the Twin Cities accounts for about 23 percent of ground water withdrawals and less than one percent of surface water withdrawals.[4]

Water availability and water quality regulations are more likely to affect water use than the cost of water intake. Water represents a relatively small share of total production expenses. As a result, changes in the price of water do not have much effect on overall water use. The costs of effluent treatment and discharge constitute the major part of the costs of water use.

The Legislative Commission on Minnesota Resources funded a study of water resources completed by the Minnesota Department of Natural Resources (DNR) in 1987 that, in part, looked at the value of water to the Minnesota economy. Two analytical methods used to estimate value were an input-output (I/O) model and linear programming. The I/O model led to a ranking of 75 industrial sectors in terms of their use of both ground water and surface water relative to output, employment and earnings. It includes the direct and indirect effects (due to the interaction among industries) of changes. The highest ranked industry provides the greatest economic return per unit of water (Table 1). The idea is to identify, based on economic return (output, jobs, earnings) the industries that should receive water if it becomes necessary to ration supplies.

Table 1

TEN INDUSTRIES USING WATER MOST EFFICIENTLY (By Source)

Summary Ranking	Ground Water	Surface Water
1	Truck Transit	Business Services
2	Business Services	Wholesale Trade
3	Finance/Insurance	Truck Transit
4	Communications	New Construction
5	Computers	Communications
6	Railroads	Logging
7	Wholesale Trade	Computers
8	Apparel/Fabrics	Sawmills
9	Education/Nonprofit	Railroads
10	Local Transit	Apparel/Fabrics

Source: Minnesota Department of Natural Resources, Summary: The Economic Value of Water, September 1987.

The highest ranking industries generate more output, employment or earnings per unit of water used in their production process. In other words, they generate more value per unit of water, and consequently, water has a higher value to them.

The flip side of this issue is the industries that use large amounts of water. Presumably, a reduction in water will have the greatest impact on these industries individually. The lowest ranked industries in the DNR study were electric utilities, primary steel producers, three mining sectors (stone/clay mining, iron ore mining, nonferrous mining), two farm sectors (food/feed grain and meat/animal) and the pulp/paper industry. Water used in these industries has a lower unit value--that is, they generate less output, employment or earnings per unit of water used.*

It is important to recognize that there are alternative ways to accomplish what water adds to the production process. As long as water is available and less costly than these alternatives, there is little incentive to use less water. In other parts of the country where water shortages are more common, industries have found it profitable to invest in various water conservation techniques.

* The I/O model did not differentiate industries that consume water from industries that withdraw water but do not consume it. For example, electric utilities that withdraw large amounts of surface water but consume little of it are treated the same as the pulp and paper industry.

For example, a recent article in the New York Times[5] points out that since 1987 some Northern California companies have faced water cuts as high as 25 percent and rapid increases in water charges. As a result, these companies have invested in systems that purify and recycle water, minimizing water discharge. Water reuse is also being explored in parts of Florida, Denver and Phoenix. Similar adjustments can be expected if the cost of water becomes high enough to make alternative investments profitable.

One way to evaluate the value of current water supply is to estimate the cost of feasible alternatives. In other words, a business should be willing to pay as much as the estimated cost to produce water of adequate quality through internal treatment and reuse. For example, when water is used for cooling, a company should research the cost of an alternative system. Another scenario might involve process water and the cost of a system to filter, purify and reuse the resource.

Outdoor Recreation/Tourism

Minnesota's natural resources are the basis for the rapidly growing tourism industry, providing quality outdoor recreation for both residents and nonresidents. Recent increases in outdoor recreation reflect, among other things, population growth and growth in real per capita income. Increased access through transportation improvements has also been a factor. Water-based recreation is a key component of this industry. Lakes and rivers are used for fishing, boating, swimming, and enhance adjacent activities such as camping and picnicking. The value of these activities that provide enjoyment for individuals and families is separate from the value of the water in lakes and rivers as a commodity itself.

Tourism has become an important industry in Minnesota. In some parts of the state it is the dominant industry. The importance of water to this industry was highlighted during the drought of 1988. Many northern Minnesotans objected to the idea of providing water for lawns in the Twin Cities at the expense of their livelihood.

The DNR estimated the economic impacts of water related to outdoor recreation as part of a water allocation project in 1987.[6] This report looked at the impact statewide and in five regions (Northeast, West, Central, Metro and Southeast). Water-related recreation accounted for 7.6 percent of regional value added (increased income) in the Northeast and between 0.7 percent and 2.0 percent in the other four regions. (The level of dollar value in Metro was actually about the same as in the Northeast, but the share was much smaller.) The average value of consumer purchases for recreation was estimated at $479 per acre of lakes with permanent fish populations.

Another part of the DNR project estimated the non-market value of recreation in Minnesota using the travel cost method and the contingent valuation method. This produced some interesting results. For example, the average value on recreation over and above the costs of participation ("consumer surplus"[**]) per acre of lake area is $166.[7] Table 2 gives the results of the contingent valuation analysis.

[**] "Consumer surplus" represents the amount consumers would be willing to pay for water minus what they actually pay (if they pay) at the current price of water.

Table 2

TRAVEL EXPENDITURES AND CONSUMER SURPLUS FOR WATER-RELATED RECREATION (1985-86)
Contingent Valuation Method

Economic Region	Total Travel Expenses	Total Consumer Surplus	Expenses Per Acre	Consumer Surplus Per Acre
West	$127,596,365	$59,052,819	$538.37	$249.16
Northeast	$503,281,601	$203,598,939	$317.79	$128.56
Central	$81,107,014	$37,501,260	$360.38	$166.63
Metro	$100,900,223	$57,060,180	$1,629.82	$921.68
Southeast	$49,400,782	$20,219,786	$295.82	$121.08
State	$862,285,985	$377,432,984	$379.08	$165.93

Source: Minnesota Department of Natural Resources, The Value of Water to Minnesota, Table 18. 1987.

The limited amount of scenic areas, particularly close to urban areas, has meant that the economic value of water for recreation has increased as demand has increased. The data in Table 2 supports this as the value for water-related recreation in the Metro Area ($922) is significantly higher than in other regions of the state ($121-$249).

Other ways to estimate the value of water for recreation are to analyze differences in property values for lakeshore property or to estimate what it costs to clean up a contaminated lake. For example, investments in metropolitan sewers in the 1970s revived Lake Minnetonka, transforming it from a seriously polluted lake to the valuable resource it is today.

Waste Assimilation

One important use of water is to assimilate wastes. The key aspect of this use of water is the effect on water quality. Different users cause varying degrees of deterioration of quality as the water carries away pollutants and waste heat from industrial processes. This assimilative capacity of water represents a real value to users in that it removes the waste and also restores the quality of the water. At the same time, the degradation in water quality may be a significant cost to other users (such as downstream users).

The ability of rivers to restore water quality depends on the level of flow and the pollution level existing in the stream. The release of water upstream to augment low flows is an important dimension of the overall water system. The value of water in this waste assimilation capacity is thus related to variations in natural streamflows, a seasonal occurrence.

Several ways to estimate the value of water in removing wastes are readily apparent. One might be able to compute what it costs to collect and dispose of the waste by alternative means. Presumably, water is used because it is the least-cost alternative. Another might be to estimate the damage in terms of reduced water quality and the damages involved. The reduction in water quality can be viewed as the value of water that is used up. Value in this instance varies with the type of pollution avoided. There is extensive literature on the costs of water pollution and the benefits of improving water quality.

Protection of the area's water was one of the initial concerns that led to establishing the Metropolitan Council. The Council is responsible for working with the Metropolitan Waste Control Commission to ensure that sewer facilities can adequately handle the area's wastewater. More recently, concerns have centered on the quality of surface water (lakes, streams and rivers) and the supply and quality of ground water resources. The drought of 1988 brought with it a realization that the area's ground water resources were not as plentiful as previously estimated.

The importance of maintaining water quality is unquestioned. The recent problems of discharges of raw sewage into the Mississippi River and the resulting fines from the Minnesota Pollution Control Agency support this. The value of the river itself in this process is less important than the state of treatment technology.

Irrigation

Irrigation is an important part of the agriculture industry in certain parts of Minnesota. Dakota County in the Metropolitan Area has a relatively large amount of irrigated acreage. Approximately 12 percent of ground water withdrawals and two percent of surface water withdrawals in Minnesota were for irrigation in 1985. The corresponding figures for the Metropolitan Area were 8 percent and 0.1 percent.

Irrigation can significantly increase yields in suitable soils. A University of Minnesota study on Swift County in western Minnesota estimated that in 1980 the average acre of irrigated land produced $338 of gross farm receipts, $213 more per acre than unirrigated land.[8]

Irrigation can be viewed as an input to crop production similar to fertilizer, weed control or machinery. The farmer weighs the costs of capital and operations against the increase in crop yield. One approach to estimate the value of water in irrigated farming is to use budget information on annual revenues and costs.[9]

The value to the farmer is the dollar increase in net revenues from an extra unit of water. The higher the price received for the crop, the more valuable the water, other things being equal. If water is scarce or more costly, the farmer has a number of options, such as more efficient use of the water or substituting other inputs for water.

Commercial Navigation

River transportation played a key role in the initial development of the Twin Cities and Minnesota. The oldest cities in the state are located on the major rivers. Waterborne commerce remains an important economic sector in the Twin Cities economy. Commercial navigation provides low-cost transportation of bulk commodities to and from other parts of the central U.S. and foreign markets.

A study completed in 1987 estimated the economic impact of commercial navigation on the Twin Cities economy using an input-output model.[10] The study estimated that the total impact from river navigation in 1984 amounted to $348 million for Minnesota, $332 million of which was in the Twin Cities. The river system is vital to several sectors: agriculture, construction and energy. The primary alternative to river transport of the commodities is the railroad. One way to estimate the economic value of commercial navigation is the volume of shipments multiplied by the savings per ton of barge transport over rail and subtracting the operation and maintenance cost of the waterway. One national study on major waterways indicates that instream use for navigation is a fairly low-valued use. For example, the long-run average value of water on the Upper Mississippi River is less than one dollar per acre-foot (1980 dollars).[11]

ECONOMIC IMPACTS OF WATER PROBLEMS

The fact that water is valuable means that water problems will have economic consequences. The increase in water problems in terms of the drought and instances of contaminated wells have intensified economic concerns. Historically, little concern was evident. This complicates current attempts to quantify values to different users and estimate what economic impacts might result from future problems, as well as determine the most economically advantageous way to allocate future water supplies.

Concern about water resources is significantly greater in other parts of the country. For example, in California, water analysts are predicting serious economic consequences such as reduced economic growth unless demand is reduced and additional supplies created. It is evident to many experts that water is being wasted and misused in the U.S. today. In large part, this is the result of historical patterns of water use. People have also begun to realize that water is valuable in new uses.

Water supplies continue to be plentiful in Minnesota. The most likely problems appear to be periodic shortages due to dry years and closure due to contamination (short- and long-term). Parts of Minnesota, including the Twin Cities, are more susceptible to problems than other areas. The specter of shortages indicates a need to expand or allocate supplies. Expanding supplies may be costly. As the true costs of expanding supply--the true value of water--becomes evident, other options such as conservation measures make more sense and result in actual savings.

From an economic perspective, it makes sense to allocate the most valuable uses first. Unfortunately, we do not currently have reliable measures of value across uses. However, recent concerns have led to attempts to develop measures of value. One of these was a study that the DNR prepared for the Legislative Commission on Minnesota Resources (LCMR) in 1987. Before discussing this study, it might be helpful to look briefly at water use in the Twin Cities and Minnesota.

Water Use in the Twin Cities

The Twin Cities area is the largest user of water in Minnesota. Water use is distributed as follows: 28 percent for municipal utilities, 57.5 percent for electric utilities, 4.0 percent for self-supplied commercial/industrial, 2 percent for irrigation and 2 percent for air cooling/heating.[12] Similar shares for the rest of the state are 11 percent for municipal utilities, 59 percent for electric utilities, 9 percent for manufacturing, 7 percent for irrigation and 0.3 percent for commercial.

It is interesting to note that the shares of total use do not represent the priority of use. For example, water for drinking has the highest priority, but this represents only part of municipal utility use and less than five percent of total use. The Minnesota legislature has established water use priorities. In a sense, priorities represent implicit values for the different uses of water. Unfortunately, the highest priority currently includes all domestic water use, essential as well as non-essential. In addition, we do not have detailed information on the different types of use to help set priorities.

The sources of information on water use in Minnesota and in the Metropolitan Area are the DNR and the Minnesota Department of Health (MDH). The DNR issues permits for all uses over 10,000 gallons per day or one million gallons per year. The MDH monitors municipal and non-municipal public water suppliers.

Table 3 summarizes information on water use by source in the Metropolitan Area between 1984 and 1988. The influence of the drought is evident in the large increase in water use in 1987. As noted, the data in Table 3 is for water withdrawal, not for consumption. For example, a significant share of water use (and of the increase after 1986) is for power plant cooling. However, most of these withdrawals are returned to their surface water sources.

Economic Impact of Water Shortages

It makes sense that industries that depend more heavily on water will be hurt to some degree by water shortages. A number of studies in other parts of the country have developed sophisticated analyses of the impact of water problems on a local economy. For example, a study on the Southern California regional economy estimated that a 30 percent reduction in water supplies in the year 2000 results in a $63.7 billion (12.6%) drop in output (gross regional product) and the loss of nearly a million jobs (10%) from what might be expected otherwise.[13] Unfortunately, studies for places like Southern California have little transferability to the Minnesota economy for a number of reasons. For example, water is more available here all year round. Consequently, the costs of water are lower here and there is currently little incentive for firms to use water more efficiently or explore alternatives. The industrial structure of Minnesota is also much different.

Studies on the effects of water scarcity on households are probably somewhat more applicable here. One recent study examined the costs of water shortages on households in Santa Barbara, California. The two primary costs resulted from actual water bills and from losses in trees, shrubs, plants, lawns and ground cover.

Table 3

METROPOLITAN AREA WATER USE
(Million Gallons Per Day)

Year	1984	1985	1986	1987	1988	1989
Waterworks	273	284	284	336	356	286
Power Plant Cooling	463	400	487	707	707	682
Cooling	22	26	26	29	30	29
Industrial	48	47	43	32	43	41
Water Level Maintenance	31	26	30	24	28	27
Irrigation	12	18	7	16	37	27
Miscellaneous	5	6	6	3	7	12
TOTAL	854	807	883	1147	1208	1104

SOURCE: Minnesota Department of Natural Resources

The DNR has done some work to estimate the economic impacts of any constraint in water supplies. As part of this project, one study estimated how output is reduced, once water is not available to meet demand (whether by shortage, contamination or diverted out of state). Figures 1 and 2, taken from the DNR report on the overall project, illustrate the results of this exercise for both surface water and ground water.

Note that the water amount required assuming current-technology production is different for surface water (1.9 million acre-feet) and ground water (0.5 million acre-feet). Also, the amount of output supported by water in each case is different. Each unit of ground water is associated with almost 13 times more output than a unit of surface water. This reflects the types of industries that use each water source and how much water is used relative to output.

A rough estimate of the reduction in output can be read directly from Figures 1 and 2. For example, a ten percent reduction of surface water results in a reduction of output of about one billion dollars. A ten percent reduction in ground water implies a reduction of about five billion dollars.

Figure 1: Value of surface water.

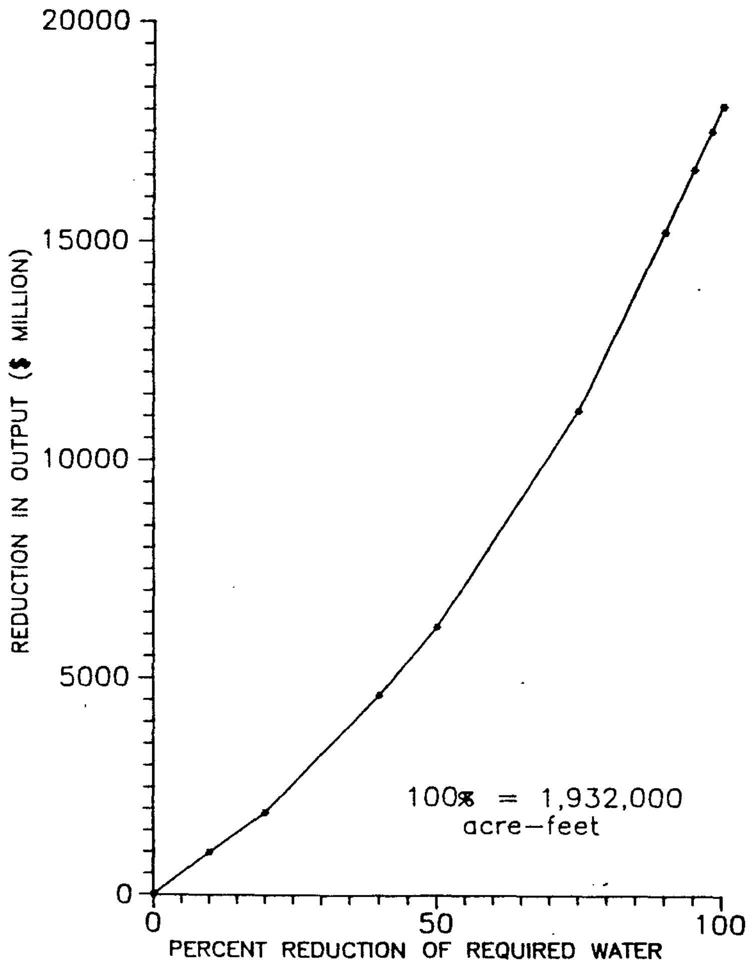
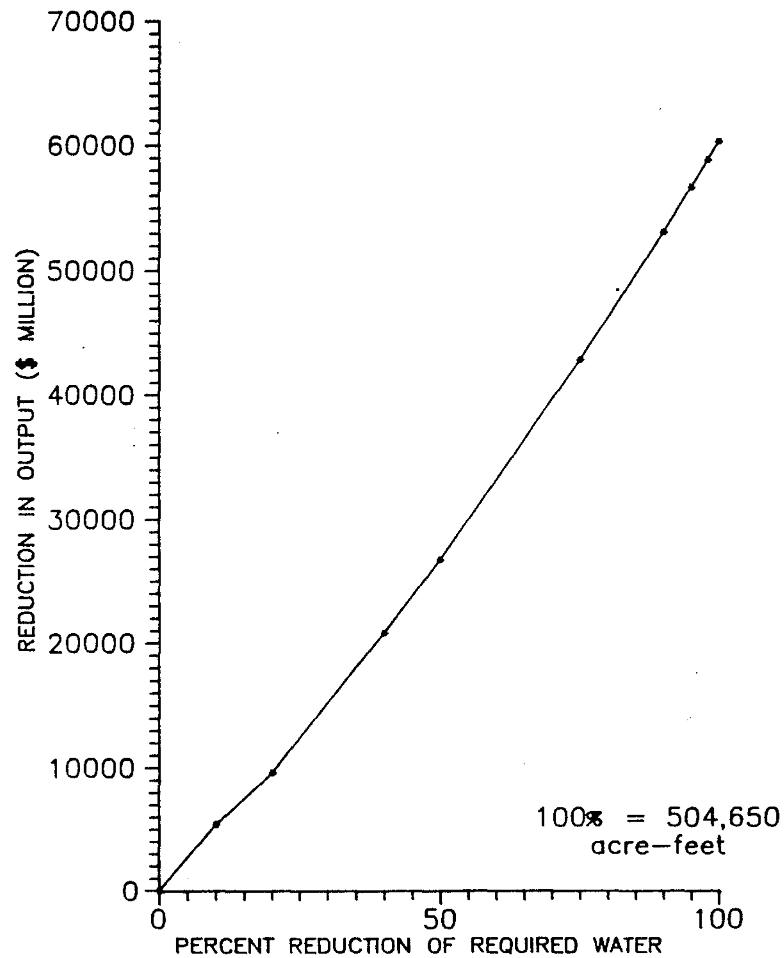


Figure 2: Value of ground water.



Source: Minnesota Department of Natural Resources, Division of Waters, Summary: The Economic Value of Water, 1987.

Keep in mind that Figures 1 and 2 assume that water has become a constraint. Another simulation done as part of the DNR project indicated that fairly severe reductions were necessary before water became a constraint--a 45 percent reduction for surface water and 14 percent for ground water. The point is that currently Minnesota does enjoy relatively abundant water.

SUMMARY AND CONCLUSIONS

People readily acknowledge the value of water, particularly for domestic uses, but for the most part we have taken water for granted. Ground water, until recently, was hardly thought about, much less worried about. Yet, as this paper has shown, water is important to our economic activities--recreational activities as well as industry, navigation, irrigation and other economic pursuits. During the 1980s, concerns about water quality made us more aware of water and raised questions about the long-term availability of quality water. The fact of the matter is that, like any resource, we must protect it and manage it responsibly.

One of the purposes of this paper is to show not only that water is valuable, but that there are different uses of water, each of which values water differently. The interdependency among uses is one factor that hampers the use of markets to estimate economic value and to allocate water supplies. We do know that water is valued more highly in western states such as California and Arizona because it is scarce. While it is not possible to develop a single, overall number for the value of water to Minnesota, the experience in arid states can serve as an upper bound.

The abundance of water in Minnesota has contributed to its low value here, since value reflects relative scarcity. This has probably also meant that water is being employed in uses that are low value, or not their most productive uses in an economic sense. Its relatively low value in fact is an incentive to misuse water. This link between value and use suggests the possibility of using water charges as a way to encourage conservation and other alternatives that might effectively expand supplies and improve water management.

The 1988 drought made us more aware of what happens when supplies are limited and users have to compete. The Metropolitan Area depends on water from the Mississippi River for domestic water. The source of the water in the Mississippi is outside the Metropolitan Area in the headwaters area. However, the lakes that comprise the headwaters reservoir system are the basis of summer resort business in northern Minnesota. Each area has a different perspective on water use and on related priorities.

Recognizing the value of water can help promote its efficient management and use. Previous sections of the paper have indicated ways to estimate value--for instance, using the cost of replacing current water systems or the cost to clean up contaminated supplies. In addition, encouraging more realistic pricing policies provides an incentive for more efficient use. To some extent, prices might be differentiated to reflect any significant cost differences. Charges during peak seasons should be higher to the extent that capacity is strained. Similarly, customers in locations that are more costly to serve should be charged more.

It is evident in Minnesota and other states that water has significant value in non-consumptive uses such as recreation. It is important to respect this value in planning for the overall water supply system and its management. Economic value by type of use can be a helpful consideration in evaluating new proposals to change the water supply system (such as the capacity of expansion and water transfers), programs to manage demand or other water policy options. For example, a recent study by two economists at the University of Minnesota proposed a "buffer value" of ground water as a way to mitigate undesired fluctuations in the supply of surface water.[14]

Given the relatively high value of water in recreation uses, it is logical that the focus of public policy has been on maintaining the quality of water. At the same time, efforts are being directed at dealing with shortages. In all these policy contexts, economic measures of value are useful in sorting through issues and the tradeoffs involved.

One difficulty in implementing a region-wide pricing strategy is that prices are currently set by about 110 municipalities in the Metropolitan Area. The price for average residential use per quarter (30,000 gallons) is different in most places and varies from $10.50 to $89.20. Different methods are used with most places using either single block approach or a decreasing block approach (unit price declines as consumption increases).

While it may not be possible to coordinate charges across the area, one alternative might be for cities or the state to adopt pricing policies that encourage lower use at certain times or for certain purposes. For example, demand varies by season, with summer use substantially higher than winter use. Much of the summer water use is non-essential (for example, lawn-watering). Cities might add a surcharge during dry periods. The charge may be uniform across the region or set by individual cities. Another example is to charge a significantly higher price for use above some basic level. The summer surcharge could be based on the estimated extra capacity costs of meeting summer demand (on-peak). In many respects, electric utilities offer models for using prices to create incentives for reducing seasonal or time-of-day demands.

One key consideration is to recognize the incentives created by the pricing system or whatever system is designed to support regulations. This would include incentives for suppliers as well as consumers. For example, water utilities have an economic interest in expanding use since revenues are directly tied to volume in most cases.

The use of financial penalties and subsidies to support policy objectives is a well-accepted strategy to address water and air pollution. For example, recent federal legislation on clean air includes provisions for trading pollution rights. Similar mechanisms might be developed using water permits. For example, if it were desirable to limit water withdrawals, permits might be issued for the desired withdrawal amount (and the current fee) to previous permit owners or on a first-come, first-served basis or some other basis. Owners of the permits could then use them or trade/sell them.

Similarly, incentives might be developed to encourage use of surface water through lower (or zero) charges. Or, revenues from ground water use or an excise tax on water bills might be used to develop the capability to store additional surface water during periods of high flows. If supplies are not available to meet demand, the value of water in specific uses and water charges provide possible ways to allocate scarce supplies and reduce demand. We need to better understand how different types of consumers will respond to higher prices. For example, consumption will change little in response to higher prices for drinking water. The response may be significant when prices are raised for summer activities such as lawn watering or car washing.

Finally, a comprehensive planning and management strategy requires the use of a range of tools--economic (as in subsidies or taxes) as well as regulatory (such as land use regulations and zoning). A fundamental piece of this is a system-wide framework that provides the context within which to evaluate the benefits and costs of policy alternatives, the essence of economic value. Economics emphasizes the evaluation of alternatives--particularly in the context of an overall system approach, including future demand and supply. This evaluation aims to identify the least-cost alternative for a given level of service, and determining who benefits and who pays under different alternatives.

ENDNOTES

1. *Minneapolis Star and Tribune*. "Chip Producer Sees Advantages Here." April 22, 1991. p. 4D. Reporter Steve Gross interviewed T.J. Rodgers, president and chief executive officer of Cypress Semiconductor Corp., about the recent purchase of Control Data's semiconductor plant in Bloomington.

2. State Water Contractors, *Economic Value of Reliable Water Supplies, Phase 1* (June 1987)

3. Diana C. Gibbons, *The Economic Value of Water*, (Washington, D.C.: Resources for the Future, 1986), pp. 9-13.

4. Minnesota Department of Natural Resources, Division of Waters, *An Analysis of Water Use in Minnesota* (November 1987), p. 37.

5. Kathleen M. Berry, "Save Money: Turn Off the Spigot," *New York Times* (April 7, 1991), Business Section (Sec 3), p. 7.

6. Timothy J. Kelly and Ronald M. Sushak, *Significance of Water-Related Outdoor Recreation to the State and Regional Economies in Minnesota*, Minnesota Department of Natural Resources, (October 1987).

7. Minnesota Department of Natural Resources, *The Value of Water to Minnesota*, Report to the Legislative Commission on Minnesota Resources, Volume 1, 1987.

8. Judith Maxwell and Ronald Dorf, *The Economic Value of Irrigation for the Swift County Economy*, Special Report 102, Agricultural Extension Service, University of Minnesota, 1982.

9. This approach was used to estimate how irrigation restrictions might affect crop yields and net returns per acre on a representative southwestern Minnesota farm. See Darrell J. Bosch and Vernon R. Eidman, *The Effects of Better Information and Pumping Restrictions on Irrigation Efficiency in Minnesota*, Economic Report ER 88-6, Department of Agricultural and Applied Economics, University of Minnesota, June 1988.

10. Temple, Barker & Sloane, Inc., *The Economic Impact of Commercial Navigation on the Twin Cities Region*, Prepared for the Metropolitan Council of the Twin Cities Area (December 1987).

11. See Gibbons, op. cit., p. 81.

12. Judith A. Hartsoe, *Water Demand in the Twin Cities Metropolitan Area*, Working Paper No. 2 (1991). Metropolitan Council Report No. 590-91-009.

13. Dames & Moore, *Regional Economic Impacts of Water Supply Shortages in Southern California*, (June 12, 1987).

14. Yacov Tsur and Theodore Graham-Tomasi, "The Buffer Value of Groundwater With Stochastic Surface Water Supplies." St. Paul: University of Minnesota, Department of Agricultural and Applied Economics, Staff Paper P90-51 (August 1990).