Water Resources in Illinois: Demand, Prices, and Scarcity Rents

Viju C. Ipe and Subhash B. Bhagwat

Illinois Minerals 126

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Front Cover: *The Harrison and Dever Cribs of the Chicago Water Department, active water-intake cribs in Lake Michigan that pump water landward to Chicago's Jardine Water Purification Plant. These two cribs are located in about 32 feet of water 2.5 miles offshore from North Avenue Beach (photo by Joel Dexter, May 2000).*

ILLINOIS DEPARTMENT OF NATURAL RESOURCES

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Abstract

Analysis of the spatial and temporal dynamics of demand, supply, and prices of water in Illinois indicates that regional scarcity of water is a real possibility within the next few decades. Alternative sources of water must be found. Current pricing policies of municipal suppliers are based on average cost and are subject to political considerations, causing actual revenues of some utilities to be lower than their listed price for water. Water prices need to be based on marginal costs. When economic concepts of scarcity rent and efficient pricing were applied to water resources in Chicago, the results showed that water drawn from Lake Michigan should have a scarcity rent of at least $1.20 per thousand gallons and an efficient price (excluding distribution cost) of at least $1.44 per thousand gallons. Currently, water in Chicago has a listed price of $1.07 (including distribution cost) and actual revenues of $0.69 per thousand gallons.

Introduction

Illinois seems to have enough groundwater and surface water resources to meet its current needs for drinking and for industrial, agricultural, recreational, and other purposes. Although availability seems to be adequate for the state as a whole, certain regions may face water scarcity in the near future. When such scarcity arises, additional water must either be piped in from distant locations, or consumption must be limited to sustainable quantities. Because there is lack of unanimity among hydrogeologists about the definition of "sustainability," we have used a common sense definition in this publication that regards sustainable use of a resource as possible in the long run only when withdrawal matches recharge rate.

Early signs of water scarcity have already become evident in Cook County and in the five collar counties (Lake, McHenry, Kane, DuPage, and Will) in the Chicago area where two-thirds of the state's population live. About 80 to 90% of the available water supplies in this metropolitan region are already being used, and the possibility of water scarcity is projected for some suburbs by the year 2020 (Northern Illinois Planning Commission 2001). An article in the *Chicago Tribune* (Kendall 1999) also raised the issue of potential water scarcity in Chicago and northeastern Illinois. This area draws its water from Lake Michigan, other surface water bodies such as the Fox and Kankakee Rivers, wells that tap areally extensive but deeply buried bedrock aquifers, and shallower wells that tap aquifers in the near surface glacial deposits in the area. Illinois already withdraws the maximum legally permissible quantities of water from Lake Michigan and almost the maximum sustainable quantity from the Kankakee and Fox Rivers, the deep aquifers, and shallow wells (Winstanley and Peden 2000). Nevertheless, the population and economy of this region are expected to grow in the future, and new suburban areas continue to be developed in Cook County and adjoining counties, requiring additional water. As the growth continues, additional demand for water can be expected for industries, power generation, and allied activities.

Although reliable estimates of available water supplies and future water demands for other parts of the state are not available, experts suggest that water scarcity is a distinct possibility in some of those regions as well. The comprehensive planning needed for water resource use and management requires good databases on the groundwater and surface water resources available for current and future projected regional demand.

The use and conservation of any resource are also affected by pricing policies. Even though water is a resource in "abundance," the price charged for its use should reflect its true economic value. There have been some attempts to review the available data on the effects of water prices and family income on per capita water demand. For example, Wong (1972) investigated the water demand in 130 systems in northeastern Illinois and concluded that household water demand was relatively unaffected by price in the City of Chicago, but was somewhat influenced by price in the suburbs. Wong attributed this difference to the fact that Chicago is supplied with surface water, which is relatively inexpensive to pump and distribute, whereas the suburbs mostly depend on more expensive groundwater.

According to Wong (1972), the price elasticity of water demand is influenced by the absolute price level. Price elasticity indicates how demand changes with a change in price. For most goods, a decrease in price results in an increase in demand. For such goods, the price elasticity of demand is said to be –1 if a 1% decrease in price results in a 1% increase in demand, and vice versa; a number between 0 and –1 indicates inelastic demand. When industrial and commercial water uses were included and community size was not considered (i.e., when a cross sectional estimate was made by Wong), the price elasticity of water was determined to be –0.26 to –0.82.

Stevens and Kesisoglou (1984) studied the price elasticity of water demand in Massachusetts. Their findings confirm Wong's values of price elasticity for water demand in northeastern Illinois. Although price changes have a small effect on water demand, the effect is undeniable. The question, then, is what price would be appropriate. This question has not been studied in Illinois.

The economically grounded way to determine the appropriate price level is to match prices with the economic value of water to society, which is reflected in the "scarcity rent." Scarcity rent refers to the implicit value associated with the resource because of its expected future scarcity. This report presents the results of our attempt to measure the scarcity rent of water in northeastern Illinois.

Dynamics of Water Demand

Water is used in all aspects of human activity, including drinking and sanitation, irrigation, generation of electricity, mineral extraction and other industrial processes, recreation, and transportation. Total water withdrawals serve as a proxy for total demand, although private withdrawals are not recorded in most cases. Private wells are not limited to remote farmhouses; these wells also supply larger demands such as electricity generation, industrial production, mineral extraction, agriculture, and recreation (U.S. Geological Survey 1999). In some cases, water demand (withdrawal) does not represent consumption in the usual sense. For example, the largest single water use in Illinois is for cooling at electricity generating plants, but much of this water is returned to a surface body of water—a river or lake—albeit at a warmer temperature. Yet this use is considered to be a demand for water in the same sense as a demand for drinking and other consumptive purposes because it involves costs that must be paid. Similarly, much of the wastewater that is cleaned before being discharged into a lake or stream was also previously consumed for drinking or other human purposes.

Estimates of the regional demands for water in Illinois are presented in table 1. The state is divided into 11 regions (appendix, table A1), and the total water withdrawal in each region is used as an estimate of the total demand. Data from year to year and region to region have been difficult to compare. Because comparable regional data on water withdrawals are available only for the years 1990 and 1992, data for those two years alone are reported in table 1. This table shows that the demand for water in the public supply systems of the state increased by about 5.9% from 1990 to 1992. Similar rates of increase in water demands occurred in all regions except in the Peoria and Central regions where demand declined.

Past trends suggest some possible future scenarios regarding demand. In areas with growing population and increasing economic activity, demand for water may be expected to increase substantially. Chicago and its suburbs are an example of one such area that may experience supply problems in the near future.

Available Water Resources and Supply

Ground and surface waters constitute the available water resources in Illinois. The Mississippi River on the western border, the Ohio and Wabash Rivers on the south and east, and Lake Michigan on the northeast are the major fresh water bodies surrounding the state. The large tributaries to these major water systems in the state's interior include the Illinois, Kaskaskia, Fox, Rock, Sangamon, Big Muddy, Embarras, and Kankakee Rivers. There are 88,417 inland lakes, excluding Lake Michigan; total lake acreage is 301,209. The Illinois-administered acreage of Lake Michigan is 976,640 (*1999 Illinois Statistical Abstract*). About 80% of the inland lakes are artificially constructed. The artificial lakes include dammed streams and side channel impoundments, strip mines, borrow pits, and excavated lakes. The natural lakes include glacial lakes found in the northeastern counties, sinkhole ponds in the southwest, and oxbow and backwater lakes along the major rivers. Most lakes provide water for drinking and cooling purposes, recreation, and fish and wildlife habitat; provide help in flood control and property value enhancement; and provide valuable ecological and aesthetic natural resources. The state has approximately 900 interior streams and 26,443 total stream miles (*1999 Illinois Statistical Abstract*). As shown in table 1, surface water accounts for the major share (94% to 95%) of the total water withdrawals in Illinois.

Table 1 Estimates of the regional demand for water in Illinois, million gallons per day.[1]

	1990		1992	
Region[2]	Surface water	Total	Surface water	Total
Chicago	9,727.42 (96.8)[3]	10,047.96	10,116.76 (97.3)	10,396.12
Rockford	73.20 (37.3)	196.13	53.16 (24.8)	214.77
Rock Island[3]	56.23 (52.4)	107.38	1,026.64 (94.0)	1,092.04
Peoria	2,257.20 (95.6)	2,360.13	1,792.14 (93.6)	1,914.53
Champaign	23.57 (32.5)	72.42	26.07 (32.3)	80.70
Decatur	548.10 (95.8)	571.92	662.77 (96.1)	689.43
Springfield	1,700.74 (96.3)	1,766.53	1,659.51 (93.0)	1,784.35
Quincy	37.99 (57.8)	65.76	31.29 (37.3)	83.90
East St. Louis	1,403.18 (94.9)	1,479.04	1,429.46 (94.3)	1,515.85
Central region	501.64 (91.1)	550.49	429.01 (87.0)	493.05
Carbondale	737.48 (92.6)	796.18	757.11 (93.5)	809.76
Total[4]	17,066.75 (94.7)	18,013.94	17,983.92 (94.3)	1,9074.50

[1]Source: U.S. Geological Survey (1996, 1999). (Although the Illinois State Water Survey has published data on water withdrawals since 1986, its data are not comparable with recent data available from the U.S. Geological Survey.) 1 gallon = 0.1337 cubic foot.

[2]See appendix table A1 for list of counties in each region.

[3]Values in parentheses are percentages of the total withdrawals.

[4]Original U.S. Geological Survey data source offers no explanation for the 10-fold increase in total demand from 1990–1992.

In addition to surface water resources, the state has an abundant supply of groundwater resources. Major aquifers underlying Illinois include (1) the saturated sand and gravel deposits left in the last 1.8 million years by repeated advances and retreats of continental glaciers and (2) aquifers in the bedrock beneath the glacial deposit—the Pennsylvanian-Mississippian aquifer, the Silurian dolomite aquifer, the Cambrian-Ordovician aquifers, and the Mt. Simon aquifer (U.S. Geological Survey 1985). Large users, especially in northeastern Illinois, generally pump water from the bedrock aquifers. Small users, such as suburban residences and farms, mostly obtain their water from aquifers in the glacial deposits and the shallow bedrock. These aquifers may offer sources of water to meet the demands from the growing population and expanding economy in some areas, but reliable estimates of reserves in the aquifers are not available.

Detailed geologic, hydrologic, meteorologic, and engineering data on ground and surface waters are needed to determine aquifer characteristics and to develop policies for the sustainable use of water resources in the state. The Chicago region, with its great population density and high annual rate of industrial and municipal growth, is one example of a region that had local water supply problems as early as the late 1950s (Suter et al. 1959). These supply concerns are likely to become more severe in the future. Where available surface water supply is a concern, groundwater seems to be the alternative.

Temporal and Spatial Variability in Water Prices across Illinois

In view of the growing demand for water and concerns regarding its supply, and because price affects use, it is essential to study and understand how water prices have varied over time and from one region in Illinois to another. In order to analyze historic trends, data were collected from the major private water supply utilities and from the public water supply agencies in Illinois. Continuous, long-term data could be obtained only from the Northern Illinois Water Corporation, now called Illinois-American Water Company (IAWC), and from the Water Department of the City of Chicago. The IAWC supplies water to consumers in Pontiac and Champaign-Urbana in the Champaign region, Streator in the Peoria area, and Sterling in the Rockford area. Surface water is supplied to Pontiac and Streator, whereas groundwater is supplied to Champaign- Urbana in central Illinois and Sterling in northern Illinois. Other divisions of the IAWC supply surface water to Alton, Belleville, Granite City, and East St. Louis and groundwater to Pekin. The City of Chicago Water Department gets most of its water from Lake Michigan.

As shown in figure 1, the inflation-adjusted prices of water in three communities supplied with surface water by IAWC and the City of Chicago decreased from 1975 through 1982 but have generally increased thereafter. Prices for groundwater in Champaign showed a similar trend (fig. 2). In Sterling, prices declined from 1975 through 1982 and then increased sharply from 1982 through 1985, declining again thereafter. Such sharp increases in prices could have been due to a sudden increase in fixed costs arising from construction and/or maintenance of plants.

Over the 24-year period from 1975 to 1998, inflation-adjusted (with 1982 to 1984 as the basis of comparison) water prices increased in all communities except Chicago, where they declined an average 1.02% per year (table 2). 1976 to 1980 was the period of greatest overall consumer price inflation in the United States, averaging 9.2% annually. Real water prices in this period declined in all cities and, in Chicago, by over 15%. After 1980, real prices generally increased in all cities, although periods of price decline occurred.

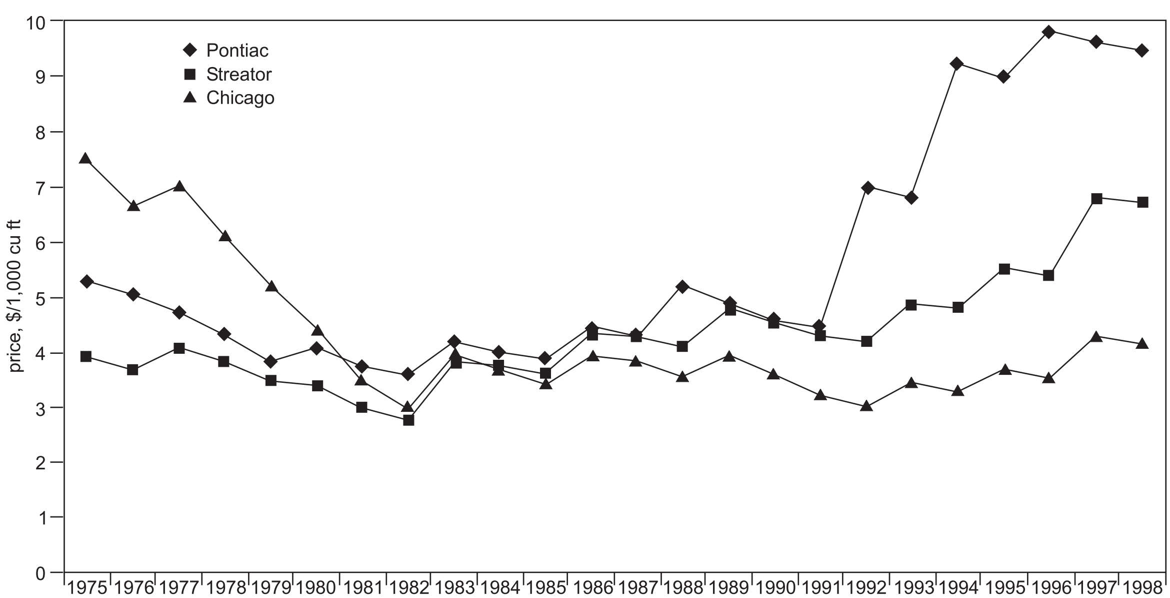

Figure 1 Prices (deflated 1982–1984 = 100) paid by consumers for surface water in selected cities in Illinois, 1975–1998. 1 cubic foot = 7.481 gallons.

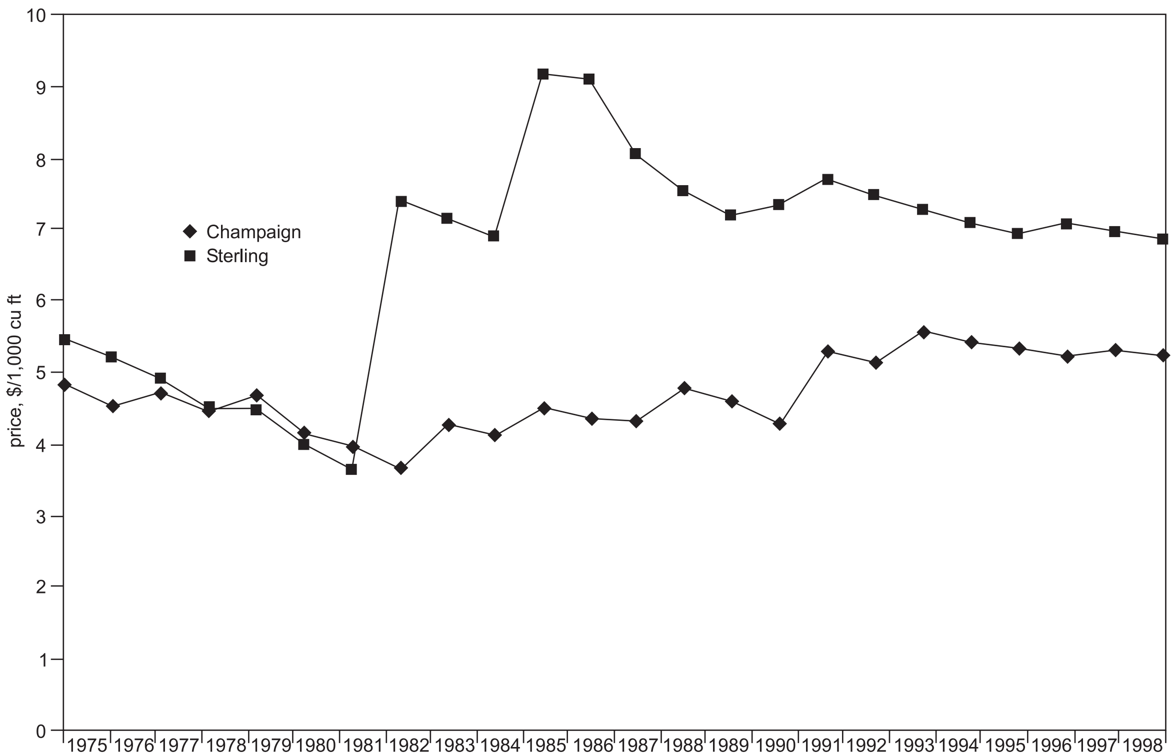

Figure 2 Prices (deflated 1982–1984 = 100) paid by consumers for groundwater in two Illinois cities, 1975–1998.

The magnitude of change in the Consumer Price Index is not necessarily the same as cost inflation for the water utilities. However, high rates of growth in the Consumer Price Index may indicate periods of large cost increases for utilities as well. Although no single reason can be given for the uneven price development over time, an important factor is pricing policy based on average costs instead of the economically more acceptable marginal cost basis. Marginal cost is defined as the cost of adding one more unit of water supply, and prices are adjusted only after costs have increased. For example, unusually high inflation rates in the 1979 through 1981 period likely contributed to increased operating costs. Modernization and expansion might also have been responsible for the price increase (e.g., Pontiac) from 1991 to 1998.

Regulatory delays in allowing price adjustments are common, and cost increases may be accommodated in other ways (e.g., by increasing meter charges and/or fire protection and franchise charges). Some cost increases may not be recognized by regulators as legitimate, but other cost increases may be subsidized, keeping prices below market cost. Drinking water is supplied by water systems owned and operated by communities or by privately owned but regulated monopolies. Regulated monopolies enjoy a competition-free market within their designated geographic area, but their prices are subject to approval by a civic body consisting of appointed or elected citizens. Regulated monopolies are permitted a certain return on approved investments. In general, the prices charged by the utilities are strongly influenced by forces other than the market. When setting prices, regulatory bodies generally are guided by the average costs incurred by the utilities instead of the marginal costs.

Customers generally pay fixed monthly charges for the facilities needed to bring water to the place of use and meter its usage. A separate fixed charge for fire protection services is also paid by customers. The portion of customer monthly payments for the amount of water used varies. Across Illinois, charges in all three categories vary widely, depending on district (table 3). Customers in the City of Chicago pay the lowest fixed charges as well as the lowest price for water usage.

Table 2 Average growth rates (percentage per year) in prices of water (dollars per 1,000 cubic feet) in selected cities in Illinois, adjusted for inflation (1982–1984 = 100) and growth in the Consumer Price Index (CPI).

Growth rate	CPI	Champaign	Sterling	Pontiac	Streator	Chicago
1976–1998	4.82	0.64	2.67	3.59	3.07	–1.02
1976–1980	9.23	–2.78	–6.14	–5.04	–2.71	–15.33
1981–1985	4.84	2.07	23.99	–0.64	2.51	–3.44
1986–1990	4.13	–0.88	–4.24	4.12	5.50	1.75
1991–1998	2.56	2.85	–0.83	11.29	5.52	2.35

Table 3 Monthly water charges and prices (dollars) of selected utilities across Illinois in 1997.[1]

Water district	Meter charge	Fire protection and franchise charge	Price ($/1,000 gal)
Southern	10.50	1.23	2.65
Peoria	10.50	3.02	2.65
Pekin	10.50	2.40	1.82
Champaign	6.25	1.87	1.79
Streator	7.20	4.12	2.59
Sterling	7.30	3.27	1.85
Pontiac	6.60	4.99	3.01
Suburban Chicago	6.50	2.60	1.93
DuPage County	6.50	2.60	3.25
Fernway	6.50	2.60	1.75
Waycinden	6.50	2.60	2.11
Kankakee	8.00	1.02	1.83
University Park	4.50	5.75	1.29
Lincoln	5.49	2.91	3.23
Chicago	NA[2]	NA	1.07
Average	7.35[3]	2.93[3]	2.19

[1]Illinois Commerce Commission, Water/Sewer Section, Rates Department, December 31, 1997.

[2]Although meter, fire protection, and franchise charges are not available separately, their total for a month for Chicago was $7.99.

[3]Without Chicago.

Many factors are responsible for this variation in water prices. The shares of industrial, commercial, and residential consumption in a water utility's total sales are an important determinant of prices charged. Also significant are the number of customers served and the number of customers per square mile. Some costs (e.g., meters for monitoring usage) grow in proportion to the number of customers served. Other costs (e.g., the pipe network serving each block) result in lower cost per customer as the number of customers increases. Maintenance costs also increase proportionally with the number of customers. The average cost per customer may be lower in high population density areas than in low density areas, and new connections cost more than previous ones. Chicago's low fixed charges reflect its high customer density and are based on average costs rather than marginal costs. Consumption patterns also affect price. Inner city and apartment dwellers, for example, generally use less water on lawns than do suburbanites and owners of single-family dwellings. Why spatial price variations exist is thus a question that requires a separate study to answer and is not included here.

The average costs in 1997 for two major utilities—City of Chicago and IAWC—were examined to identify possible links between prices and cost because most water utilities base their pricing on average extraction costs (Howe et al. 1986, Moncur and Pollock 1988). Accounting methods of the two utilities differ significantly. Within IAWC itself, cost reporting details vary between Champaign, Alton, and Pekin divisions (table 4). For example, the operation and maintenance costs are included in the extraction cost in the Champaign division but not in the Alton division. In the Alton and Pekin divisions, interest payments are not reported separately. The total costs of all systems, however, are comparable. A comparison of total costs per thousand gallons of water sold with average prices per thousand gallons in this limited sample of four companies indicates only a weak statistical correlation.

Table 4 Annual costs (million dollars) for water supply across Illinois in 1997.

Cost category	City of Chicago	Champaign, Sterling, Streator, Pontiac[1]	Alton, Belleville, Granite City, East St. Louis[1]	Pekin[1]
Extraction[2]	36.70	10.74	NA[3]	0.65
Operation and maintenance	104.20	NA	9.76	NA
Depreciation	10.50	2.25	4.57	0.39
Interest	11.20	2.30	NA	NA
Other	59.20	2.94	NA	NA
Total cost	221.80	18.23	14.33	1.04
Average total cost, $/1,000 gal	0.55	2.23[4]	0.86	0.30
Price, $/1,000 gal	1.07	1.79	2.12	1.82

[1]IAWC.

[2]Cost of source of supply, power, and pumping.

[3]NA, not available separately.

[4]Costs exceed price per 1,000 gallons in 1997. Company officials pointed out that the rate-making procedure often results in delays in cost recovery, and some costs, for example charitable sales of water, are borne by shareholders. Longer-term aggregated accounting is needed for an accurate financial picture of the company.

Economic Value, Scarcity Rents, and Prices: The Case of Chicago

When an existing source of water is exhausted, additional investments are required to make a new source available. In general, the costs of accessing the new source are greater than the current costs because the lowest cost source is accessed first. Underpricing occurs when the increased costs from a shift to the new source over the lifetime of the new source, also called "scarcity rent," is not accounted for in pricing decisions. Underpricing can occur, for example, when water utilities base their pricing decisions on average costs and on regulatory guidelines received from the Illinois Commerce Commission. There are also strong political incentives to hold down water prices. However, in view of concerns about the adequacy of future supply to meet growing demands, it may be worthwhile to examine the true economic value of water, which is reflected in the scarcity rent and the efficient price considering the scarcity rent.

Suppose that a water supply utility obtains its water from a source that has limited capacity or, like Chicago, has quota restrictions on the amount of water that can be pumped. Suppose also that the demand exceeds the supply. Then the utility must look for alternative sources to supply water as the currently available reserves are exhausted or the quota limitation has been reached. The utility must anticipate higher costs for supplying water in the future. Prudent use of water resources requires that water pricing policies consider the scarcity rent. Data are sufficient to estimate scarcity rents and values for water for the Chicago region.

The Chicago area water supply system is an example of a utility facing the problem of expected future scarcity from its current source and, hence, higher future cost. Northeastern Illinois, with the City of Chicago and the nearby suburbs in Cook, Will, DuPage, McHenry, Kane, and Lake Counties, could start suffering from water scarcity in the decades ahead (Injerd 2000, McConkey 2000, Northern Illinois Planning Commission 2001). The population in this area is expected to grow by about 25% in the next two decades; this growing population and accompanying industrial growth will increase the demand for water, but, as stated earlier, the area is already near its maximum withdrawal allowance. The scarcity rent would be the cost savings that would result from postponing the need to access an alternative source or resorting to backstop technology (Turvey 1976). A backstop technology is an alternative high-cost technology or extraction from an alternative high-cost reserve. Depletion of current reserves and/or degradation of the quality of the current resource are possible reasons why backstop technologies are adopted. Desalination of sea water, which is more expensive today than use of conventional water sources, is one example of a backstop technology suitable for coastal areas. In the case of Chicago, exploration for and pumping of groundwater from deep aquifers or obtaining water from distant areas using extensive pipelines could be possible higher cost alternatives. If the new source requires additional steps for water purification, cost increases further. In addition, other potential users may be considering the new source, leading to competition in the water market.

Theory of Scarcity Rents and Pricing of Natural Resources

For the efficient use of a natural resource such as water, the price should equal the sum of the marginal cost of extraction and the scarcity rent (Howe et al. 1986, Moncur and Pollock 1988). Let *C* be the marginal extraction cost θ and be the scarcity rent; then, the efficient price of a marginal unit of water may be represented as shown by Moncur and Pollock (1988):

$$P = C + \theta. \tag{1}$$

Assume that water scarcity problems will occur in *T* years. After *T* years, a higher-cost alternative source will have to be found to supplement the currently available reserves. Assume that the costs in both the periods—up to and after year *T*—increase at an exponential rate. Let the growth rates of costs during the first (before the year *T*) and second periods (*T* and later) be g_1 and g_2, respectively. Letting C_t denote the extraction cost function in year *t*, then

$$C_t = \begin{cases} C_1 = K_1 e^{g_1 t} & 0 < t < T \\ C_2 = K_2 e^{g_2 t} & t \geq T. \end{cases} \tag{2}$$

where C_1 is the extraction cost until year *T*, C_2 is the extraction cost after *T* years, and K_1 and K_2 are constants. The postulated extraction cost curve represented by these functions is shown in figure 3.

At the end of year *T*, the cost curve is assumed to shift up because an alternative source of water supply or a backstop technology is more expensive. After *T* years, the cost curve rises at the exponential rate, g_2. The expected upward shift in the cost curve after *T* years should result in scarcity rents in the period before *T* . The magnitude of the scarcity rent then is equal to the decrease in the present value of future costs if year *T* can be postponed, thus postponing the use of the alternative source or backstop technology (Moncur and Pollock 1988). Given the cost functions presented in equation (2), the present value of the future stream of costs at time *t*, assuming that the cost function shifts at year *T*, is

$$\int_t^T K_1 e^{g_1 t} * e^{-r(q-t)}\, dq + \int_T^\infty K_2 e^{g_2 t} * e^{-r(q-t)}\, dq \tag{3}$$

where r is the discount rate, and q corresponds to T, the base change of the integration. Conservation and/or an increase in efficiency of water use can postpone the year T. Now assume that the current water conservation practices result in more efficient use of water and that the supply agency does not have to shift to the higher-cost alternative at year T. The present value of the future stream of costs, then, is

$$\int_t^\infty K_1 e^{g_1 t} * e^{-r(q-t)}\, dq. \tag{4}$$

The present value of the additional costs (C_{PV}) of resorting to the next higher-cost alternative and/or backstop technology is

$$\begin{aligned} C_{PV} &= \int_t^T K_1 e^{g_1 t} * e^{-r(q-t)}\, dq + \int_T^\infty K_2 e^{g_2 t} * e^{-r(q-t)}\, dq - \int_t^\infty K_1 e^{g_1 t} * e^{-r(q-t)}\, dq \\ &= \frac{K_2 e^{g_2 T - r(T-t)}}{g_2 - r} - \frac{K_1 e^{g_1 T - r(T-t)}}{g_1 - r}. \end{aligned} \tag{5}$$

The derivative of C_{PV} with respect to time, T, measures the present value of savings in costs from postponing the switch to the higher cost alternative by one time period. Thus, the scarcity rent, SR, is

$$SR = \frac{dC_{PV}}{dT} = K_2 e^{g_2 T - r(T-t)} - K_1 e^{g_1 T - r(T-t)}. \tag{6}$$

In other words, equation (6) measures the savings in costs per unit time if the water supply agency can postpone resorting to the higher-cost alternative sources of water supply to meet the demands.

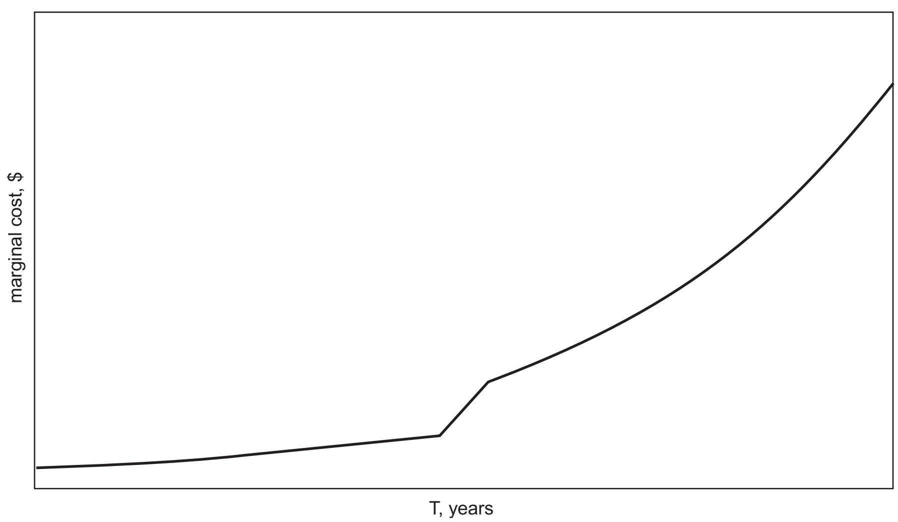

Figure 3 Marginal extraction costs.

Estimate of Scarcity Rents and Efficient Prices in the Chicago Region

In order to estimate the scarcity rent, *SR*, estimates of *T*, g_1, g_2, and *r* are needed. *T* is assumed to be 50 years based on expert assessment that the Chicago area may experience water shortages from current sources by the middle of the twenty-first century or earlier (Injerd 2000, McConkey 2000, Northern Illlinois Planning Commission 2001). Extraction costs for the Chicago water system in the 1987 through 1997 period grew at an annual exponential rate of 5.0%. This rate is assumed to continue in the future. Thus, g_1, and g_2 are both assumed to be 5.0% (table A2). At this time, neither the alternative water sources after *T* nor the future costs are known. Therefore, three alternative scenarios are considered. The first scenario assumes that the cost curve shifts upward by 10% at $T = 50$ years. The second and third scenarios consider cases in which the cost curve shifts up by 20% and 30%, respectively, at $T = 50$ years. The discount rate *r* is assumed to be 2%.

In order to compute the current extraction cost, we used the expenditures associated with source of supply, power and pumping, and purification in the 1997 financial report of the City of Chicago water supply system (table A3). The extraction costs in 1997 were about $0.22 per 1,000 gallons (table 5).

The future extraction costs were estimated on the basis of current costs, projected growth rates, and estimated upward cost shifts at $T = 50$ years; these costs are depicted in figure 4. Cost curve MC1 represents the projected marginal extraction costs under the assumption that the cost shifts up by 10% in year *T*. Curves MC2 and MC3 depict the projected marginal costs when the cost curves shift up by 20% and 30%, respectively, at year *T*.

The projected marginal extraction costs, scarcity rents, and estimated efficient prices under the three hypothetical scenarios over 50 years, starting in 1998, are presented in table 6. All scenarios

Table 5 Cost of extraction and purification of water in the City of Chicago in 1997.[1]

	Expenditure (million $)	Average cost ($/1,000 gal)
Source of supply	0.20	0.00
Power and pumping	36.50	0.09
Purification	48.10	0.12
Total operating expenses	84.80	0.22[2]

[1]Source: Department of Water, City of Chicago.

[2]Total does not add up due to individual rounding.

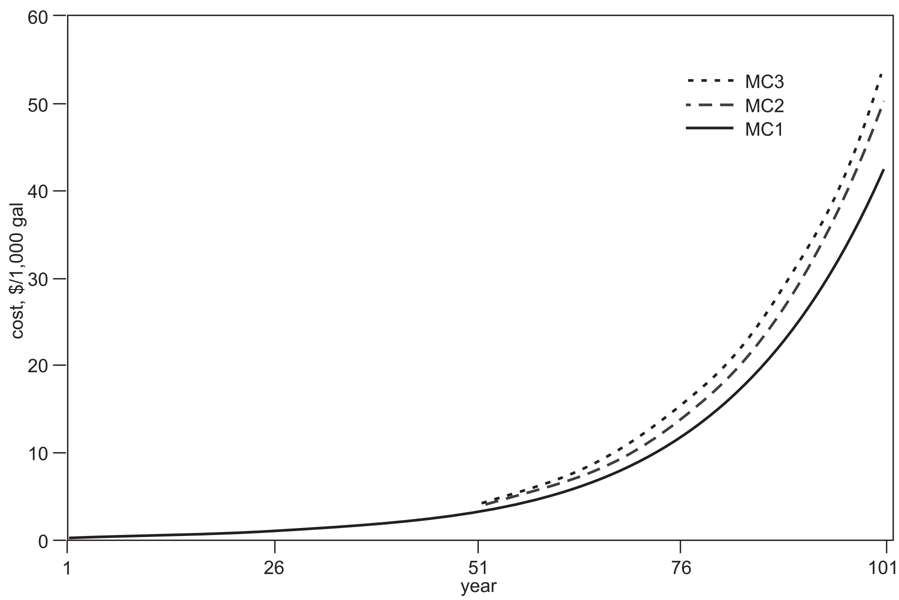

Figure 4 Projected marginal extraction cost (MC) of water in the City of Chicago starting in 1998.

Table 6 Marginal extraction cost (MC), scarcity rent (SR), and efficient price (EP) for the marginal unit of water in the City of Chicago.

T[1]	MC	SR1	EP1	SR2	EP2	SR3	EP3
1	$0.24	$1.20	$1.44	$1.31	$1.55	$1.42	$1.66
5	$0.30	$1.31	$1.60	$1.43	$1.72	$1.55	$1.85
10	$0.38	$1.45	$1.84	$1.59	$1.97	$1.72	$2.11
15	$0.50	$1.61	$2.11	$1.76	$2.26	$1.91	$2.41
20	$0.65	$1.79	$2.43	$1.95	$2.60	$2.12	$2.76
25	$0.84	$1.98	$2.82	$2.17	$3.00	$2.35	$3.19
30	$1.09	$2.20	$3.28	$2.40	$3.49	$2.60	$3.69
35	$1.41	$2.43	$3.84	$2.66	$4.07	$2.88	$4.29
40	$1.83	$2.69	$4.52	$2.94	$4.77	$3.19	$5.01
45	$2.37	$2.98	$5.35	$3.25	$5.62	$3.53	$5.90
50	$3.08	$3.30	$6.37	$3.60	$6.67	$3.90	$6.98
51		$0.00		$0.00		$0.00	

[1]T, time in years, starting in 1998.

assume a 2% discount rate and a switch to the higher cost alternative in 50 years. Assuming a 5.0% exponential growth rate, the average extraction cost will increase from $0.24 per thousand gallons to $3.08 per thousand gallons in 50 years.

The results in table 6 suggest that, under scenario 1, the water reserves in the Great Lakes in 1998 would have a scarcity rent of $1.20 per thousand gallons. Under scenarios 2 and 3, the estimated scarcity rents would be, respectively, $1.31 and $1.42 per thousand gallons. In 50 years (in 2047), the rents would rise to $3.30 per thousand gallons in scenario 1, $3.60 in scenario 2, and $3.90 per thousand gallons in scenario 3. In all three scenarios, the scarcity rents fall to zero in the 51st year because the water supply system, by assumption, shifts to the higher cost alternative in year T and then remains on the higher cost trajectory after year T. Efficient prices recoup the marginal cost as well as the scarcity rent. As shown in table 4, the total average cost per thousand gallons in Chicago in 1997 was $0.55. The marginal cost per thousand gallons in 1997 was $0.22 (table 5). Thus, the average cost was about $0.33 higher than the marginal cost to cover the costs of distribution and administration. This relationship may or may not continue in the future; marginal cost may exceed the total average cost. Therefore, future water prices should be determined by the greater of either the average or the marginal cost, plus the scarcity rent.

Scarcity rents provide an indication of the suggested price that will account for the potential scarcity of the resource in the future. A suggested price incorporating this consideration then would be the sum of the average cost and the scarcity rent. In 1998, the total cost of supplying water would have been $1.78 per thousand gallons ($0.24 marginal cost + $0.34 distribution cost + $1.20 scarcity rent), assuming that distribution and administration costs increased by 5.0% from 1997 to 1998. Similarly, under scenarios 2 and 3, the prices would be $1.89 and $2.00, respectively. These results indicate that the current price charged by the City of Chicago, $1.07 per thousand gallons, is substantially less than the estimated efficient price. Actual water sales and revenues received in 1997, according to the accounting report of the City of Chicago water system, indicate that the effective average receipts were only about $0.69 per thousand gallons. The real magnitude of the underpricing thus remains uncertain because of discounts for greater use, charitable activities, and the absence of any consideration of marginal cost and scarcity rents.

Conclusions and Policy Implications

This report considers the economic value of water as an essential resource in the state in relation to its growing demand, especially in the fast-growing northeastern areas. Indications of an impending water shortage in the Chicago area are revealed by expert opinions from important water research agencies in the state. The City of Chicago water system already pumps about 85 to 90% of the maximum legally allowable quantity of water from Lake Michigan and is probably approaching the limits of sustainable groundwater extraction from aquifers in the area. Because of the lack of sustainable yield estimates for the various aquifers, however, it is impossible to make definitive assessments as to when water scarcity may become a reality and what additional costs will have to be paid to secure alternative water resources. It appears certain that, as demand grows, water scarcity will eventually occur. Previous research has indicated that water demand responds to price changes, although neither strongly nor uniformly across communities. Water demand is influenced also by factors such as household income. However, little research exists to determine what price levels would be economically rational.

The concepts of marginal costs and scarcity rent are used in this paper to present a guideline to calculate an economically rational price level for water in the Chicago area. Data show that current prices are determined more by average costs than by marginal costs. Moreover, prices currently charged by water utilities do not account for the true value of water in the face of anticipated scarcity. Political factors also have a strong influence on water pricing policies. Real water prices in the Illinois communities studied followed a downward trend from 1975 until 1982, which continued in Chicago through 1998. In the other studied communities, real water prices generally have been increasing since 1982, although neither consistently nor uniformly among communities.

Scarcity rents provide a means to price current water supplies to account for future scarcity costs. However, relevant data for estimating scarcity rents of water resources were available only for the Chicago region. Those data strongly suggest that computed prices including scarcity rent would be much greater than the prices Chicago currently charges for water. The results of the study also suggest that consideration of scarcity rents and marginal costs in the pricing of water could encourage reduced water consumption and help postpone the occurrence and/or intensity of the anticipated water scarcity.

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Appendix

Table A1 Counties in 11 Illinois regions.

Region	County
Chicago	McHenry, Lake, Kane, DuPage, Cook, Kendall, Will, Grundy, and Kankakee
Rockford	Jo Daviess, Stephenson, Winnebago, Boone, Carrol, Ogle, DeKalb, Lee, and Whiteside
Rock Island	Rock Island, Henry, Mercer, Knox, Warren, Henderson, McDonough, and Hancock
Peoria	Bureau, LaSalle, Putnam, Marshall, Stark, Peoria, Tazewell, Fulton, and Woodford
Champaign	Livingston, McLean, Ford, Champaign, and Vermilion
Decatur	DeWitt, Piatt, Douglas, Edgar, Coles, Clark, Cumberland, Shelby, Moultrie, and Macon
Springfield	Mason, Logan, Menard, Sangamon, Cass, Morgan, Macoupin, Montgomery, and Christian
Quincy	Adams, Schuyler, Brown, Pike, Scott, Greene, Calhoun, and Jersey
East St. Louis	Madison, Bond, Clinton, Washington, St. Clair, Monroe, and Randolph
Central	Fayette, Effingham, Jasper, Crawford, Marion, Clay, Richland, Lawrence, Wayne, Edwards, Wabash, and White
Carbondale	Jefferson, Hamilton, Perry, Franklin, Jackson, Williamson, Saline, Gallatin, Union, Johnson, Pope, Hardin, Alexander, Pulaski, and Massac

Table A2 Cost (millions of dollars) of providing water in Chicago, 1987–1997.[1]

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Source of supply	1.1	0.1	0.9	0.7	0.6	0.6	0.1	0.4	0.5	0.5	0.2
Power and pumping	33.7	31.2	35.0	31.3	30.3	31.6	32.7	33.4	38.1	37.8	36.5
Purification	27.7	25.9	28.8	26.8	30.5	33.0	35.7	43.2	45.6	47.0	48.1
Total	62.5	57.2	64.7	58.8	61.4	65.2	68.5	77.0	84.2	85.3	84.8

[1]Source: Department of Water, City of Chicago.

Table A3 Costs of pumping and supplying water in the Chicago area in 1997.[1]

	Expenditure (million $)	Average cost ($/1,000 gal)
Source of supply	0.20	0.00
Power and pumping	36.50	0.09
Purification	48.10	0.12
Transmission and distribution	56.10	0.14
Accounting and collection	10.50	0.03
Administration and general	11.20	0.03
Central services and general fund reimbursement	56.80	0.14
Other expenses	2.40	0.01
Total operating expenses	221.80	0.55[1]

[1]Individual rounding causes total not to add up exactly.

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