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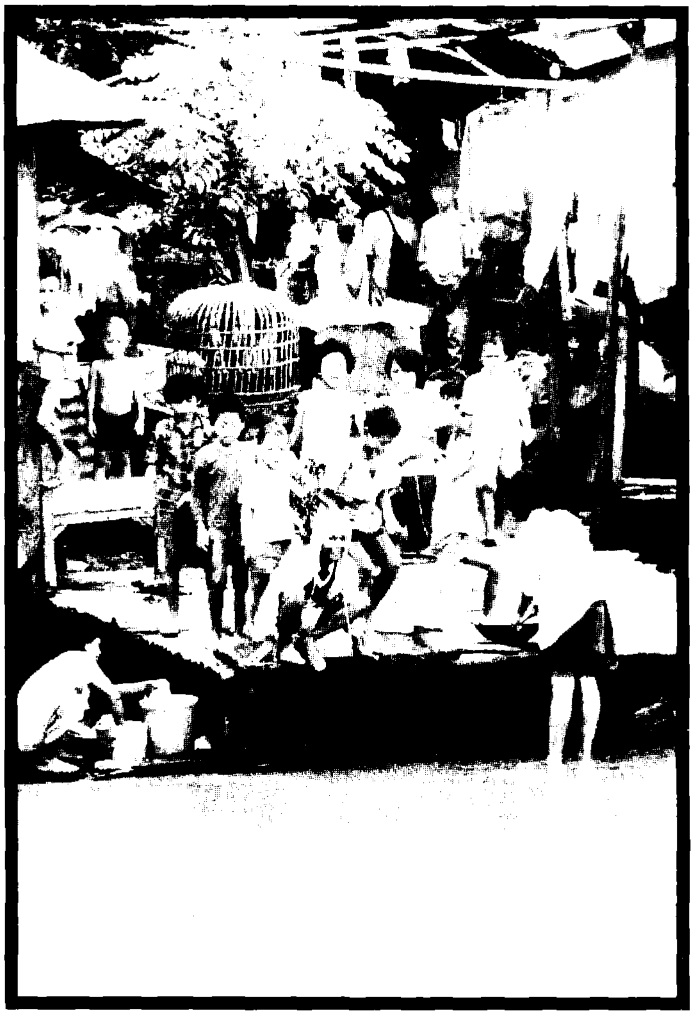

Water Conservation and Reallocation:

Best Practice Cases in Improving Economic Efficiency and Environmental Quality

A World Bank-ODI Joint Study

by Ramesh Bhatia, Rita Cestti and James Winpenny

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Rishi Sharma: Groundwater Markets in India. (Case 6.2.2)

Executive Summary

Current water resource management practices in most developing countries result in unnecessarily high economic and environmental costs. Leakage from piped water supply distribution systems, for example, is frequently as high as 60 percent; and irrigated agriculture, which accounts for over 80 percent of total water withdrawals, can result in water losses as high as 70 percent. Such costs are especially difficult to bear for countries that are facing increasing water demands, widespread water quality degradation, fiscal constraints that limit options for water supply development projects, and a history of poor sector performance.

The magnitude and consequences of such costs have spurred the emergence of a global consensus on principles for improving water resource management. The principles – which have been articulated at the International Conference on Water and the Environment in Dublin in 1992, in Agenda 21 of the UN Conference on the Environment and Development, and in the World Bank's Water Resources Management Policy Paper – state that water should be managed as both an economic and social good, at the lowest appropriate level using a demand-driven participatory approach, and with a comprehensive, cross-sectoral perspective.

Improving water management will require that developing countries address the major constraints that currently undermine the allocation and efficient use of their water resources. As part of the learning effort, this study is a first attempt to: (i) explore the implications of the management principles for changing current inefficient practices and (ii) identify "best-practice" cases where implementation of the principles has resulted in conservation and improved allocation among competing uses. As such, the study is intended not only to broaden perspectives about the options available (in addition to supply augmentation) for reducing the gap between water supply and demand; it is intended to promote confidence in these options through its detailed review of experiences–some well known, others less known–being gained world wide.

Experiences in both developing and developed countries, as documented in this report, show that improved policies for conservation and reallocation can have major benefits. In general, three levels of intervention are necessary:

1. actions that alter the institutional, legal, and macroeconomic framework (the enabling environment) that governs water use
2. market-based and nonmarket-based instruments (incentives) that directly or indirectly influence the behavior of water users and providers
3. project lending that provides for efficient technologies, demand management, retrofitting and other targeted programs (direct interventions)

The examples analyzed in this report show that these elements are not substitutes for one another but are interdependent and mutually reinforcing. Indeed, a major finding of the study is that no single intervention is decisive in achieving the desired results. A synergistic mix of interventions is required for efficient and sustainable resource use. For example, appropriate pricing polices are necessary, but not sufficient, for improving allocation and water-use efficiency; the reviewed cases indicate that water pricing works best when combined with supportive regulatory measures, economic incentives, and other non-market instruments such as water licensing and educational programs.

Similarly, a careful mix of elements (including regulations, tariffs, pollution-control charges, and fiscal incentives) can influence industrial users to reduce water demands and increase user efficiency, with significant environmental as well as economic benefits. Successful experiences with water markets shed light on the mix of elements (clear legal rights, physical means for water transfer, and interventions to prevent adverse third-party and environmental effects) required to improve water allocation among competing users.

Evidence from countries at different stages of development suggests that water conservation and reallocation solutions are widely applicable with local variants and adaptations. Still, the chances for success will be greatest when there is public support for and understanding of the policies to be adopted and if the policies are compatible with overall economic efficiency, environmental quality, and equity objectives.

CONTENTS

Abbreviations

af	acre-foot	maf	million acre-feet
BCM	billion cubic meters	MCM	million cubic meters
BOD	biological oxygen demand	mg	milligram
COD	chemical oxygen demand	mgd	million gallons per day
m^3/sec	cubic meter per second	ppm	parts per million
m^3	cubic meter	sq m	square meter
ft	foot	SS	suspended solids
ha	hectare	TCM	thousand cubic meters
kg	kilogram	ton	ton UK
l	liter	gal	imperial gallon
lcd	liters per capita per day	US gal	US gallon
m	meter		

Conversion factors

1 hectare	2.741 acres	1 Imperial gallon	4.546 liters
1 cubic meter	1,000 liters 264 US gallons	1 acre-foot	325,900 US gallons 1,233 cubic meters 0.365 hectare-foot
1 liter	0.264 US gallons 0.001 cubic meters	1 million cubic meters	811 acre-feet
1 US gallon	3.788 liters		

Typcial water requirements

Domestic Use		*Industrial Use*	
Drinking and cooking	3-6 lcd	Steel	500 m^3 of water/1 ton
Laundering	20-40 lcd	Pulp	600 m^3 of water/1 ton
Washing	4-6 lcd	Textile	400 m^3 of water/1 ton
Personal hygiene	10-15 lcd		
Bath, shower	20-40 lcd	*Agricultural Use*	
Flushing toilet	20-40 lcd		
House cleaning	3-10 lcd	Paddy (one season)	5,000-6,000 m^3/ha/year
Watering garden	50-75 l/sq-m/day	Wheat (one season)	6,000-6,500 m^3/ha/year
Average	150-200 lcd 55-75 m^3/capita/year	Vegetables	7,000-10,000 m^3/ha/year

INTRODUCTION

This study[1] is part of the learning process on water resources management. It explores how to translate the new consensus on water resources management into practice. This consensus is based on principles which focus on demand, water as an economic good, and institutional arrangements. The study also reviews efforts to improve the allocation of water resources and encourage efficiency in its use in various ecological, developmental, and institutional settings. It reviews best practice cases where water demand management has improved not only economic efficiency, but also has helped to achieve environmental benefits.

For the purpose of this study, the term "water demand management," which encompasses conservation and reallocation, refers to any measure designed to reduce the volume of fresh water being withdrawn from surface or groundwater sources but without reducing consumer satisfaction and/or output. Under this broad definition, the introduction of transferable water use rights becomes a water demand management measure because it encourages water trading between agricultural and municipal uses and can reduce the gap between urban water supply and demand without the need to withdraw water from additional sources.

Part one reviews best practices and examines the policy messages which emerge. It is organized into four sections: chapter 1 describes the rationale for considering conservation and reallocation as least-cost means of meeting growing urban demands; chapter 2 reviews experiences with conservation and reallocation in both developed and developing countries; chapter 3 summarizes the policy variants that have been used for water conservation and reallocation, and presents some conclusions about their effectiveness; and chapter 4 draws some general conclusions and recommendations from this review of experiences.

Part two provides greater details of the various experiences with water demand management in order for the reader to see what principles are illustrated and to gain whatever additional insights their own experience makes possible. This part has two sections: chapter 5 introduces the case material on conservation by user sectors; and chapter 6 presents the case material on reallocation among sectors.

PART ONE

POLICY INSTRUMENTS THAT ENCOURAGE BEST PRACTICE: A REVIEW OF EXPERIENCE

Chapter 1
The Growing Interest in Conservation and Reallocation

This section describes the rationale for considering conservation and reallocation as a least-cost means of meeting growing urban demand.

1.1 The Need for Conservation and Reallocation

The need to conserve water and encourage its allocation to higher-value uses has not always been evident. In most countries, water has been treated as though it were available in unlimited quantities and supplied at zero or low cost to consumers who would resent the notion that water has an economic value. Sectoral water allocations have been made without considering their economic implications. Investments in the water sector, in turn, have been guided by a "requirements approach," ignoring the significant role of the price of water and its potential effects upon the quantity of water consumed.

Rapid urbanization and industrialization have increased water demand for household, commercial, and industrial uses in urban areas both absolutely and relative to agricultural demand. The share of industrial and domestic demand is almost certain to increase from the current share of around 20 percent. These trends have given rise to serious conflicts between agricultural and municipal users. New supplies have to be brought from long distances, often 50-200 kilometers from metropolitan areas, adding high investment costs for conveyance systems and additional pumping costs. Both quantity and quality problems mean that the costs of supplies of adequate quality are rising rapidly. The cost of a unit of water from the "next" project is often double or triple the cost of a unit from the current project.

It is no longer possible to take an exclusively supply-oriented approach that takes requirements as given and concentrates on finding the water to meet them. Alternatives to investment in new capacity augmentation exist on both the supply and the demand side. Supply-side measures include the reduction of evaporation from reservoirs and water channels, and reduction of leaks from water conveyors. Improvements to the distribution network to reduce waste and losses can be regarded as either supply or demand-side measures, depending on their location and the degree of cooperation required from the user [Boland 1991]. Demand-side measures include actions that influence water user behavior while providing an acceptable level of service with a reduced volume of water in most of the cases.

Technical, regulatory, and market-oriented measures that affect water use and reduce waste and losses from the source point will be called "demand management" in this study. In general, these options enable rising levels of consumption to be met without major new investment, and they also avoid serious environmental costs. Such measures include: leak detection; waste reduction (encouraging consumers to cut out wasteful uses); investment in appliances, processes, and technologies that reduce water input without reducing consumer satisfaction and/or output; treatment of industrial effluent and wastewater for recycling and reuse; and redirecting water to the highest social value.[2] The policies that encourage demand management include pricing water and charging for pollution, regulations and restrictions on water use, exhortation and education, and encouraging water trading among and between users.

Reallocation of water resources is an issue that is rapidly gaining importance. Reallocation or diversion of water from agricultural to municipal uses is increasingly recognized as an option by decision makers seeking to reduce the gap between urban water supply and demand. As population and economic activities expand, greater demands are made on relatively limited supplies. At present, municipal and industrial demands are in direct competition with other water uses, especially agriculture. However, in many instances, the agricultural use is guaranteed by previous allocation decisions or customary rights, which did not take into account the economic scarcity value of water. In earlier years, there was generally enough water for all reasonable uses.

Institutional arrangements prevailing in developing countries to allocate water have encouraged the use of excessive quantities of water in agriculture because of the strong bias of governments to expand irrigated agricultural frontiers. Nowadays, water has become increasingly scarce, and the economic implications of that misallocation are extremely high. Today more than ever, there is a need to reallocate water now used for irrigation to places of highest and best uses, e.g., domestic and industrial uses.

The scope for reallocation can easily be grasped by looking at how much water needs to be taken away from the agricultural sector and transferred to urban areas and the net economic gains involved. Many studies of the western United States indicate that only 10 percent of the water presently consumed by the agricultural sector would almost double the water available to other consuming sectors. This volume, in many instances, would be enough to meet future needs of rapidly growing urban areas. In doing so, water will be moved to higher value uses, since water used for municipal purposes is valued at more than ten times its agricultural use [Gibbons 1986].

1.2 Inefficient Use of Water Resources

Water resources sectors in developing countries are characterized by inefficiencies in allocation among alternative uses and significant waste in individual subsectors. Water used in irrigated agriculture, over 80 percent of total water withdrawals in developing countries, is very often "high volume, low quality, and low value." Only a small fraction of water diverted in most large developing-country systems is available for plant use, typically 25-30 percent, compared to 60-70 percent in advanced-country systems. In the urban water supply sector, there is also tremendous waste (40-60 percent) of water in distribution systems and homes, industries, commercial establishments, and public facilities.

Most developing countries do not have instruments–either regulations or economic incentives–and related institutional structures and rules that reflect scarcity supply and internalize the externalities that arise when one user affects the quantity and quality of water available to another. In both irrigation and water-supply sectors, prices charged for water are much lower than the cost of providing supplies.[3] Piped water tariffs are based on average-cost pricing rather than marginal-cost pricing, and they ignore the opportunity cost of water. Similarly, the effects of damages caused by pollution of surface and groundwater are ignored in setting water tariffs. From an economic viewpoint, excess quantities of water are used, and excess pollution is produced.

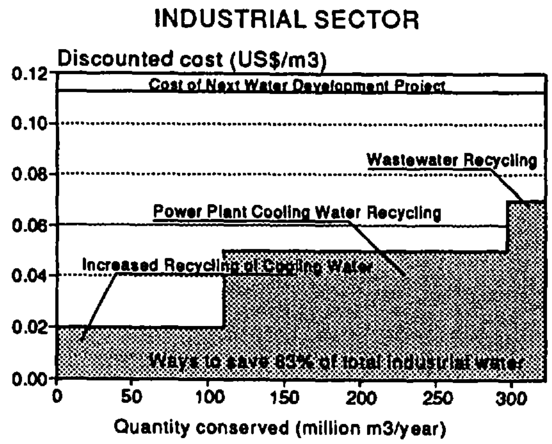
1.3 Conservation and Reallocation Can be Low-Cost Options

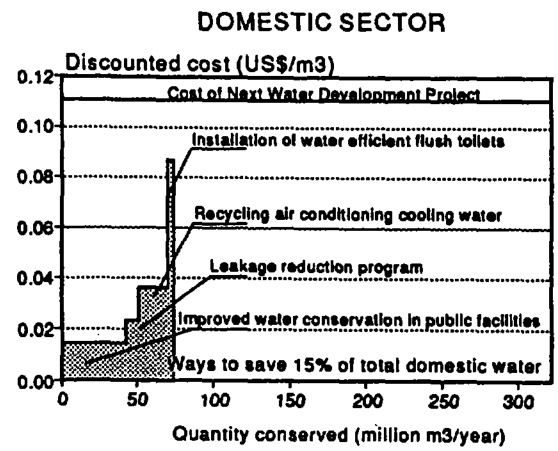
Where incremental supplies can be provided only at high cost, water conservation can be more cost-effective than increasing supply. From the private viewpoint, improving the efficient use of water is economic as long as the unit cost of saving water is less than the cost of obtaining additional water. From the point of view of a public utility taking a social perspective, conservation is preferable as long as its costs are less than the resource cost of new supplies. For instance, a recent study of water management policy options for Beijing has determined that a variety of different conservation strategies can be cost effective relative to the cost of supply augmentation (Box 1.1).

The results of the study show that, domestic water use in Beijing could be reduced by about 15 percent and industrial demand could also be reduced by one third at unit costs ($0.03/m^3 to $0.09/m^3) which are substantially lower than the cost of the next water development project ($0.13/m^3).[4] Water savings in domestic use could be realized through leakage reduction programs, water conservation in public facilities, and installation of water-efficient flush toilets. Industrial savings, in turn, could be obtained through recycling industrial water and reuse of treated municipal effluent.

Reallocation of water through voluntary transfers from relatively low-value agricultural use to higher-value municipal or industrial use in response to economic incentives may also avoid the high costs of developing new supply sources and can increase the benefits gained from the use of water. A recent study under-

Box 1.1: The cost of conserving water in Bejing, China





A comparison between the economics of different conservation measures against alternative supply investment has been made across industrial and domestic users of the Bejing area. Alternative supply and demand management measures have been ranked in increasing order of cost. This provides the supply curve for conserved water in the domestic and industrial sector. The supply curves above show cumulative water savings versus the unit cost of conserved water. This analysis shows that the cheapest way of increasing water supply is through more efficient management of existing water supply systems.

Managing Domestic Water Demand. Domestic water use can be reduced by about 15 percent through leakage reduction programs, water conservation in public facilities, and installation of water-efficient flush toilets. The associated costs are substantially lower than the marginal cost of new water supplies.

Managing Industrial Water Demand. Industrial water demand can also be reduced by one third by recycling industrial water and reuse of municipal wastewater. The associated costs are substantially lower than the cost of new supplies.

Source: M.M. Hufschmidt, J. Dixon, and Zhu, "Water Management Policy Options for the Bejing-Tianjun Region of China", East-West Center, Hawaii, 1987.

taken by the water company in Santiago de Chile, for example, shows that the most economic means to expand its supplies to serve the city is to buy additional water shares from farmers along the Maipo river. The ratio between the cost of buying water shares and the cost of constructing a new dam is 1 to 5. The system of transferable water-use rights introduced in 1981 allows market forces to allocate water, making possible the occurrence of voluntary transfers [Hearne 1993].

A mix scheme of conservation and rural/urban transfer has also proven to be a cost-effective option in the western United States. The existence of water markets provides farmers with the right incentives to increase their efficiency of water use and conveyance making possible the selling of conserved water to urban users. The same outcome can also be realized by having those who benefit from the rural/urban transfer to pay for the costs of conservation measures.

1.4 Environmental Benefits of Conservation and Reallocation

Water demand management policies intended to modify water use and allocation patterns result not only in reduced demand, but also in reduced adverse environmental effects of polluted return flows. An appropriate mix of water price, effluent charges, and fiscal incentives can encourage water users to invest in water-saving technologies, increase recycling, and reuse their treated effluent. These measures provide, in many instances, environmental benefits, over and above the economic benefit of lower water costs, by lowering volume and pollution loads of wastewater discharge into water bodies. Thus, water demand management has implications for improvements in environmental quality.

Additional environmental quality benefits are likely to be obtained by further improvements on current institutional rules aiming at encouraging transfers of water from low-value uses to high-value uses. Elimination of existing constraints can result in balancing economic efficiency, environmental quality, and other social objectives.

CHAPTER 2

EXPERIENCE WITH CONSERVATION AND REALLOCATION

There is compelling evidence that improved water resources policies can have major impacts. In a number of cases in developed and developing countries, on the one hand, pricing and tariff combined with regulations have produced savings of 20 to 30 percent and more. On the other hand, altered institutional structures and rules have improved efficiency in water use by allowing water transfers among and between users. This section reviews experiences with conservation and reallocation in both developed and developing countries.

2.1 Water Conservation in the Household Sector

In a number of developed countries–Israel, Canada, United States, Australia, and Great Britain–empirical analysis has shown that household water demand drops by 3-7 percent when prices rise by 10 percent. Water prices play an important role in determining consumption levels.[5] In many developing countries, there is a myth that prices do not play a significant role because the water bill is a small percentage of total household expenditure. In fact, there are few studies of household water demand in developing countries that support this belief. Price elasticities in urban Brazil and Mexico, as reported in table 2.1, were found to be -0.6 and -0.38, respectively [Gomez 1987]. In general, since water tariffs have been traditionally low, the incentives for efficient use in households have been low.

It is difficult to estimate elasticity of demand where there is no metering of consumption and price changes have not been significant. However, where "sharp" increases in prices have been made offsetting the "income effects" from rising living standards and consumers have had to pay higher prices for additional quantities (increasing block rates), consumers have reduced consumption. "Sharp" means large enough so water conservation goals are achieved. To the extent that tariffs have been low and people have not developed the habit of conserving water, the potential for savings is considerable if the right pricing policies are put in place. If water for domestic users were priced at the marginal cost of providing it (including the opportunity cost of water), consumers could be expected to respond by eliminating and reducing some uses [Hanke 1982]. Higher prices will reduce demand since the demand curve has a negative slope.

More experiences in developing and developed countries are summarized below.

2.1.1 Household Demand in Bogor, Indonesia

The water supply enterprise of Bogor, PDAM, faced high investment costs: the average incremental cost per cubic meter of the "next" scheme was double that of the current one. A decision was made to combine the augmentation of water supplies with demand management measures, e.g., price and non-price instruments, to bring down average water consumption and balance demand and supply (case 5.1.1).

Increased progressivity and the substantial increase in the average level of water rates were effective in reducing household consumption. As a result of the tariff increase of June 1988, average domestic water use decreased from 38 m^3 to 27 m^3. A 29 percent reduction in domestic water use was achieved after one year under the new water rate structure.

In March 1989, PDAM initiated a campaign to reduce water use aimed especially at customers with monthly consumption above 100 m^3. The campaign had three objectives: (a) to make customers aware of their water use habits; (b) to give advice on how to change those habits; and (c) to provide customers with estimates of costs and savings associated with conservation

Table 2.1: Water price and income elasticities for domestic water user groups

Investigator	Price Elasticity	Income	Elasticity Comments
World Bank (1994)	-0.37	+0.15	Average water prices. Survey of 138 households in Northern Jakarta, Indonesia. Data taken from World Bank (1988).
IWACO (1989)	-0.29 to -0.33	+0.4 to +0.5	Monthly sales of metered domestic consumers in Bogor, Indonesia
IWACO (1992)	-0.68	+0.37	Average water price. Cross-sectional analysis for 100 household in Jakarta, Indonesia.
IDB (1985)	-0.377	+0.323	Survey of 480 urban households in Mexico. Listed in Gomez (1987).
IDB (1984)	-0.37 to -0.44	+0.58	Survey of 4452 urban and rural households in Costa Rica. Listed in Gomez (1987).
IDB (1983)	-0.597	+0.784	Survey of 408 urban households in Brazil. Listed in Gomez (1987).
Jones and Morris (1984)	-0.34	+0.46	Average water price. Survey of 326 metered single-family households in Denver, Colorado, USA.

measures. This campaign was very effective in reducing wasteful use of water. Three months after the campaign started, average monthly water use decreased by 29 percent, from 159 m^3 to 113 m^3.

2.1.2 Household Demand in Arizona and California, USA

Water price increases plus increased use of water-saving technologies, regulations, and public education produced a substantial drop in Tucson's average per-capita consumption by 22 percent in 15 years, from 760 lcd in the mid-1970s to the current 590 lcd (case 5.1.2). The conservation program has allowed Tucson to postpone investment in groundwater wells and transmission facilities estimated at $45 million in 1983. The resulting average cost of saving water was $0.10/$m^3$, about 60 percent of the cost of treated water from the Central Arizona Project supplies.

The East Bay Municipal Utility District in California illustrates how a comprehensive water conservation program can improve the efficiency of municipal water use and ration scarce resources during droughts (case 5.1.3). During the 1988 and 1989 drought years, a drought program with mandatory conservation goals by customer group (single-family residential, multifamily residential, industrial, commercial, and irrigation), strict ordinances on water use, an extensive public relations program, and most important, a steeply progressive water rate structure produced large reductions in water use. The overall conservation target of 25 percent during the summer of 1988 over 1986 was exceeded: the actual reduction was 30 percent. Similarly, during 1989, the actual reduction was 27 percent against the target of 15 percent.

2.1.3 Household Demand in Perth, Newcastle and Melbourne, Australia

In Perth, Newcastle and Melbourne, Australia, significant reductions in domestic consumption of between 20 percent and 30 percent were achieved by the "pay-for-use" charging system, increasing the efficiency of water-using household appliances, an advertising campaign, and an education program aimed at school children (cases 5.1.4 and 5.1.5).

2.2 Water Conservation in the Industrial Sector

Significant conservation in the industrial sector is possible if an appropriate environment is created. Evidence suggests that regulatory measures and economic incentives, mainly water tariffs, have caused significant reductions in water demand in industrial units. There are examples where administrative and legislative

Table 2.2: Water price elasticities for industrial water user groups

Investigator	*Price Elasticity*	*Comments*
Williams and Suh (1986)	-0.721, -0.43, -0.72 to -0.98	For the average price, the marginal price, and the bill price, USA.
Ziegler (1984)	-0.98	Paper and chemical plants, USA. Average price.
Leone et al. (1974)	-0.96, -0.77, -0.88	Chemical, petroleum and steel industries, respectively, USA.
Rees (1969)	-0.958	Chemical water use, UK.
Gupta and Goldar (1991)	-1.32	Cross-sectional data for cotton, textile, paper, dairy product, ball-bearing, and distillery, India 1983-84.
Metaplanners (1992)	-0.45	Steel and related industries, India.

measures (licenses, quotas on water use and effluent discharge, and the introduction of water-saving technologies) have reduced industrial water consumption by 40-70 percent. Many different economic incentives can promote efficient use of water and improve water quality: water tariffs; effluent charges; pollution permits; and subsidized interest rates or soft loans for water-saving and/or effluent treatment equipment.

Empirical analyses of industrial water demand reveal that industrial water demand is more price responsive than residential water demand. In general, reported values of water price elasticity, which are listed in table 2.2, are much higher than the estimates of price elasticity obtained for residential demand, as presented in table 2.1. This relatively higher price elasticity of industrial water demand shows that industrial users are more likely to find alternative water supply sources or to go for conservation and recycling in adjusting to price increases (see table 2.2).

In many developing countries, since industrial units and thermal power plants often enjoy low water tariffs and easy availability, they often use "once-through" processes and cooling ponds instead of more water efficient cooling towers. Further, if pollution control regulations are either nonexistent or not stringent, there is no incentive for industrial units or thermal power stations to treat their industrial effluent and sewage for recycling in their plants. To the extent that they have to meet some effluent quality standards, the industrial units or thermal plants find it convenient (and inexpensive due to low water tariffs) to dilute their pollutants rather than treat their effluent.

In industrialized countries (with higher water prices and more rigorously enforced pollution control programs) demand for water has not increased in tandem with industrial output. Changes in process, technology, mix of industrial output, and increased recycling of effluent water have yielded increased output without adding to water requirements. In OECD countries, water use in 2000 will be, in many cases, 50 percent below the levels of 1975 [Carmichael 1987]. Specific examples of situations where conservation in the industrial sector has been or may be achieved are presented below.

2.2.1 Fertilizer Units in Goa and Kanpur, India

In Zuari Agro-Chemical Limited (ZACL), a fertilizer plant at Goa, water consumption was reduced by 50 percent over a six-year period (between 1982 to 1988) from 22,000 m^3 per day to 11,000 m^3 per day in response to the high price of water and government pressure to reduce industrial effluent discharged into the sea (case 5.2.1). Water consumption in ZACL in 1990 was 10.3 m^3 per ton of nutrient, only 40 percent of the water consumed in another fertilizer unit, Indian Explosives Limited (IEL) at Kanpur. The significantly lower consumption in ZACL was a response to the higher price of water ($0.12/$m^3$) charged by the Public Works Department compared with the cost incurred ($0.01/$m^3$) by the IEL in self-provisioning. Implementation of pollution control regulations by the government also differed between the two locations. While the management of IEL could get away with discharging the untreated effluent into the river, the management of ZACL was forced to make investment in pollution control and reuse facilities resulting in almost 100 percent recycling of liquid effluent.

2.2.1 Refinery and Petrochemical Industries in Madras, India

In response to shortages of water supplied by the Water Supply Agency in Madras, two major industrial units have adopted water conservation measures and reuse of effluent water: Madras Refineries Limited (MRL) and Madras Fertilizers Limited (MFL) (case 5.2.3). Their plans for expansion are contingent on obtaining additional water. It was unlikely that they would be able to continue operating without additional water supply, unless conservation was practiced.

MRL and MFL introduced water conservation measures including an increase in the number of cooling water cycles from 3 to 6, processing condensate recovery, hydrolyzed stripping, and the use of regenerated water. MRL doubled capacity to 5.6 million ton per year while keeping consumption of water unchanged at 2.5 mgd. Similarly, MFL has maintained capacity while reducing water use from 4 mgd to 3.6 mgd. The second response of MRL and MFL has been tertiary treatment of sewerage effluent obtained from the water supply and sewerage agency. Both MRL and MFL expect to meet about 30 percent of their total water requirements with reuse of treated municipal sewage.

Unlike the other two companies, Manali Petrochemical Limited (MPL) has responded to water shortage by relying on secondary sources of much higher price and by reducing output. MPL was unable to engage in tertiary treatment because its small size prevented it from capturing economies of scale that would justify the investment.

2.2.3 Steel Plant in Jamshedpur, India

A recent field survey of 26 industrial units and 1,000 households in the steel-producing city of Jamshedpur, in eastern India, showed that inefficient water use and heavy pollution of the Subernarekha river and its tributaries are encouraged by not treating water as an "economic good." Because fresh water is available at low cost, industrial firms use more water than is technically required, pollutants are diluted rather than abated, and wastewater reuse is not practiced even though part of the municipal sewage is treated (case 5.2.2).

Since the Tata Iron and Steel Company (TISCO) accounted for over 80 percent of the total water intake and effluent discharge, a policy "simulation" exercise was carried out to determine the management response to alternative policy instruments. Based on field data and a simulation model, it was possible to assess the right mix of incentives—water price and effluent tax—for improving ambient water quality and managing the use of the resource. Assuming that the society would like to encourage TISCO to reduce water purchased and effluent discharged by 54 percent and 91 percent, respectively, then it would imply raising water price and effluent tax from their current levels of $0.066 and $0.001 to $0.10 and $0.04 per cubic meter, respectively. The total cost for TISCO would be about $4.5 million, which represents 0.6 percent of annual manufacturing expenses or 5.3 percent of annual profits.

Using cross-sectional data for the 26 industrial firms in Jamshedpur, a water demand function was estimated. The empirical results showed that elasticity of demand for water with respect to price is -0.49 and is statistically significant. This means, that, other things remaining constant, a firm that pays 10 percent higher price for water is likely to reduce its water demand by 5 percent. For obvious reasons, this conclusion is valid for those industrial units that have technological options to conserve or recycle water.

2.2.4 Automobile and Textile Units in Jakarta, Indonesia

During a recent industrial water survey covering the Jabotabek region, visits were conducted to an automobile (Toyota-Astra Motor) and a textile (Southern Cross Textile) industrial units. The automobile unit uses 300,000 m^3 of water per year and relies on three water sources: almost one third comes from piped supplies ($1.20/$m^3$), half comes from groundwater ($0.60/$m^3$), and the rest comes from tankers ($2.40/$m^3$). The management of the firm is planning to triple its output by the year 2000, which will require 140 percent more water Despite the fact that groundwater is the cheapest source, this firm cannot further rely on it because of its heavy contamination (case 5.2.7).

Because of the short-supply of piped water and the relatively expensive water from tankers, the management of the company is fully committed to reducing its water intake by cutting waste and reusing treated effluent. By means of conservation and reuse, the company plans to cut water and pollution control costs by 25 percent and water intake by 40 percent.

In the case of the surveyed textile industrial unit, as with other textile units in Jakarta, the location of this firm was determined by the closeness to the river. At present, the river provides 7,200 m^3 per day or 88 percent of its daily requirements; the rest comes from local groundwater (case 5.2.8). Since water from the river is withdrawn free of charge, the firm uses more water than technically necessary. Total water use per unit of output is about 560 m^3 per ton. This level of consumption is much higher than similar industries in developed countries (180 m3 in Israel and 250 m^3 in Belgium). According to the management, the firm can save as much as 36 percent of total intake at a relative low cost. However, at present the firm lacks of economic incentives to reduce water use, i.e. absence of water charges.

2.2.5 Pharmaceutical, Food-Processing and Dairy Units in Sao Paulo, Brazil

When the Sao Paulo sewage treatment plant was designed, the planners did not anticipate changes in wastewater volume and strength caused by the imposition of pollution charges on users. By the time the facility was completed, industrial units had reduced the volume of water purchased and effluent produced through the use of water-efficient production processes, improved housekeeping, and increased recycling. The significant reduction in the volume of water purchased and wastewater produced caused revenue losses to the public utility estimated at $0.4 million (in December 1982 prices). An overdesigned wastewater treatment plant sat idle for years (case 5.2.4).

Three industrial plants that were asked to pay effluent charges to the central effluent treatment facility reduced the amount of water used in their processes and the volume of effluent discharged, with reductions ranging from 42 percent to 62 percent in 1982 over 1980. In the pharmaceutical industry, the volumes of water purchased and effluent discharged per unit of output in 1982 was 49 percent below 1980. In the food processing industry, purchased water and discharged effluent were reduced by 42 percent per unit of output in 1982 compared to 1980. In the dairy industry, the unitary coefficients of volume of effluent and water use were reduced by 62 percent.

Water savings and industrial discharge reductions were an unexpected effect of the establishment of the industrial effluent charge in the early 1980s under which industries paid according to the volume and biological and chemical quality of the wastewater. The sewerage company failed to determine criteria to be used in estimating the charges to industries that would encourage them to connect to the sewer network. The company assumed that industrial units would always prefer to discharge their waste into the sewage treatment plant and pay the corresponding fees. Technological changes and price elasticities of demand were not taken into account in the planning process.

2.2.6 Reuse of Municipal Wastewater by Industrial Firms, Mexico

The driving forces behind the involvement of the private sector in wastewater treatment were the increasing water price and the imminent water shortage. In 1989, a group of 26 industrial units in the Vallejo area of Mexico City decided to find an alternative to the piped water supplied by the municipality. The result was the creation of a for-profit company, Aguas Industriales de Vallejo, to rehabilitate and operate the old municipal wastewater treatment plant [World Bank 1992].

These 26 companies represent a variety of sectors including paper, electronic supplies, and chemical. Each provided equity on the basis of its water requirement, approximately $8,000 per each liter per second or $0.25/m³ per year. The total equity of $0.9 million was enough to renovate and operate the municipal treatment plant. At present, Aguas Industriales de Vallejo, one of the stakeholder companies, operates the wastewater treatment plant under a ten-year renewable concession from the Departamento del Distrito Federal.

The plant, with a total capacity of 100 liter per second, receives mostly residential wastewater and provides 60 liters per second of treated effluent to the shareholder companies and 30 liters per second to the government as payment for the concession. At present, the shareholder companies get water at 75 percent of the price charged by the municipality. Industrial units use the water mainly for cooling, but some units use this water for processing purposes also. The government uses this water for irrigation and for washing government vehicles.

2.2.7 Industrial Demand in Tianjin and Beijing, China

In many Chinese cities, water conservation and wastewater reuse have become increasingly important in view of the water shortage. With propaganda, education, and various economic, administrative, and legislative measures, Tianjin has increased the rate of industrial output per cubic meter of water from $18.5/m^3 in 1981 to $45.5/m^3 in 1988 (1980 prices), a reduction of 14 percent per year in the average industrial water consumption per unit of industrial output. In Beijing between 1978 and 1984, the increase was from $7.6/m^3 to about $20/m^3. The average annual water consumption per unit of output was reduced by 17 percent per year. The applied measures include: (a) a strict water quota and effluent quota per production unit; (b) a penalty price system under which consumers who exceed their allocation have to pay 10-50 times the normal charge; (c) a similar penalty fee for pollutant discharge exceeding the limits; and (d) a water audit program and regular water flow surveys under which industrial enterprises are inspected for leaks and effectiveness of water saving measures (case 5.2.5).

2.2.8 Industrial Demand in Israel

In Israel, the rate of industrial output per cubic meter of water jumped 230 percent, from $14/m^3 in 1962 to $48/m^3 in 1982. The average amount of water consumed declined from 70 m^3 to about 21 m^3 per thousand dollars of industrial product output at 1969 prices. The increasing efficiency in industrial water use can be attributed to policies adopted by the Water Commission: (a) licensing of water supply (water is supplied to industrial firms under a license, and the allocated quantity depends on the nature of the end product, the production processes, the existing equipment, the raw materials, etc.; (b) introduction of water saving technologies; (c) imposing a penalty price system; and (d) subsidized financing for investment in water saving processes and appliances (case 5.2.6).

2.2.9 Industrial Demand in France, Sweden and The Netherlands

To control direct abstractions of both surface water and groundwater, France has imposed a comprehensive charging system with charges differentiated by zone, season, quantity abstracted, quantity consumed, and whether it is surface or groundwater. The imposition of charges by the Picardy Agence de Bassin in 1970 reduced industrial water consumption by half over ten years [OECD 1987].

In Sweden after the 1969 Environmental Protection Act, industrial withdrawal fell by 55 percent between 1964 and 1977. The volume of water withdrawn in the mid-1970s was half the volume estimated 10 years before. The pulp and paper industry, for example, adopted recycling technologies as a response to the strict pollution control requirements. This recycling technology increased water use efficiency fourfold. Total output was increased by 400 percent without increasing water withdrawal [Carmichael 1987].

In the Netherlands, industrial units responded to the 1970 Pollution of Surface Water Act by reducing water consumption. The Act allowed imposition of levies on polluters. The water pollution charge has provided incentives to industries to improve their pollution abatement practices. To reduce their costs, industries opted for reducing total wastewater, or purifying it themselves, or both. The overall result has been a 210 percent increase in the rate of industrial value-added per cubic meter of water, from $8.6/m^3 in 1967 to $18.4/m^3 in 1980 constant 1970 prices [Carmichael 1987].

2.3 Increasing Supply-Side Efficiency

This section presents some of the successful experiences in improving supply-side efficiency of water use.

2.3.1 Reduction of "Unaccounted-for Water" in Brazil and Thailand

In many countries, the so-called "unaccounted-for water" (UFW) is a high proportion of supply, often reaching 25-50 percent of gross production in developing country networks [Munasinghe et al. 1991]. This category is made up of technical losses such as leaks, undermetered supplies, authorized nonpaying customers (e.g. public services), and deliberate theft (unofficial connections or evasion of payment). The reduction of nontechnical losses is equivalent to tariff increases for these categories, and their effects on benefits and welfare can be assessed accordingly. The case for reducing technical losses is a straightforward matter of comparing the costs of the program with the value of water saved. This is often a more attractive investment for a water utility than the development of new supplies.

A program in Sao Paulo, Brazil, reduced UFW from 36 percent to 31 percent between 1980 and 1985. It consisted of the installation of meters, leak detection programs, updating cadastre to discover which houses had legal connections and which did not, improving maintenance, and renovating old installations. Although a modest proportion of total supply, the savings that resulted were equivalent to the entire supply for a city with 2-3 million people [World Bank 1991].

Investing in leak detection and repair programs has also proven to be the most cost-effective way to conserve municipal water supply in Bangkok, Thailand. The Metropolitan Waterworks Authority was able to reduce the level of UFW from 45 percent in 1983 to 34 percent in 1988. Moreover, the reduction in UFW yielded $4.2 million per year as net benefit for the utility, i.e., the total volume of saved water times the marginal cost of supply minus the cost of the program (case 5.4.1).

2.3.2 Increasing Efficiency of Irrigation Systems in Bihar, India

A large proportion of irrigation water is lost through leaks from canals. Whether it is worth lining the canals to reduce these losses depends on a straightforward comparison of the costs of the program with the benefits of the water conserved. The evidence of two cases in Bihar is that canal lining can be a very attractive solution to water supply problems.

In Bihar, India, lining the full length of a main irrigation canal was found to be economically justified. The distribution of benefits was equitable since the less influential farmers at the end of the system tended to suffer from irregular supplies. Leakage along a conveyor is sometimes necessary to replenish an aquifer, a possible concern to small farmers, but in this particular case the repaired leakage had caused water-logging, and its reduction counted as a benefit (case 5.3.2).

A recent study carried out in Bihar, India, reveals that the lining of the conveyance system and water courses plus improved management practices—on-farm development such as leveling and contouring fields, improvement in communication system, control and regulating structures, setting up of Agrimet stations, and enforcing scheduling—can save 20 percent of total irrigation requirements at a cost of $0.03/$m^3$. This represents 60 percent of the cost of new water supply (case 5.3.3).

2.3.3 Effects of Source Reliability on Investments, Indonesia

The choice of level of reliability to be provided for sources of water supply is important because of the high cost involved in building capacity for reducing the frequency of shortages, which is only used when a serious drought occurs. In Indonesia as in many other developing countries, the capacity of unregulated water sources is designed based on a 98 percent reliability standard, i.e., 98 percent of the time the source in question would be able to deliver the capacity ascribed to it.

However, by reducing the design capacity it may be possible to delay the construction of major storage facilities. A study carried out by Indec et al. shows that the additional supply that can be abstracted from the unregulated Cisadena river (at Serpong) amounts to 6.5 m^3 per sec if the 98 percent reliability standard is chosen. If the 90 percent reliability standard is used, then the reliable supply would be 9.4 m^3 per sec, sufficient to postpone the construction of additional facilities until 2010 [Indec et al. 1987].

2.3.4 Privatization of Public Services to Improve Efficiency, Côte d'Ivoire

Since 1960 the urban water sector in Côte d'Ivoire has been operated by a private company under concessions and lease contracts. Following a competitive bid, Société de Distribution d'Eau de Côte d'Ivoire (SODECI) began to operate the Abidjan water supply system as a subsidiary of a large French water utility, Société d'Aménagement Urbain et Rural (SAUR), under a concession contract. Privatization of water public services in Côte d'Ivoire was effective in raising urban tariffs, curbing excessive consumption, especially by the industrial sector, reducing unaccounted-for water, and maximizing revenue collections [Triche 1990 and World Bank 1990b].

Industrial demand was depressed as industrial units began to recycle water and to use less-costly groundwater sources. A regression analysis over the period 1974 and 1988 reveals a price elasticity of -0.47 for industrial consumption. In this particular case industrial water tariffs were carried to unacceptable lengths because of the need to cross-subsidize rural from urban consumers. In fact, they were almost certainly above the level of long-run marginal costs. The water company also had a strong incentive to maintain a high level of operating efficiency in urban areas, with unaccounted-for water of only 12 percent, and high collection rate of 98 percent for private customers. The productivity of SODECI was almost double the productivity of any other water utility in West Africa, i.e., 130 connections per employee (case 5.4.2).

2.3.5 Leak Detection and Repair Program in New York, USA

The Westchester Joint Water Works (WJWW) in Mamoroneck, New York, reduced the amount of unaccounted-for water from 29.5 percent in 1974 to 16.3 percent in 1981 through a leak detection and repair program, the testing and repair of water meters, and management changes. The WJWW directed its efforts to conserve water as a response to the high price charged by New York City. As long as the volume used by WJWW was lower that the per capita consumption in New York, the utility had to pay $0.03/$m^3$. If the water used exceeded that level of per capita consumption, the utility was charged at a rate of $0.19/$m^3$. The total volume of water saved over six years was estimated at 10.5 MCM, representing a total net saving of $160,000 for the water utility [Moyer 1985].

2.3.6 Integrated Water Management in Washington, D.C., USA

By doing three sensible things–requiring three utilities to cooperate, devising more refined reservoir operating rules, and reducing the allowable frequency of shortfalls from one in 100 years to one in 10 years—the Washington DC Metropolitan Areas reduced the number of reservoirs required from 16 to one, and the cost of investments from $400 million to $31 million. Substantial increases in water supplies were obtained by using the water from the Potomac River during periods of high flows while saving the stored water in reservoirs for period of low-flow [McGarry].

2.4 Reallocation of Water Between Sectors

There are a number of institutional arrangements that can be used for reallocation of water supplies among and between sectors. The most significant are water markets, trading of water rights, water banking, and water auctions. Some of these options have been successfully used to reallocate water from lower- to higher-value uses.

2.4.1 Water Markets in Chile

Chile is the only developing country to date with a comprehensive water law that has encouraged the development of water markets. The 1981 National Water Law entitles secure, tradable, and transferable water-use rights for both surface and groundwater. Water is a national resource for public use which can be granted to individuals [Hearne 1993].

A number of reports on the Chilean experience indicate the major achievements of the water reform: (a) farmers have shifted from water-intensive crops such as corn and oilseeds to higher-valued crops, less intensive crops such as fruits and vegetables; (b) an expansion of the agricultural frontier has been achieved during the last 20 years without building any major irrigation facility–Chile has shifted from a negative agricultural trade of $500 million during 1975 to a positive one of $1,500 million in 1993; (c) growing cities have bought a small proportion of total water rights owned by farmers instead of developing new water sources [Gazmuri 1992].

2.4.1 Groundwater Markets in India

Water markets have been successful in reallocating groundwater from "low-value" to "high-value" uses. In India, agroeconomic surveys indicate that in many areas large number of farmers, especially marginal and small ones, purchase groundwater to meet irrigation requirements. These farmers cannot afford to invest in their own wells. For instance, in Gujarat 40-60 percent of total groundwater extracted is sold. Thus, water is being diverted to those uses with the highest value (case 6.2.2).

Two features of the groundwater market in India suggest that both buyers and sellers tend to increase the efficiency of water use. First, the high value of output per acre and the high cropping intensity obtained by buyers indicate that groundwater markets have encouraged both marginal and small farmers to use better crop production methods. Second, the development of piped irrigation networks in Gujarat, which minimizes seepage and evaporation losses, supports the view that sellers display interest in efficient water conveyance systems once water has been pumped.

In India, markets play a triple role in the development and utilization of groundwater. First, the markets enable marginal and small farmers to get the benefits of capital-intensive groundwater lifts and thereby help enhance their income. Second, markets help the owners improve the economic viability of their lifts by increasing capacity utilization. Third, these markets help society by minimizing investment in lifts.

For the owners of lifts, water sales increase capacity utilization and economic viability. The average per-owner income from sale of water in Gujarat villages was as high as $2,310 per year, enough to pay back the original investment in three to four years. Nevertheless, there is a major problem with these groundwater markets: the environmental effect of aquifer depletion since the profitable outlets for water encourage greater pumping.

2.4.2 Water Banking in California, USA

During the 1991 drought, California purchased approximately 920 MCM of water from farmers to meet critical urban and agricultural needs. This represents about 10 percent of the municipal and industrial demand of the state under normal conditions. The Department of Water Resources, through the newly created "water bank", acquired water from farmers on a voluntary basis. The offered price was high enough to compensate rice, corn, and tomato farmers For example, a rice grower was offered $925 for every hectare not planted, an amount that is 25 percent higher than the benefit the farmer could otherwise receive. Since each hectare of rice uses about 9,100 m^3 of water a year, the farmer received $0.10/m^3 of water. Water thus obtained was sold at an average price of $0.14/m^3, of which about 80 percent went to satisfy higher valued urban needs and the remaining 20 percent was used for agricultural needs (case 6.1.3).

2.4.3 Exchange of Water Rights in California, USA

The Metropolitan Water District of Southern California expects to develop additional supplies by financing water conservation projects, especially improvements in irrigation efficiency, within the Imperial Irrigation District in exchange for rights to use conserved water. The cost per cubic meter of water so obtained was about half that of a cubic meter from the next available undeveloped source (case 6.1.2).

2.4.4 Water Auction in Victoria, Australia

In Victoria, Australia, the Department of Water Resources has adopted the auction approach to allocate new irrigation water (case 6.2.2). By doing so, the State tries to maximize the economic return of the investment, ensure equity between irrigators, and recover part of capital costs. During 1988-89, six auctions were held in which 31 MCM of water were offered for sale. About three quarters of that volume was sold at an average of 50 percent higher than the "reserve price," which was set at $0.076/m^3. Technically, the "reserve price" was set to equal the financial value of water in growing lucerne (alfalfa).

Since new irrigators bid on the basis of their willingness to pay for water supplies and there were quantities of water unsold, this experience illustrates the problem of getting the correct "reserve price." The justification for setting a "reserve price" was basically one of trade-off between economic efficiency and distributional equity: the "reserve price" was supposed to protect the position of the smaller farmer, and improve the auction's public acceptability, but in so doing it sacrificed some efficiency gains, e.g., maximization of bid prices and revenues.

2.4.5 Water Markets in Colorado, USA

The Northern Colorado Water Conservancy District (NCWCD) was formed in 1937 to represent regional water interests and proved to be a helpful mechanism in negotiating the approval of the Colorado-Big Thompson (C-BT) scheme. A contract was signed between the NCWCD and the Bureau of Reclamation governing the allocation of costs, repayment, and quantities of water to be supplied. When the scheme was about to come on-stream, vigorous discussions took place among potential water users concerning initial allocation of new supplies. Since new water resources constituted supplemental supplies to the District, they had not yet been allocated under the traditional ("first in time and first in right") Colorado Water Law. Instead, the NCWCD opted for an initial allocation of its new supply according to the farmers and municipalities' needs and possibilities of making beneficial use of the water [Kamper 1993].

The C-BT project was originally constructed to deliver 310,000 acre-feet of water per year. This supplemental supply was evenly divided between 310,000 allotment units, which were then assigned to water users as water use rights. Each water use right represents a freely negotiated contract between the District and the water right holder for 1/310,000th of the C-BT scheme delivery quota, which, in turn, depends on hydrological conditions.

At present, the 310,000 allotment shares are actively traded and may be sold and rented at a price determined by market clearing conditions. The absence of third-party effect claims has greatly facilitated water transactions. This water market mechanism has allowed cities to secure supplies on a permanent basis.

CHAPTER 3

POLICY VARIANTS FOR WATER CONSERVATION AND REALLOCATION

This chapter summarizes policy variants for water conservation and reallocation that have been used. It starts with a classification of the various policies, and continues with a discussion of the three principal types that together constitute an "enabling environment" which provides incentives for both conservation and reallocation. Some conclusions about the effectiveness of the policy variants based on the examples cited in this study are presented here.

There are various possible ways to classify policies acting primarily on the demand for water. The taxonomy used in this study considers the way in which policies directly or indirectly influence the behavior of water services providers and water users through the set of incentives they provide to achieve an efficient and sustainable use of the resource. Three layers of interventions are required:

- *Enabling conditions.* Actions to change and alter the institutional, legal, and macroeconomic framework within which water is supplied and used (they are the "rules of the game").
- *Incentives.* Policies to influence directly the behavior of water users (individuals or organizations) by providing them with incentives for improving water use efficiency (allocation and productivity) and sustainability (economic and environmental). These actions include both market-based and nonmarket-based devices.
- *Direct Interventions.* Through direct investments, spending programs, or targeted programs to encourage the use of water-efficient and water-saving equipment.

The three layers of policy discussed above, which are set out in table 3.1, are not alternatives; ideally, they should strongly reinforce each other. For instance, the promotion of efficiency measures will be more successful if effective water pricing polices are adopted. The promotion of water-efficiency among households is pointless unless water charges are high enough to provide consumers the necessary incentive. Water utilities have a better incentive to reduce unaccounted-for water when the anticipated savings can generate significant revenues.

The argument in this study is that greater acceptance of competitive market forces is necessary for improving efficiency in water use and the level of performance of providers of services. Water pricing and other economic incentives may have a very important role to play towards that end depending on the relative value of water [World Bank 1993].

However, improving the use of water resources cannot rely entirely on market forces. In this regard, there is a close analogy with the attempt to increase the role of the market in the economic programs of formerly socialist countries where a number of interdependent actions are required to create the necessary critical mass and synergy [Gelb and Gray 1991] for reform.

The balance between the three layers of policy is also related to the mix of policy reforms, as opposed to spending projects. Spending projects are often substitutes for necessary, but politically difficult, policy reforms. However, one must recognize that policy reforms and spending projects can have strong mutual benefits: policy reforms can increase the profitability of projects, and projects that increase micro-level responsiveness improve the prospects for policies to remove macro-level distortions [Kanbur 1990].

3.1 Enabling Conditions

3.1.1 Institutional and Legal Measures

Many of the problems of the water sector can be traced to the way water is planned, regulated, managed, and financed. The laws governing the use of water and the institutions that have

Table 3.1: Policy categories

Categories	*Examples in text*
Enabling Conditions	
Institutional and Legal Changes	Israel (5.2.6), USA (6.1.1), Australia (5.1.5), China (5.2.5)
Reforms and Privatization of Utilities	Cote d'Ivoire (5.4.2), Argentina (box 2.1), Hungary (box 3.2)
Macro-Economic Policies	North Africa, Middle East (3.1.3)
Creating Incentives	
Priced Based	
Active Use of Water Tariff	USA (5.1.2), Australia (5.1.4 and 5.1.5), Bogor (5.1.1), France (2.2.9)
Pollution Charges	Brazil (5.2.4), India (5.2.2), The Netherlands (2.2.9)
Groundwater Extraction Fee	France (2.2.9)
Fiscal Incentives	Israel (5.2.6 and 5.3.1), India (5.2.2), USA (5.1.3),
Establishing Water Transfers	Chile (2.4.1), India (6.2.2), USA (6.1.1, 6.1.2 and 7.1.3) Australia 6.2.1)
Non-priced Based	
Restrictions and Sanctions	Australia (5.1.4 and 5.1.5)
Quotas, Norms and Licenses	Israel (5.2.6), China (5.2.5)
Exhortations, Public Information	USA (5.1.2 and 5.1.3)
Direct Interventions	
Pollution Control Programs	India (5.2.2 and 6.2.1), Sweden, The Netherlands (2.2.9)
Leak Detection and Repair Programs	Brazil (6.4.1), Bangkok (6. 4.1), USA (2.3.5)
Water-Efficient Appliances	Tucson (5.1.2), Australia (5.1.5)
Conservation Programs	Israel (5.2.6 and 5.3.1) , Brazil (5.2.4), India (5.2.3, 5.3.3, and 5.3 2)
Industrial Audit Programs	China (5.2.5), Israel (5.2.6)

arisen to manage it are frequently obstacles to making more rational use of the resource. There is, however, no single successful blueprint:

"Many types of institutions have been successful; indeed, there is no universally suitable model that can be prescribed. Institutions are the products of a country's history, society, and economy. The choice of which institutions are developed is a local prerogative" [Okun 1991].

Among the many successful models for institutional development in the water sector are: government administrative, regulatory, and operating agencies at both national and local level; national and local quasi-governmental agencies; local public utilities; private companies owning and operating water utilities; publicly owned agencies contracting with private firms for operation and management; and river basin organizations [Okun 1991].

Although the precise model for institutional development in the water sector cannot be specified without some knowledge of local circumstances, a few general guiding principles emerged for the review of cases.

1. Although professionals pay wistful tribute to the notion of a comprehensive framework approach to effective management of water resources, there are few signs of its being used in practice (cases 5.2.6 and 5.2.5). The participants in the Dublin Conference on Water and the Environment, for example, have made a call for policies that stress integrated water resource management and consider water as an integral part of an ecosystems, e.g., water is a natural resource as well as a social and an economic good.

"Since water sustains life, effective management of water resources demands a holistical approach, linking social and economic development with protection of natural ecosystems. Effective management links land and water uses across the whole of a catchment area or groundwater aquifer.

"Past failure to recognize the economic value of water has led to wasteful and environmentally damaging uses of the resource. Managing water as an economic good is an important way of achieving efficient and equitable use, and of encouraging conservation and protection of water resources [Dublin 1992]."

2. There is value in prescribing and encouraging the participation of stakeholders The Dublin Conference also acknowledged "Water development and management should be based on a participatory approach, involving users, planners, and policy-makers at all levels... [This] means that decisions are taken at the lowest

appropriate level, with full public consultation and involvement of users in the planning and implementation of water projects [Dublin 1992]."

3. There is also value in having an arms length relationship between the responsible government ministry and the organization entrusted with water supply. This has a number of aspects. First, the UK privatization experience has shown the value in separating regulation and standard-setting from delivery of water supply services. Previously, water authorities had been both judge and advocate for their attempt to meet water quality standards.

Second, experience shows that the organization charged with water supply can easily be "captured" by powerful user interest groups. The subservience of the United States Bureau of Reclamation to agricultural interests is well documented [Reisner 1990]. In Israel, water supply has become inextricably linked with agricultural development, and the Water Commissioner is its servant: "Water resource development in Israel was a product of planning frames and organizational forms which arose almost entirely within the agricultural sector [Sexton 1990]."

Third, water supply is often a natural monopoly at the local level, and for urban supplies this is usually the most efficient form of provision. But the market can be "contestable" as a way of imposing efficiency or other performance criteria on operators. Concessions and management contracts with private companies are usually of a limited term, and conditional on performance. Competition is for, rather than in, the market. In Paris, for instance, the two major French water companies have contracts to serve different parts of the city [Triche 1991]. In practice, contestability is usually a feature of privatization, but in principle it can also involve competition between public and private agencies, or between public institutions, for the right to supply services or more limited functions within the sector.

4. It is the responsibility of governments to set environmental standards and enforce them. This is a precondition of internalizing environmental costs, for instance, in water prices or pollution charges and fines. Enforcement is obviously important: several countries have model environmental standards on the statute books but have a poor record of enforcing them. The fact that many polluters are state enterprises or government departments makes it more difficult to enforce the law. In East European countries, fines for water pollution are low: they are not collected in most cases, and where they are collected, they tend to be passed on as a cost of production in imperfect product markets [Wilczynski 1990].

5. The reallocation of water is often hamstrung by legal restrictions. For instance, efficient and flexible allocation of water resources can be obtained in the long-run with well-defined property rights to water and minimal constraints to market-based transfer systems in which third party effects are internalized. At the very least, users must have clear title to transferable water rights regardless of its use in order to develop water markets (cases 6.1.1 and 6.2.1). If this is not so, users have a strong incentive to maintain their level of use, however wasteful. Similarly, for auctions to be possible the auctioneer must have uncluttered title to the resource, and the bidders must not have entrenched rights to it. Changes in water prices or amounts supplied are often governed by long-term contracts—in the Western states of the United States, typically 40-50 years for Bureau of Reclamation water. Contracts of this length obviously frustrate the active use of pricing and, where water rights are sold, leaves the rent with the farmer.

3.1.2 Reform and Privatization of Utilities

Strong government control in the development and management of water resources is justified for the public good characteristics of water resources activities. However, most of the government agencies responsible for water resources show serious institutional deficiencies: they are unaccountable and inefficient, which seriously affects the cost and quality of the services provided.

A growing number of countries throughout the developing world have decided to address the above-mentioned problems by promoting greater private participation. Private companies already account for a high proportion of supply in several large economies. In France, private water supply companies serve around two thirds of the population, and 40 percent of all sewerage services are private. In the United States, investor-owned water companies account for 56 percent of all systems. In the United Kingdom, even before the recent full privatization of water supply, 25 percent of

Box 3.1: Privatization of the Water Supply Sector in Argentina

Obras Sanitarias de la Nacion (OSN) was responsible for providing potable water supply and sewerage services to a total population of about 11 million inhabitants in the Greater Buenos Aires metropolitan area. Between 4 million to 6 million people are without adequate water supply or sewerage facilities. The wastewater collected from the city is discharged into the La Plata River with little or no treatment, which creates a serious health and environmental hazard. The biggest challenge during the privatization of OSM was how to provide an adequate incentive to satisfy the demand for water and sewerage services and at the same time improve the environmental conditions of the area. Investments of as much as $4 billion will be required to expand service and upgrade it to an acceptable level.

Because OSM was owned by national, provincial, and municipal governments, a tripartite government commission was established for the privatization. The commission agreed to forgo any sales price or royalty, which would have been passed on to the consumer. Instead, a thirty-year concession was awarded on the basis of the greatest reduction on overall tariff levels. The winner, a consortium led by a French water operator, is to reduce tariffs by 27 percent and has been given twelve years to meet its investment and service-level commitments. Operation of the privatized service began in May 1993. Privatization also provided for the establishment of an inter-governmental body to regulate the new operator's performance, and responsibility for monitoring water quality shifted to the Secretary of Environment.

Source: The World Bank, "Argentina's Privatization Program Experience, Issues and Lessons," Washington DC 1993.

water was supplied by private companies [Coyaud 1988]. In Argentina, two private consortiums serve already the Greater Buenos Aires Metropolitan Area and the Province of Corrientes (box 3.1).

There are several options for private sector participation. One option is to keep ownership on the hands of the government but to get the private sector to bid for contracting arrangements such as management contract, leasing, and concessions. A second option is the full privatization of water services. A third option is the transfer of ownership and/or operational responsibility to the community. Major participation of the private sector through alternative mechanisms is not inherently good or bad. Its success depends basically on the built-in incentives as shown in table 3.2.

A new approach that is gaining notable importance and support within the water supply sector is to develop a new partnership between public and private interests. The partners would be governments, regulators, and providers of services [World Bank 1994a]. The government's role is to propose and execute the "rules of the game" for water supply and sanitation services, which include among others the drafting and submission of the sectoral legislation to introduce commercial principles in the provision of the services and to ensure competition (by allowing new entrants as service providers). Financial and tariff polices, including the forms of subsidies, should also be defined by the government. Regulators role, in turn, comprises monitoring compliance with the "rules of the games" by both services providers and governments. In a way, they will restrict the freedom of water utilities to set prices, to decide on investment plans, and to vary the quality of services. Regulators are expected to have greater autonomy, so political interventions are avoided.

Finally, the role of service providers includes bidding for service concessions or leasing, and delivering the services according to the contract signed with the government. They have to comply with economic and financial performance criteria set by the regulator. Service providers could either be public or private, or a combination of both.

Certain West African countries have applied the French model of the contract plan to govern the relations between public utilities and government overseers. The utility has, in effect, to propose a corporate plan for approval by its sponsoring ministry setting out its objectives, investment plans, pricing policy, etc., in a form that can be monitored. Any objectives that are purely noncommercial, e.g., loss-making provision to deserving social groups, are clearly identified, so that separate financial provision can be made to cover them.

Reforms of water utilities have different motives: investment finance, economic effi-

Table 3.2: Participation of the private sector in the delivery of water supply services

Contract	Incentives	Example
Services	Permits competition among multiple providers, each with short and specific contracts.	EMOS, a public company in Santiago, Chile, encouraged employees to leave the company and compete for service contracts for tasks previously performed internally. That resulted in large productivity gains.
Management	Contract renewed every one to three years, and remuneration based on physical parameters, such as volume of water produced and improvement in collection rates	Electricity and Water Company of Guinea-Bissau (EAGB) awarded a contract to a French company, which guaranteed 75% of the remuneration and the 25% left was based on performance.
Lease	Contract bidding, with contract duration of about ten years; provider assumes operational risk.	Water supply of Guinea leased the operation and maintenance of the system to SEEG, government-foreign consortium owned, for ten years. Large increase in billing collections has been achieved.
Concession	Contract bidding, with contract period up to thirty years; provider assumes operational and investment risk. In some cases, the contractor assumes all commercial risk and may disconnect users who do not pay their water bills.	Côte d'Ivoire's urban water supply concession went to SODECI, a consortium of Ivoirian companies. SODECI receives no operating subsidies and all investments are self-financed. In Buenos Aires, Argentina, a 30-year concession was awarded to Aguas Argentinas, a consortium of local and international companies. Aguas Argentinas assumes full responsibility for system, and must finance and execute investments according to targets set in the contract.

ciency, and financial efficiency. Making public-sector water authorities become more financially self-sufficient was an important reason for Hungary's radical reforms (box 3.2). In the case of the Latin American countries, e.g., Argentina, Peru, Chile, and Venezuela, their governments have turned their attention to the private sector looking for debt and equity capital which would eventually result in commercially viable operations. Similarly, the case of Côte d'Ivoire demonstrates that privatization was effective in raising urban tariffs and curbing excessive consumption, especially by industry. The company also had a strong incentive to maintain an efficient urban system and minimize unaccounted-for water (case 5.4.2). In Macao, privatization since 1985 has not led to an increase in the real value of the water tariff, but it has led to increased collections, a doubling of the number of meters in use, and continued reduction in system leakage to its present level of 11 percent [Lyonnaise de Eaux 1991].

3.1.3 Macroeconomic Policies

Policies affecting exchange rates, import protection, taxes, and subsidies on output and input prices, inflation, interest rates, and price fixing for key goods determine the incentives for the production and consumption of goods that differ widely in their "water-intensity" and "pollution intensity." These policies affect water use and discharge at every level, e.g., the structure of the economy, the choice of products and technology, efficiency of water use, and the care with which it is discharged.

Macro policies can support or frustrate rationalization of the water system at the sector or user levels. The encouragement of more efficient irrigation practices, and even raising agricultural water prices, will fail if crop prices strongly favor water-intensive crops and if other subsidies reinforce prevailing cropping patterns and farm practices. In industry, whatever is done about industrial water prices will be refracted by the prism of industrial protection, which often promotes water-intensive sectors.

In Jordan, for instance, expansion of the irrigated farm area has been a central objective of policy since the early 1950s. The expansion of irrigation has led to increased production of relatively low-value crops that have high water demands. These crops are surplus to the local market, and have been exported. But policies supporting a strong local currency have reduced the export competitiveness of irrigated

Box 3.2: Reform of the Water Sector in Hungary

As part of the economic reform in Hungary, the government has removed the responsibility for providing public water supplies from the central government and legally transferred it to local authorities, along with ownership of existing water assets. At present, 28 out of 33 water utilities are operating independently. The remaining five enterprises are note easily divisible into independent systems for transfer to their respective municipalities, and so they are still owned and operated by the state.

A major impetus for these reforms has been a desire to reduce the high state subsidy for water. Over the last three years, subsidies from the state budget have decreased from 100 percent to 30 percent, and they will be phased out completely by the upcoming year. Water tariffs for domestic consumers and industries are generally based on a formula that includes the cost of inputs, depreciation, maintenance, and a mark-up on the order of 1 to 2 percent. Water charges have begun to increase dramatically in some areas, and sizeable differences in charges are occurring between localities. The lowest combined tariff for water and sewerage is Ft 23 ($0.31) per cubic meter in Budapest, and the highest is Ft 107 ($1.42) per cubic meter in Siofok. In the past three years, the price of water in Budapest has increased tenfold.

Consistent with the objective of financial self-sufficiency for water utilities, in 1991 about two thirds of the investment cost of the sector came from local sources; 50 percent was raised by water companies and associations, 8 percent came from interested citizens, and 8 percent was added by municipalities. Non-local sources included about 28 percent from the state budget and 7 percent from water and environmental funds.

crops. The overproduction of vegetables is a serious economic distortion with fiscal consequences, and it is absorbing precious water in a water-scarce economy. Yet there has been little attempt to curtail the production of low-value, water-intensive crops. National agricultural policy has thwarted rational water use [Sexton 1990].

The promotion of water-intensive and water-polluting sectors like iron and steel, petrochemicals, and pulp and paper is deeply embedded in the industrialization strategies of many countries. These industries typically pay only a fraction of the economic cost of their water, and little or nothing for their pollution. They often develop in an policy environment with few incentives to curb waste or recycle water. Even if water and pollution charges could be raised to economic levels, their effect on water use would be buffered by an array of counter-signals: subsidies on other key inputs like power and raw materials; high protection against imports; ability to pass increases in costs back to the government or on to a monopoly state-owned customer; shortage of investment funds for water-efficient processes; and high import tariffs and/or overvalued exchange rates raising the cost of such equipment.

For water pricing and pollution charges to be fully effective, there would have to be a radical change in the industrial regime in many countries. A review of industrial pollution in Turkey, Egypt, Yugoslavia, and Algeria, concluded: "Although such measures as pollution charges, tax incentives, and subsidies are potentially useful, their economic significance is dwarfed by those of input and output pricing policy and trade and credit policy." [Kosmo 1989]

Water pricing measures would frequently have to contend with incentives to attract foreign investment in water-using and polluting industries, which create a countervailing policy environment. Certain countries have consciously sought to attract industries shunned by other countries for their environmental effects [Leonard 1988].

The importance of potential changes in the structure of industry, and its balance between different branches, on the demand for water is evident in many developing countries. For example, in Tianjin, China, the petrochemical and the pulp and paper industries have the highest water-intensity rates and account for almost 23 percent of industrial water use [Hufschmidt 1987]. Restructuring of the mix of industries is required because it is impossible to support continuing the expansion of these heavy water-consuming industries.

3.2 Incentives

The second dimension of the enabling environment is the creation of incentives for the economically rational use of water. These can entail using the price of water to encourage more efficient use, or nonmarket devices including restrictions, diktat, or persuasion. This section considers these measures under the headings of market-based and non-market-based devices.

3.2.1 Market-Based Devices

The market can be used in two related ways to promote a more economically efficient use of water. Raising the price of water or auctioning it to the highest bidder is the most direct means of encouraging conservation and reallocation to higher-value uses. Assessing pollution charges based on the volume of wastewater is an indirect method of raising the cost of using water, with similar results for large users. The second approach is to raise the opportunity cost of using water by developing water markets. This will set higher water prices and create an incentive for consumers to relate their use more closely to marginal value, and then sell the rest.

This section considers pricing through water tariffs and pollution charges, then discusses the fiscal incentives and kinds of water exchanges, including water markets, water auctions, and water banking.

WATER TARIFFS

A viable means of achieving efficient resource allocation is marginal social cost pricing. On that basis, users would consume water until its marginal value is equal to its marginal cost of supply, so the benefit from consuming the last unit of water equals the cost of providing it. Applying this principle requires that the consumption of water be measured (by metering) and that charges be volumetric, that is, proportional to the amount consumed. It also assumes that the marginal social cost of supply (usually interpreted as the long run marginal cost because of the lumpiness of investments) is known reasonably accurately. Strictly, the resource cost of water (as it is or its opportunity cost) and other measurable environmental costs should be included. Thus, the minimum conditions for an optimal economic allocation of water would be:

- To price it at its average unit cost of incremental output;
- To include, besides storage, treatment, and transport costs, the opportunity cost of the water itself; and
- To account for the environmental costs associated with return flows in situation in which the society decides that those costs are going to be borne by the users, i.e., polluters-pay principle. It may be the case that the society decides that the environmental costs of return flow should be borne by others.

Although water tariffs are in widespread use in countries at all stages of development [OECD 1987], they are usually perceived as a means of cost recovery rather than as a way of managing demand. Even those that successfully recover the costs of the supply system do not necessarily equal the long-run marginal cost, which is typically higher than average current costs.

Water pricing can be an effective means of conservation. Its impact on the volume of water used depends on the significant water price elasticity compared to income elasticity of water demand (as noted earlier), as well as on the specific use, location, and time. Empirical studies of water price elasticity for different water user sectors are presented in table 3.3.[5] Among household consumers, elasticity depends on the existence of a margin of "discretionary" water use (typically for outdoor purposes), existence of leakages within the house, and availability of cheap flow-reduction devices such as shower heads, toilets, etc. The cases of the household sector in Bogor (case 5.1.2) and Tucson (case 5.1.2) reviewed in this study show enough evidence of price elasticity to justify water pricing in the cause of conservation. In agriculture, elasticity exists where the farmer has sufficient choice over quantities grown, the choice of crops, the method of application, etc. In industry, the elasticity of demand depends on the scope for using water-saving processes, recycling, reusing treated effluent, etc.

Table 3.3: Empirical estimates of water price elasticity

Sector	*Price Elasticity*
Residential	-0.29 to -0.60
Industrial	-0.45 to -1.37
Irrigation	-0.37 to -1.50

The studies of Indian, Indonesian, and Chinese industries demonstrate an active demand response to water price increases. In two private Indian fertilizer companies of similar size (case 5.2.1), the one paying a high price for municipal water achieved a unit water consumption only 40 percent of that in the other company, which depended on both its own wells and low-priced public supplies. In

Jakarta, Indonesia, the management of the automobile industrial unit (case 5.2.7) is fully committed to reducing its water intake and cutting waste in view of the imminent increase in water cost. Similarly, in China (case 5.2.5), the progressive price system in combination with other conservation measures have promoted a notable increase in the value of output per cubic meter of water; industrial units have made efforts to drastically reduce cooling water by increasing the rate of recycling and conserving process water by making technological changes.

In Egypt a clear link can be made between low water prices and the limited extent of water recycling in the power sector and industry:

"Even though industrial water prices have risen tenfold in the past two years, they are still at most only 20 percent of marginal costs...the costs of treating cooling water may be economic for the power sector if water tariffs were increased further.... the power sector accounts for 79 percent of industrial water consumption.

By reducing water usage and encouraging reuse of wastewater, higher water prices will also facilitate the separation of toxic and nontoxic waste for treatment and safe disposal and thereby help to reduce water pollution. Industries such as chemicals and iron and steel (which are expected to increase their water consumption tenfold by 2000...) would have a greater incentive to conserve and reuse water. Presently, the rate of water reuse is only about 14 percent" [Kosmo 1989]. The impact of tariff increases on the poor can be mitigated through the tariff structure. "Lifeline" rates are commonly applied to the first increment of consumption to avoid penalizing poorer users and discouraging consumption considered desirable on social grounds (cases 5.1.1 and 5.1.3). In considering the equity aspects of tariffs, it is also relevant to note that adequate cost-recovery is a precondition of investment in new services and in maintaining the condition and reliability of the present network. On both counts the poor are vulnerable to shortages of funds by the water utility to extend coverage services in their communities. In the end, providing cheap water does not ensure greater equity. Instead, its ends up benefiting the rich rather than the poor in terms of money spent in buying drinking water. While a poor family of a "Pueblo Joven" in Lima, Peru, spends between $3.00 to $5.00 per cubic meter buying water from tankers, a medium-income family spends only $0.20 per cubic meter of piped water from the water utility.

POLLUTION CHARGES

The widespread and universal acceptance of the "polluter-pays" principle has eased the way for introducing charges on effluent discharge.[7] In principle, an economic charge would be related to the environmental damage caused by the discharge, or the cost of prevention, treatment or restitution, whichever is least. In practice, pollution charges tend to be set lower than this to recover costs of monitoring, administration, and, occasionally, treatment [Bernstein 1991 and OECD 1987].

Charges for water pollution are of interest in the present context for the effect they have on the demand for water. If polluters are penalized according to the volume of their liquid discharges they have an incentive to recycle water and economize on its use. This reduces their demand for fresh water and–where a high proportion is for consumptive use and not available for reuse by others–releases it for use elsewhere.

The environmental impact of industrial effluent depends on its quality, the presence of toxic substances, and the location of the discharge, as well as its quantity. Hence pollution charges are often combined with "command and control" regulations to take account of these local factors. The economic incentive for firms to reduce their wastewater flows can consist either of a volumetric pollution charge, or a user charge/license fee varying according to volume or pollutant loads. The Brazil's experience with the effect of pollution charges on water use is reviewed in details in Part Two (case 5.2.4). In three industries in Sao Paulo, the introduction of effluent charges led within 2 years to a 40-60 percent reduction in water consumption. Industrial water consumption in the Netherlands also fell by 30 percent in the period 1970-76 following the introduction of water pollution charges in 1969, during a period when industrial output increased [OECD 1987].

Pollution charges are effective in inducing firms to reduce their demand for fresh water. They are particularly useful where it is not feasible to charge firms for using their own water sources, such as wells. Provided certain minimum standards of water quality can be met (e.g., by refusing permits for discharges that are toxic or close to areas of public use), volumetric

Box 3.3: Privatization of the Water Supply Sector in Argentina

L. Simpson, formerly general manager of Northern Colorado Water Conservancy District, has identified the following conditions as prerequisites for the successful functioning of water markets:

- A defined property right to the use of a certain amount of water
- Competing demands for the scarce supply
- A reasonable degree of reliability on the resource
- General acceptability by the society of the concept of transfer of water rights
- A good administrative and regulatory structure
- Adequate infrastructure to ensure water mobility
- A fair and adequate initial allocation of water rights
- An equitable system for reallocating water rights as needs arise

Source: "Are Water Markets a Viable Option?" by Larry Simpson, Finance and Development, June 1994, pp 30-2, Volume 31, Number 2.

charges can serve environmental purposes and provide an incentive for efficient water use. Even though the application of the "Polluter-Pays" principle may benefit poorer groups insofar as they are affected by—and in some cases especially vulnerable to—environmental pollution, one must balance environmental benefits with distributional equity impacts, especially when pollution charges are imposed on necessity goods that have low income elasticity. It may be the case that the burden of pollution charges is distributed regressively, impacting lower income groups in a disproportional fashion.

It is also worth noting that the mix of public policies based upon changes in water supply prices and assessing effluent charges needs to be carefully orchestrated. The case of the Indian steel plant reviewed in Part Two (case 5.2.2) shows that with low water prices the firm finds it cheaper to pay an effluent charge than to practice conservation and recycling options.

Fiscal and Direct Incentives

In the industrial sector, other market-based measures include subsidies, tariff concessions, and tax incentives (cases 5.2.2, 5.2.5, and 5.2.6) for investments in effluent treatment plants and equipment for recycling aiming to achieve water quality goals. This can be used independently or as a "stick and carrot" approach with pollution charges. At the household level, municipalities may offer rebates to contractors or direct payments to the homeowners for the installation of water-conserving fixtures (cases 5.1.5 and 5.1.3).

There are cases when fiscal and direct incentives may be the easiest way to encourage water conservation and pollution abatement. For example, several localities in California have found that giving discounts on connection fees for new buildings in which ultra-low flush toilets are installed is more effective than to try to regulate water consumption habits of the population. Similarly, the State provides financial incentives (loans of up to $5 million) for voluntary and cost-effective capital outlay projects designed to save water. Loans are available to any public agency. These incentives are sometimes expedient means of achieving a desired end, even if they may not be the most desirable means from other points of view

Water Exchanges

Exchange of water among and within sectors can take the form of water markets, water auctions, water banking, or transfer of water-use permits.

Water Market: Among the several prerequisites for the successful development of water markets, which are presented in box 3.3, the ones of greater relevance are legal and physical. Sellers must have both: a clear title to their water and the freedom to sell it. There must also be third party protection. Likewise, the physical means to make water transfers must be available and economic. Given these conditions, the key to the wider development of water markets clearly lies in the adequate recognition of the various third-party and environmental effects. This will, however, set up a trade-off with efficient private exchanges:

"Public policy must seek a balance between unrestricted markets which can impose high external costs, and market restrictions which reduce external costs, but make transfers more expensive, both to market participants and to agencies which evaluate transfer proposals [Saliba 1987]."

One of the oldest and most successful water markets is the Colorado-Big Thompson scheme (case 6.1.1). Allotments of water are bought and sold, principally to enable cities to secure supplies, and a short-term rental market has arisen whereby cities can rent back water to farms on a seasonal basis. The absence of third-party claims greatly facilities transactions and is an unusual feature of this case.

Where users have entrenched rights to water supply, reallocation is possible if they can be encouraged to sell some of their water to others. If that is possible, there would be a strong presumption that the water would be used for higher-value purposes. The existence of alternative outlets for water creates an opportunity cost for its continued use by, for example, a farmer. All water, not just the farmer's "surplus," becomes potentially marketable, and farmers have an incentive to drop low-value applications if they can earn more by selling the water. Such a scheme also avoids the economic and environmental costs of developing new water sources.

The Jamshedpur's case (case 5.2.2) illustrates the operation of water markets among industrial firms. Unlike the Indian power sector, where companies with excess power are not allowed to sell either to the national grid or to other firms, there is no restriction on firms trading water. Large companies with their own captive supplies or with a surplus from their recycling or treatment processes can and do sell water to other firms, some of which are too small for water savings or effluent treatment to be economic.

Most of the evidence on the evolution of surface water markets has been derived from the Western states of the United States (case 6.1.1). States differ in the degree to which laws permit users to transfer water amongst themselves and to other parties. The Bureau of Reclamation now permits sale of its own water. It will authorize such transfer provided that the environment and third parties are not harmed, and that the transfers do not harm the federal government financially, operationally, or contractually [Moore 1991].

The markets for groundwater in Gujarat, India, have existed for 70-80 years and typify a number of others in South Asia (case 6.2.2). Owners of wells have ownership rights over the water they draw, and they sell surplus water to other farmers. Although the typical transaction is one-time transaction, there are several high-volume water dealers selling large quantities to regular buyers.

Water Auctions: Water auctions are rare, although they have long existed in parts of Spain. The situation considered in Part Two (case 6.2.1) comes from Victoria State, Australia. The precondition of the auction that the authorities are free to sell the water to the highest bidder implies that consumers do not have customary or legal entitlement to the water in question. The auction enables users to reveal their valuation of the water; it maximizes the social benefit from its use; and it enables the public supplier to extract the surplus (or rent) from the sale. The auction is economically efficient provided the bidders do not engage in collusive or monopolistic behavior.

Water Banking: Water banking is a common water exchange mechanism in the western states of the United States. It is a sort of institutionalized water trading facility to promote water transactions between water buyers and sellers. Some are permanent institutions, such as the Idaho Water Bank Supply, while others have just temporary permanency, as the ones created in California during the droughts of 1976-77 and 1987-1991 (case 6.1.3).

There are some features worth noting in the 1991 California experience with water banking, especially when one looks at water banking as a possible longer-term means of water exchange. The first observation has to do with the basis for price setting. Prices offered to farmers were market-related, but not on a full "willing buyer, willing seller" basis. Even though the water price offered by the Department of Water Resources reflected the opportunity cost of water in alternative uses, many rice growers were reluctant to sell water at that price. Less than 2 percent of the contracts to sell water were with rice growers.

The second observation refers to the legal assignment of water rights. The fact that most of the responses to the water banking came from those farmers who had water rights reveals the existence of some constraints imposed by the current institutional structure. Many farmers revealed that they were not reluctant to part with their water, but they faced a constraint for selling it since water rights reside in the Irrigation District and not in the farmer.

Lastly, water banking has not come to terms with the third-party and environmental costs imposed by the transaction. This, on the one hand, may imply a high degree of public intervention in order to correct those market failures. However, on the other hand, one must look at this conclusion with caution since sometimes the cost imposed by government interventions to correct these secondary effects may outweigh the benefit [Gardner and Warner 1994].

Transferable Use Permit: The transferable water-use permit is another market device to persuade farmers in the Western states of the United States, currently with long term contracts for Federal Bureau of Reclamation water, to conserve and reallocate their supplies (case 6.1.1) [Leonard 1988]. If legal barriers can be overcome and efficient water markets developed, permits could become an effective reallocation device. They could apply potentially to all existing contracts. Transfers would implicitly take place at prices above the shadow value of the water, and information would be economized in that the irrigation authorities would have no need to find out what these values were.

In order for the permit scheme to take into account third-party and environmental concerns, it has therefore been suggested that a hybrid program might be the most effective option, combining quantitative restrictions (to satisfy environmental needs and third-party effects) with transferable permits. In Australia, for instance, state governments are allowed to veto exchanges on environmental grounds. As an alternative, the state government could acquire the right to outbid offending transfers in the public interest.

3.2.2 Non-market Devices

Non-market devices can take a variety of forms such as laws and sanctions, administrative fiat, persuasion and example, public education, etc. The most basic distinction is between compulsion and persuasion.

Restrictions and Sanctions

Users can be compelled to conserve or reallocate water by various means. In an authoritarian system where consumers have little power, water can be turned on and off and reallocated at the discretion of system managers. Supplies can be cut off at times of shortages, causing involuntary conservation. Such measures are effective but do not guarantee efficiency or equity.

Legal sanctions can be applied to users who exceed norms set by law. Restrictions are commonly placed on certain activities as a response to temporary or seasonal drought and shortage (e.g., bans on the use of outdoor sprinkling or hose-pipes as in cases 5.1.5, 5.1.3 and 5.1.4). Rough notions of efficiency and equity can be served by targeting nonessential and low-priority applications, and such measures can reduce consumption, even over an extended period (case 5.1.4). However, their success depends on a high level of public compliance, which in turn relies on widespread understanding of the problem and support for the restrictions.

Quotas and Norms

Quotas and norms may be set for water users as an attempt to allocate scarce supplies in an equitable manner. Rationing can be effected by issuing fixed quotas and monitoring compliance, or by charging punitive tariff rates on consumption that exceeds the norms or allotment. The latter is a hybrid of "command and control" and economic instruments. The penal tariff has a psychological effect similar to a fine, but it is more efficient since it is levied in proportion to the "excess" consumption, and firms that badly need the extra water may continue to draw it.

The East Bay Municipal Utility District in California (case 5.1.3) made use of a progressive water rate structure to allocate water during the 1988-89 drought. The water district allocated a "base" volume of water to all consumers except to single-families. Consumption in excess of the "base" volume was subjected to an increasing block rate structure. For example, those who consumed 140 percent of their allocated volume had to pay a rate 6 times the normal charge. Moreover, the public perceived the use of this instrument as a more equitable means to allocate water during a drought compared to direct mandatory reductions.

Israel (case 5.2.6) has a comprehensive system of industrial water licensing based on norms that take into account best practice technology, modified by the specific circumstances of each firm. In Tianjin, China, norms based on regular detailed water audits are promulgated for industrial consumers, and users who exceed their norms are subject to a rate up to 50 times the normal charge, depending on the extent of the transgression (case 5.2.5).

Education and Persuasion

Exhortation and appeals to public-spiritedness are often used as a temporary device, capitalizing on public concern over droughts. During the latest drought in California, San Diego cut demand by 30 percent entirely through an exhortation program. In certain cases they become a permanent feature of policy: for example, the Casa del Agua in Tucson is a demonstration center for water technology, and the "Slow the Flow" program promotes conservation in Pima County (in which Tucson is located).

In several situations (cases 5.1.1, 5.1.2, 5.1.3, 5.1.4, and 5.1.5) tariff increases were part of a comprehensive package of measures that included public education, persuasion, and promotion of water saving devices. Quantifying the relative impact of combined measures is quite difficult. However, in the most comprehensive assessment of the Tucson experience (case 5.1.2), the impact of nonprice measures is minimized, though this may underplay their importance in "softening up" the public reaction for price increases.

Regulations and restrictions, if properly enforced, are predictable in their effects, and consumers can readily understand the need for them. If fairly administered, they can be equitable in their impact on different socioeconomic groups, and can penalize large and wasteful users disproportionately. But if implemented by weak and corrupt administrations, they tend to bear down with greatest severity on the poorest groups. However, they do not necessarily maximize the benefits from water use, and they may be excessive from the point of view of "optimum" water use (case 5.1.4).

Exhortation, on the other hand, is far less certain in its effects, though it has fewer political and administrative costs. Although it can, in the short term, help to bolster the impact of more rigorous measures, its long-term impact is doubtful, for example in Tucson (case 5.1.2).

3.3 Direct Interventions

Demand management also includes direct interventions to improve the efficiency of the water delivery network, or programs specifically to encourage user efficiency, recycling, reuse, pollution abatement, etc. The common element in these programs is the aim of reducing technically feasible losses[8] and protecting water quality. Unfortunately, in many instances very little attention has been given to the economic costs imposed and the gains obtained. As one survey points out: "The conserving of one resource will usually imply use or depletion of one or more other resources...[Moreover] losses to an upstream user are the downstream user's supplies, and technically efficiency solutions may have unexpected basin-wide implications [Young and Haveman 1985]."

Interventions may take place at different points on the supply-demand chain: "Distinctions between supply and demand are not always consistent throughout the literature. The precise meaning of these terms depends on the point in the water delivery system where "supply" is defined. [In this report]...supply will be defined at the entry point to the distribution system; after source, bulk storage, transmission and treatment works, but before distribution piping, distribution storage, and customer taps... [Boland 1991]"

Another distinction is whether the prime mover is from the consumer or supply side. There are examples of supply improvements undertaken by consumers and suppliers in their own interests. The intervention has proven to be an efficient allocation of resources: the MWD lining irrigation canals (case 6.1.2); installation of more efficient irrigation equipment and water application control devices (case 5.3.1); the piped irrigation network in Gujarat (case 6.2.2); introduction of water conservation measures and construction of on-site wastewater treatment plants by industrial units in Sao Paulo (case 5.2.4) and Madras (case 5.2.3); reuse of treated municipal wastewater for industrial purposes in Mexico City; and programs to reduce unaccounted-for-water in Sao Paulo, Bangkok (case 5.4.1) and Côte d'Ivoire (case 5.4.2).

Chapter 4

Conclusions and Recommendations

The underlying theme of this study has been the need for users to recognize water as an economic resource. The study provides a compendium of "Best Practice" situations where institutions and policy makers have effectively met the challenge of treating water as an economic resource by means of conservation and reallocation. Evidence drawn from a wide variety of countries at different stages of development suggests that the solutions are widely applicable with local variants and adaptations.

The growing evidence of greater competition for scarce resources and widespread deterioration of water quality has made water demand management imperative in the developing world. This study shows that water demand management has spread beyond traditionally water-scarce countries, and it has emerged, in many instances, as an alternative means to respond to the increasing water demands and the environmental and economic costs imposed by traditional water resources policies.

Compared to supply augmentation projects, water demand management can be economically and environmentally attractive. A number of cases reviewed here show that managing demand through conservation and reallocation can be more cost-effective options than developing new supplies and disposing of more wastewater. Cities are now buying out other users (notably farmers), paying for irrigation improvements in return for saved water, or reducing waste and leakage rather than investing in costly new supply schemes. Options such as efficiency improvements, recycling process water, and treating wastewater for reuse can make industrial firms part of the solution to water shortages, rather than part of the problem. Domestic and agricultural consumers can also reduce demand by adopting water-efficient appliances and other water-saving methods.

4.1 Main Conclusions

The main conclusions from the variety of experiences reviewed in this study are outlined below.

4.1.1 Lack of a Policy Framework

Most developing countries lack a policy framework and associated instruments to preclude excessive quantities of water from being used and excessive pollution. Developing countries do not have instruments–either regulations or economic incentives–and related institutional structures that reflect the value of water to the users and internalize the externalities that arise when one sector affects the quantity and quality of water available to another. The existence of institutional rigidities, market exchange restrictions, and low water prices have facilitated the imposition of high opportunity costs by certain privileged users on other potential users

4.1.2 Demand Management Options in Most Water User Sectors

This study documents that demand management options which produce positive net benefits exist in most water user sectors. There is scattered but compelling evidence that improved policies can have major impacts: at least 20-30 percent of water currently used by households and industries in developing countries can be saved by adopting appropriate policy instruments such as water tariffs, quantitative allocations, fiscal incentives, and technological policies. Similar savings are possible in irrigated agriculture by making investments in canal lining, upgrading on-farm irrigation technologies, encouraging less water-intensive crops, and altering water pricing policies.

4.1.3 Higher Water Prices Reduce Demand

The experiences reviewed show that there is considerable diversity in the policy instruments adopted by countries. No one instrument has been decisive to achieve the desired result. Several compelling instruments do, however, emerge as major contributors. Nevertheless, it is useful to note that almost all experiences share an identical feature: the greater reliance on water pricing.

Low water tariffs promote excessive use and unnecessary waste by those with access; while higher tariffs would reduce demand and encourage less pollution. Examples in this study show that water tariffs are important in determining consumer decisions. Water tariffs provide the necessary signals for the economic scarcity of water, and consumer's response to increased tariffs has been documented.

All consumers seem to be sensitive to water price. In the household sector, for example, price elasticity varies between -0.29 and -0.60. This means that a 100 percent increase in price will produce a 29 to 60 percent decline in water demand. Similarly, in the industrial sector, the majority of estimates of price elasticity are in the range of -0.45 to -1.37. In the irrigation sector, although the limited number of empirical studies, the range of water price elasticities seems to be a little wider, between -0.37 to -1.50. The above suggests that higher water prices for industrial and irrigation consumers may encourage them to conserve water by means of introducing water saving technologies.

4.1.4 Prices Alone are Not Enough

The greater use of water pricing policies is a necessary but not a sufficient condition to improve economic efficiency in the use of water. The reviewed cases show that they work best in combination with supportive regulatory mechanisms and other economic incentives, including increased options for reallocation of water among water users.

Improving the use of water resources cannot rely entirely on market forces. A number of interdependent elements should be present in the policy framework: appropriate legal and institutional reforms affecting the water resources sector; creation of a macroeconomic context in which prices can function effectively; nonprice incentives such as legal restrictions in controlling water pollution, quotas and norms; and public support.

4.1.5 Pollution Control, Charges, and Taxes Encourage Reduction in Water Use

Encouraging industries and power plants to treat their effluent and wastewater and recycle or reuse it in their own processes has the double benefit of environmental improvements and reduction in total water intake. The reduction in industrial water intake provides an economic benefit if the marginal cost of water is higher than the cost incurred to conserve it or if the opportunity cost in alternative uses at the point of withdrawal is relatively high. It also provides an environmental benefit by reducing the volume of liquid effluent and pollutants discharged by industrial users, which further improves water quality in rivers and streams for downstream users.

It is important to note that the above-mentioned improvements in economic efficiency and environmental quality require a careful mix of elements: an effective institutional arrangement to enforce legislation regarding pollution abatement and control; an appropriate industrial water tariff policy that incorporates economic and environmental costs, a system of pollution charges; and fiscal incentives such as tax concessions, low interest loans, and/or subsidies for installation of effluent or sewerage treatment plants.

4.1.6 Defined Water-Usage Rights and Appropriate Physical Infrastructure

The successful experiences with water markets reviewed in this study shed some light on which elements contribute to improvements in water allocation among competing demands by means of transferring water from the agriculture sector to urban areas: users must have clear legal rights to the use of a certain amount of water; and physical means must be present to ensure water mobility. Once these conditions are met, voluntary transfers may take place yielding economic benefits for both buyers (cities) and sellers (farmers).

Although water transfers achieve greater economic efficiency in water use, a word of caution is in order regarding the trade-offs between economic efficiency, equity, and environmental quality. The reviewed experiences indicate the need for some sort of government intervention to prevent third-party and environmental effects.

4.2 Recommendations

Based on the reviewed experiences in developed and developing countries, the following elements emerge as major contributors to the adoption of water demand management and are recommended for consideration in the design of large water supply augmentation projects or pollution control programs.

• Appropriate legal and institutional reforms affecting the water sector and the creation of a macroeconomic context in which water prices can function effectively are key elements of the enabling environment. Removal of institutional rigidities and water market exchange restrictions play a very important role in improving allocation of scarce resources by encouraging rural/urban water transfers.

• The use of a policy of water pricing at levels more nearly approximating incremental costs than is the prevailing practices would have the effect of damping water demand and reducing waste. Unless pricing of water reflects its real economic cost, excessive consumption, greater pollution, steady resource depletion, and premature investments will persist.

• A "demand/supply approach," which considers the significant role of water price and its potential effects upon the quantity consumed, rather than a "requirement approach" should guide investment decisions in the water sector.

• Market-based instruments may need, in some cases, to be reinforced with mandatory measures such as legal restrictions (especially in controlling pollution and managing drought situations), quotas, and norms.

• Public support and understanding for the adopted policy package needs to be generated through publicity and education campaigns. The more compatible the package is with overall social interest of economic efficiency, environmental quality, and equity distribution, the more chances for success exist.

• The reviewed successful experiences have benefited from a combination of features (market and non-market-based instruments), unfortunately lack of data has prevailed to make an adequate evaluation of the instruments taken separately. A priori, one cannot ensure if all measures or instruments were necessary for the success, but certainly, one can say that together they were sufficient.

• Even though some experiences have achieved overall success, some may have been too costly. Thus, the role of policy-makers is to keep those costs under control and, wherever possible, try to make the best use of market-based instruments.

Part Two

Analysis of Best Practice Cases

CHAPTER 5

WATER CONSERVATION AND POLLUTION CONTROL

5.1 Managing Household Demand

5.1.1 Effects of Increased Tariffs on Household Demand in Bogor, Indonesia[9]

Bogor, located in West Java, is one of the major population centers in the province. As of 1985, its population was more than 250,000. Currently the major portion of Bogor's municipal water supply is drawn from three main springs located a few kilometers from the city. Water is also taken from the Cisadena river and two small deepwells. With the exception of the deepwells, water is transmitted and distributed via a gravity system.

In 1984, the level of coverage was far below that of the target of the government development plan REPELITA IV. The goal of the development program of the Government of Indonesia (GOI) was to serve 75 percent of the population with piped water by 1990.

The rapid population growth in the supply area combined with the need to expand coverage means that there will be a large increase in raw water requirements in Bogor. Estimates of raw water demand for 2000 and 2010 are shown in table 5.1. From these figures, it is evident that water requirements go far beyond current system capacity. The additional water requirements will be 1.7 m^3/s by 2000 and 2.9 m^3/s by 2010, three and five times the volume that can be currently supplied.

The Bogor water supply enterprise, PDAM Bogor, has initiated the first phase of the development of the water supply system. This enlargement project has a planning horizon to 1995 and plans to take approximately 940 l/s of raw water from the Cisadena river. With this additional supply, by 2000 the deficit will be about 0.9 m^3/s or 40 percent of total requirements.

Table 5.1: Raw water requirements in Bogor, Indonesia

	1984	*2000*	*2010*
Total population	251,390	956,871	1,356,701
Coverage[a]	49%	82%	87%
Per capita consumption[b]	169	130	132
Water requirement (l/s)	483	2,267	3.454
Available supply (l/s)[c]	420	540	540
Additional raw water (l/s)	63	1,727	2 914

a. In accordance with REPELITA IV Policy with respect to water supply levels.
b. It has been anticipated that water consumption levels will be reduced over time.
c. In March 1988 a surface water treatment plant with a capacity of 120 l/s was taken into operation.

Source: Adapted from "Bogor Water Supply Project Feasibility Study," IWACO-WASECO, 1987.

The total investment cost of the current scheme was estimated at Rp 83.6 billion (price of January 1990) [IWACO-WASECO 1990]. This represents a discounted unit cost of about Rp 410/m^3 (\$0.23/m^3). A calculation has been made to assess the increase in cost of this new scheme based on surface sources compared to the old scheme based on spring sources. Using estimates of the investment costs for small urban water-supply systems in West Java [GOI 1989], the relationship in terms of average incremental cost between a system that depends on spring water and a system that relies on surface water is 1:2.

Despite the lack of available data on the marginal cost of the future scheme it is possible to estimate that the cost will be almost double the cost of current scheme. The proposed system for Bogor after 1995 is similar to the new piped water system of Jakarta (Cisadena I), whose unit cost is estimated at Rp 800 (\$0.45) [GOI 1989]. PDAM Bogor was aware that it would face higher investment costs in the near

Table 5.2: Old and new rate structures, PDAM Bogor, Indonesia

			Old rate		*New rate*	
Tariff group		*Meter use per month (m^3)*	*Unit price (Rp)*	*Monthly cost (Rp)*	*Unit price (Rp)*	*Monthly cost (Rp)*
B2:	*House connection*					
	Administrative		300		400	
	Meter rent		200		750	
	Connection fee		250		350	
		0 - 10	50	1,250	100	2,500
		11 - 20	75	2,000	150	4,000
		21 - 30	125	3,250	300	7,000
		> 30	250	> 3,250	700 >	7,000
C2:	*Commercial connection*					
	Administrative		500		700	
	Meter rent		200		750	
	Connection fee		400		500	
		0 -10	150	2,600	300	4,950
		11 - 50	250	12,600	750	34,950
		> 50	400	> 12,600	1,200	> 34,950

future. Thus, a decision was made to combine the augmentation of water supplies with water demand management measures to reduce average water consumption to about 30 m^3 per month per household[10] and achieve higher coverage. The current level of water use in Bogor is 82 percent higher than the level defined in REPELITA IV.

ADOPTED MEASURES

In order to ration water use and balance demand and supply, PDAM introduced both price and nonprice policy instruments.

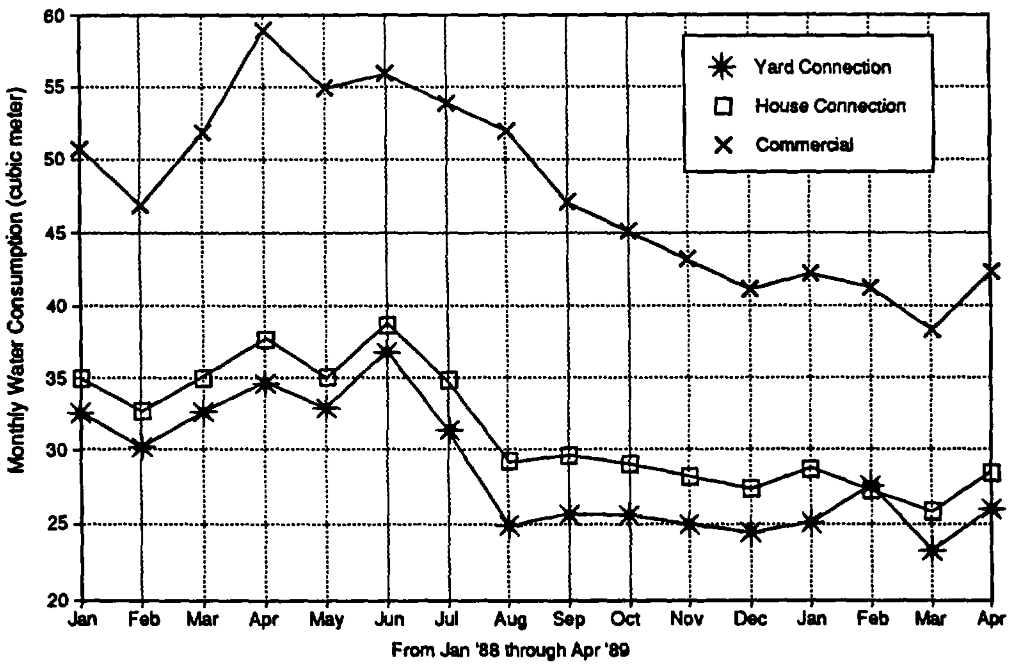
Price Policy Instrument: In June 1988 [IWACO-WASECO 1989b], after a new water surface treatment plant began to operate, PDAM adjusted the water rates. Water consumption in Bogor before the price increase was much higher than the proposed level in REPELITA IV. The difference was mainly caused by the relatively low water price. The average charge for a residential user consuming 30 m^3 per month before June 1988 was only Rp 108 per m^3 while the unit cost of production was around Rp 440.

The tariff structure in Bogor, which incorporates two categories of consumers (domestic and nondomestic) and five subcategories (yard and house connection for the former; and institutional, commercial, and government connection for the latter), is based on a progressive rate per cubic meter plus fixed charges. This progressive tariff structure has the purpose of improving equity, since a lower rate would be charged to those who consume less water, e.g., the ones who have lower incomes.[11]

The features of the June 1988 water rate structure of Bogor, which is partially presented in table 5.2, were: (a) the increased progressivity of the water rate structure; (b) the high increase of water rates; and (c) the higher fixed service charges.

This tariff schedule was much more progressive than the old one, that is, the differences between rates increased. Domestic consumers' rates became more progressive beyond a monthly consumption of 30 m^3. In addition, the price increase was significant, from 100 percent to 280 percent. As a result, the price of the last unit of water consumed increased remarkably. Fixed service charges increased between a minimum of 50 percent and a maximum of 275 percent. The above features hold true especially for the domestic and commercial connection rates, while the rate changes for the institutional and government connections were less pronounced. Table 5.2 shows that a domestic consumer with a monthly demand of 30 m^3 paid Rp 7,000 per month or 115 percent more than previous to the change. However, government consumers or institutional consumers with a monthly consumption of 50 m^3 paid a price that just doubled the old price.

Figure 5.1: Average water use by household and commercial users in Bogor, Indonesia



Nonprice Policy Instrument: In spite of the tariff increase of June 1988 [IWACO-WASECO 1989a], 51 percent of the customers were still using more than 30 m³ per moth. Therefore, in March 1989 PDAM initiated a campaign to reduce water use design especially for customers with a monthly consumption above 100 m³. The campaign was organized into three steps.

Step 1: PDAM sent every customer pamphlets and brochures describing ways to reduce water use within the house and instructions for reading water meters.

Step 2: PDAM sent customers with monthly consumption greater than 100 m³ additional information on possible reasons for high consumption. Home visits by PDAM employees were offered through the Consumption Level Evaluation Program (CLEP).

Step 3: When customers joined the program, PDAM employees visited their homes to look for leaks. If leaks were found, an estimate of repair costs and projected savings were provided. During the visit, PDAM employees carried out a survey of the household's water use habits and made recommendations for improving water use.

IMPACTS

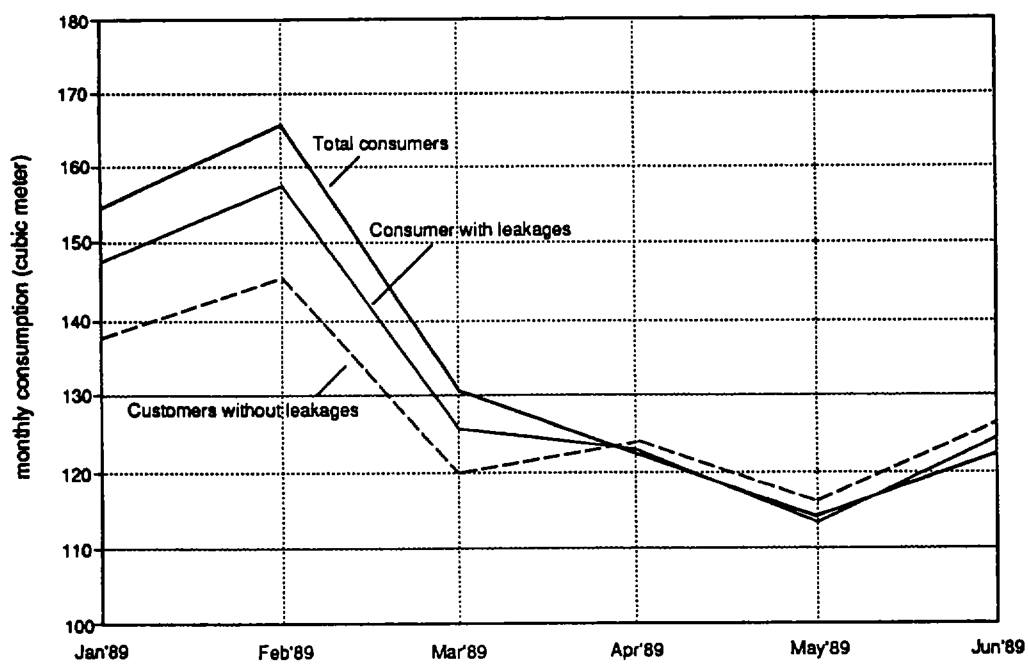
This section describes the effectiveness and economic efficiency of the two measures.

1. Effectiveness

Price Policy Instrument. As a result of the substantial water rate increase, domestic and commercial water use decreased by 30 percent. The evolution of the average monthly water use for different categories of customers from January 1988 to April 1989 is shown in figure 5.1. In the case of domestic customers with yard connections and house connections, from June 1988 to April 1989, average monthly consumption decreased from 39 m³ and 37 m³ to 28 m³ and 26 m³, respectively, which represents a 28 percent and a 30 percent reduction in water use. Commercial customers also responded to the price increase by decreasing their consumption by 29 percent on average. As illustrated in figure 5.1, in April 1988, the average water consumption of commercial customers was 59 m³. But one year after the new water rate was set, consumption dropped to 42 m³.

Nonprice Policy Instrument. Three months after the campaign for reducing water con-

Figure 5.2: Impact of the consumption level evaluation program in Bogor, Indonesia



sumption started, average monthly water use decreased by 29 percent, from 159 m^3 in February 1989 to 113 m^3 in May 1989. Figure 5.2 presents the impact of the CLEP on domestic customers B2. This reduction was due to leak repairs by customers and changes in their water-use habits. Customers with leaks reduced their consumption by 31 percent, but customers without leaks reduced consumption by 21 percent. The success of the campaign was attributed to the goodwill and commitment of the water utility, the public participation, and the combination of communication, motivation, and technical skills of PDAM employees. Moreover, customers were very pleased with the services provided by the water utility.

2. Economic Efficiency

A cost-benefit analysis was conducted to determine whether the price rise and the conservation campaign were economically efficient conservation policies. The analysis follows the benefit-cost approach presented by Hanke (1982). As quoted by Hanke, a conservation policy is desirable only if its benefits exceed its costs. The incremental benefits are estimated by multiplying the reduction in water use (Q) that resulted from a policy measure times the marginal cost of water (MC). Incremental costs are estimated by adding the following three costs: (a) the resource cost to the water utility by adapting the policy (e.g. education, enforcement, meters, etc.) (U); (b) the resource cost to the consumer (repair of leaks, change of taps, time spent, etc.) (E); and (c) the value of the "useful" consumption forgone (F). The above can be mathematically expressed by the following equation:

$$Q * MC \geq U + E + F$$

The results of the above methodology to the two policies implemented by PDAM are as follows.

Figure 5.3: Water demand curve of customers with yard connection in Bogor, Indonesia

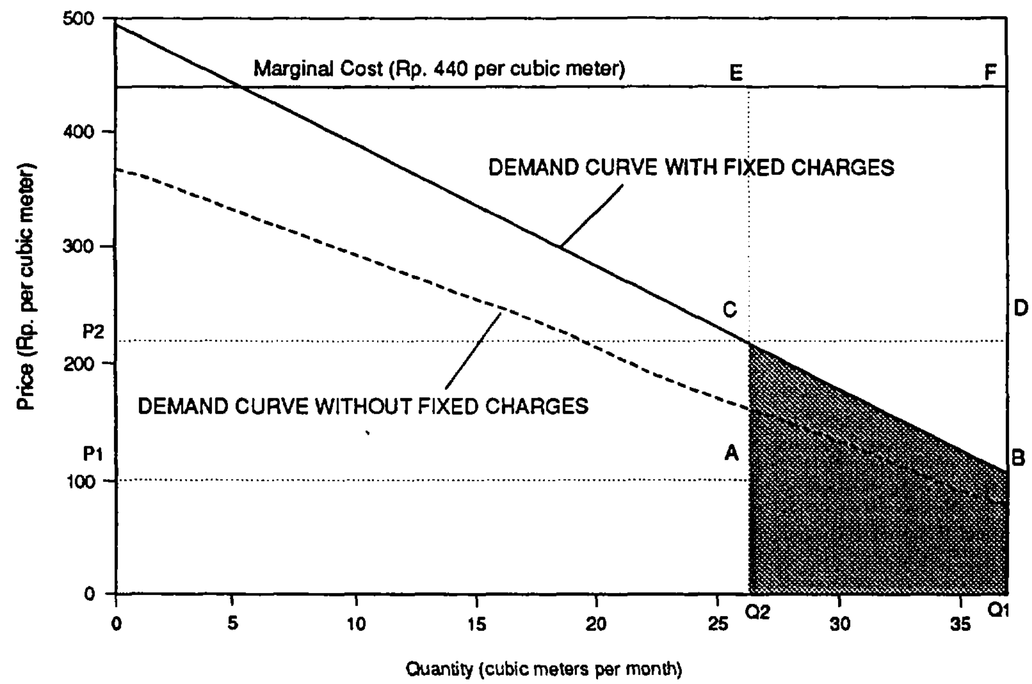


Figure 5.4: Water demand curve of customers with house connection in Bogor, Indonesia

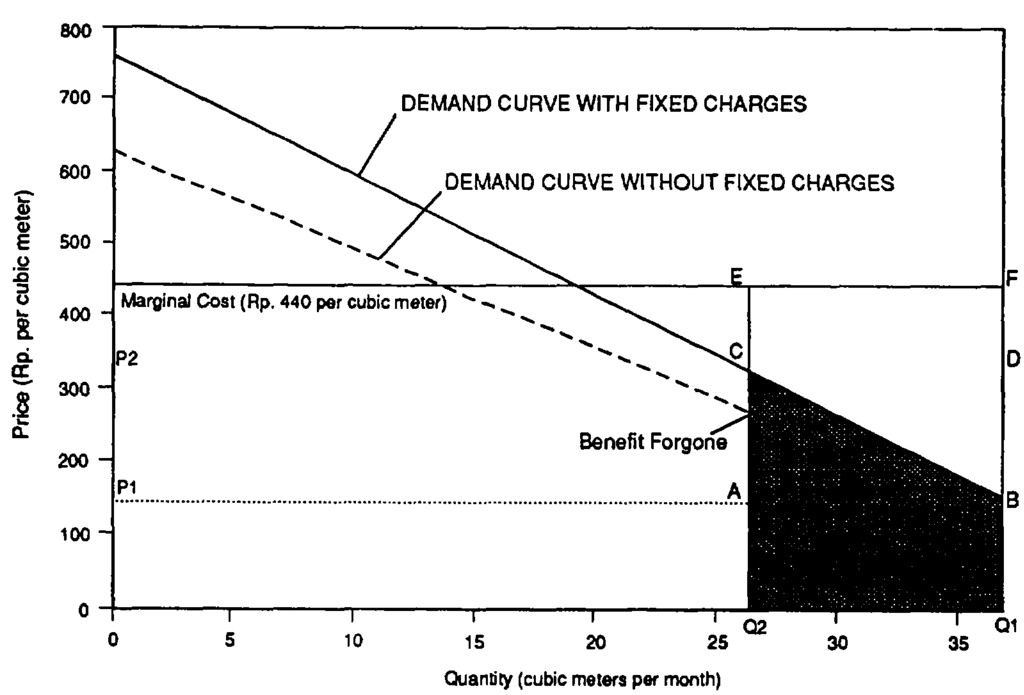
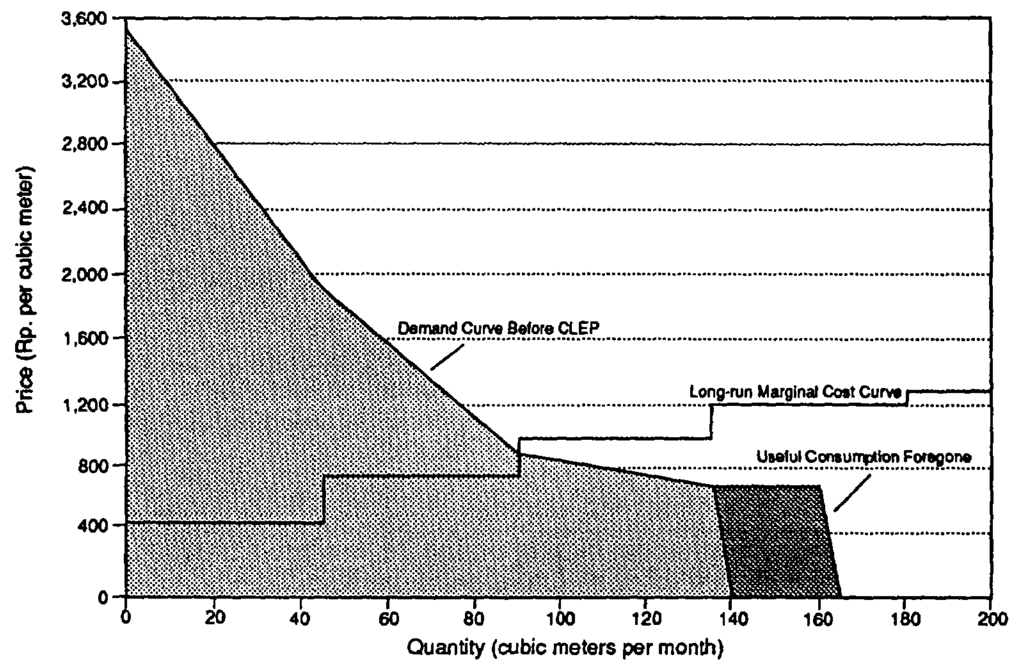


Figure 5.5: Demand of households consuming above 100 m³ per month in Bogor, Indonesia



Price Policy Instrument. In this case, values of both "U" and "E" are zero. Neither the utility nor customers incurred extra costs. A value of Rp 440 per m3 was assumed as the marginal cost of water of Bogor. To assess the value of "F," it is necessary to determine the water demand function. In this case, demand functions have been constructed using price elasticity coefficients calculated by IWACO. Estimated average price elasticities for domestic customers with yard connection are -0.27 with fixed costs included and -0.29 without fixed costs. For domestic customers house connections, estimated average price elasticities are -0.23 including fixed costs and -0.24 excluding fixed costs. These demand curves are shown in figures 5.3 and 5.4.

For a domestic customer with yard connection, the total change in benefits that resulted from a price increase equals the reduced water use of 10 m³ times the marginal cost, Rp 440/m³. Thus, Q * MC is Rp 4,400 per month [(36-26)*440]. The value of "F" is estimated as the integral of the demand curve over Q_1 and Q_2, which corresponds to the shaded area Q_2CBQ_1 of figure 5.3. The value of the area is Rp 1,875 [(36-26)*104+(36-26)*(271-104)*0.5].

For a domestic customer with house connection, the total benefit is equal to Rp 4,840 [(39-28)*440], while the related cost is Rp 2,503 [(39-28)*141+(39-28)*(314-141)*0.5]. The results show that the higher price has generated net benefits of Rp 2,525 and Rp 2,337. Thus, the measure was economically efficient.

Nonprice Policy Instrument. The total change in benefits due to the campaign equals the reduced water use of 35 m³ per month, from 160 to 125 m³, times the marginal cost. In this case the marginal cost is not Rp 440/m³ as assumed earlier, since that value is the marginal cost of a system with capacity to produce only 45 m³ per month per household. A system with capacity to produce 160 m³ will bear a cost of at least Rp 1,120.[12] Thus, the total change in benefits is Rp 39,200. In this case, lack of data precludes to determine the value of "U." The value of "E," which corresponds to the cost for leak repairs, is estimated at Rp 6,080.[13] The value of "F" or "useful" consumption forgone is estimated as the area encompassed by the demand function "before" the campaign and the demand function "after" the campaign.

In figure 5.5, the first curve represents the standard demand function, while the latter represents a shift to the left of about 23 m^3 per month.[14] As can be seen, there is not movement along the demand curve since the relationship between price and demand for water remains basically the same. The loss of consumer's surplus is equal to Rp 14,790 per month [23*630]. The net benefit from this policy is about Rp 18,330 per month.

From the consumer's point of view, the reduction of leaks produces a net saving. It has been estimated that a hole of 1.5 mm in a pipe can waste almost 1,500 liters of water per day under normal pressure. Such a leak represents a monthly loss of 45 m^3 or Rp 31,500, calculated at a tariff rate of Rp 700/m^3). The estimated cost to repair such a leak is Rp 101,241. Based on these assumptions, the total cost of repair work may be balanced by the saving on the water bill in about 3.2 months (101,241/31,500).

Conclusions

This case study documents the impressive reduction of municipal water demand in Bogor, Indonesia, through the use of price and nonprice policy instruments. The Bogor experience demonstrates that when sharp increases in water prices are made and higher prices for additional quantities (increasing block rates) have to be paid, water customers respond by eliminating or reducing wasteful use. In Bogor, domestic and commercial water use decreased by about 30 percent within one year as a result of the tariff increase ranking between 200 percent and 300 percent in different consumption blocks. The campaign for reducing domestic consumption also produced positive results since customers with monthly consumption above 100 m^3 decreased consumption by 26 percent. This latter reduction was achieved by the customers' repairing leaks and changing water use habits. Both measures were effective and economically efficient.

5.1.2 Role of Prices in Water Conservation in Tucson, USA[15]

Tucson, Arizona, is located in a desert, and until recently it was almost wholly dependent on groundwater for its supply. Surface supplies from the Central Arizona Project will only postpone the need to reduce the city's total water consumption, which is causing severe mining of the surrounding aquifer. Since the 1970s, water charges have been periodically raised and adjusted to a two-part progressive structure that reflects the real costs of supply. Pricing measures and conservation programs have achieved reductions in per capita water use.

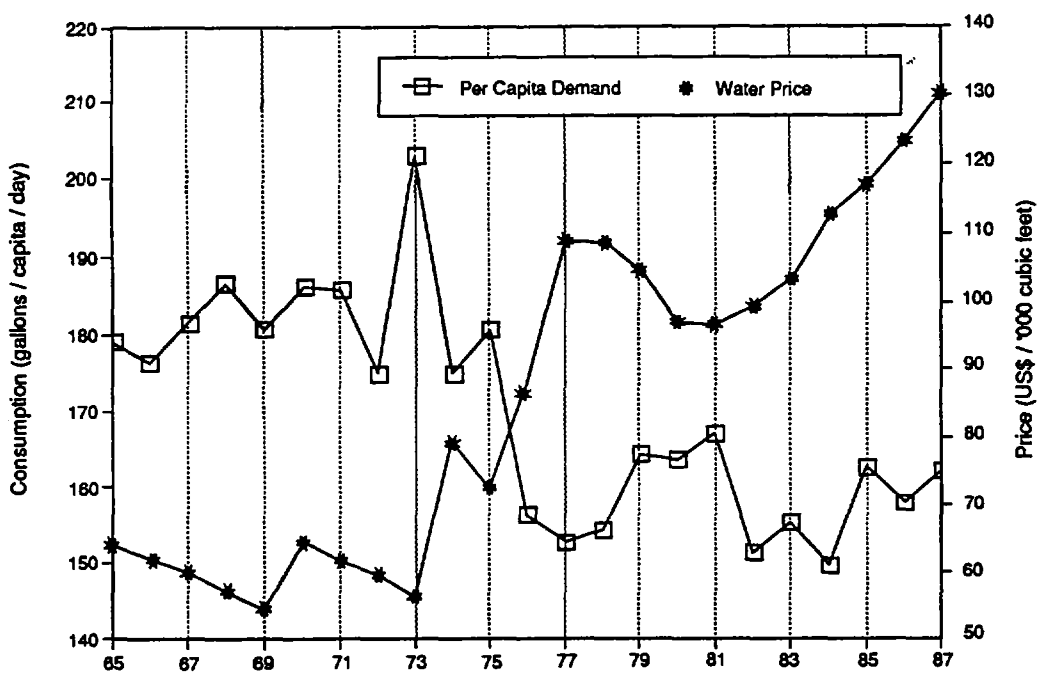
Since 1950, the population of Tucson has mushroomed to its current 700,000 inhabitants, and it is projected to continue rapid growth. Almost 80 percent of the city's water comes from groundwater pumped from well-fields along the dry Santa Cruz river bed south of the city. The rest is obtained from former agricultural land bought by the city for its water entitlement and taken out of production. Both sources have heavy economic and environmental costs. Groundwater costs include the energy cost of pumping, the risk of land subsidence, and the externality arising from mining of the aquifer. The costs of diverting agricultural water for city use include the direct costs of pumping and the environmental costs of erosion on the abandoned land.

Adopted Measures

Tucson made its first tentative steps toward economic pricing of water in the mid-seventies, after the abrupt increase in the energy costs of pumping. However, this came at a time of mounting concern over the consequences of the heavy groundwater overdraft. In 1974, a rate increase of 30 percent was enacted and the rate structure was made mildly progressive. Although the gradient between the blocks was too small to have much effect on conservation, Tucson was one of the first cities to adopt a progressive water rate structure in contrast with the more usual declining block structure.

The tariff was changed again in 1976, mainly for financial reasons. At the time, the city authorities anticipated having to spend large sums on alternative long-term water sources, including substitutes for the large quantities of Santa Cruz water claimed by the Papago Indians. Tariffs were based on the average cost of supply, with steeper progressivity than before and a high-lift surcharge recognizing the extra costs of servicing certain consumers. The tariff revision was very unpopular, and in the 1977 recall

Figure 5.6: Water price and urban water use in Tucson, Arizona



Source:" Water Price as a Public Variable in Managing Urban Water Use: Tucson, Arizona," Martin and Kulakowski 1991.

election several new council members took office and scrapped the lift charges. Developers were also required to pay the full capital cost of the extension of supplies to new houses. This provision was widely anticipated, its impact was effectively evaded, and its revenues failed to materialize.

The resulting revenue shortage facing the water utility plus the Arizona Supreme Court's decision to place one of the well fields effectively out of bounds for water, led to urgent consideration of a new capital improvement program and revenue sources by a citizens' advisory committee. This Committee accepted the general principle that water charges should be in proportion to the cost of supplying and servicing consumers. The committee also argued that if the community were fully informed about the water situation and the major savings in capital spending and the consequent savings in water bills, it would willingly accept a conservation program.

The upshot was the adoption of another new tariff structure in 1977, incorporating differential summer and winter rates, and a moderately progressive block structure for residential and small commercial consumers. A "lifeline" rate was introduced for small consumers and an "isolated zone" surcharge was retained. In the same year, the city council adopted "Beat the Peak," a campaign to persuade householders to shift water use away from peak hours, water lawns every other day, and invest in desert landscaping rather than lawns. After a few years the campaign started, per capita use dropped by 16 percent, allowing Tucson to cut its water supply augmentation cost by $75 million (in 1990 prices) [Postel 1992].

Since 1976, water rates have increased each year, though not always at the rate of inflation. The Central Arizona Project (CAP) provides significant quantities of federally subsidized surface water to Tucson. This prospect enabled the Tucson authorities to plan a gradual reduction of groundwater abstractions and a phasing in of CAP supplies. Some reduction of water demand was called for in any scenario. In 1980, water conservation became official policy of Arizona, with a mandated goal of zero groundwater overdraft by 2025. Tucson has to set goals for per capita water consumption which, if exceeded, would in theory attract a fine of $10,000 per day from the Arizona Department of Water Resources.

In short, Tucson has an official policy of conservation, and has made active use of prices to help manage demand. The rate structure adopted in 1977 and revised in 1980 was basically an average-cost system, but the incorporation of seasonal peak pricing and the increasing block structure were steps in the direction of marginal cost pricing. Tucson's experience has been unusually interesting, and it has been the subject of a number of econometric studies of water demand and its responsiveness to prices.

IMPACTS

The overall assessment of Tucson's experience over more than two decades is that the demand for water is sufficiently responsive to price to make tariffs a crucial method of conservation. However, water prices have not been used actively enough to achieve conservation goals, and in particular to offset the strong "income effect" from rising living standards. The trend in water consumption is shown in figure 5.6. Econometric studies that attempt to control for climate variations from year to year and for the increase in income of residents indicate a price elasticity of demand for water ranging between -0.27 and -0.70.

Water price increases plus water-saving technologies, regulations, and public education have produced a substantial drop in Tucson's average per capita consumption, 22 percent in 15 years, from 760 lcd in the mid-1970s to the current 590 lcd. The conservation program has allowed Tucson to postpone investments in groundwater wells and transmission facilities estimated at $75 million in 1990.

CONCLUSIONS

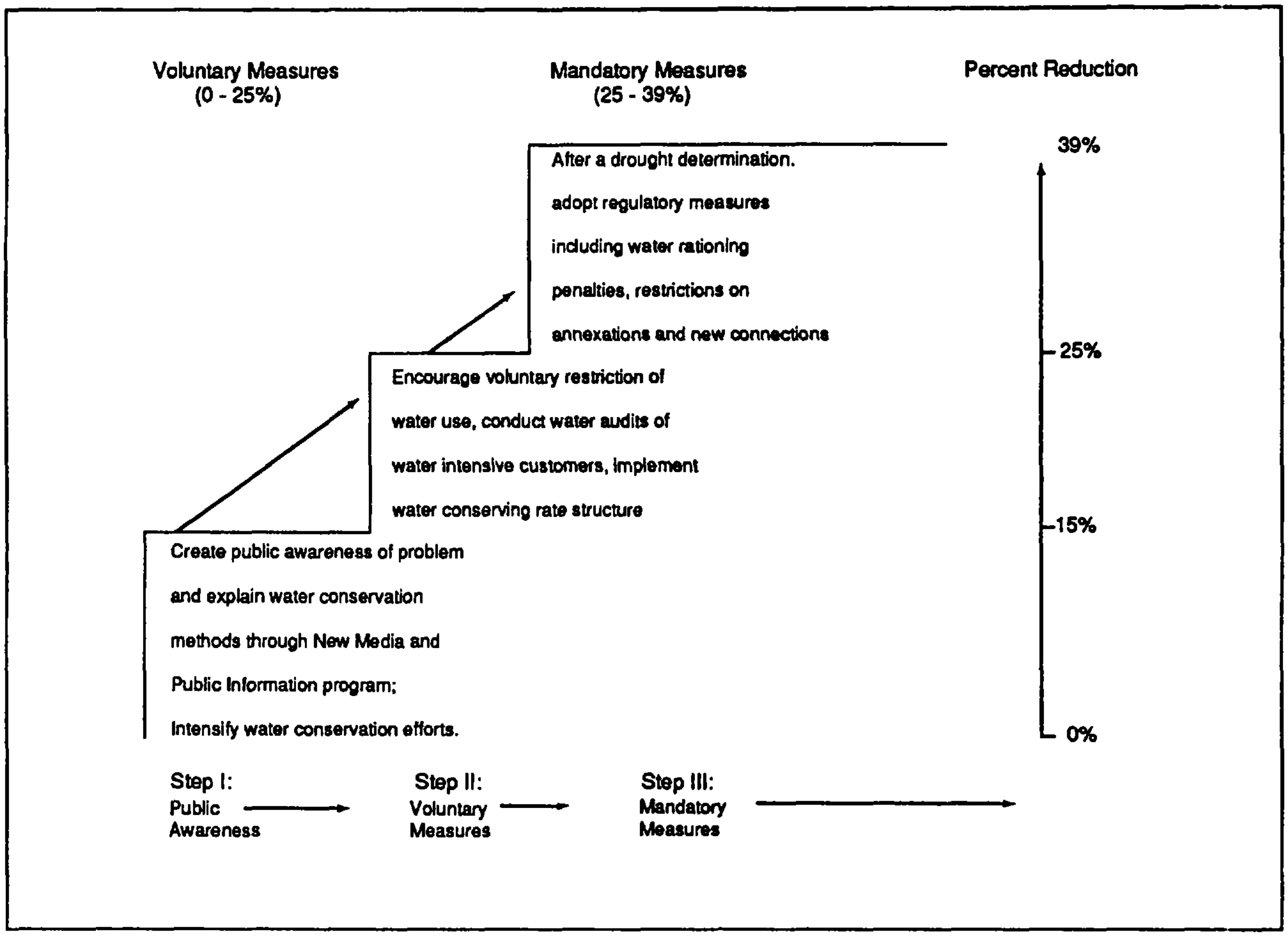
Tucson's experience can be called a qualified success, with the potential to be much more successful, and the following elements of the enabling environment appear to have been important:

- Water problems received widespread study, publicity, and debate during the 1970s, when the present policy was set. This included an influential report by the Citizens' Advisory Committee. In the city's desert setting, water is guaranteed a high profile and is rarely out of the news. The fact that most of the water was drawn from a finite underground source that was clearly being depleted helped convince the public of the severity of the problem.
- Until the formulation of the CAP, there were no easily available alternative water sources, except at high cost. The start of implementation of the CAP took some of the urgency out of water planning from the late 1970s onwards, but the amounts likely to be available were never going to detract from the need from long-term conservation.
- The general principle that water charges should be proportional to the cost of supplying different classes of consumer was accepted, and the main features of the tariff structure were intelligible in the light of that principle. A lifeline rate for small consumers was retained against professional advice, and further helped to defuse resistance.
- Tariff increases have been linked to the cost of providing an expanding network, dating back to the structure adopted in 1976.
- Water conservation has been adopted as an official policy of Arizona, to which Tucson must respond by law.

5.1.3 Managing Water Demand During Droughts in California, USA[16]

In 1986, the population served by the East Bay Municipal Utility District (EBMUD) was about 1.2 million in a service area of approximately 800 square kilometers, including 20 cities and 15 annexed communities. The EBMUD has a legal entitlement during normal years of up to 449 MCM from the Mokelumme river, 50 percent more than the annual water requirement of the district (270 MCM). However, during drought periods, its available supply is less than the maximum entitlement. Two reservoirs, Pardee and Camanche, provide protection against a single dry year since their combined storage capacity is 790 MCM per year. But, when two or more succeeding dry years occur, the quantity

Figure 5.7: Short-term measures to reduce water demand in California, USA



available for carry-over storage declines and supply deficiencies arise.

To deal with the 1988-89 drought, the EBMUD adopted the Water Supply Availability and Deficiency Policy enacted in May 1985. In general, this policy requires an annual review and evaluation of the adequacy of water supplies to meet customer's demands in the current and following year. If deficiencies are projected, then appropriate demand management measures must be implemented to reduce water consumption. According to the policy, the acceptable maximum level of demand is 330 MCM per year and customers should not suffer from water deficiencies greater than 39 percent, which occurred during the drought period 1976-77. Figure 5.7 presents the steps involved in implementing short-term measures for reducing demand according to the policy.

The EBMUD experienced a sharp drop in storage supplies during a three-year period starting in October 1986. By March 1987, the combined storage from the Pardee and Camanche Reservoirs was 90 percent of normal level. By the end of September 1987, the storage was nearly 70 percent of normal level, and it was predicted to fall below 50 percent. The perceived water shortage in the near future was an impetus for the EBMUD to consider and implement a water conservation program.

Adopted Measures

Between June and September of 1987, the EBMUD adopted a voluntary conservation program aiming at 12-percent reduction in consumption. This reduction was measured against the consumption of 1986. As a result of the voluntary program, only 3.5 percent reduction was achieved, equivalent to one-third of the reduction target. The discouraging result forced EBMUD to adopt a more stringent drought program aiming to achieve conservation targets of 25 percent and 15 percent during 1988 and 1989, respectively. The new program was implemented by mandatory conservation goals

Table 5.3: 1986 Water consumption by customer group and by season in MCM

Customer	Annual Total	Annual Percent	Summer Monthly	Summer Total	Winter Monthly	Winter Total	Summer greater than winter Percent
Single-family	125.3	46.3	13.6	67.8	8.2	26.6	62.8
Multifamily	43.5	16.1	4.0	19.9	3.4	3.0	7.1
Industrial	46.6	17.2	4.2	20.8	3.7	2.3	5.5
Commercial	38.8	14.3	3.6	18.0	3.0	3.2	7.5
Irrigation	16.6	6.1	2.2	11.1	0.8	7.3	17.1
Total	270.9		27.5	137.6	19.0	42.4	

Table 5.4: Conservation targets by customer group, EBMUD, USA in MCM

	15 Percent Summer Reduction Total	15 Percent Summer Reduction Percent Share	25 Percent Summer Reduction Total	25 Percent Summer Reduction Percent Share
Single family	21.6	31.9	13.0	19.1
Multifamily	2.4	12.2	1.5	7.3
Industrial	1.9	9.1	1.1	5.5
Commercial	2.6	14.3	1.5	8.6
Irrigation	5.9	52.9	3.5	31.7
Total	34.4	25.0	20.6	15.0

by customer group, strict ordinances on water use, an increasing block rate structure, and an extensive public awareness program. Some of the measures adopted by EBMUD to cope with the drought are described below:

Increasing Block Rate Structure or "Drought Water Rate". To provide financial incentives to all customers, the utility established an increasing block rate structure that progressively increases the cost of water use above a minimum allocation. Once the EBMUD estimated that the shortfall of supply would be about 25 percent of the normal summer consumption level, then three different conservation targets of 20 percent, 25 percent and 35 percent were looked at. Finally, the 25 percent conservation target of peak summer consumption (defined as the summer consumption greater than the winter one) was selected for implementation. In terms of volume, the 25 percent conservation target represented 34.4 MCM reduction of summer consumption.

Table 5.3 shows the annual and the seasonal water consumption by customer groups, as well as the peak summer consumption. To derive the conservation target for each custor er group, the EBMUD distributed the total volume supposed to be saved among all customers in proportion to their peak summer consumption. In the case of the single-family group, for example, the total target reduction was 21.6 MCM or 32 percent of summer consumption. Table 5.4 presents conservation targets per customer group for a 25 percent and a 15 percent overall reduction of the summer consumption.

To design the respective rate structure, the EBMUD determined the appropriate financial or neutral rate corresponding to a reduction on the sale volume. Under normal conditions, the financial water rate was $0.25/m^3. However, in order to reflect the reduction of overall sales of either 25 percent or 15 percent, the estimated neutral water rates were $0.37/m^3 and $0.32/m^3, respectively.

For each percentage of reduction in water demand, the water utility designed two different rate structures. The first one was for single-family customers based on "consumption blocks",[17] and the second one was for other customers (multi-family, industrial, commercial, and irrigation) based on the "percentage of prior use."[18] Figures 5.9 and 5.10 present drought rates for a 15 percent and 25 percent reduction in consumption. A rate of $0.25/m^3 was applied to the first block from 0 to 22.7 m^3 (basic needs) of single-family consumption.

Regulations. The EBMUD passed the "28 Drought Ordinance" that included:

- Cars or other vehicles could not be

Figure 5.8: Drought rates for single-family customer group, EBMUD, USA

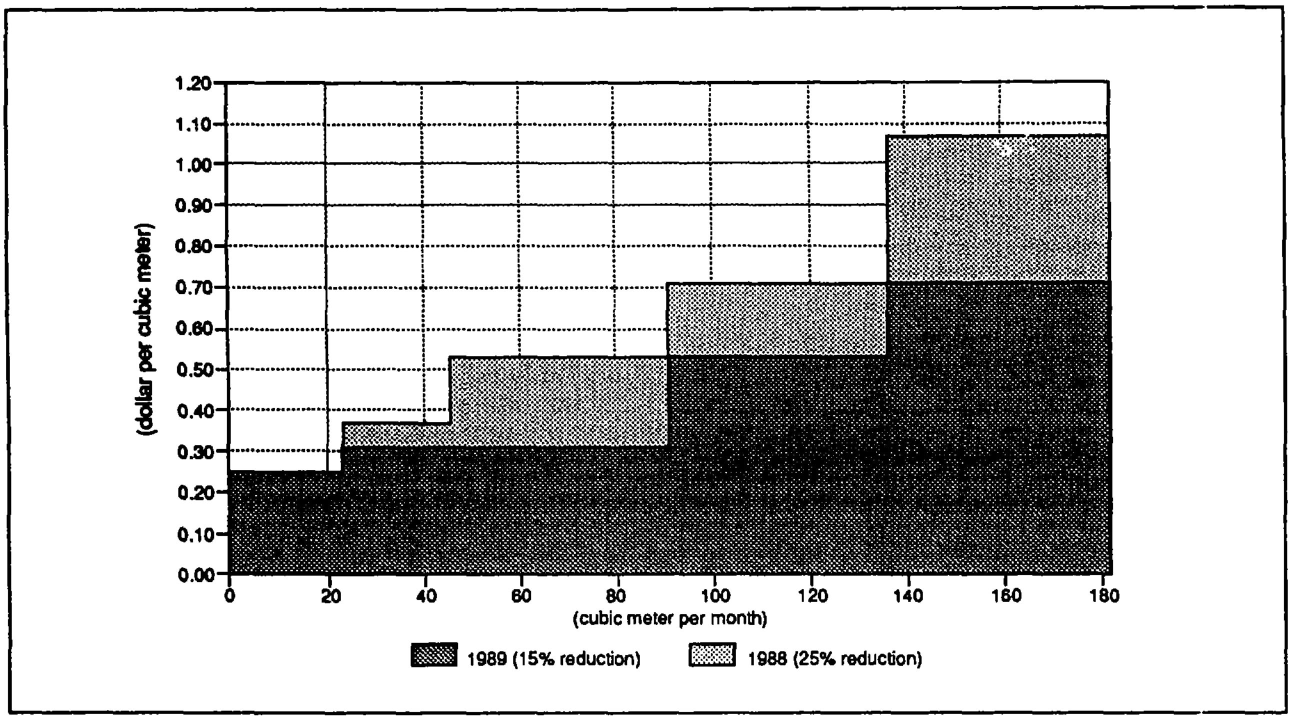


Figure 5.9: Drought rates for customers other than single family, EBMUD, USA

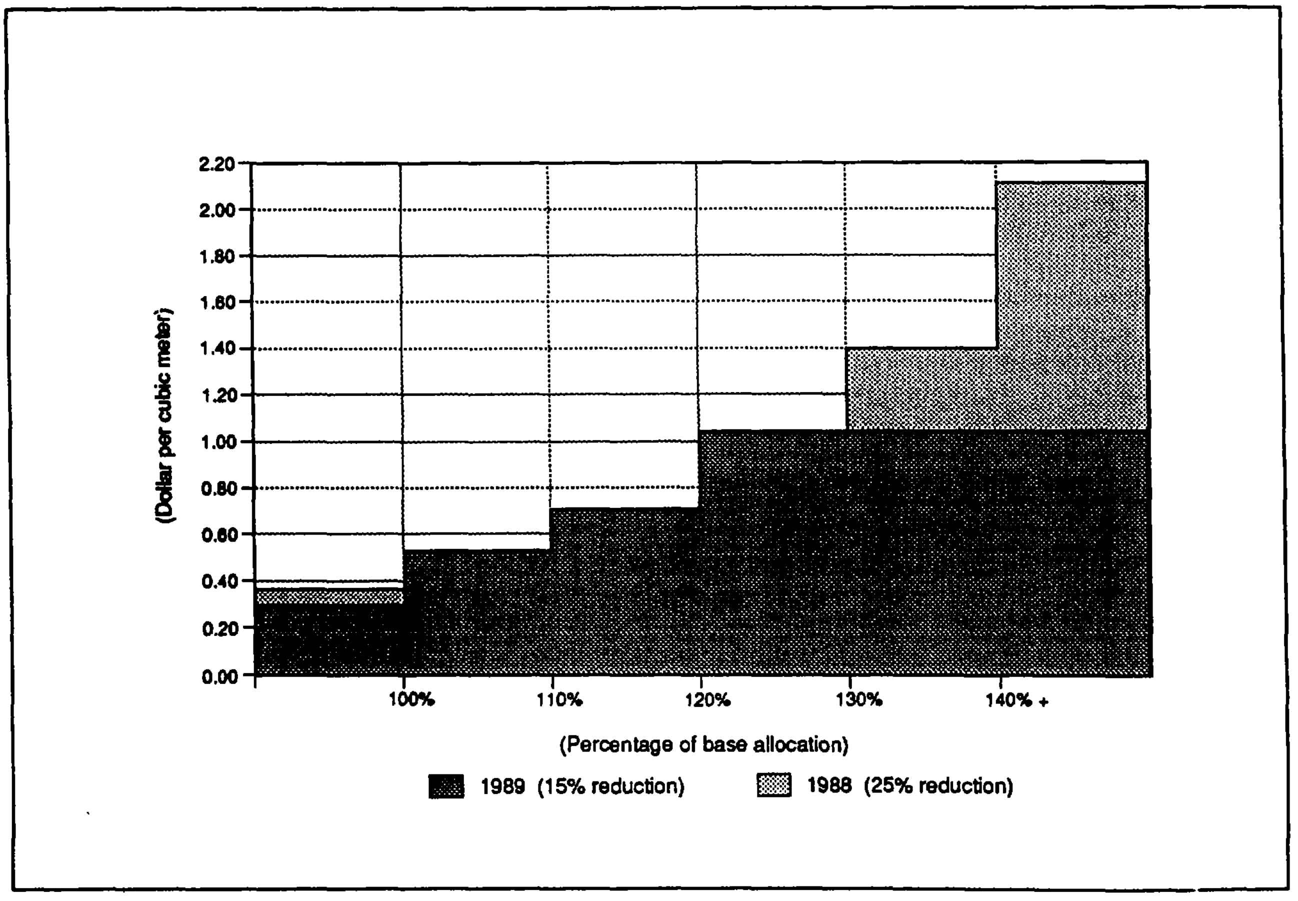
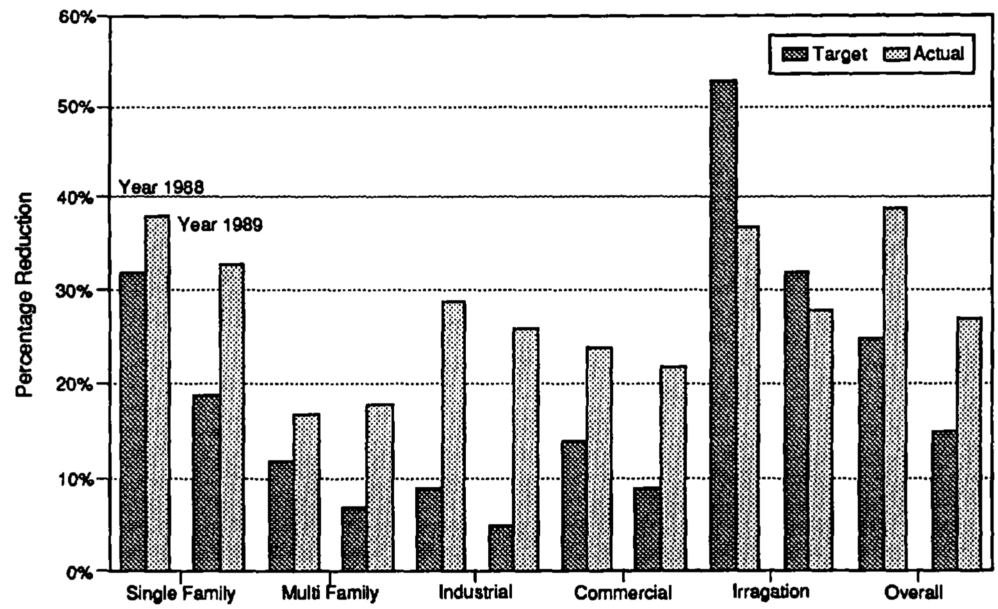


Figure 5.10: Percentage reduction from 1986 level by customer group, EBMUD, USA



washed without the use of a shutoff nozzle.

- No new turf could be installed, and only drought-tolerant planting was allowed.
- New service connections were adhered to a written drought-compliance agreement.
- No annexations of territory outside the district's ultimate service boundary were allowed.
- A wastewater patrol was established to identify violations.
- Flow-restricting devices could be installed in the event of prolonged noncompliance.

Other Measures. To inform the public of the severity of the drought, a campaign was conducted by radio, TV, newspapers, billboards, and shopping-mall displays. Educational programs on conservation were provided in local schools. In addition, 55,000 conservation kits[19] were distributed free of charge among 20 percent of the customers. About 90 percent of these kits were installed.

Impacts

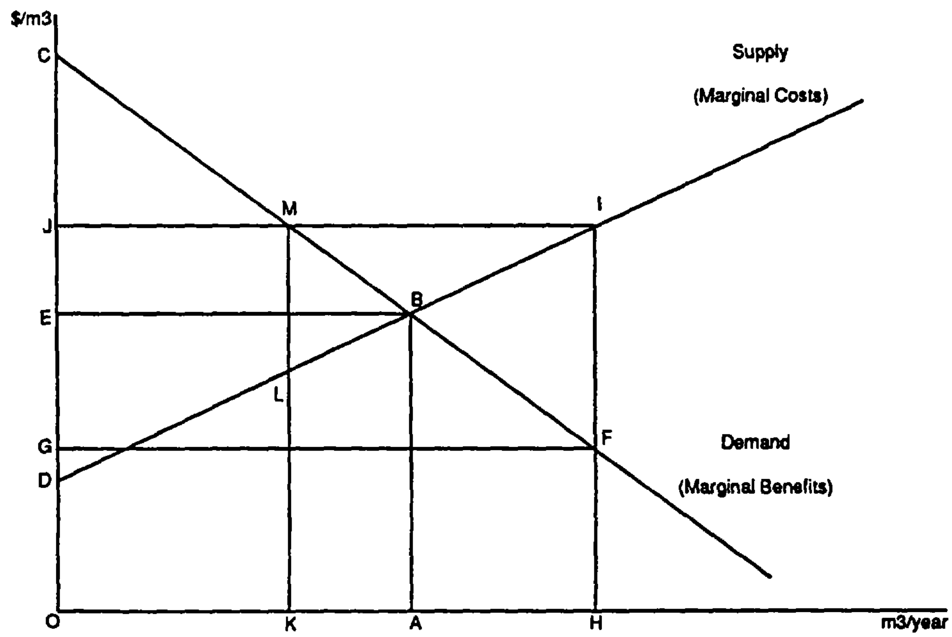
During the summer of 1988 the overall conservation target of 25 percent was exceeded with an actual reduction of 39 percent (figure 5.10). Similarly, during 1989, the actual reduction was 27 percent against the target of 15 percent. All customer groups except irrigation were able to respond to the mandatory reduction. Apparently, the reduction target of 53 percent for irrigation was unrealistic since two thirds of its annual consumption takes place during the summer.

Regarding the program's economic efficiency, a rigorous analysis is constrained by the lack of data. Nevertheless, a rough assessment has been made. The unit cost of saved water was estimated at $0.08/m^3 by dividing the total cost of the program, about $2.5 million, into the volume of saved water, on average 32 MCM per year. If the utility had chosen to buy water from farmers (at a minimum unit cost $0.16) or to bring in water by tankers (at a minimum unit cost of $0.65) instead of carrying out this program, the cost of additional water would have been several times the cost of saved water.

Conclusions

The case of the East Bay Municipal Utility District (EBMUD), California, illustrates the role of a comprehensive water conservation program

Figure 5.11: Cost-benefit analysis of marginal cost pricing



in improving efficiency of water use and reducing water demand during drought periods. The program was implemented by a mandatory conservation program, strict ordinances on water use, a progressive water rate structure, and an extensive public relations program. During the summer of 1988, the actual reduction in consumption was 30 percent, well above the target of 25 percent conservation over 1986. Similarly, during 1989 the actual reduction was 27 percent, well above the target of 15 percent.

The success of the program, measured as the reduction of demand, was a response not only to the increasing block rate structure, but also to other factors such as the severity of the drought, public awareness, and community involvement. Nevertheless, the steeply progressive water rate structure has emerged as the main instrument to achieve water rationing targets. The public viewed these rates as a more equitable means to allocate water during a drought compared to direct mandatory reduction. In terms of equity, the poorest were less affected by this policy, since predrought rates were applied to single households consuming less than 23 m^3 per month (about 150 lcd for a family of 5 members).

5.1.4 Water Demand Management in Perth, Australia[20]

Perth, located on Australia's West Coast, has a markedly seasonal climate with dry summers. Most of the population live in the suburbs in detached single-family houses with a low density of development. In 1975, there were 245,000 water accounts or connections. Water was distributed as follows: metered residential in-house use 20 percent; metered residential sprinkling outdoor use 36 percent; metered nonresidential use 15 percent; unmetered use 14 percent; and leakage 15 percent. About 73 percent of annual water produced was in the summer period.

ADOPTED MEASURES

Hanke (1982) analyzed the various ways open to the Perth water authorities for managing the demand for water to conserve it and avoid costly investments in new supply. A simple economic model of supply and demand was used to evaluate costs and benefits of the main options which were: the use of marginal cost pricing, with and without seasonal differentiation; the implementation of a leak detection and control program; the introduction of meters; and the regular application of summer restrictions.

IMPACTS

The analysis of the various options used the cost-benefit methodology described in case 5.1.1.

Marginal Cost Pricing. In theory, this will always be justified in cost-benefit terms, since the value of the decrement in demand AHFB in figure 5.11 will be less than the savings in marginal cost of supply AHIB. The opposite situation, where prices are too high, is rare in practice, though the same kind of reasoning would still apply to justify lowering them to marginal cost levels. In practice, the benefits of using price as a conservation policy are the savings in long-term marginal costs from reduced consumption. These are compared to costs, of which three types are distinguished: the resource cost incurred by the water utility in implementing the policy, which in this case is presumed to be nil; the resource costs falling on the water consumers, also taken to be nil; and the value of useful water consumption foregone, equivalent to the reduction in the area under the demand curve. Comparing benefits and costs thus conceived shows that the net benefit is $A75,000.[21]

Differential Summer-Winter Pricing. In principle, prices should reflect the different marginal costs of producing the water in winter (the "base" load) and summer (when demand peaks with the addition of outdoor sprinkling, etc.). However, seasonal pricing would entail reading meters quarterly and rendering seasonal bills. The extra resource costs to the utility would exceed net cost savings from reduced supply, and this course is not therefore economically justified.

Leak Detection and Control. These programs would apply to the system before the water reaches the consumer's premises, hence would not affect users directly. The cost-benefit analysis is therefore a straightforward matter of comparing the resource costs of the programs with the cost savings from the reduced supply of water. In this case, two programs were analyzed, respectively reducing leaks by half (to 7.5 percent) and by two thirds (to 5 percent). Both are found to have high economic rates of return.

Increased Installation of Water Meters. In Perth in 1977, unmetered water use was 14 percent of total production. Almost 18,000 customers were not metered. Likely reductions in water use were estimated from multiple regression analysis of historical demand, resulting in an estimate of 35 percent reduction. The costs of metering are made up of resource costs falling on the utility and consumers, plus the value of water foregone by consumers. Benefits comprise the saving in marginal cost of supply taken here to be $A 0.125/m^3. The analysis shows metering to be an economically attractive option in this case.

Restrictions on Water Use. Restrictions on the use of outside sprinklers in the summer season are estimated to reduce consumption by 11-14 percent, based on historical data. The benefit is the marginal cost saving of reduced supply. The value of foregone water use constitutes the sole cost of the policy. However, the benefit in this case falls short of the cost, and the policy is not economically justified.[22]

CONCLUSIONS

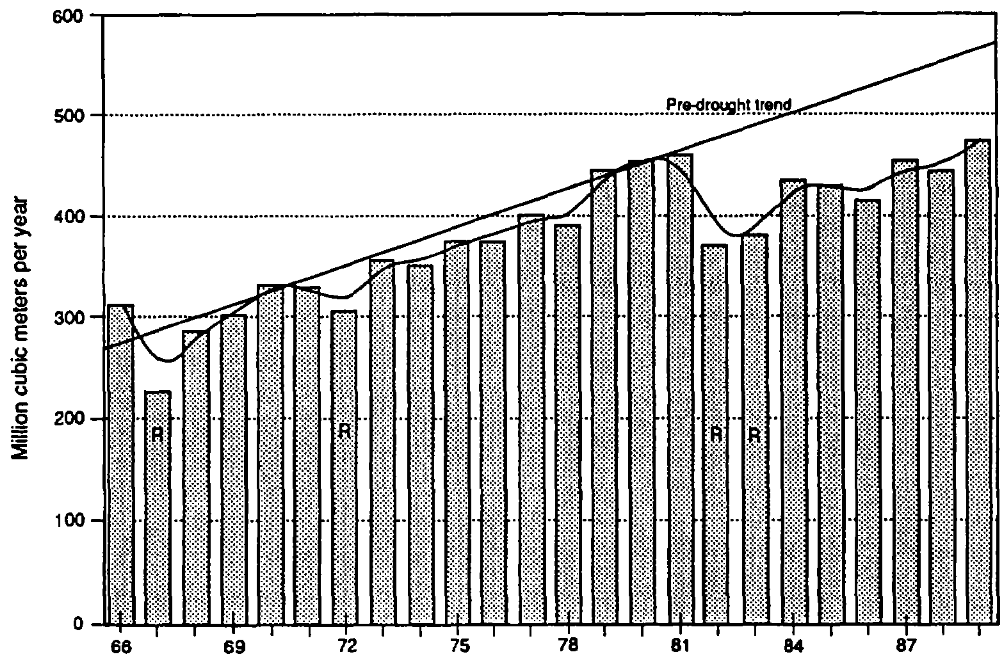
Not all water conservation measures are supposed to be cost-effective. Policy makers should adopt and implement those measures for which their benefits surpass their costs. From an economic-efficiency point of view, only 3 out of the 5 conservation measures adopted by the water utility were found to be desirable during normal conditions; e.g, marginal cost pricing, leak detection and control program, and metering. Restrictions were found to be desirable only during drought situations. The analysis also reveals that costs involved in implementing a summer-winter water pricing structure during normal conditions exceed its associated benefits.

5.1.5 Water Demand Management in Melbourne, Australia[23]

In Melbourne, as in many other Australian cities, water demand management measures were initially introduced to cope with droughts. Nowadays, they are extensively used for deferring future water supply investments by curbing demand growth.[24]

The case of Melbourne differs from other cases where the adoption of water demand management measures during dry years have resulted in temporary reduction of consumption. The normal behavior is that water con-

Figure 5.12: Water demand trends in Melbourne, Australia



Note: "R" means restrictions.

sumption decreases by as much as 30 percent during the drought. But when everything becomes normal again, consumption reaches a level even higher than before the drought. In the case of Melbourne, however, water consumption was kept on average 16 percent lower than the predrought consumption. Moreover, the growth rate of demand was reduced by one third, from 3 percent to only 2 percent per year.

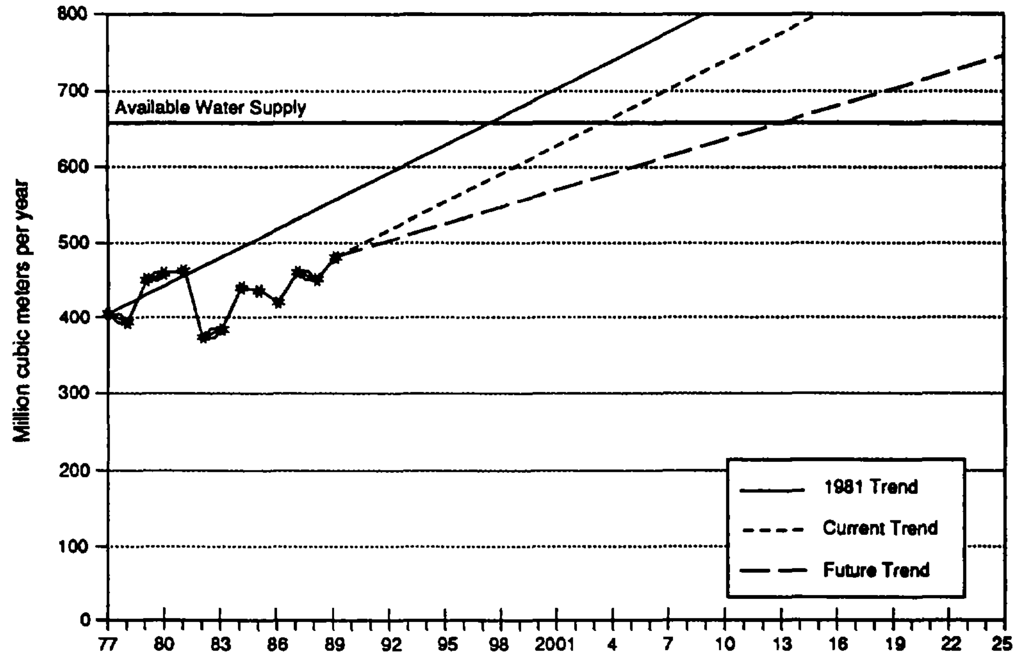
The Melbourne Metropolitan Board of Works (MMBW) adopted a rigorous water conservation program after the severe drought of 1982-83, during which severe restrictions were imposed on domestic consumers. Awareness arose among the authorities regarding the increasing demand in the long run; demand was growing at 3 percent per year. The MMBW realized that something had to be done, otherwise the capacity of the water supply system would have to be doubled every 24 years to match demand. In addition, the authorities were aware of the pronounced increase in development and environmental costs since the cheapest and closest sources were already developed and next alternatives contemplated more costly sources.

ADOPTED MEASURES

The first step to improve the situation of the water supply sector was the creation of a Task Force on demand management in 1983, replaced in 1985 by the State Liaison Committee. The objective of the task force was to promote more efficient use of the resource without exceeding the limits dictated by "economic principles." Its main responsibility was to implement measures that would reduce domestic water use by 20 percent. The adopted measures were as follows:

Advertising. Initially, the program was based solely on advertising campaigns that started as soon as the drought was over. As shown in figure 5.12, between 1982 and 1983, when water restrictions were imposed, water demand fell to 27 percent below normal level. Once all restrictions were lifted, demand rose only by 9 percent. Thus, a new trend started at a level substantially lower than the one before the disruption. This reduction was originated by changes in consumer behavior and attitudes toward water. These changes, in turn, were induced by the advertising campaign on water conservation via television, radio, local newspaper, posters, stickers, calendars, and brochures.

Figure 5.13: Impact of the conservation program on water demand in Melbourne , Australia



Public Education. The second measure adopted by the MMBW to reduce water consumption was a comprehensive educational program aimed at school children in 1986. The purpose of the program was to develop "an appreciation of the value of water in everyday lift" that would eventually influence the whole household's attitude toward the use of water. It was estimated that the education program caused a drop of about 15 percent.

Introduction of Water-Saving Devices. The third measure adopted by the MMBW was the redesign and promotion of water-saving devices, for example, dual-flush cisterns that require only 9 and 6 liters per flush replaced those that require 11 liters; shower heads that deliver 9 liters per minuted instead of the usual 12 liters per minute.

Water Pricing Reform. The introduction of a new water tariff system was the last conservation measure adopted by the MMBW. The price reform of June 1986 established two components for the water bill: one based on the domestic property value, and the second one based on the volume of water used. This measure provided an economic incentive to change wasteful use of water. It was estimated that after this price reform domestic consumption dropped 2 percent in the first year.

IMPACTS

Figure 5.13 presents the impact on total water demand of the water conservation efforts made by the MMBW. Melbourne's current water demand projection differs substantially from the 1981 trend. The shift to the right of the water trend curve has delayed the need for additional supplies by about six years, from 1998 to 2004. This deferral of investment was evaluated at $A32 million (in 1991 prices). Increased water conservation efforts in the future could provide additional lead-time for new water supply augmentation projects by another 10 years, up to 2014. Thus, the total present value of demand management could be as high as $A72 million.

CONCLUSIONS

The Melbourne Metropolitan Board of Works has considered adapting water demand management measures on a regular basis in order to balance water supply and demand. Incorporating conservation measures into its long-term planning has allowed the city the need for new water augmentation investments by reducing water demand growth by one-third, i.e. from 3 percent per year to 2 percent per year. Currently, the MMBW perceives its mandate as one of controlling rather than just meeting water demand. The motive for such transformation has been the imminent increase in both developmental and environmental costs associated with the expansion of the system's capacity.

5.2 Managing Industrial Demand

5.2.1 Effects of Water Tariff and Regulations on the Fertilizer Industry, Goa, India[25]

Many industrial processes require large quantities of water. Apart from ensuring leakage control, water conservation strategy in industries should include introduction of appropriate technology to ensure efficient use of cooling and process water and necessary pollution control mechanisms. The quantity of water used by industries depends on raw materials used and the type of processing technology employed.

Sound water budgeting in industry can considerably reduce water demand. Industrial water conservation measures in industry usually include review of alternate technologies from the viewpoint of water consumption; ensuring proper plant maintenance practices and housekeeping; minimizing spills and leaks; and optimization of treatment to achieve maximum recycling.

This case examined water conservation practices in the fertilizer industry, whose water requirements are very high. For comparison, two fertilizer industrial units, the Zauri Agro Chemical Limited (ZACL) in Goa on the Arabian Sea and the Indian Explosives Limited (IEL) located in Kampur on the Ganges in Uttar Pradesh, were chosen for the analysis. As shown in table 5.5, these units are almost of the same size.

MOTIVES

Higher Price of Water Supply. During the period of analysis, from 1982 to 1988, the ZACL was meeting all its needs using municipal water costing Rs 2.50/m^3, whereas the IEL was meeting its water needs mainly from lower Ganges Canal and tubewells at a cost of Rs 0.16/m^3. This cost includes the nominal fee of Rs 0.002/m^3 paid to the Irrigation Department and the related pumping of water.

Table 5.5: Comparative profile of ZACL and IEL

	ZACL	*IEL*
Water consumed per month (m^3)	330,000	630,000
Water cost (Rs per m^3)	2.50	0.16
Total Water Cost (Rs)	825,000	100,000
Total output of nutrient ($N+P_2O_5$) per month (ton)	32,070	25,875
Water cost per ton of nutrient (Rs)	25.72	3.86
Water use per ton of nutrient (m^3)	10.29	24.35

Public Pressure and Stringent Pollution Control Measures. In the early stages of setting up the fertilizer unit at Goa, there was a loud protest of activist groups against the way the firm was disposing its liquid effluent. Untreated effluent was dumped into the sea, harming fish, cattle, plant life, agricultural production, and drinking water quality in the area. The Water Prevention and Control of Pollution Act of 1974 provided for the creation of Central and State Pollution Control Boards as the agencies for monitoring and enforcement of the Act. In particular, these Boards set water quality and effluent standards and permit or prohibit the discharge of wastes into water bodies.

IMPACTS

In the fertilizer plant at Goa, water consumption was reduced from 22,000 m^3 per day to 11,000 m^3 per day over a six-year period (1982-88) as a result of a number of measures involving a capital cost of Rs 6.5 million ($0.23 million) for effluent treatment and water conservation and reuse. In contrast, the water consumption in the IEL unit at Kampur is about 21,000 m^3 per day. In terms of water consumption per ton of nutrient, the water rate in the ZACL was only 10.3 m^3 compared with 24.4 m^3 in the IEL factory (table 5.5).

The significant water reduction in the ZACL was mainly a response to the higher price of water and government pressure to reduce industrial effluent. The price of water and its availability seem to be the most important factors influencing the adoption of water conservation practices by the ZACL. Since the ZACL was dependent on municipal water, which could be supplied in limited quantities, the management made concerted efforts to reduce water consumption. Apart from taking various measures to make suitable modifications in the plant, an attempt was also made to reuse and recycle water. The ZACL has done everything to see that even lower-quality water does not go to waste by using it for sanitation. Seepage has been reduced by preparing cemented drains.

The loud protest of activist groups forced the management of the ZACL to pay compensation to farmers (Rs 32,000 each to about 50 farmers) and fishermen, and to install 22 taps for drinking water in affected areas. In subsequent years, the environmental consciousness created by activist groups, combined with the government pressure to reduce effluent discharge, caused this industrial unit to invest in a number of water pollution control and reuse facilities.

In contrast, the IEL has not so far experienced the problems of Zauri, such as limited access to water and high cost. At the time of the analysis, the IEL was able to get adequate supply through the Ganges and from tubewells at a cost of about 16 paise/m^3. The discharge of 6,000 m^3 per day compared to an intake of 21,000 m^3 per day was easily disposed of. Thus, the IEL had absolutely no incentive for initiating any special measures to reduce its use of water, mainly because of the low cost of water to the unit. The IEL had of course to meet the pollution standards prescribed by the Water Pollution Board, but beyond that, given the low cost of water, the industrial unit did not find it worthwhile to reduce the quantity of discharge.

Conclusions

Water conservation in Zauri was the result of a combination of factors: (i) the environmental consciousness created by activists through protests; (ii) the stringent measures by the Central Water Pollution Board; and (iii) the dependence on a high-priced and limited municipal water. Nevertheless, the above case study supports the notion that the price of water and its availability are the most important factors in influencing the adoption of water conservation practices by industrial units.

5.2.2 A Mix of Water Tariffs, Pollution Charges, and Fiscal Incentives Encourages Conservation and Pollution Abatement, India[26]

Jamshedpur, in eastern India, is known as a "steel city" because one of the oldest steel mills in India (Tata Iron and Steel Company, TISCO) is located there. Over time, a number of associated companies of the Tata Group have been established in the city, along with a number of ancillary units. In the metropolitan area, there are 13 major industrial units, 16 medium industries, and 472 small industrial units. Total water withdrawals by these industrial units in 1990 were estimated at 57.5 MCM. An additional 66 MCM of water was treated and distributed for domestic and institutional uses to the estimated 1.0 million population.

In Jamshedpur, there are three sources of water supply for the industries: a private company (TISCO), a public agency (the Public Health and Engineering Department of the Government of Bihar, PHED), and self-provisioning by industries through borewells and tankers. TISCO supplies water to its own steel plant and to its associated companies, while PHED supplies are mainly available to industrial units in Adityapur. TISCO accounts for 96 percent of the total water intake by industries while PHED's share is only 3 percent. TISCO is not only the major supplier of industrial water but is also its major user, accounting for 88 percent of total intake.

TISCO pumps water from Subernarekha river. The cost of pumping water has been reported as Rs 1.68/m^3 ($0.066/$m^3$) inclusive of the amount paid to the irrigation department for water released from the Getalsud reservoir (upstream of Jamshedpur). TISCO charges Rs 1.68/m^3 ($0.066/$m^3$) for raw water provided to its associated companies.

Although TISCO supplies water to the associated companies at $0.066/$m^3$, its cost of operation and maintenance is estimated to be $0.03/$m^3$. At this low price, there is no incentive for TISCO to economize on the use of water. For example, the 1.6 MCM per year of effluent coming from the coke oven plant, which contains high levels of phenol and ammonia, is not treated before discharge but instead is diluted using 5 MCM of fresh water to reduce the level of concentration.

The PHED also supplies water to the Adityapur Notified Areas from a small dam and from deep tubewells. In 1990, PHED supplied 1.83 MCM of water to industrial units at a fixed charge of Rs 2.5 per thousand gallons ($0.021/$m^3$), about one-third of the price charged by TISCO to its associated companies. This fixed charge is only one-third of the estimated operation and maintenance cost, which implies a subsidy of Rs 1 million per year to industrial

Table 5.6: Unit cost and quantity of water conserved and recycled by various processes

Type of conservation or recycling	*Type*	*Quantity (MCM)*	*Unit Cost ($/m³)*	*Investment ($ million)*
Reuse of effluent from existing wastewater treatment plant	R1	1.0	0.035	0.20
Treatment and reuse of cooling water presently being discharged	R2	11.8	0.035	3.00
Treatment and reuse of acidic discharge from pickling plant using neutralization through alkali and settlement	R3	2.0	0.048	0.40
Treatment and reuse of waste from coke ovens and blast furnaces containing high levels of phenol, ammonia, suspended solids, COD, through bioxidation, settlement, and chlorination	R5	5.0	0.000	0.00
(5 MCM of fresh water added for dilution)	R4	1.7	0.450	3.90
Treatment and reuse of waste (fly ash and coal particles) from power plant by adding coagulants and settlement	R6	6.2	0.127	3.60
Replacement of cooling ponds by cooling towers	C1	12.0	0.135	7.30
Reuse of treated effluent from sewage treatment plant	C2	11.6	0.145	10.00

consumers.

Three medium-size industrial units depend partly on their own supplies (borewells) where their shares range between 4 percent to 60 percent. The average cost of pumped water is reported as $0.133/m^3$, about six times the price charged by the PHED. One industrial unit also purchases one-third of its needs from private tankers at $0.14/m^3$.

In Jamshedpur, most industrial units discharge their virtually untreated industrial effluent to the Subernarekha river or its tributary. TISCO accounts for almost 90 percent of the total industrial pollution in the region. Other contributors are TELCO (3 percent) and major companies in Jamshedpur (about 1 percent each). Although part of the municipal sewage is treated, it is not recycled for industrial use because fresh water is available at low cost. Adityapur's industrial waste is discharged into open drains that ultimately discharge into the Kharkai river, the main tributary of the Subernarekha river.

POTENTIAL MEASURES

Water tariffs and pollution charges. Since TISCO's plant accounts for over 90 percent of total water intake and effluent discharge, a policy simulation exercise has been carried out to simulate the responses of the company's management to the following policy instruments: (i) increase in the price of water purchased or the cost of water intake from its own sources; (ii) increase in effluent charges to be paid by the industrial unit to the municipality or the government for the effluent discharged in the river; and (iii) financial incentives for installation of effluent treatment plants.

Assuming that management would like to minimize the total costs of provision and use of water, its responses depend on the following information: (i) the cost of conservation of water through process change so that both water intake and effluent discharge are reduced (table 5.6); (ii) the cost of effluent treatment and recycling to reduce water intake and effluent discharge (table 5.6); and (iii) the effects of subsidies or soft loans for investment and operating costs of treatment plants.

Available data show that for the process side there are five stages where demand can be reduced by reducing leakage and waste, and by recycling treated effluent. On the cooling side there are two stages possible (table 5.7) The simulation model keeps track of the volume of

Table 5.7: Technological options to reduce water purchased and effluent discharged in MCM

Stage	*Water intake*	*Total recycled*	*Total losses*	*Total outflow*	*Add'l treated*	*Total treated*	*Add'l saved*	*Total saved*	*Total discharge*
Process									
Current	19.00	0.00	0.40	18.60	0.00	0.00	0.00	0.00	18.60
Stage R1	18.03	1.00	0.43	18.60	1.00	1.00	0.00	0.00	17.60
Stage R3	16.08	3.00	0.48	18.60	2.00	3.00	0.00	0.00	15.60
Stage R4	11.20	5.00	0.60	18.60	5.00	8.00	0.00	0.00	10.60
Stage R5	9.59	9.65	0.64	18.60	1.65	8.75	0.00	0.00	8.95
Stage R6	3.52	15.88	0.80	18.60	6.23	15.88	0.00	0.00	2.72
Cooling									
Current	30.80	0.00	19.00	11.80	0.00	0.00	0.00	0.00	11.80
Stage R2	19.60	11.80	19.60	11.80	11.80	11.80	0.00	0.00	0.00
Stage C1	7.60	0.00	7.60	11.80	0.00	11.80	12.00	12.00	0.00

Table 5.8: Technological options available to TISCO, India

Option	*Description*	*Water Purchased MCM*	*Evap/Losses MCM*	*Effluent Discharged MCM*
Current	Current situation	49.80	19.40	30.40
Option I	Stages R1 plus R2	37.63	20.03	17.60
Option II	As Option I, plus stage R3	35.68	20.08	15.60
Option III	As Option II, plus stages R4 and R5	29.19	20.24	8.95
Option IV	As Option III, plus stage R6	23.12	20.40	2.72
Option V	As Option IV, plus C1	11.12	8.40	2.72
Option VI	As Option V, plus C2	11.12	8.40	2.72

water to be purchased and the volumes of effluent to be disposed of, treated, recycled, and saved by cooling process changes. The effluent from the plant is assigned an effluent charge added to the total cost of water use seen by the plant managers. The five process choices and the two cooling choices are added together to give six technological options, which are shown in table 5.8.

Table 5.9 shows the minimum cost option for a given combination of water price and effluent tax. While the water price varies from zero to \$0.32/m³, the effluent charge varies from zero to \$0.40/m³. The higher the water price, the more treatment and conservation will be chosen. More important, these results allow for the derivation of demand curves for the effects of the price of water and effluent charges on the demand for water and effluent discharges. For instance, figures 5.14 and 5.15 show the derived demand curves for a given effluent tax of \$0.04/m³.

The above analysis allows to estimate the implications for TISCO if the price of water and the effluent charges are increased from their current levels. For example, an increase in the price of water and the effluent tax from \$0.066 and \$0.001, respectively, to \$0.10 and \$0.04/m³, respectively, will encourage TISCO to reduce its water purchased and effluent discharged by 54 percent and 91 percent, respectively, by adopting technological option IV. The total annual cost for TISCO will be about \$4.5 million, which represents 0.6 percent of annual manufacturing expenses and 5.3 percent of annual profits.

Water Tariffs Alone. Using available data the "cost of conserved water" curve (figure 5.16) has been prepared for 26 industrial units in Jamshedpur, i.e. the marginal cost of water obtained through demand management measures. The estimated curve shows that if the water tariff is fixed to cover financial costs, it may encourage industrial units to invest in water-saving technologies and permit conservation of up to 15 MCM or 25 percent of total industrial water demand. If water tariff is set to reflect economic costs including the opportunity cost of water in alternative uses, it may encourage conservation of an additional 5 MCM.

However, even when the tariff includes the opportunity cost of water, it does not "internalize" another important externality, which is the cost of damages borne by downstream users. Since it is difficult to estimate "damage func-

Table 5.9: Minimum cost option for a given combination of water price and effluent tax

Effluent Tax / Water Price	0.00	0.02	0.04	0.06	0.08	0.10	0.12	0.14	0.40
0.00	C	C	I	II	II	II	III	IV	IV
0.02	C	I	II	II	II	III	IV	IV	IV
0.04	I	II	II	II	III	IV	IV	IV	IV
0.06	II	II	II	III	IV	IV	IV	IV	IV
0.08	II	II	III	IV	IV	IV	IV	IV	IV
0.10	II	III	IV	IV	IV	IV	IV	IV	IV
0.12	III	IV	IV	IV	IV	IV	IV	IV	IV
0.14	V	V	V	V	V	V	V	V	V
0.16	VI	VI	VI	VI	VI	VI	VI	VI	VI
0.32	VI	VI	VI	VI	VI	VI	VI	VI	VI

Technological Option	Water Purchased MCM	Effluent Discharged MCM
CURRENT	49.8	30.4
OPTION I	37.6	17.6
OPTION II	35.7	15.6
OPTION III	29.2	9.0
OPTION IV	23.1	2.7
OPTION V	11.1	2.7
OPTION VI	11.1	2.7

tions" for deterioration of water quality, the "clean-up" cost required after a particular use may be an alternative of the likely adverse impact of water quality deterioration. In Jamshedpur, wastewater treatment costs for recycling were $0.137-0.45/m^3 (Rs 3.5-11.5/m^3). Raising the water tariff by 45 percent will provide an incentive to treat and reuse at least 18 MCM.

Regulatory Measures and Fiscal Incentives. Improved efficiency and environmental quality may be achieved by means of legislation requiring treatment of effluent water, and providing soft loans and/or subsidies for wastewater treatment plants. In India, there is no experience of implementing pollution control legislation, and it is difficult to visualize the extent to which such regulatory measures could be enforced legally and administratively.

Given the administrative difficulties of enforcing pollution control regulations on powerful industrialists by low-paid government officials, it will be necessary to use financial incentives, e.g., soft loans, investment support, and direct subsidies for the investment cost, to make it worthwhile for industrial units to reuse treated effluent. In Jamshedpur, the required subsidy would be 25-30 percent of the investment cost, about $4.5 million.

IMPACTS

Pollution Abatement and Water Savings. Encouraging industries and power plants to treat their effluent and recycle or reuse it in their own processes provides the twin benefits of environ-

Figure 5.14: Demand for water as a function of water price

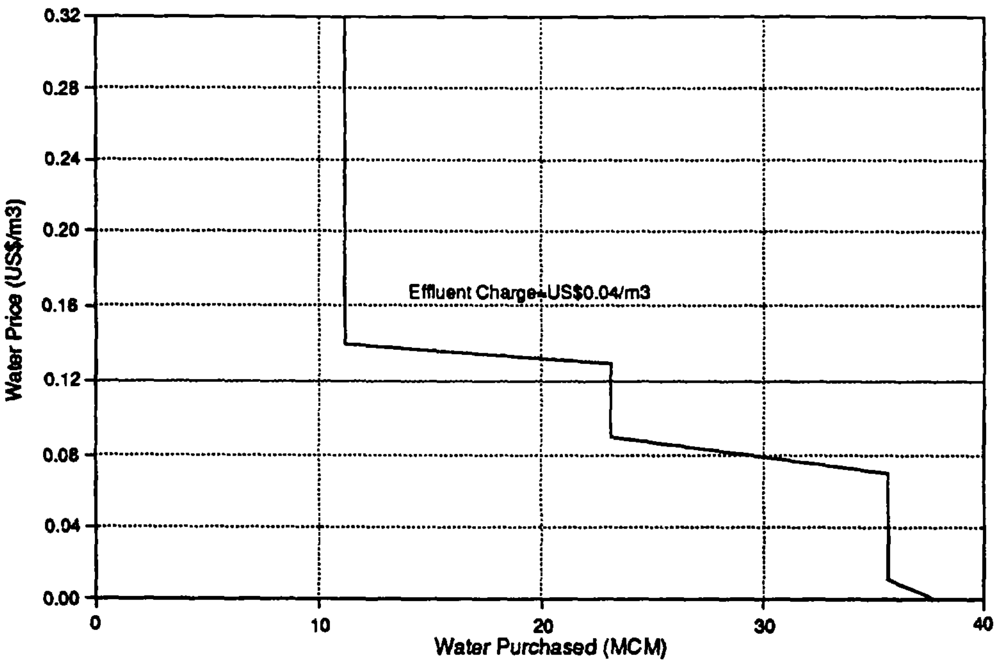


Figure 5.15: Effluent discharged as a function of water price

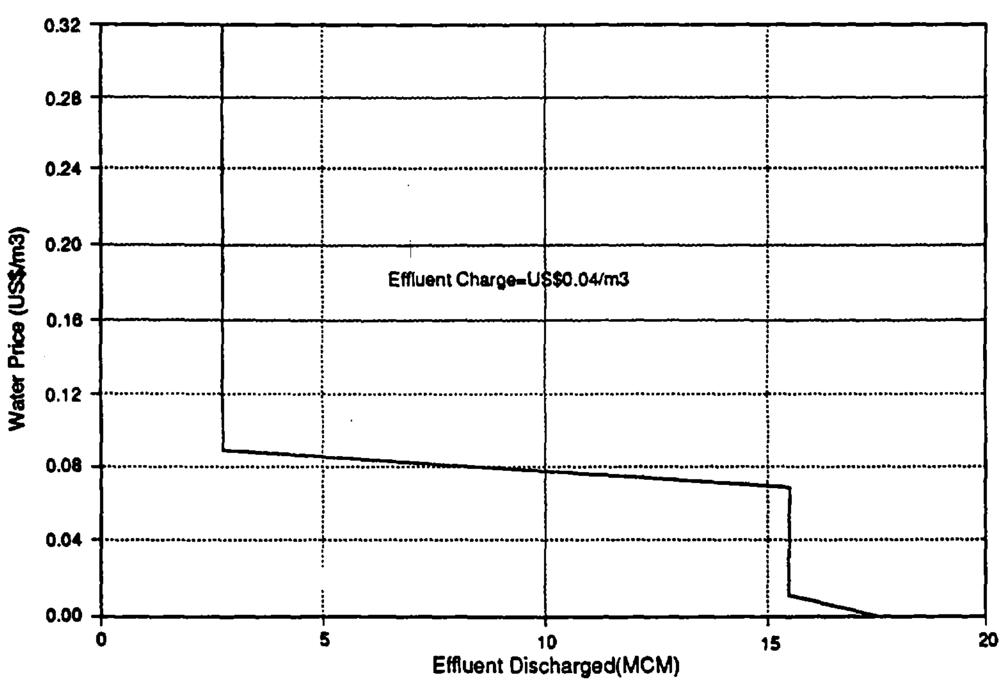
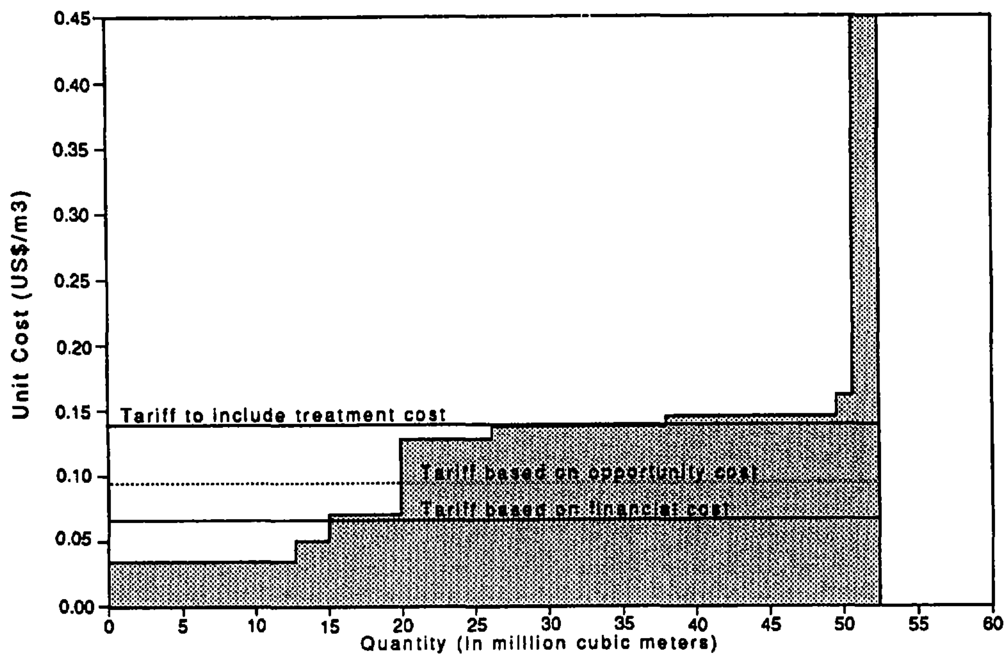


Figure 5.16: Cost of conserved water for industrial use in Jamshedpur



Notes: 1. Includes conservation plans in TISCO, Tin Plate
2. Includes cost of reuse of treated municipal effluent.

mental quality improvement and economic gain. It reduces withdrawals of water for industrial use since part of its requirements are met from recycled water. This reduction provides a net economic benefit if water at the withdrawal point has a higher economic value than if it were used downstream. It also provides an environmental benefit by improving the quality of water bodies.

Effect of Reduced Industrial Withdrawals on Domestic Water Supply. In 1990, about 90 percent of the water required for domestic and commercial use in Jamshedpur and surrounding areas was supplied by TISCO, and the municipality supplied the rest. For almost 60 percent of the population, the quantum of water supplied in the TISCO area was around 280 lcd. The level of coverage of water supply in areas served by the municipalities is much lower: average consumption is around 60-140 lcd.

The distribution of water could be made more equitable if additional supplies were made available by encouraging conservation and recycling. Economic incentives for recycling and reuse could ensure that an industrial unit treats its effluent for its own reuse. Water quality would not be lowered by industrial pollution, and fresh water supplies that could be significant for the urban poor would be made available.

Industrial units in Jamshedpur could save as much as 38 MCM (about 50 percent of total industrial use) of water through demand management measures. This volume would increase the drinking water supply to areas that were getting inadequate water and would provide a more than adequate 220 lcd to about 0.6 million persons.

Conclusions

Many policy instruments can promote efficient, environmentally sound use of water resources. Demand for water is influenced by pricing policies and technology, and by the cost and the technologies of wastewater disposal. Policy makers can choose to influence the user's behavior either through water supply prices or effluent charges and fiscal incentives for technological change.

This case illustrates that the mix of public policies based upon changes in water supply price and assessing effluent charges needs to be carefully orchestrated. When prices of water supply are set at low levels, conservation and recycling do not appear attractive options regardless of the level of effluent charges because cheap water can be used to dilute the effluent and make it palatable for recycling.

5.2.3 Conservation in Refinery and Petrochemical Industries, Madras, India[27]

In response to shortages of water supplied by Metrowater, the Madras water supply agency, three major industrial units—Madras Refineries Limited (MRL), Madras Fertilizers Limited (MFL), and Manali Petrochemical Limited (MPL)—have adopted water conservation measures and reuse of effluent. The first two industries are public-sector enterprises, and the third is privately owned. The MRL and MFL are the largest industries in the metropolitan area. Manali Petrochemical, established as an import-substituting industry in 1990, is about one-fifth their size.

The three industrial units have indicated clearly that present levels of water supply are inadequate for current production and planned expansion. The MFL, for example, plans expansions that will require at least an additional 5 mgd. The responses of the industrial units to the water shortage differ according to their sizes.

Adopted Measures and Impacts

In-Plant Water Conservation Measures. The MRL and MFL have responded to the shortage of water by adopting water conservation measures including an increase in the number of cooling water cycles from 3 to 6, process condensate recovery, hydrolyzed stripping, and the use of regenerated water. The MRL has doubled capacity to 5.6 million ton per year but keeping water consumption unchanged at 2.5 mgd. Similarly, the MFL maintained capacity while reducing water use from 4 to 3.6 mgd. Both industries have indicated, however, that a ceiling had been reached on water conservation, and no further scope existed for additional water savings. Operation and maintenance costs associated with water-savings measures were minimal. It is worth noting that there is an implicit cost and real danger with increasing the number of cycles in cooling. Increasing the cooling water cycle results in an increase in the salt content of the residue. The subsequent build-up may corrode the pipes, leaving a coating behind. The normal concentration rate in India is 250-300 ppm. Currently, the MFL runs cycles as high as 1,500 ppm.

Tertiary Sewage Treatment Plants. The second response of the MRL and the MFL has been tertiary treatment of sewerage effluent obtained from Metrowater. The MFL plant's cost was Rs 230 million ($9 million), and treatment cost is expected to be Rs 24/m^3 ($0.94/m^3). Additional staff required is estimated to be at least 60 persons, including six or more supervisors. Both the MRL and the MFL expect tertiary-treated water to meet about 30 percent of their total requirements. However, the water from the treatment plant is three times as expensive as water from Metrowater, which is currently sold to industries at Rs 8.4/m^3. Moreover, since water supply from this source is variable, treated effluent can be used only as a supplement to water from Metrowater.

Secondary Sources. The MPL has responded to the water shortage by an increased reliance on secondary sources. Over 1-2 months in 1990 MPL bought water from private trucks. The company required an average of 100 trucks per day, each with a capacity of 10,000 m^3. The cost was Rs 190-200 per truck, approximately two and a half times higher than water from Metrowater. Water from these secondary sources was more silica and thus of much poorer quality, and the supply from private tankers became very scare over the period June-September 1991.

Reduction of Output. The MPL was been forced to shut down operations 2-3 days per week over one month. The estimated financial loss from these shutdowns was Rs 5 million ($200,000) per month, and they have considerably eroded the company's profits. Operating capacity was only 75 percent from the yearly average capacity. In addition, the causal labor force of about 90 persons a day was asked not to come in on shut-down days. The company also restored to an 11,000 m^3-storage tank, sufficient for three production days. Unlike large companies, the MPL can not engage in tertiary treatment since its size prevents it from capturing economies of scale that would justify the investment. It will also not be feasible to buy treated water from either MRL or MFL in the future for technical reasons, i.e. use of treated effluent would require investment in a dual-pipe system and two processing systems.

Conclusions

Overall, it appears the larger public-sector companies have been able to maintain current (close to full) operating capacity using a number of strategies. First, a higher fraction of their demand is being met by Metrowater. Second, their scales of operations are large enough to enable them to invest in recycling, although recycled water is expensive and not a fully adequate substitute for that currently supplied by Metrowater. Third, there are high initial learning costs since this is the first project of its kind in India. It is unlikely that the companies will be able to maintain operational capacity in the future without additional water, and plans for expansion appear to be contingent on obtaining additional water. The experience of the smaller private-sector companies is probably more similar to the MPL's. These firms receive less priority in having their water requirements met, and face more costly alternatives.

5.2.4 Effects of Effluent Charges on Reducing Industrial Water Demand in Sao Paulo, Brazil[28]

Sao Paulo is the richest and most populated state in Brazil. In Sao Paulo, the water supply and sewage systems are operated by the municipalities and by SABESP (Companhia de Saneamiento Basico do Estado de Sao Paulo). Water services are constitutionally delegated to the municipalities in Brazil; therefore SABESP, as all state water companies in Brazil, operates under concessions granted by the municipal governments. SABESP, created in 1973, is a limited corporation 93 percent owned by the state of Sao Paulo. Some service indicators are shown in table 5.10.

Table 5.10: Statistics of Sao Paulo water supply system in 1988, Brazil

Number of municipalities of Sao Paulo	572
Total urban population	28 million
Municipal water systems operated by SABESP	295
Urban population in SABESP's systems	19 million
Population connected to water	17 million
Percent connected to water	90 percent
Population connected to sewerage	11 million
Percent connected to sewerage	61 percent

Brazil's water supply and sewerage utilities operate under a uniform tariff structure set by the 1978 National Tariff Law (NTL). The NTL seeks to meet two general objectives: financial equilibrium and social equity. To improve social equity, utilities are required to accommodate users' ability to pay through the use of minimum consumption levels and increasing block tariffs. Financial equilibrium is guaranteed by requiring each utility to set its average tariff for water supply and sewerage service at a level that will cover its service cost, which is defined as the sum of exploitation expenses, annual allowance for depreciation, doubtful accounts, and amortization of expenses; and remuneration for investment (interest payments and capital amortization).

The NTL also requires water tariffs to be differentiated by final use, and average rates for commercial and industrial users to be greater than the average rate for all customers. Subsidies are denied to commercial and industrial customers. Effluent charges might be set at the same level than water rate.

The Sao Paulo Metropolitan Region (SPMR) concerns Sao Paulo city (the state capital) and more than 37 municipalities spread over 8,000 square kilometers. In 1984, there were about 11,000 industries in this region, which generated 35 percent of Brazil's GNP.

The water supply is assured by an integrated system of many reservoirs and linked distribution pipes operated by the SABESP and by small isolated systems operated jointly by the SABESP and the municipalities. The water distribution is assured by SABESP to 28 municipalities or by the other municipalities themselves. The sewage system is structured in an important number of networks and treatment plants, mainly operated by SABESP. Pretreatment of industrial sewage is required only if high concentrations of certain toxic substances are detected. The aim of this policy is to minimize industrial treatment costs and optimize the use of SABESP's treatment plants. According with a decree of the Sao Paulo State (No 15425 of 07/23/80), all industries located in areas with sewage systems must discharge their effluent into sewerage networks unless the quality of the effluent is such that it can be discharged directly into a body of water. In localities without sewage systems, industries must truck their effluent to the nearest treatment plant.

ADOPTED MEASURES

In 1978, SABESP began to implement a new tariff policy for industrial effluent. The tariff covered operation and maintenance costs and subsidized low-income customers. The objective of this policy was to keep industrial tariffs below the cost of individual treatment facilities.

The formula below was used to calculate the monthly charge when discharging into SABESP's network.

CM = (0.63 + 0.37K)TV + F
if effluent is discharged directly to SABESP
CM = 0.37KVT
if effluent is discharged by trucks
K = (BOD + SS)/600

CM: Monthly Payment (Cr$/month)
T: Unitary effluent charge (Cr$/$m^3$)
V: Volume of effluent (m^3/month)
K: Overcharge factor
BOD: Concentration of biochemical oxygen demand (mg/l)
SS: Concentration of suspended solid (mg/l)
F: Monitoring fee (Cr$/month)

The value of T was reviewed and corrected for inflation every three months. Depending on the type of contract, the value of T differed among industries. The value of F was also corrected by changes in the wage rates, and prices of chemicals, fuel, and other inputs. In the case of an industrial unit without metering, the monthly volume of effluent was estimated on the basis of the water supplied by SABESP and adjusted by the self-supplied water, if any. Concentrations of BOD and SS were determined from samples taken once a month in the different discharge points (if any) on random dates and then weighted by the respective effluent flows. In cases where meters were not available, the adopted value of BOD or SS concentration was the mean of the sample ignoring those values lower than 300 mg/l.

IMPACTS

Miglino and Harrington (1984) assessed the impacts of the industrial effluent tariff policy described above on one pharmaceutical industrial unit, one food-processing industrial, and one dairy industrial unit located in SPMR, and whose effluent were treated by SABESP since 1980. The analysis considered monthly data on production, water consumption, effluent volume, BOD concentration, and SS concentration. Statistical regressions (taking into account seasonal effects) were used to assess the evolution of parameters. In addition, unitary coefficients of effluent volume and pollution (annual averages) were estimated. Below are the results of the analysis.

The Pharmaceutical Industrial Unit Level. The main output of this unit was heparin, an expensive drug, made from the intestinal mucosa of pigs and cattle. The firm used to dispose its effluent through trucks into a SABESP treatment plant, at a frequency of 52 trips per month. Tables 5.11-5.13 show production data, effluent characteristics, and unitary coefficients of volume and pollution. Between 1980 and 1982, production increased from 1,399 kg/year to 1,709 kg/year, but the monthly volume of effluent decreased from 2,051 m^3 per month to 1,270 m^3 per month. The average concentration of BOD and SS were also reduced from 58 ton/month to 50 ton/month and from 10 ton/month to 6 ton/month, respectively. The unitary coefficients of effluent, BOD, and SS per one ton of production decreased by 49 percent, 30 percent, and 46 percent, respectively.

The firm's manager attributed the reduction in the volume of effluent to the improvements made in the production process and to stock products kept by the previous owner. The reductions in the concentration of BOD and SS were the results of modifications within the plant: input substitution, changes in the production process, and recuperation and sale of a part of the final effluent.

To evaluate the economic impact of the improvements made by the firm, a comparison has been made between the unitary cost of water and waste service between 1980 and 1982. The analysis has assumed the following: (i) a basic tariff "T" equals to Cr$123,00/$m^3$ ($0.49/$m^3$); (ii) the firm buys all its water from the public utility at a price of Cr$123,00/$m^3$ ($0.49/$m^3$); and (iii) the consumptive use of water is negligible. An estimate of the firm's annual payment is shown below.[29]

UWC = 12 T'V/P
USC = 12 K'TV/P

Where:
K' =(0.63 + 0.37K) or 0.37K
(if the firm discharges its effluent into the network or by trucks, respectively)
UWC = Unitary annual cost of water (per unit of production)
USC = Unitary annual cost of waste services (per unit of production)
T' = Water tariff
P = Firm's annual production (in mass of output) K, T and V are described above.

Table 5.11: Annual production of a pharmaceutic firm in Sao Paulo

Year	*1980*	*1981*	*1982*
Minimum (kg/month)	31	0	0
Maximum (kg/month)	169	230	206
Average (kg/month)	117	124	142
Total (kg/year)	1,399	1,490	1,709

Table 5.12: Effluent characteristics of a pharmaceutic firm in Sao Paulo

		1980			*1981*			*1982*	
Parameters	*Vol*[a]	*BOD*[b]	*SS*[c]	*Vol*[a]	*BOD*[b]	*SS*[c]	*Vol*[a]	*BOD*[b]	*SS*[c]
Minimum	1,840	0.0	0.0	1,700	11	1.3	200	0.5	0.1
Maximum	2,300	117	48	2,040	102	84	1,860	96	26
Average	2,051	58	10	1,901	51	20	1,270	50	6
Total	24,615	698	115	22,807	612	240	15,240	600	76

a. cubic meters/month
b. tons BOD/month
c. tons SS/month

Table 5.13: Unitary effluent coefficients of a pharmaceutical firm in Sao Paulo

Parameters	*1980*	*1981*	*1982*	*1980/1982*
Volume[a]	17,595	15,307	8,917	49
BOD[b]	500	410	351	30
SS[c]	82.5	161	44.4	46

a. m^3 of effluent per ton of production
b. tons BOD per ton of production
c. tons SS per ton of production

1980

UWC = 12*(0.49*2,051)/1,399 = $8.64
USC = 12*(0.37*55.13*0.49*2,051)/ 1,399 = $175.80
Total = $184.44 per kg of heparin

1982

UWC = 12*(0.49*1,270)/1,709 = $4.32
USC = 12*(0.37*73.78*0.49*1,270)/1,709 = $119.28
TOTAL = $123.60 per kg of heparin

The results show that between 1980 and 1982 there was a 33 percent reduction in total water and waste service costs. If the firm had not taken the above measures to conserve water and reduce effluent loads, it would have had an additional cost of about $100,000 during 1982.

The Food-Processing Industrial Unit Level. The main outputs of this firm were margarine, soap, glycerine, and mayonnaise. The firm was directly connected to the interceptor of SABESP. The volume of wastewater discharged into the system was measured by a flow metering located just before the point of discharge. About two thirds of total waste was generated by the refining of edible oil, a principal input for most of firm's products. Tables 5.14-5.17 show data on production, effluent characteristics, and unitary coefficients of volume and pollution loads. Even though production increased by 6 percent between 1980 and 1982, the annual volume of effluent decreased by 39 percent over the same period. As shown in table 5.14, the unitary coefficients of total effluent volume and concentration of BOD and SS per ton of output were also reduced by 42 percent, 42 percent, and 43 percent, respectively.

The firm's manager attributed these reductions to improvements in the washing process of the edible oil, reduction of the frequency that floors and equipment should be cleaned and the quantity of water used for those purposes, improvements in sewage and drainage systems, and reduction of losses of the edible oil and of other inputs (these lowered concentrations of BOD and SS in the effluent). The increasing effluent charge was mentioned as the main incentive to undertake such modifications. As in the case of the pharmaceutical industrial unit,

Table 5.14: Annual production of a food-processing firm in Sao Paulo

Year	*1980*	*1981*	*1982*
Minimum (ton/month)	9,973	7,451	9,367
Maximum (ton/month)	12,403	12,329	13,750
Average (ton/month)	11,083	10,779	11,720
Total (ton/year)	132,996	129,348	140,645

Table 5.15: Effluent characteristics of a food-processing firm in Sao Paulo

		1980			*1981*			*1982*	
Parameters	*Vol*[a]	*BOD*[b]	*SS*[c]	*Vol*[a]	*BOD*[b]	*SS*[c]	*Vol*[a]	*BOD*[b]	*SS*[c]
Minimum	18,476	15	0.9	11,984	1.8	1.3	5,741	17	0.9
Maximum	21,028	332	68	24,433	64	27	14,880	92	46
Average	19,804	74	27	15,581	41	15	12,118	45	16
Total	237,654	887	318	186,971	494	182	145,415	541	191

Table 5.16: Unitary effluent coefficients of a food-processing firm in Sao Paulo

Parameters	*1980*	*1981*	*1982*	*80/82*
Volume[a]	1.79	1.45	1.03	49
BOD[b]	6.66	3.82	3.85	42
SS[c]	2.39	1.40	1.36	43

a. m^3 of effluent by ton of production
b. kg BOD by ton of production
c. kg SS by ton of production

Table 5.17: Annual production of a dairy firm in Sao Paulo

Year	*1980*	*1981*	*1982*
Minimum (ton/month)	300	370	690
Maximum (ton/month)	550	900	990
Average (ton/month)	463	573	858
Total (ton/year)	5,560	6,880	10,290

Table 5.18: Effluent characteristics of a dairy firm in Sao Paulo

		1980			*1981*			*1982*	
Parameters	*Vol*[a]	*BOD*[b]	*SS*[c]	*Vol*[a]	*BOD*[b]	*SS*[c]	*Vol*[a]	*BOD*[b]	*SS*[c]
Minimum	500	17	0.6	495	15	0.4	488	3	0.3
Maximum	949	36	1.9	796	32	2.5	519	27	1.6
Average	713	26	1.0	525	19	1.1	498	20	0.8
Total	8,558	308	12.0	6,303	227	14.0	5,970	243	0.0

Table 5.19: Unitary effluent coefficients of dairy firm in Sao Paulo

Parameters	*1980*	*1981*	*1982*	*80/82*
Volume[a]	1.54	0.92	0.58	62
BOD[b]	55.33	32.94	23.72	57
SSc	2.18	1.98	0.92	55

a. m^3 of effluent per ton of production
b. tons BOD per ton of production
c. tons SS per ton of production

the unitary water and waste service costs have been calculated for 1980 and 1982. Since the firm discharged its waste into SABESP's network, the first formula has been used. Below is an estimate of the firm's annual payment.

1980

UWC = 12*(0.49*19,804*0.60)/11,083 = $6.36
USC = 12*(0.67 + 0.37*8.45)* 0.49*19,804/ 11,083 = $39.84
TOTAL = $46.20 (water and waste costs per ton of output)

1982

UWC = 12*(0.49*12,118*0.60)/11,720 = $3.60
USC = 12*(0.67 + 0.37*8.40)*0.49*12,118/ 11,720 = $22.92
TOTAL = $26.52 (water and waste costs per ton of output)

As with the pharmaceutical industrial unit, if the food-processing firm had not taken measures to save water and reduce pollution loads, it would have incurred an additional cost of about $2.8 million in 1982. The lack of information on the cost of the program precludes making a cost-benefit analysis.

The Dairy Industrial Unit Level. The major outputs of this industrial unit were yogurt, desserts, and petit suisse cheese. The effluent coming from cheese production was trucked to a SABESP's treatment plant at a frequency of 41 trips per month. Information about total production, characteristics of the effluent, and unitary coefficients of pollution for the period 1980-82 are shown in tables 5.17-5.19. Total water consumption decreased by 30 percent despite an 85-percent increase in production. Also, the unitary coefficients of total volume of effluent and concentration of BOD and SS per ton of product decreased by 62 percent, 57 percent, and 55 percent, respectively, between 1980 and 1982.

To reduce its volume of effluent and concentration levels of BOD and SS, the firm expanded the capacity of its on-site pretreatment plant, improved its production process, and reduced the amount of water used in the washing process. The motive behind these changes was the high effluent fee imposed by the SABESP. The firm installed an anaerobic digester to treat part of its waste. Unfortunately, the costs involved in this operation were not mentioned, but the firm's manager stated that the cost of the treatment plant was paid off in less than a year.

An estimate of the magnitude of the firm's annual payment for water and waste services is shown below. Since the firm delivered its effluent to SABESP by trucks, the second formula has been used.

1980

UWC = 12*(0.49*713.2)/5,560 = $0.72
USC = 12*(0.37*62.28*0.49*713.2)/5,560 = $17.40
TOTAL = $18.12 (water and waste costs per ton of output)

1982

UWC = 12*(0.49*497.5)/10,290 = $0.28
USC = 12*(0.37*70.69*0.49*497.5)/10,290 = $7.44
TOTAL = $7.72 (water and waste costs per ton of output)

As with the previous industrial units, if this firm had not taken measures to save water and reduce pollution loads, it would have incurred an additional cost of about $100,000 per year.

The SABESP Level. Miglino (1984) estimated the impact of the industrial effluent tariff on SABESP's total revenue expectations. Assuming that all industrial firms in the Sao Paulo Metropolitan Region would respond in the same manner as the industrial units described early and that the price elasticity of effluent service demand for the whole industrial sector equals the average of the three price elasticities, then total annual revenue losses of SABESP would be about $112 million or 29 percent of expected revenue.

CONCLUSIONS

The three industrial units that were asked to pay effluent charges to the central effluent treatment facility reduced the amount of water used in their processes and the volume of effluent discharged, with reductions ranging from 42 percent to 62 percent in 1982 over 1980. In the pharmaceutical industry, the volumes of water purchased and effluent discharged per unit of output in 1982 was a 49 percent below 1980. In the food processing industry, water purchased and effluent were reduced by 42 percent per unit of output in 1982 compared to 1980. In the dairy industry, the unitary coefficients of volume of effluent and water use were reduced by 62 percent.

Water savings and industrial discharge reductions were an unexpected effect of the establishment of the industrial effluent charge in the early 1980s under which industries paid according to the volume and biological and chemical quality of the wastewater. The sewerage company failed to determine criteria to be used in estimating the charges to industries that would encourage them to connect to the sewer network. The company assumed that industrial units would always prefer to discharge their waste into the sewage treatment plant and pay the corresponding fees. Technological changes and price elasticities of demand were not taken into account in the planning process.

The implementation of the tariff policy for industrial effluent can be qualified as a "market-based incentive affecting water use." With respect to SABESP's financial interests, the policy implemented was not successful, but society benefited from it since pollution was abated and public investment in water supply postponed.

5.2.5 *Effects of Quotas and Penalty Fees in China*

China, despite its vast water reserves, faces shortages in a number of urban centers, especially in the northern region. Urbanization and industrialization have escalated demand for water in urban areas. Reservoirs originally designed for irrigation are now being used to supply urban areas. At the end of 1988 total urban domestic and industrial demand was estimated at 44 BCM [ADB 1990]. Total urban water demand is expected to grow at 7 percent per year and reach 85 BCM by 2000 [Zhongjie].

Industrial water demand is approximately 75 percent of the water supplied to the cities, and domestic consumption accounts for 22 percent. Despite of the government efforts to promote conservation in the industrial sector, factories in some cities are still being designed to waste water, using three to ten times the volume required by similar industries in developed countries to produce the same output [Zhongjei].

Adopted Measures

Since the late 1970s, China has been planning water supply augmentation and practicing strict economies in its use.[30] The government has enacted laws, regulations, and policies to promote conservation, especially in the industrial sector. A few cities have adopted administrative, legislative, economic, and technological measures required to encourage recycling, reuse, and adoption of more water-efficient processes. Some of these measures are described below.

Water allocation or quotas. Each factory has been assigned water and effluent quotas based on factors such as total value of production, industry type, machinery type, and size. The national policy mandates that all factories install and maintain water- and effluent-metering devices. Industrial water use is monitored by the Water Saving Office (WSO) [The World Bank 1990a], which maintains files for each industrial unit containing water flow balances for every machine and workshop and for the whole factory.

Water saving administrative organization. The Water Conservation Minister is in charge of the formulation of water supply policies, the planning of water resources development, the allocation of water resources among users, and the administration of legislation. This Minister has also set up the Construction Committee to operate the WSO.

Penalty for overuse. Under the current water pricing system, consumers who exceed their allocation have to pay triple, e.g., Yingkuo [LUCEC 1988], to as much as fifty times,[31] e.g., Tianjin [The World Bank 1990a] and Beijing [Zhongjie], the standard tariff of Y 0.35/m^3 for the volume of water beyond the assigned quota.

Industrial water audit programs. For industrial users consuming more than 3,000 m^3 per month, water audit programs are carried out by WSO's staff to inspect for leaks and evaluate the effectiveness of the factory's water-saving measures. Recommendations are made for cost-effective changes to improve water use-efficiency. In Tianjin about 1,700 factories, 42 percent of industrial customers, have been audited by the WSO [The World Bank 1990a].

Economic incentives. Rewards have recently been introduced for consumers who use less than their quotas. In Fuxin, for example, customers are awarded a discount equivalent to the volume saved times 20 percent of the standard rate [LUCCEC 1988].

Impacts

Statistics maintained by the WSO on the 82 major Chinese cities show that at present water recycling remains low. The nation-wide average rate is 56 percent; however, this rate varies among cities according to their water scarcity index [Zhongjie]. In the southern cities with relatively abundant water, the average rate is 22 percent, while in the northern and coastal cities, with limited water, the rate reaches 73 percent. Cities like Da-tong, Zibo, and Baotou, with serious shortages, have recycling rates of 93 percent, 92 percent and 88 percent, respectively.

Between 1981 and 1988, Tianjin was able to achieve a 250 percent increase in its value of industrial output per cubic meter of water, from Y 28 to Y 69 (1980 prices). In 1988 the rate of recycling was about 65 percent [The World Bank 1990a]. Beijing was also able to achieve a 270 percent increase in its value of industrial output per cubic meter of water between 1978 and 1984, from Y 11 to Y 30 [Zhongjie], respectively. The Dalian City's comprehensive conservation program has led it achieve a recycling rate of 93 percent resulting in a value of industrial output of Y 110/m^3, the highest in China.

Since cooling water accounts for about 70 percent of industrial water demand, efforts have been made to reduce this specific water use. Many Chinese industrial units have achieved remarkable results by recycling cooling water [Zhongjie]: the Taiwan Nitrogenous Fertilizer Factory in Luzhou City,[32] a small factory producing about 500 ton per year, used about 241 m^3/hr of water for cooling. However, after the factory installed a recycling system, only 7 percent of that volume was needed as supplementary water. Also its effluent volume has decreased by 94 percent, from 380-520 m^3 to 20-30 m^3 per ton of ammonia.

Industries have also made technological changes to conserve process water. For example, the Tianjin No. 5 timber mill has adopted wet-process fiberboard production with a recycling rate of 90-98 percent. Water consumption per ton of output has dropped from 80 m^3 to only 5 m^3, and the level of COD has also decreased by 74 percent.

CONCLUSIONS

Some Chinese cities have adopted conservation and recycling of water in response to water shortages. With education and various economic, administrative, and legislative measures, Tianjin and Beijing, for example, have increased their rate of industrial output per cubic meter of water by 250 percent and 270 percent during 1981-88 and 1978-84, respectively. The adopted measures include: a strict water quota and effluent quota per production unit, a penalty water price system, and a water audit program and regular water flow surveys under which industrial enterprises are inspected for leaks and effectiveness of water saving measures.

5.2.6 Effects of Restrictions, Quotas, and Licenses in Israel

In light of the scarcity of its water resources, Israel has made intensive efforts to reduce water demand in all sectors. Water conservation and efficient use of water have evolved over more than 40 years, and the achievements have been remarkable. This case study documents Israel's efforts to improve efficiency in industrial water use.

In view of the scarcity of water, in 1952 the Government of Israel began formulating a comprehensive water legislation. In 1959 it enacted the Water Law which adopted the following principles [Arlosoroff 1977]:

- *Public property*. "Water resources are public property, subject to the control of the State, to be used to provide for the needs of the population and the development of the country."
- *Ministerial responsibility*. "Executive authority is vested in the Water Commission (headed by the Water Commissioner), a separate entity under the jurisdiction of the Ministry of Agriculture. The Water Commission is responsible for the planning, management and supervision of all matters related to water."
- *Water rationing*. "No withdrawal, supply or use of water is permitted from any source except under an annual license issued by the Water Commission. The criteria for water allocation vary according to hydrological conditions, water requirements, water qualities and supply possibilities."
- *Water metering*. "Water metering is obligatory without exception."

ADOPTED MEASURES

To ensure efficient water use, the Water Commission has adopted the measures described below.

License of water supply. Water is allocated to each industrial firm according to a licensing provision. The total volume is determined by norms that consider the nature of the end product, the production process, the existing equipment, raw material(s), the technology available for efficient use of water, and the quality of effluent. The norms are updated from time to time as new technologies become available. In the dairy industry, for example, the approved norm was 3.5 liters of water per liter of milk in 1964, but in 1973 the norm was reduced to 1.7 liters. By 1977, the norm was reduced again, to 1.45 liters [Arlosoroff 1977]. The annual water allocation to each industrial unit is then calculated by multiplying the planned volume of production by the appropriate norm.

Metering. Metering of water is the most important administrative instrument for enforcing allocation. Industrial water use is metered at each firm, with a differentiation between water qualities.

Surcharges. In order to keep consumption within the volume allocated to the industrial unit, a special surcharge of about 200 percent is levied on the volume used beyond its quota.

Water-saving technologies. The licensing system forces industries to adopt water-saving measures. The government, in turn, supports research and development of technologies to reduce industrial water consumption and pollution. Recycling of cooling water through cooling towers has became a standard practice, and other improvements include recycling of blowdown water from steam and heating systems; recycling of seal-water in vacuum pump systems; introduction of accessories such as pressure regulators, valve regulators, automatic or semiautomatic valves; reuse of rinsing water; and use of low-grade water.

Promotion and dissemination. The Water Commission provides technical advisory services to disseminate information about water-saving technologies. The Commission also participates with the private sector in research and development activities.

Subsidized financing for investment. The government has established a fund to provide low-cost financing to construct projects that can reduce water consumption at a cost at least 10 percent below the marginal cost of supply. Thus, from the industrial unit's point of view, an investment in water saving is justified only if the value of water saved equals or surpasses the cost of improving water-use efficiency. However, from the public's point of view a conservation project is justified if its cost equals or is below to the marginal cost of water supply. To encourage industries to invest in water conservation, the government offers low-interest loans for up to 80 percent of the related investment.[33] Low-cost financing is also available for separate metering for each production process to identify where leaks take place.

Impacts

Figure 5.17 shows that the overall industrial water use in terms of cubic meters per thousand Israeli pounds (in constant prices) of output has decreased steadily during the period 1962-82, from 20 m^3 to 6 m^3. A 300 percent increase in industrial output was achieved with only a 20 percent increase in water consumption. During the same period, the overall value of industrial output per cubic meter of water has increased by 233 percent, from NIP 50,000/m^3 to NIP 166,700/m^3 (figure 5.18).

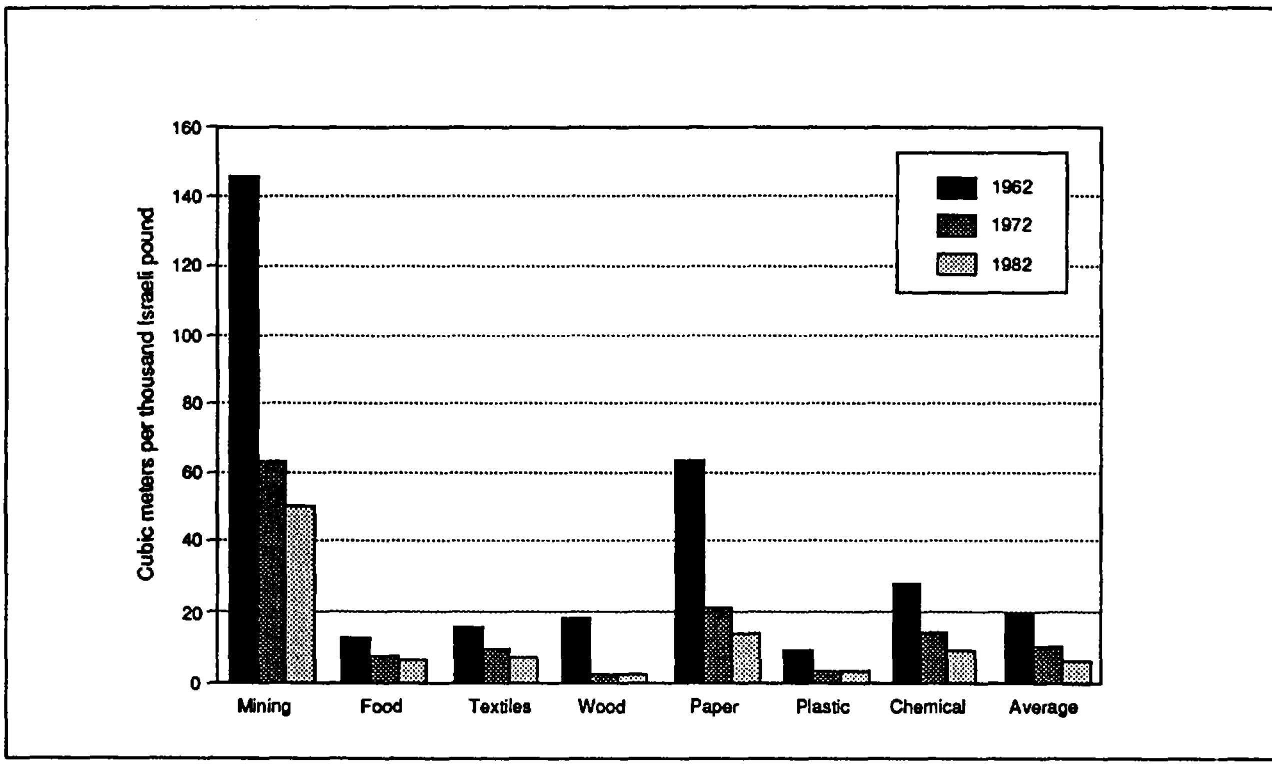
It is worth noting that the approach adopted by the Water Commission has been always to examine costs and benefits involved in increasing efficiency in the use of industrial water. On that basis, one can say that the adopted measures are justified in cost-benefit terms. However, there still exits the uncertainty about the cost-effectiveness of this command-and-control policy. It may be the case that more reliance on market-based incentives could have produced the same results at a lower cost. The absence of data precludes the undertaking of a cost-effective analysis.

Conclusions

Israel's policy encouraging industrial water conservation and recycling is based on: (i) annual water allocation on the basis of efficient production norms; (ii) introduction of water saving technologies; (iii) subsidized financing for investments in water saving processes and appliances; and (iv) undertaking of research and development programs. The result has been a steady decline on the average amount of water consumed per unit value of production. Between 1962 and 1982, industrial water consumption fell from 20 m^3 to about 6 m^3 per thousand Israeli pounds of production, a 70 percent saving.

The approach taken by the Water Commis-

Figure 5.17: Industrial water consumption per unit of output, Israel



Source: Saul Arlosoroff, "Water Management in Arid Zones," Ivory Coast, 1985.

sion has evolved around the following principle: If the unit of water would not have been saved, an extra unit would have been developed, produced, and conveyed to users with all the associated investments required. On that ground, the adopted measures are justified in cost-benefit terms. Lack of data precludes the undertaking of a cost-effective analysis to assess the cost-effectiveness of the command-and-control policy as opposed to a market-based incentives policy.

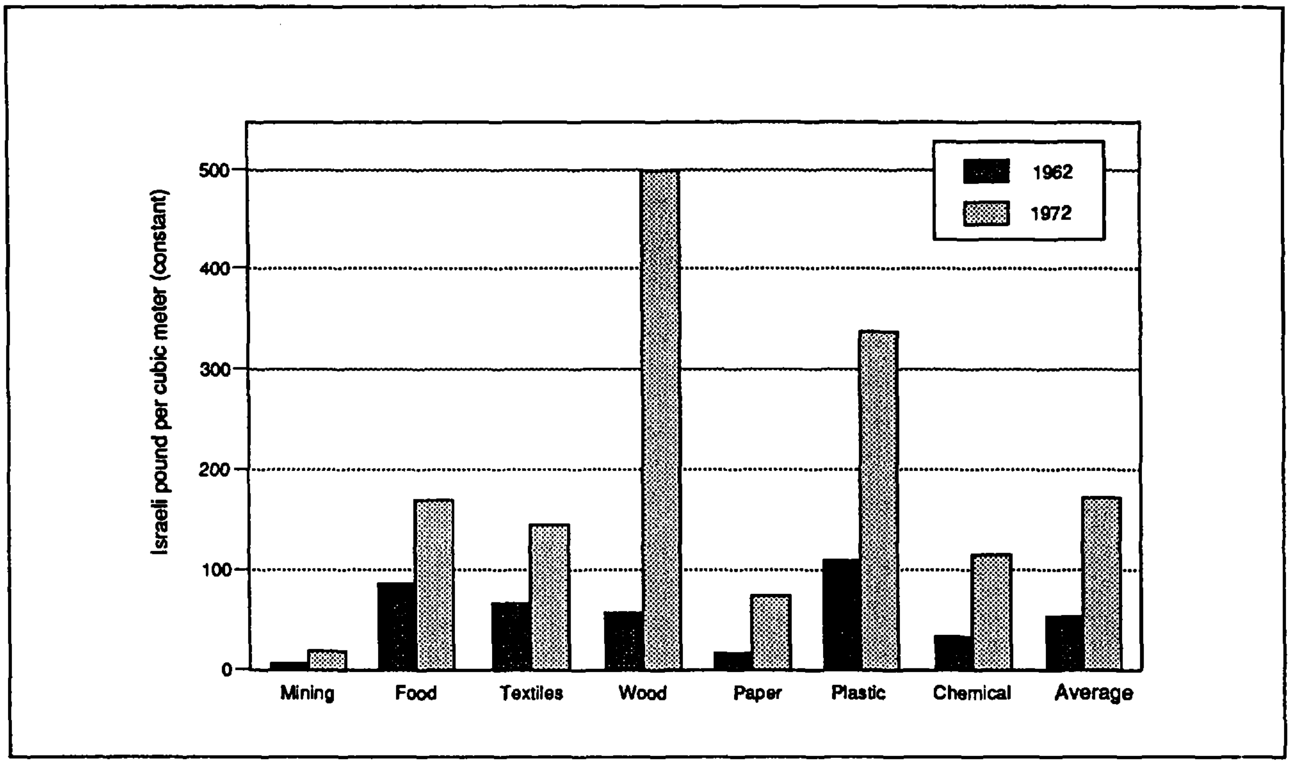
5.2.7 Reuse of Treated Municipal Effluent in Mexico City, Mexico

Water resources problems are very serious in Mexico City because of its rapid economic growth, industrialization and urbanization, which has led to an increasing water demand for domestic, industrial, and commercial purposes. In order to satisfy increasing demand and prevent the further deterioration of the Mexico Valley aquifer, it has become imperative to undertake increasingly costly projects, e.g., pumping water over an elevation of 1,000 m into the valley of Mexico from the Cutzamala river through a pipeline of about 180 km. The average incremental cost of water from the current scheme is about $0.82/m^3$. The newly designed water supply project for the city is expected to be still more costly; it would have an even longer transmission line, and the water would have to be pumped over an elevation of 2,000 m to the city [Cestti 1989].

ADOPTED MEASURES AND IMPACTS

In 1989, a group of 26 industrial units in the Vallejo area of Mexico City decided to find an alternative to the piped water supplied by the municipality. The result was the creation of a for-profit company, Aguas Industriales de Vallejo, to rehabilitate and operate the old municipal wastewater treatment plant. These 26 companies represent a variety of sectors including paper, electronic supplies, and chemical. Each provided equity on the basis of its water requirement, approximately $8,000 for each liter per second or $0.25/m^3$. The total equity of $0.9 million was enough to renovate and operate the plant. No debt was incurred, and it was expected that the companies would recover their investment in less than three years. One of the shareholder companies, Compañias

Figure 5.18: Value of output per cubic meter in selected industries



Source:Saul Arlosoroff, "Water Management in Arid Zones," Ivory Coast, 1985.

Mexicanas de Aguas which manufactures water treatment equipment, maintains and operates the wastewater treatment plant under contract to Aguas Industriales de Vallejo [The World Bank 1992].

Aguas Industriales de Vallejo operates the wastewater treatment plant under a ten-year renewable concession from the Departamento del Distrito Federal. The plant with a total capacity of 100 liters per second receives mostly residential wastewater and provides secondary-level treated effluent. At present, the plant provides 60 liters per second of treated effluent to the shareholder companies (eventually this will increase to 70 liters per second) and 30 liters per second to the government as payment for the concession. The agreement contemplates receiving up to 200 liters per second of wastewater from the municipal system. Plans are under way to expand the capacity of the treatment plant by 100 percent within the next five years. It is important to note that the Departamento del Distrito Federal built the distribution system linking each company to the treatment plant [World Bank 1992].

As of November 1991, the shareholder companies were getting water at 75 percent of the price charged by the municipality, e.g., $0.71/m^3. Industrial units use the water mainly for cooling, but some units use this water for processing purposes also. The government uses this water for irrigation and for washing government vehicles [The World Bank 1992].

Conclusions

The increasing price of municipal water supply and the imminent water shortage have motivated the adoption of municipal wastewater reuse for industrial purpose in Mexico City. Contrary to the general belief that reuse of wastewater requires public financing support, this case demonstrates that the financing, organization, execution, and operation of such projects can be entirely in the hands of the private sector.

5.2.8 Potential for Conservation in the Jabotabek Region, Indonesia[34]

The Jabotabek region has changed drastically in the last few years and a continuing dramatic change is foreseen. Its current population is about 20 million and it is expected that by the year 2025 it will rise to about 50 million. This population growth in conjunction with an increasing industrialization of the region will inevitably increase competition for the most readily available water sources between all water-use sectors. At present there is clear evidence of the existence of water shortage in the region.

Recent estimates of future water demand show that although present water requirements for municipal and industrial purposes is not high in relation to total water demand (only 20 percent), this will steadily increase in the near future. By the year 2025, it is expected that its total share will reach 46 percent. Although industrial water demand is marginal compared to other demands, by year 2025 it will represent approximately 40 percent of household demand in the region.

POTENTIAL MEASURES AND IMPACTS

During the course of an industrial water use survey covering 100 industrial units in the Jabotabek region, Southern Cross Textile, a textile industrial unit, and Toyota-Astra Motor, an automobile industrial unit, were visited to assess the potential for improving efficiency in water use. The major findings of the analysis are as follows.

Textile Industrial Firm. Southern Cross Textile unit is a very large industrial unit of about 1,550 employees located in east Jakarta that runs processes for scouring and bleaching of raw cotton and spinning and dyeing of cotton. Apparently the location of the firm was determined by closeness to the river. Presently, the river provides 7,200 m^3 day or 88% of daily requirements; while the rest comes from groundwater. This is a self-supplied industrial unit.

Since water from the river is withdrawn free of charge, the firm is using more water than what is technically necessary. Total water use per unit of output is about 560 m^3/ton, which is more than similar industries in developed countries (180 m^3 in Israel and 250 m^3 in Belgium). According to the management, this firm could save as much as 0.37 MCM per year or 36% of total intake at low cost; however, at present the firm does not have incentives to implement measures that will reduce water use.

Water intake in this textile industry can be reduced through better housekeeping of rinse water, increasing recycling of cooling water, and reuse of treated effluent coming from the wastewater treatment plant. The final rinse water after bleaching or dyeing operations can be easily recycled without affecting the overall production or increasing overall cost. This can save about 480 m^3 per day (0.14 MCM per year) at very low cost (Rp. 210/m^3). Increased recycling of cooling water can save about 0.26 MCM per year at a cost of Rp. 250/m^3. The reuse of treated effluent will save an additional 0.42 MCM at a cost of Rp. 735/m^3.

At present, this industry is treating only the effluent of the process water to meet current quality effluent standards, discharging the final effluent to the nearby river. However, the management of the firm is concerned with water conservation projects in the event that regulations become more stringent or a charge has to be paid for raw water taken from the river, as in happening in the Botabek region.

This firm will adopt measures to save water due to water quantity and quality constrain only when authorities send it the right signals. In this regard, a simulation model has been developed to assess how a tax on discharged effluent and a higher price for river water may affect the decision of the firm regarding conservation, recycling, and reuse of treated affluent within the firm. This analysis follows more or less the methodology presented in the case (5.5.2).

This textile firm was assumed to be facing the supply curve for water presented in table 5.20 (unit cost is estimated as the sum of annualized investment and operation and maintenance costs at 10% divided by the annualized volume). As can be seen, besides the traditional water sources, the firm has three new options to meet water demand: better housekeeping, increasing recycling, and reusing treated effluent. Assuming that these options can be added to each other, then the firm will face the technological options presented in table 5.21. By doing so, the firm will be able to reduce its water intake and

Table 5.20: Water supply costs for the firm

Item	*Unit Cost*	*Maximum Volume*
Status Quo		
Water from River	200	2,246,000
Water from Groundwater	1,285	316,000
Treatment of Effluent	1,180	421,000
Modifications		
Better Housekeeping	210	144,000
Increased Recycling	250	262,000
Reuse of Treated Effluent	750	421,000

Table 5.21: Technological options to reduce water demand and effluent discharge

Option	Intake Water	Additional Sources Conservation	Recycling	Reuse	Final Discharge Total	Treated	Untreated
C	2562000	0	0	0	1786000	421000	1365000
I	2418000	144000	0	0	1642000	421000	1221000
II	2156000	144000	262000	0	1380000	421000	95900
III	1735000	144000	262000	421000	959000	0	95900

Note: Measured in m^3 per year
C = Current situation.
I = Better housekeeping of rinse water.
II = Increased recycling of cooling water.
III = Reuse of current treated effluent.

Table 5.22: Water demand and effluent discharge for a given option

Technological Option	Water Withdrawal in MCM	Reduction From Current	Effluent Discharge in MCM	Reduction From Current
C	2.56	--	1.79	--
I	2.42	5.5%	1.64	8.4%
II	2.16	15.6%	1.38	22.9%
III	1.74	32.0%	0.96	46.4%

final effluent by the amounts given in table 5.22.

An analysis of the minimum cost option available to the firm for a given combination of river water price and effluent charges shows that the higher the water price and effluent charge the more conservation will be chosen. The results also infer that if the effluent tax and water price are set at Rp. 350 and Rp. 450, respectively, then this firm will cut back water intake by 32% and effluent discharge by 46% in order to maximize profits. This implies the establishment of a river water users' charge of about Rp. 150/m³.

Automobile Industrial Firm. The Toyota-Astra Motor, a foreign company located in northern Jakarta, assembles 50,000 automobiles per year. At present, this firm uses 300,000 m³ per year. Almost one-third of its water requirement comes from piped supplies (Rp. 2,500/m³), one-half comes from groundwater (Rp. 1,250/m³) and the rest comes from tankers (Rp. 5,000/m³). The management is planning to triple its level of output by year 2000, which will demand about 720,000 m³ per year. However, the likelihood of getting more water from PDAM Jaya is very low. The second source is becoming heavily polluted. Thus, the only alternative source is to buy water from tankers.

The management of this comp..ny is fully aware of the water situation of Jakarta and is fully committed to conserving water in order to maximize profits and reduce costs. In this case, the firm's responses to the high price of water from tankers include the following points listed below.

- Better housekeeping, at a cost of Rp. 300/m³, saving 72,000 m³.
- Reuse the current treated effluent after sand filter and activated carbon treatment for toilet flushing, water gardening, and other low quality purposes, at the cost of Rp. 1,300/m³.
- Construction of a wastewater treatment plant that will treat all effluent including wastewater from toilets, showers, and kitchen, and reuse half of the treated effluent within the plant at an additional cost of Rp. 1,400/m³.

Despite the firm's investments in wastewater treatment facilities, at present it lacks economic incentives to reuse the effluent within the plant, which would reduce their water intake. The cost of conserved water is a little higher than the current cost of groundwater.

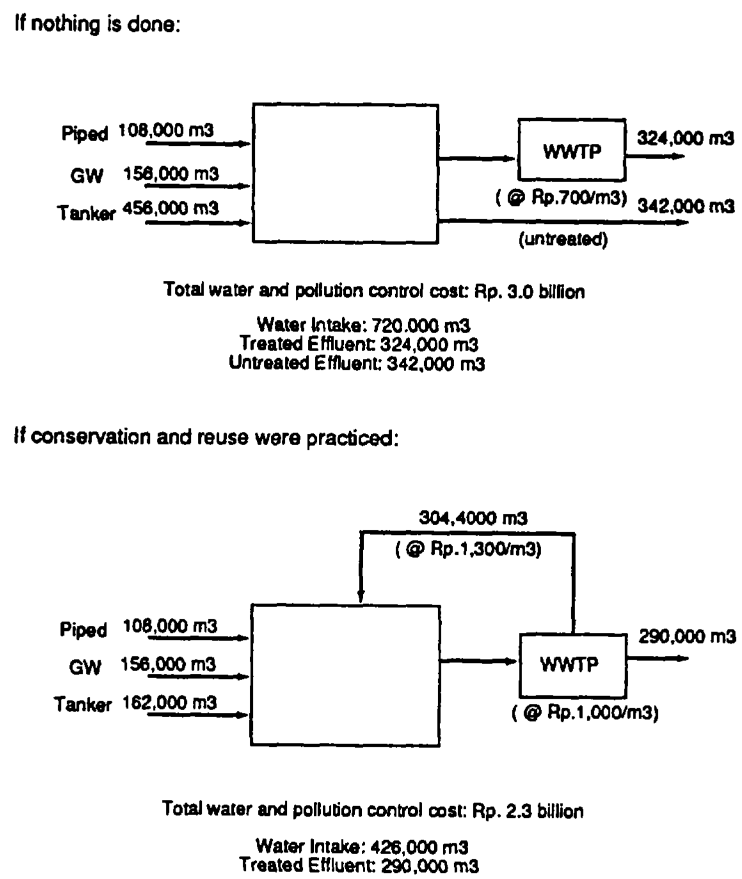
The diagram below (figure 5.19) explains the cost minimization behavior of the firm. If conservation and reuse are practiced, then water and pollution costs decline by 25 percent, and water intake decreases by 40 percent.

5.3 Managing Agricultural Demand

5.3.1 Effect of Quotas and Volumetric Charges in Israel

Israel's water resources are inadequate to meet the demand for water for its total irrigable area. Total renewable fresh water available is ap-

Figure 5.19 : Cost-minimization behavior of an automobile industrial unit, Indonesia



proximately 1.6 BCM per year, enough to irrigate 10 percent of the total gross area. In addition, Israel faces high unit costs for new water supply, estimated at about $0.35/m³ [Tahal Consulting Engineers 1991]. Scarcity of water has motivated the government and citizens to make special efforts to attain the maximum return per unit of water through increased efficiency in water use, specially in irrigation, the country's largest water user (Tahal Consulting Engineers 1991).

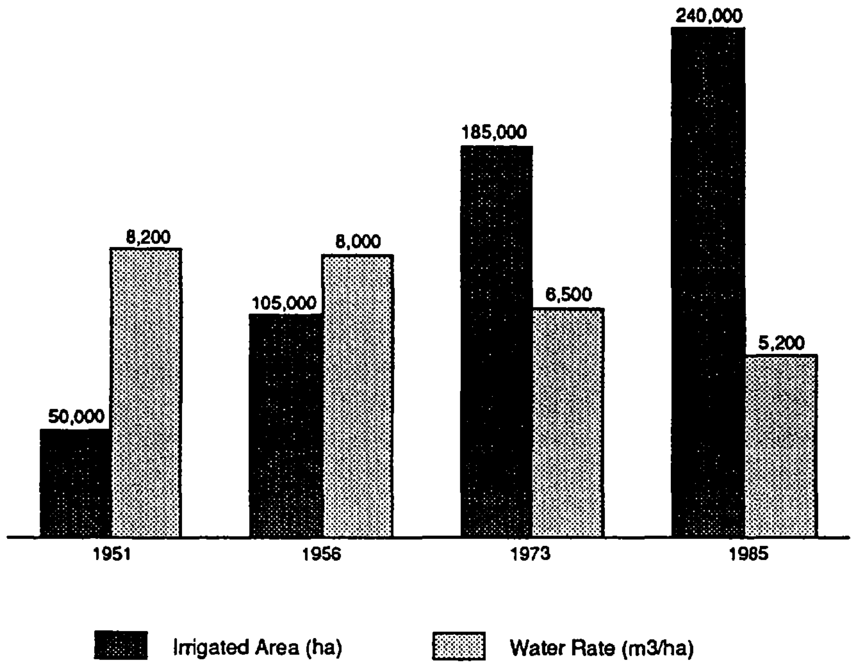
Development and adoption of efficient irrigation techniques have made possible an increase in the area under irrigation without increasing water use. From 1951 to 1985, irrigated area increased fivefold, but water use increased only threefold. Water use per hectare dropped, on average, from a high of 8,200 m³ ["Irrigation News for Israel" 1982] to about 5,200 m³ [Idelovitch 1987], a decrease of about 40 percent. Total output from irrigated land grew tenfold (at fixed prices) during the same period [Tahal Consulting Engineers 1991], yields increased significantly, and productivity per cubic meter almost tripled.

ADOPTED MEASURES

The Water Commission of the Ministry of Agriculture is responsible for administration of the Israel's water policy. To ensure an efficient use of irrigation water, the Water Commission has adopted the following measures:

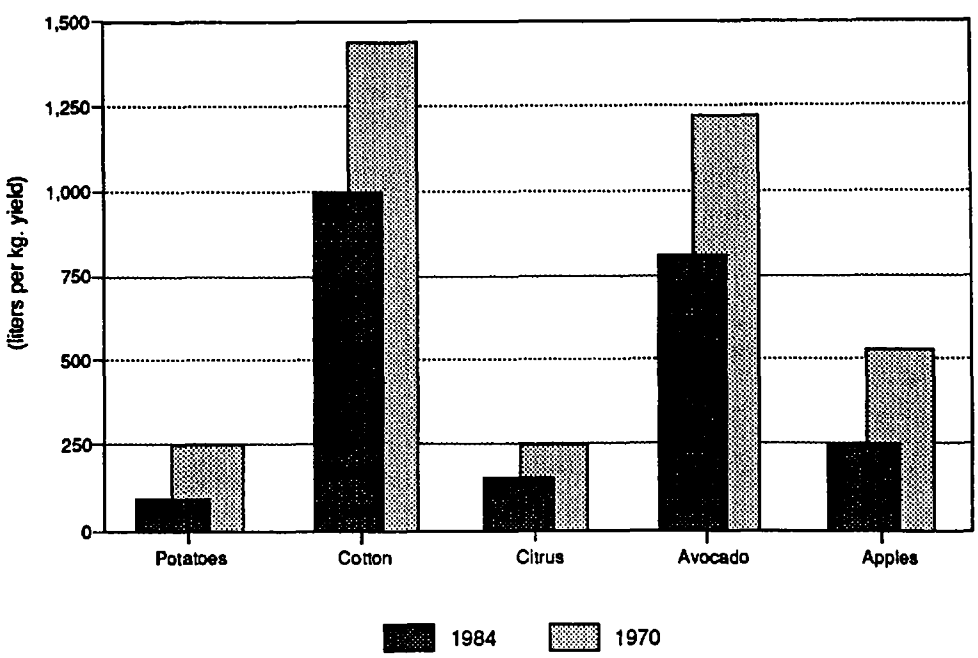
Water allocation and pricing. Allocations of water to the irrigation sector are fixed. Allocations are based on annual licenses. Each farmer's allocation is based on the area cultivated, the crop mix, and water requirements of each crop. There are norms and maximum quantities of water allowed for different crops,

Figure 5.20: Efficient use of water in the irrigation sector, 1948-1988



Sources: "Irrigation News from Israel," Irrinews, 1982 and "Israel Water Sector Review," Tahal, 1990.

Figure 5.21: Irrigation water application rates for major crops, 1970-1984



as determined by field estimates. The allocation system provides an incentive for efficiency since farmers must sustain their farms on the allocated volume. Wasteful practices may cause farmers to reduce their irrigated areas or pay penalties for overconsumption.

Charges for irrigation water are based on a progressive block rate structure. In July 1990, for example, water charges were as follows [Tahal Consulting Engineers 1991]: 80 percent of the allocated volume was charged at $0.125/m^3, the remaining 20 percent was charged at $0.20/m^3, and consumption above the allocated limit was charged at $0.26/m^3. Seasonal pricing is also practiced. During peak months (July-August), a 40-percent premium is charged because the energy required per unit of water supplied increases due to greater hydraulic losses in overloaded pipelines.

Metering. To keep effective control of the resource, the Law of Water Metering was introduced in 1955. Under this law, "no one will produce, supply, or consume water without being measured."

Research and Development. The government, through the Irrigation Efficiency Unit, under the Efficient Water Utilization Division of the Water Commission, supports research for development of water-saving devices and systems, including automatic control systems, aiming at reducing consumption of water per unit of crop area and per unit of crop yield. The Irrigation Efficiency Unit also promotes pilot projects and sets up large-scale demonstration farms and projects.

Extension Service. To introduce proven technologies, a special agency, the Irrigation and Soil Field Service, now a unit under the Ministry of Agriculture Extension Service, was established in the 1950s to deal exclusively with extension services.

Soft Loans. The government makes loans at attractive interest rates to water users for installing more efficient irrigation equipment and water application control devices. In addition, the market prices of these devices have been reduced.

IMPACTS

The major contributors to the increase in area under irrigation have been the increase in irrigation efficiency and the decrease in water application rate per hectare (figure 5.20) from some 8,000 m^3 in the mid-1950s to about 6,000 m^3 in the 1970s and 5,200 m^3 in recent years, with steadily increasing yields (figure 5.21).

Efficiency has been increased by use of pressure methods, sprinkle and drip irrigation, water-saving devices, and computer-controlled systems. Gravity irrigation had been completely replaced by sprinkler and drip irrigation. At present about 90 percent of total irrigated area is watered by sprinklers and the rest by drip methods. Efficiencies of 80 percent or more have been obtained in most areas under sprinkle and drip irrigation. For example, drip irrigation has produced higher crop yields with lower water consumption rates on a 700-hectare banana field [Tahal Consulting Engineers 1991] (table 5.23).

CONCLUSIONS

The adopted policy to encourage efficient use of water in the irrigation sector is based on: (i) annual water allocation on the basis of efficient norms determined by field estimates; (ii) implementation of an increasing water rate structure; (iii) introduction of water metering; (iv) subsidized financing for investments in more efficient irrigation equipment and water application control devices; and (v) undertaking of research and development programs and extension services. The results have been a steady decline on the average water application rate per hectare and a notable increase in irrigation efficiency. Between 1951 and 1985, water application rate fell from 8,200 m^3/ha to 5 200 m^3/ha [Arlosoroff 1985], a 36 percent reduction. Irrigation water use in this period increased by 200 percent, whereas the area under irrigation increased by 380 percent.

5.3.3 Economics of Irrigation Canal Lining, Bihar

SUMMARY

The Auranga Main Canal in Bihar, in northeastern India, extends 135 miles and has a full supply capacity of 1,840 m^3/sec at its head, tapering to 337 m^3/sec at the end. Central government guidelines were to line main canals up to the point where they carried 1,000 m^3/sec, whereas the project authorities were planning to line it up to 550 m^3/sec, an additional 20 miles. Sinha and Bhatia (1982) examined the economic case for lining different lengths of the canal.

The five options examined were (i) leaving the canal unlined, (ii) lining up to 64 miles, (iii)

Table 5.23: Improved efficiency in a 700 ha banana area under drip irrigation

Year	*Drip Irrigation Percent*	*Annual Water m³/ha*	*Yields t/ha/year*	*Consumption m³/t*
1972	0.0	50,000	30.5	1,640
1973	8.3	47,000	26.9	1,750
1974	14.1	42,740	24.2	1,770
1975	20.7	45,580	39.1	1,170
1976	35.6	39,000	42.4	920
1977	48.3	40,700	36.1	1,130
1978	61.3	38,300	41.7	920
1979	77.8	37,170	44.2	840
1980	75.8	32,030	40.2	800
1981	80.6	28,540	40.9	700

lining up to 84 miles, (iv) lining up to 122 miles, and (v) lining the full length of 135 miles. The cost of lining was expressed in social cost terms, taking shadow prices for unskilled and semi-skilled labor and deducting taxes and transfer payments.

The benefits of lining were less land required for construction; lower conveyance losses from seepage and evaporation, releasing more water for domestic, industrial, or irrigation use; lower maintenance costs; less danger of breaches; less risk of passing excessive discharges; reduced water-logging in adjacent land; and increased operational efficiency.

The first three items were figured into the cost-benefit analysis, and the remainder were treated as intangible benefits. Discounted at 10 percent over 25 years, all the lining options show handsome rates of return against the unlined option. The net present value is maximized when the canal is fully lined, giving a benefit-cost ratio of 5.2.

CONCLUSION

Lining the full length of a main irrigation canal was found to be economically justified. The distribution of benefits was equitable since the less influential farmers at the end of the system tended to suffer from irregular supplies. Leakage along a conveyor is sometimes necessary to replenish an aquifer, a possible concern to small farmers, but in this particular case the repaired leakage had caused water-logging, and its reduction counted as a benefit.

5.3.3 Economics of Improving Irrigation Efficiency, Bihar, India[35]

This case study illustrates the economic aspects of conservation in the irrigation sector. The analyzed project is the Subernarekha Multipurpose Project, which is planned for irrigation of 160,00 ha in Bihar, 90,000 ha in Orisa, and 5,000 ha in West Bengal.

POTENTIAL MEASURES

In this situation, improvement in irrigation efficiency could be effected mainly through lining of the canals in different subsystems and better water management practices such as on-farm development works (levelling and contouring of the fields); additional infrastructure; and enforcing scheduling.

LIKELY IMPACTS

This section presents a cost-benefit analysis for each one of the improvement measures outlined above. The estimated capital costs of these improvements are shown in table 5.24. The

Table 5.24: Cost of irrigation improvements

Measure	*Cost Rs mln*
Additional cost of lining	
Main canal, branches, distributors and minors	673.4
Water courses	860.0
Field channels	2,468.6
Better water management practices	
On-farm development works	
Land leveling and shaping	105.4
Field channels (unlined)	63.4
Drainage	25.0
Infrastructure improvement	
Communication	50.0
Agrimet station	2.0
Control and regulation structures	50.0
Total	4,297.8

additional capital outlay of Rs 4,298 million annualized at 12 percent opportunity cost of capital (with 50 years of economic life) is Rs 518 million. Adding to this operation and maintenance costs estimated at Rs 50 per hectare gives a total annual cost of Rs 526 million.

The benefits derived from improvements in terms of increased irrigation efficiency are shown in table 5.25. In terms of volume of saved water, the benefits are as follows (table 5.26):

- By lining the canal system down to minors, the saving in water is about 234 MCM.
- By lining of water courses the saving in water is about 29 MCM.
- By lining of field channels, the saving is 34 MCM.
- By improvement in field application through scheduling and rotational water supply, the saving in water could amount to 91 MCM. This will be possible only with the construction of field channels, additional control and regulating structures, and better management.

Table 5.27 compares the four conservation options in terms of total capital cost per cubic meter of water saved. Table 5.28, in turn, compares the improvement measures in terms of their annualized cost per cubic meter of water saved, including both capital, operation and maintenance costs. All options with the exception of lining of field channels have a unit cost below marginal cost of water supply, e.g. Rp. 3.5/m^3. If all options are implemented, the average cost of saving water would be equal to Rs 1.42/m^3. If field channels are not lined, the average cost of conservation would be equal to Rs 0.73/m^3.

CONCLUSIONS

Water economy measures should be subjected to cost-benefit analyses to determine whether or not it makes sense to devote scarce resources to save all possible water. Conservation measures should be adopted when the associated cost is below the cost of producing and transporting an additional unit of water. In the case of the Subernarekha Multipurpose Projects, lining the conveyance system may save 13 percent of irrigation water at a relative low cost, e.g. 10 percent of marginal cost of water. Improvements in system performance, e.g., additional control/regulating structures, strengthening communication systems, enforcing schedules, may save an additional 5 percent of irrigation water at 24 percent of the cost of marginal water.

5.4 Managing Municipal Water Supply Systems

5.4.1 Unaccounted-for Water Program in Bangkok, Thailand[36]

The Metropolitan Waterworks Authority (MWA), an agency under Thailand's Ministry of Interior, is responsible for the water supply of Bangkok and environs. The MWA is in charge of the production, supply, distribution, and sale of water to the service area, which includes metropolitan Bangkok and the neighboring provinces of Nonthaburi and Samut Prakan. The service area covers 475 square kilometers. As of 1986, the production capacity of the water supply system was 911 MCM of treated water, which provided service to 67 percent of the population in MWA's service area (4.8 million).

ADOPTED MEASURES

In 1983, the MWA updated its projections of water demand made in the 1970 Master Plan. The new estimates showed that demand would increase by 4.6 percent per annum, a very high growth rate. MWA decided to curb the rate of demand growth through a water conservation program. The program contemplated the following measures: increasing tariff on consumers with high demand; a public information campaign to promote conservation; and a program to reduce UFW.

Available data show that before the implementation of programs to reduce UFW, the MWA's level of UFW had increased steadily, reaching 56 percent in 1973. Between 1974 and 1980, efforts were made to reduce the level of UFW, but without great success. The UFW level was reduced by 1 percent per year and reached 49% of total production in 1980. This level was so excessive that MWA could no longer disregard the problem of UFW, especially when the public utility realized that any increase in the system's production and delivery capacity would incur higher investment and operating costs. Thus, the increasing cost of water supply marked the beginning of the implementation of water conservation programs by the MWA that would minimize water losses. In 1983, it was estimated that the major components of UFW in

Table 5.25: Efficiency of the current irrigation system, Bihar

	Kharif		*Rabi and Hot Weather*	
	Lined	*Unlined*	*Lined*	*Unlined*
Subsystem I: Conveyance from head to end of minor	85.0	77.0	83.0	75.0
Operational	94.0	91.0	92.0	90.0
Conveyance efficiency	80.0	70.0	76.5	67.5
Subsystem II: Channel water course	97.0	94.0	95.0	92.0
Field channel	93.0	90.0	92.0	87.0
Channel losses	90.0	85.0	87.5	80.0
Subsystem III: Field application				
Without scheduling	85.0	85.0	75.0	75.0
With scheduling	95.0	95.0	83.5	83.5
Overall efficiency				
Without scheduling	61.2	50.4	50.2	40.5
With scheduling	68.5	56.3	55.9	45.[illegible]

Table 5.26: Water savings by conservation measures, Bihar

Subsystem	*Water saved in MCM*	*Percent of water use*	*Percent of saving*
Lining conveyance system down to minors	234.1	12.9	60.4
Lining of water courses	29.3	1.6	7.6
Lining of field channels	33.5	1.8	8.6
Improvement in system performance	90.7	5.0	23.4
Total	387.6	21.3	100.0

Table 5.27: Capital outlay on conservation measures

Conservation measures	*Capital outlay Rs mln*	*Saving in MCM*	*Cost Rs/m³*
Lining conveyance system down to minors	673.4	234.1	2.9
Lining of water courses	860.0	29.3	29.4
Lining of field channels	2,468.6	33.5	73.7
Improvements in system performance	295.8	90.7	3.3

Table 5.28: Discounted cost of saved water

Conservation measures	*Capital*	*Annual cost O & M Rs mln*	*Total*	*Water saved MCM*	*Water cost Rs/m³*
Lining of conveyance system	81.1	(4.25)	77.8	234.1	0.33
Lining of water courses	103.0	(1.70)	101.9	29.3	3.48
Lining of field channels	297.3	(2.55)	294.7	33.5	8.80
Improvement in system performance	35.6	42.50	77.1	90.7	0.85
Total	517.5	34.00	551.5	387.6	1.42

Bangkok were as follows: leakage, 32-42 percent; public use, 1-2 percent; illegal use, 2-5 percent; and metering losses, 2-6 percent.

In addition to leak detection and control programs, the utility adopted meter replacement, pipe replacement, establishment of a Water Loss Reduction Office to carry out systematic leakage detection, improved metering efficiency, tracing illegal connections, and improving distribution system operation and control.

IMPACTS

The MWA was able to reduce UFW at a rate of two percentage points per year, from 45 percent in 1983 to only 34 percent in 1988. The efforts of MWA to reduce UFW took into consideration the range of UFW beyond which the cost to reduce UFW is not worth the expected benefits. An extensive study carried out in Bangkok by Camp Dresser & McKee, Inc. in conjunction with Metropolitan Engineering Consultants, Ltd. estimated that UFW could be reduced to 30 percent in an economic way (leakage 24 percent, metering losses 2 percent, illegal use 3 percent and public use 1 percent).

The total change in benefits from adopting this policy is the product of the total saved water times the marginal cost of supply. In this case, it was assumed that as a result of this policy leaks were reduced by 12 percent over the six-year period 1983-1988. Total water savings were 110 MCM. The average incremental cost of producing water, based on 1975 projections and 1975 prices, varied between $0.15/m^3 (B 3.00/m^3) and $0.20/m^3 (B 4.00/m^3) [Saunders 1976]. Average annual benefits amounted to $5.6 million in 1987 prices (B 145 million). To estimate the change in costs, it was assumed that the utility invested about $13.6 (B 350) per connection as capital cost. In addition, a 10-year lifetime was assumed for the repair works. Consequently, at 10 percent annual discounted rate, the change in costs reached $1.36 million (B 35 million). Thus, the adopted policy was economically justified since the net cost savings for the utility were $4.2 million (B 110 million) per year.

CONCLUSIONS

This case shows that water utilities can cope with growing demands and capital shortages by other actions besides establishing economic incentives. Reduction of unaccounted-for water offers, in most of the cases, substantial savings for the utility.

5.4.2 Privatization as an Impetus for Conservation in Côte d'Ivoire[37]

During the early 1970s, most of the urban centers of the Cote d'Ivoire enjoyed piped water supply. Systems were generally well equipped and maintained, but the population growth in connection with the rapid urbanization strained the capacity of the infrastructure. The results were that by 1975 only 50 percent of the population in Abidjan had access to piped water, while the level of coverage in the urban centers outside the capital reached only 15 percent. In rural areas, the situation was even more serious. Most of the rural population relied on wells, while others were supplied with water from boreholes. The government, in its efforts to reduce the disparity in living conditions between urban and rural areas, assigned high priority to the water supply sector. As part of the 12-year water development program 1974-85, the government undertook a redefinition of the institutional responsibilities for the sector including among other things the transfer of the operation and maintenance of the system from the electricity corporation to a private company, Societé de Distribution d'Eau de la Côte d'Ivoire (SODECI).

ADOPTED MEASURES

In the past 25 years the urban water sector in Côte d'Ivoire has been operated by a private company, SODECI, under concessions and lease contracts. SODECI was established in 1960 as a subsidiary of the Société d'Amenagement Urbain et Rural (SAUR), a large French water utility, to operate the water supply system of Abidjan under a concession contract. Subsequently, the majority of the equity was acquired by Ivorian shareholders and the shares are traded on the Abidjan stock exchange.

In 1974 SODECI's contract was extended to include three new elements: a lease contract for the operation and maintenance of all urban and rural water supply outside the capital; a concession contract for Abidjan including investment in boreholes as well as the operation and maintenance of the system; and a maintenance contract for Abidjan's sewerage and drainage. The Water Directorate of the Ministry of Public Works and Transportation was responsible for planning and investment, without consulting SODECI. SODECI collected the approved tariff from consumers, subtracted its due fees, and transferred the remainder to the two public funds in the water and sanitation sector.

IMPACTS

For some years this arrangement performed well in important respects. By 1989, 72 percent of the urban population had access to safe water, compared to 30 percent in 1974. About 80 percent of the rural population was served by water points equipped with handpumps, compared to 10 percent in 1974. There was a high level of operating efficiency in urban areas, with unaccounted-for water only 12 percent and the collection rate for private consumers 98 percent. Urban tariffs were high, especially on industrial users, to subsidize the rural programs. They were almost certainly above the level of long-term marginal costs, and subsequent changes have been in a downward direction. Demand was depressed and revenues fell as industries began to recycle water–a desirable result provided it was not taken to uneconomic lengths–and used cheaper private sources.

In the context of conservation, Ivorian experience shows that privatization can be a good opportunity for raising urban and industrial water tariffs, reducing unaccounted-for water, and maximizing revenue collections. In this case urban tariff increases were carried to unacceptable lengths because of the need to cross-subsidize rural from urban consumers.

CHAPTER 6

IMPROVED WATER ALLOCATION

6.1 Reallocation Among Different Sectors

6.1.1 Development of Water Markets in Colorado, USA[38]

The Colorado-Big Thompson Project (CBT) transfers water from the western slopes of the Rocky Mountains to northeastern Colorado, where it is distributed by the Northern Colorado Water Conservation District (NCWCD). Since 1957, the CBT has provided an average of 230,000 acre-feet, or 17 percent of the region's total water supply. Although CBT water is used mainly for supplemental irrigation, it is also used as a fresh-water supply by urban and nonagricultural industrial consumers. The water markets that have evolved are unusually efficient and can serve as models for study by other systems.

The NCWCD was formed in 1934 to represent regional water interests and proved helpful in negotiating the passage of the CBT scheme, which turned out to be difficult and costly. A contract was agreed to in 1983 between the NCWCD and the Bureau of Reclamation governing the allocation of costs, repayment, and quantities to be supplies. Two features were important to the subsequent evolution of water markets. First, the NCWCD owned all return flows of water under the scheme and thus avoided any legal claims against the return flows and relieved buyers and sellers from possible legal damages. This provision was possible because all CBT water was new to the receiving basin. Second, the usual Bureau of Reclamation limits on the size of farms allowed to benefit from federal water did not apply, and this also promoted free transfer of water between users.

ADOPTED MEASURES

When the scheme was about to come on-stream in the mid-1950s, there was vigorous discussion among users about allocation arrangements. The NCWCD included areas of very different water supplies; some areas had senior rights to large, reliable supplies, while others had inadequate and unreliable access to water. In public meetings people rejected a mandatory and uniform assignment of water and preferred to choose whether or not to subscribe to the new source. As a result, in 1957 an allotment was defined as a freely transferable contract between district and holder, subject to demonstration of beneficial use within the district boundary. The CBT supply was evenly divided between the fixed number of allotments, with water allocation based on the proportional system. Proportional rights systems are more efficient where user demand functions and risk avoidance are similar. They also mean homogeneous allotments, which help market creation.

The NCWCD decides annually how much of the potential maximum water available will be requested from the Bureau of Reclamation, and this request sets the size of a single allotment. Buyers and sellers of allotments must have their proposal examined by a field crew to verify beneficial use, and this increases transaction costs. Brooking services have risen.

Since the mid-1960s, urban and industrial growth on the eastern flanks of the Rockies have been rapid. Most of the water needed by these new users has been provided by the transfer of NCWCD allotments from agriculture. In 1957, irrigators started with 85 percent of the allotments, whereas by 1982 their share had fallen to 64 percent (though this exaggerates the shift, since cities tend to acquire more allotments than they are likely to need and rent back the surplus to farmers). Average allotment prices increased by a compound annual rate of 19 percent between 1960-73, and by 33 percent between 1973-80. Prices then fell back as a rival source of water became available.

A refinement of the market for allotments has been that for rentals (transfers of water for only one season). These rentals are usually arranged directly between buyer and seller, but are also often advertised and occasionally auctioned. Around 30 percent of all CBT water is rented, largely from towns by farmers. Rentals have shown little or no real increase in value since the 1960s because they are uncertain and less reliable, and the water is more likely to be applied to low-value, low-cost crops. Another reason is the strong moral pressure that the district exerts on renters not to profiteer at the expense of farmers.

CBT water delivered through NCWCD auspices is in allotments that are uniform, easily transferred, and reliable. These factors favor the creation of markets compared, for example, to individually owned water rights established under state law. The implicit cost of holding an allotment is $174 per acre-foot of water, whereas its marginal value in agriculture is only $32 according to one estimate. The implication is that farmers are holding water allotments in the expectation of price increases.

IMPACTS

The efficiency of the CBT-NCWCD water market arrangements has been assessed: "...the NCWCD system is more efficient than the typical Bureau of Reclamation contractual arrangements, which tie water perpetually to the same land and, in many cases, to the same uses....Inflexibility in patterns of water use like those found in central Arizona and the Central Valley of California either stifle further economic development or require enormously expensive new water projects to supply water for growth. The Central Arizona Project and the California State Water Project are two of the most expensive projects every undertaken anywhere in the world. The well-known study of the role of water in affecting the growth of the Arizona economy ...showed decisively that an efficient transfer of relatively small amounts of water out of low value agriculture to the newly-emerging urban and industrial uses was adequate to maintain rapid state growth without the Central Arizona Project. In a water market system, such transfers take place." [Howe et al. 1986].

The success of water markets as an allocation device can be attributed to these factors:

- CBT water accounts for only 17 percent of total supply, but it is widely held throughout the area. Since its transaction costs are the lowest, it represents the easily tradeable margin and plays a disproportionate role in ensuring the efficient use of all water. The fact that other sources are effectively nontransferable or transferable only at high cost is less important where the tradeable margin is widely held.
- Return-flow externalities were not at issue in this case, since the district owned return flows. Apart from the legal position, the net third-party effects of the sale and rental of allotments are likely to be positive. Since the initial transfer is likely to be from a less productive area to a more productive one, gains to users downstream from buyers are likely to exceed losses from users downstream from sellers. Moreover, many of the return-flow effects will accrue to parties much further downstream, who would be unaffected by transfers of water within the same district.

As a generalization: "...allocative efficiency requires evaluation of third party effects, and market efficiency in particular requires the establishment of property rights in return flows...these property rights must be quantifiable in value and enforceable by law. [Ideally,]...return flow externalities...are best treated by identifying and quantifying the externalities, facilitating compensation to damaged parties, and allowing the buyer to sell return flows. "[Howe et al. 1986]

- The development of the market for allotments was supported by a majority of users from the outset.
- Making more efficient use of existing supplies avoids the costs of developing new supply sources, including compensating the basins of origin, and avoids the increasingly high cost of conflict resolution in western water issues.

CONCLUSIONS

Water markets in the western United States function well in allocating water to higher-value uses in agriculture and between agriculture and urban and industrial sectors. The process is efficient and, at least between the parties to the transaction, equitable since sellers are compensated at market prices. Whether a transaction that is efficient in private terms (net benefits after transaction costs) is socially optimal depends critically on whether third-party and

Table 6.1: Cost per acre-foot for proposed water projects

Alternatives	Projected yield maf	Unit cost 1981 $/acre-foot
State Water Project (SWP)		
Cottonwood Creek	0.07	310
Thomes-Newville	0.08	355
Los Vaqueros	0.10	435
Los Baños Grandes	0.05	440
Federal Central Valley Project		
Enlarge Shasta Dam	NA	85
Surplus water	1.0	NA
Demand management		
Through pricing at SWP rates	0.30-0.45	NA
Through pricing at SWP incremental cost	0.49-0.73	NA
During droughts	0.50	NA
Colorado River Contracts-Imperial		
Spill-interceptor canals	0.03	199
Tailwater recovery	0.20	210
Lining main canal	0.10	253
Lining All-American Canal	0.07	300

environmental effects are internalized.

6.1.2 Exchange of Water Rights in California, USA[39]

Since early in this century Los Angeles has engaged in long-term planning to secure water supplies. Despite a succession of major investment projects, notably the Los Angeles Aqueduct from Owens Valley, the Colorado River Aqueduct, and the California Aqueduct, by the early 1980s the Metropolitan Water District (MWD) projected a supply deficit by 2000. This deficit was expected to arise in part from continued population growth and also because the city could not count on a constant volume of water. Available supply, estimated to be 3.47 million acre-feet (maf) per year, would fall 140,000 acre-feet short of projected demand in an average year.

Adopted Measures

The MWD examined various options for coping with the deficit, in particular: (i) enhancing the State Water Project (SWP) by constructing reservoirs in central California; (ii) enlarging the Shasta Dam on the Federal Central Valley Project (FCVP); (iii) demand management through increasing the price of water; and (iv) water conservation in the Imperial Irrigation District (IID) with the savings pumped along the Colorado River Aqueduct. The first two schemes would pump water south along existing aqueducts

Any of these schemes would comfortably bridge the projected supply deficit. The four options were compared according to the amount of water made available and their respective costs per acre-foot (table 6.1). The "cost" of the demand management option was not considered, on the assumption that the loss of consumers' surplus is less than the savings in the resource cost of supplying that increment. Among the other options, the enhancement of the SWP is the most expensive. A deal with the FCWP would be cheaper but would have to recognize prior rights of farmers using federal water.

Conservation in the IID eventually became the favored option. It had considerable scope. About one third of water delivered to the scheme from the Colorado was being lost to productive use. The irrigated area was large (450,000 ac), there was an extensive, complex network of canals, drains, gates, spillways, etc., and the main feeder (the All-American Canal) was earth-lined. Given the low price paid for water ($9 per acre-foot), farmers had little incentive to conserve it: seepage and spillage were widespread.

The unit cost of three of the four schemes for water conservation in the Imperial project compared favorably with the other supply-based options, and the fourth (lining the All-American Canal) was close to the cost of the Shasta Dam option. The cost of the Imperial conservation schemes includes an allowance for a small loss of energy potential in the Parker Dam and at hydroelectric units on the All-American Canal, and the more substantial costs of pumping the water to the MWD. The largest item, however, is salinity cost, owing to the higher salinity of water supplied from the Imperial scheme compared to other sources available to the MWD. Salinity costs would fall on the fabric of the water system and on user appliances.

IMPACTS

MWD agreed with the IID to provide $10 million annually toward conservation investments in the IID in return for 100,000 acre-feet of water. Among other reasons, apart from cost, this option was selected because:

- Demand management through price increases would have provoked public resistance and would have triggered similar supporting action by 27 member agencies of the MWD. Marginal-cost pricing would have given MWD a revenue bonanza that would have violated its revenue constraint.
- The legal situation was more favorable to this option than others. IID holds the water rights, but in the Federal project the Bureau of Reclamation owns the water, and there are various obstacles to be overcome in using it for nonfarm purposes [Veux 1991]. Other parties with prior legal rights to any water saved were prepared to waive their rights in favor of the MWD. California had already taken steps to permit water agencies to sell, exchange, or transfer surplus water, and to define conservation and transfer as "beneficial use," a basic tenet of appropriative water rights doctrine.
- IID needed little persuasion to enter into the deal because it was under pressure to reduce the environmental harm caused by its high volume of wastewater.
- The economic benefit of the water transfer was overwhelmingly clear to the parties involved. The IID did not feel threatened by the transaction. No farmers served were to get less water (unlike the bitter fight over the Owens Valley water earlier in the century). But it was evident that the value of water saved would be much greater to the MWD than to expand irrigation: the economic benefit of irrigation water was estimated to be $35 per acre-foot in Imperial Valley land, far less than the cost of alternative supplies to the MWD.

6.1.3 Water Banking in California, USA[40]

From 1987 through 1991, California experienced a critical drought during which annual run-off barely reached 50 percent of normal. In early 1991, storage in several reservoirs fell to 60 percent of average. Some urban areas suffered 50-percent shortages of water.

ADOPTED MEASURES

To cope with the drought, the governor directed the Department of Water Resources (DWR) to establish the Drought Water Bank to allow and facilitate water transfers. The interconnected "plumbing" system of California, formed by aqueducts and reservoirs of the State Water Project (SWP) and the Central Valley Project (CVP), made possible the sharing and exchanging of water. Through the Water Bank, the state was able to allocate water for critical urban and agricultural needs, fish and wildlife, and 1992 carryover storage. The purpose of the Drought Water Bank was to establish a centralized account for total sales and purchases of water. The DWR was responsible for negotiating and coordinating all transfers.

IMPACTS

From January through June 1991 [Kennedy 1991], farmers sold approximately 925 MCM on a voluntary basis. There were 340 separate purchase contracts. The total volume represents about 11 percent of municipal and industrial demand of California under normal circumstances. The water supplied to the Bank came from these sources:

- Reduced consumption by following farmlands (53 percent);[41]
- Pumped groundwater (28 percent);[42] and
- Releases of water in excess of their requirements from local reservoirs (19 percent).

The offered price was sufficient to compensate rice, corn, and tomato farmers for all fixed costs including investment in land and income forgone. For example, a rice grower was offered $925 for every hectare not planted, 25 percent more than the benefit he or she could get otherwise. Each hectare of rice requires about 9,100 m^3 of water per year, so the farmer was paid the equivalent of $0.10/$m^3$ of water that some get free of charge.

By June 1991, almost half (500 MCM) of the

Table 6.2: Total water cost

Service area	Purpose	Water bank $/'000 m^3	Variable	Total
South Bay	Urban	142	14	156
San Joaquin Valley	Agriculture	142	8	150
Southern California	Urban	142	53	195

water was sold at an average price of $0.14/m³, and the remaining supply stayed in the Water Bank as water stored for future allocation. There were in total 10 purchasers from the Bank. About 80 percent of the water sold was used to satisfy critical urban needs, and 20 percent went to satisfy critical agricultural needs. The irrigation agencies used the Water Bank's supply only to maintain permanent trees and vine crops with high capital investments.

The difference between the price paid by the Water Bank and the sale price ($0.04/m³) covered all administrative costs of the program and compensated operational losses due to the water transfers. Those who purchased water from the Water Bank incurred mostly one additional variable cost, the pumping power, since the necessary infrastructure for delivery of the water was already in place. Table 6.2 shows water costs to three service areas of the SWP.

Despite its benefits, the Water Bank has sometimes had a negative impact, especially to third parties. The drought-related transfers, for which expedited approval procedures have been established, do not take economic and environmental externalities into account.

Conclusions

This case shows that the Drought Water Bank was in general a success. The state was able to supply 11 percent of its normal delivery to urban users. This experience also illustrates that water transfers and exchanges are playing an important role in California's water management. They allow more efficient use of existing water storage and conveyance facilities.

6.2 Reallocation within the Same Sectors

6.2.1 Water Auctions in Victoria, Australia[43]

Three quarters of the water harv 'st of Australia's Victoria state is distributed through public irrigation systems to 10 irrigation districts. In 1986, 2.5 BCM of irrigation water were provided to 18,000 farms. Over 80 percent is used for annual and perennial pasture. Historically, Victoria has sought to promote settlement by small family farms. Water was made available to irrigators, based on the amount of land held, at the cost of operating and maintaining the system. Water is also allocated to individuals through a system of water rights, licenses, and permits. Private diverters account for 10 percent of irrigation water and pay $A 0.003-0.004/m³ ($0.0023-0.003/m³) to cover direct and administrative costs of supply. In contrast to farms in public irrigation districts, private diversions serve more market gardens, orchards, and vines.

Victoria's water economy has now matured to the point where many of the low-cost dam sites have been developed and consumption matches availability on most streams. The completion of the Dartmouth Dam gives supply security to the whole region, making a further 35 MCM available for private use. The Department of Water Resources has decided to allocate this water in ways that maximize the economic return to the state, ensure equity between irrigators, and recover a portion of capital costs.

Adopted Measures

Victoria has established a water auction to allocate new irrigation water. The auction was limited to private irrigation diverters, and they were required to bid for a 15-year license on the basis of their willingness to pay for one thousand cubic meters of water. Provided the reserve price was reached, the highest bidder could have an unlimited amount of water up to 10 percent of the volume available. Any water not taken up was available to other bidders at the same price. A reserve price of $A 0.10/m³ ($0.076/m³) was set, notionally equal to the financial value of water in growing lucerne. This price is considered to be below the true value of water to many farmers.

Impacts

Six auctions offered a total of 31 MCM of water were for sale. About 23 MCM were disposed of

Table 6.3: Results of the water auctions in Victoria, Australia

River	*Volume offered '000 m³*	*Volume sold '000 m³*	*Median price $A/m³*	*Average price $A/m³*
Loddon	2,000	2,000	0.239	0.330
Goulburn	10,100	10,100	0.175	0.158
Broken	10,000	5,100	0.107	0.105
King	2,400	569	0.102	0.105
Goulburn-Broken	4,885	4,611	0.106	0.100
King-Ovens-Buffalo	1,800	588	0.103	0.100

Source: Benjamin Simon and David Anderson, "Water Auctions as an Allocation Mechanism in Victoria, Australia."

through the auction, most at the reserve price. The range of prices and the median price in each case are shown in table 6.3. Fifty of the 200 successful bidders were new irrigators, and half of these bought 20,000 m^3 or less.

The higher prices were paid for smaller quantities of water, and lower prices for larger amounts. Those who paid high prices for small volumes tended to be involved in high-value crops such as vines. Some water remained unsold in the later auctions, implying that the market clearing level was below the reserve price. Differences in the bid prices reflect differences in rainfall in the various basins, differing opportunities to grow higher-value crops, and variations in the extent to which farmers had already invested in land levelling and other preparatory work.

One of the aims of the auction—to allocate water to its highest-value uses—was not met. "The bulk of water purchased in all of the auctions appears to be destined for low-value uses such as pasture production [Simon and Anderson 1990]." The reason is that most existing irrigated land is used for pasture, and large-scale shifts in production have not occurred. In addition, some producers are buying water for drought security.

The design of the auction included trade-offs that prevented it from maximizing bid prices and revenues. The staging process and volume limits were intended to protect the smaller irrigators and prevent large corporate farmers from taking most of the water. Limiting bids to private diverters meant excluding the much larger number of public irrigation district members as well as urban consumers. Both these features helped protect small farmers and made the auction more acceptable to affected parties. But they also limited its benefits for public finance and restricted the potential rise in prices, which suppressed the incentive to put the water to higher-value uses.

6.2.2 Groundwater Markets, India[44]

In several parts of India, the green revolution (based on high yielding varieties of seeds and fertilizers) is largely attributed to the large expansion in area under assured irrigation from modern groundwater lifts, the number of which has increased from 0.4 million in 1961 to 6.7 million in 1982. In several states, especially Punjab, Uttar Pradesh, and Haryana, groundwater has become the major source of water for irrigation. According to the latest official estimates, the net area irrigated by tubewells accounts for 61 percent, 57 percent and 48 percent, respectively (table 6.4). Furthermore, these three states together account for 75 percent of the total area irrigated by tubewells in India.

The widespread diffusion of groundwater lifts has produced sizeable growth of groundwater markets in several areas. Agroeconomic surveys indicate that in many areas a large number of farmers, especially marginal and small farmers, depend on purchased groundwater for irrigation. For instance, in Gujarat 40-60 percent of total groundwater extracted is sold. The value of water sold is estimated to be around Rs 3 billion per year [Shah and Raju 1988]. In many areas groundwater markets have become an important component of the rural economy. Although several studies indicate the size of groundwater markets, analysis of the structure, role, and operation of these markets has received scant attention. Shah's analysis of the groundwater markets in selected areas is the first major effort in this direction.

This case study gives a brief review of the available evidence on groundwater markets in India. It focuses on the principal aspects of groundwater markets: their size, structure and impact, pricing, and implications for efficient and equitable development and utilization of groundwater resources.

Table 6.4: Net irrigated area, 1986-1987

	Canals '000 ha	*Tanks '000 ha*	*Tubewells '000 ha*	*Tubewells Percent*	*Other wells '000 ha*	*Others '000 ha*	*All '000 ha*
Bihar	1,106	116	934	7.6	132	669	2,957
Orissaa	853	234	226	1.9	360	—	1,673
West Bengal[b]	717	263	689	5.6	23	219	1,911
Haryana	1,203	1	1,126	9.2	14	4	2,348
Punjab	1,440	—	2,263	18.5	10	4	3,717
U.P.[b]	3,356	142	5,768	47.2	565	301	10,132
Andhra Pradesh	1,780	777	193	1.6	690	110	3,550
Karnataka	799	259	75	0.6	449	234	1,816
Tamil Nadu	819	510	120	1.0	890	17	2,356
Gujarata	434	28	321	2.6	1,536	5	2,324
Madhya Pradesh	1,394	198	119	1.0	1,310	324	3,345
Maharashtra	410	281	—	0.0	1,063	127	1,881
Rajasthan	1,205	124	264	2.2	1,790	38	3,421
All India	16,320	2,983	12,211	100.0	8,835	2,700	43,049

a. 1984-85.
b. 1985-86.
Source: Fertilizer Statistics, 1989-90

SIZE AND STRUCTURE OF GROUNDWATER MARKET

The existence of groundwater markets is essentially due to the indivisible nature and high cost of modern electric and diesel groundwater lifts. Five-horsepower (5 HP) lifts are the most common, although smaller lifts are marginally cheaper. Smaller lifts are suitable only for areas with a very high water table. Even in such areas farmers prefer 5HP or larger lifts to draw the maximum volume of water during the short periods when electric power is available. Indeed, the chronic problem of inadequate, erratic supply of electricity accounts for the installation of large numbers of oversized lifts.

The minimum farm size for optimal use of a 5 HP life is about 4 hectares. The high investment cost of a 5 HP lift puts it beyond the reach of marginal and small farmers, about 73 percent of all farmers in the country. Ownership of groundwater lifts is highly skewed in favor of large farms despite two decades of substantial institutional credit and subsidies to marginal and small farmers for installation of groundwater lifts.

The indivisibility factor also affects holdings of larger size. For instance, if a lift of 5 HP is viable for a 4-ha farm in a region, the next available size (7.5 HP) is not viable for farms between 5 to 7 ha. In order to meet their irrigation requirements, these farms either continue to own 5 HP lift and purchase additional water from others or install a bigger lift and sell extra water to other farmers. Both situations create a demand for water markets. The problem of indivisibility is further compounded by fragmentation of holdings. In order to insure irrigation, many large farmers install lifts on more than one fragment and sell extra water to other farmers. On the other hand, some large farmers install a lift only on their largest fragment and purchase water for other fragments. In fact, there are many large farmers who are both buyers and sellers of groundwater. It is thus obvious that the purchase of groundwater is not confined to small farmers. Likewise, sale of water is not confined to medium and large farmers. Many small farmers have installed tubewells with the help of official subsidies and credit. For them selling groundwater is essential to make their investment economically viable.

The size of groundwater markets is also influenced by the locational pattern of farms and pattern of ownership of groundwater lifts. Given the pattern of location of farms, conveyance of water beyond adjoining farms is not feasible. Therefore, a lift owner can sell water only to a few adjoining farms. Likewise, those not owning lifts can purchase water only from adjoining farmers who own lifts. The result is that groundwater markets are small and segmented. This problem has been solved in some villages of Gujarat with the help of underground pipes running across farms [Shah and Raju 1988]. This has enabled resourceful farmers to install large tubewells (15-25 HP) and expand the market for groundwater. Many of these large tubewells are owned by so-called "water companies" formed by a group of farmers. These companies are professional enterprises, and they keep accounts of their sales, and issue receipts to water buyers.

Table 6.5: Groundwater markets in Walidpur village, U.P.

Farm size in acres	*Marginal up to 2.5*	*Small 2.5-5*	*Medium 5.0-10*	*Large 10+*	*All*
Farm households in the village	50	13	22	16	101
Households owning tubewells	22	10	22	16	70
Households having joint ownership	22	10	13	4	49
Water sellers	4	3	2	3	12
Average annual income household from water sale per (Rs)	575	883	675	486	667
Water Buyers					
Households	28	6	4	2	40
Average water charges paid per buyer (Rs)	103	625	1,101	125	283
Percent net irrigated area by purchased water	48	26	25	1	16

Source: Tyagi 1988

Table 6.6: Groundwater markets in Andhra Pradesh and Gujarat

	Andhra Pradesh	*Gujarat*
Number of sellers	34	26
Number of buyers	72	115
Average number of buyers per seller	2.6	15.6
Average area of buyer land irrigated per seller (acres)	7.8	43.8
Average hours of tubewell used per buyer	56.0	27.0
Average water charge	Rs 3	Rs 25.2
Total investment	Rs 7,358	Rs 88,602
Average annual sale of water per seller	Rs 1,370	Rs 30,000
Gross value of output per acre		
Sellers	Rs 7,986	Rs 5,428
Buyers	Rs 7,302	Rs 2,620
Cost of irrigation as percent of gross value of crop output		
Sellers	2.4	7.0
Buyers	4.7	27.6

Joint or cooperative ownership of groundwater lifts restricts groundwater markets. A recent socioeconomic survey of a village in west Uttar Pradesh shows that 70 out of 101 farmers in the village owned tubewells [Tyagi 1988]. The percentage of tubewell owners was lowest (44 percent) among marginal farmers and highest among medium and large farmers (100 percent). The most significant feature is that as many as 44 percent of marginal and 77 percent of small farmers owned tubewells, and all of them were joint owners (table 6.5).

One tubewell was jointly owned by eight marginal farmers. It is evident that joint ownership has enabled a large number of marginal and small farmers to get the benefit of assured irrigation. On the other hand, joint ownership of tubewells by sizeable numbers of marginal and small farmers has restricted groundwater sale to 27 farmers not owning tubewells and 13 tubewell-owning farmers. As shown in table 6.5, the portion of farmers reporting purchase of water is highest (56 percent) among marginal farmers and lowest (12 percent) among large farmers. Average annual water charges paid per buyer varied from Rs 103 for marginal farmers to Rs 1,101 for medium farmers. Only 12 tubewell owners reported water sales. The portion of water sellers was highest (33 percent) among small farmers. Significantly, the portion of water sellers does not show a consistent pattern. Further, the total income from sale of water reported was about 25 percent below the total water charges paid by water buyers in the village. Obviously, a few water sellers did not report sales, and others underreported their income. This is a common practice and, therefore, data collected from water sellers should be used with caution.

Studies of groundwater markets in Andhra Pradesh and in Gujarat [Shah and Raju 1988] illustrate the role of various factors mentioned above on the size and pattern of these markets. The two villages have comparable groundwater resources and limited alternative irrigation from canals. Both have had well-developed groundwater markets for over a decade, but the two markets differ considerably. The Andhra Pradesh village has shallow tubewells of 60 feet average depth and investment cost of Rs 7,358 per lift (table 6.6). The low investment cost has encouraged many small farmers to install tubewells. In contrast, in the Gujarat village only a few prosperous farmers have installed deep tubewells with average depth of 160 feet and investment cost of Rs 88,602 per tubewell, 13 times greater than in the Andhra Pradesh village.

The impact of the investment cost of tubewells is reflected in the pattern of tubewell ownership and the size of groundwater markets. In the Andhra village over half the tubewells are owned by small farmers, while in the Gujarat village most of the owners are medium and large farmers. Water buyers in both are mostly marginal and small farmers. In the Gujarat village all the owners sell water, and a few are also buyers of water. The groundwater market in this village is quite large: a network of underground pipelines constructed by the same seller partnerships that constructed the wells and pumping systems has allowed tubewell owners to supply large numbers of water buyers. An average tubewell owner sells water to 16 farmers and the average season acre of water sold per seller is about 44. A tubewell owner earns a gross revenue of about Rs 30,000 per year from sale of water. In contrast, in the Andhra Pradesh village water sellers serve only the adjoining farms. Many owners of tubewells do not sell water for lack of buyers. Therefore, the average number of buyers per seller in this village is only 2.6 farmers, and the average area of buyer land irrigated per seller is much smaller, 7.8 acres versus 43.6 acres in Gujarat. Average gross revenue from water sale is much smaller (Rs 1,370) than in the Gujarat village.

A 1979 survey of tubewells in Punjab provides some useful information on groundwater markets. The survey covered 49,887 farm holdings spread all over the state. However, the scope of the study was very limited and the report largely consists of a few aggregate tables. According to this study about 56 per cent of farmers owned tubewells (table [illegible]). The proportion of farmers owning tubewells varied from 29 per cent among small farmers to 76 per cent among the large farmers. Altogether 61 per cent of tubewells were owned by farmers cultivating more than 10 acres each. Most (84 percent) of the tubewells were of medium size (5-10 HP). Average gross area irrigated per tubewell varied from 15 acres for 5 HP tubewells to 44 acres for tubewells over 20 HP in size. Only 1.8 percent of tubewell owners reported sales of water. The proportion of water sellers was marginally more (2 percent) among the small farmers compared with the large farmers. Hours of tubewell service used for water sale increased for larger farms, 209 hours per tubewell for small farmers and 624 hours for large farmers. This is mainly due to the ownership of large size tubewells by large farmers. Average annual income from water sales was Rs 3,307 among large farmers and Rs 767 for small farmers. The study shows that the groundwater markets in Punjab were very limited and confined to a few tubewell owners who earned sizeable income from water sales.

NABARD (1987, 1988a and 1988b) has carried out several ex post evaluations of tubewells financed by commercial banks with the help of refinancing facilities from NABARD. Most of these surveys do not provide information about groundwater markets. A few of these do provide some information about water sales by tubewell owners. For instance, the study of shallow, diesel-powered tubewells in the Purnea district of Bihar [NABARD (1988a)] during 1981-82 shows that about a third of tubewell owners reported sales of water amounting to 45 hours per farmer and annual income from sales of water of Rs 270 each. Each owner served two to three farmers. The limited water markets are partly due to the existence of a large number of relatively cheap tubewells fitted with bamboo pipes, and partly to the problem of recovery of water charges. It may be noted that the cost of a bamboo tubewell was Rs 6,606 compared with Rs 10,400 for the conventional tubewell. Another problem highlighted in the study is that the increase in the bamboo boring increased income of owners of mobile diesel pumps. The average cost of bamboo boring was only Rs 720, and the mobile diesel pump rented for Rs 9 per hour, compared to Rs 10 per hour for pumping water from a fixed, diesel-powered pump.

A study of the Muzzafarnagar District of Uttar Pradesh by NABARD (1987) shows larger groundwater markets. About 60 percent of tubewell owners reported water sales. The

Table 6.7: Pattern of groundwater markets in Punjab, 1979

Farm size in acres	*Less than 5*	*5-10*	*10-20*	*More than 20*	*Total*
Number of sample farm households	13,550	14,990	14,134	7,213	49,887
Percent households owning TW/PS	29	57	69	76	56
Number of lifts owned per owner	1.06	1.16	1.31	1.29	1.31
Percent of lifts involved in water sales					
Kharif	1.74	2.10	1.42	1.02	1.54
Rabi	2.07	2.10	1.71	1.12	1.78
Total	2.00	2.38	1.71	1.12	1.78
Hours used for water sale per TW/PS					
Kharif	106	141	85	233	133
Rabi	103	138	79	391	155
Total	209	279	164	624	288
Annual income from water sale per TW/PS used for water sale	Rs 767	Rs 948	Rs 552	Rs 3,307	Rs 1,172
Water charges per hour	Rs 3.92	Rs 3.61	Rs 3.69	RS 5.49	Rs 4.33

TW = Electric lift
PS = Diesel lift.
Sources: Survey of Tubewells and Pumping sets in Punjab, 1979, Economic & Statistical Organization, Punjab 1981.

proportion of water sellers among small farmers was higher, 76 percent. The study noted the use of tubewells for running threshers on custom hire. A few of the tubewell owners, mostly small farmers who invested in threshers to improve the economic viability of their investments in tubewells, earned as much as Rs 2,000 per year.

Given the large variations in farm size and fragmentation of holdings and the pattern of ownership and investment costs of groundwater lifts, the size and structure of groundwater markets vary enormously across regions and villages within the same region. Much more information is required for a clear understanding of the groundwater markets in India.

OPERATION OF GROUNDWATER MARKET

Important issues relating to the operation of groundwater markets are: (i) prices and related terms of the contract; (ii) timing and mode of payment of water charges; (iii) coverage of the contract (for example, one-time or seasonal watering of a crop or group of crops); and (iv) the relationship between water charges and timeliness of delivery. Littie is known about the terms of water contracts, and information about groundwater prices is scarce and cannot always be compared between regions. The available evidence, however, reveals several broad features of pricing.

First, groundwater prices are generally set on "cost-plus" basis. However, the composition of the costs considered for pricing varies depending upon the conditions of demand for and supply of groundwater in the village and the electricity tariff prevalent in the area. Most owners of lifts are "marginal" sellers who use only the excess capacity of their lifts for selling water. They try to charge both incremental fixed and operating costs, plus a profit, but many can cover only incremental costs and make no profit. In areas with a flat-rate tariff for electricity, incremental power costs are nil, and lift owners charge on the basis of fixed costs plus profit. Shah has pointed out that in one Gujarat village (45 km from the village in his study), canal irrigation greatly reduced the bargaining power of lift owners and, therefore, many sold water below the average pumping cost. On the other hand, a few farmers have installed large-capacity lifts mainly to sell water. For these, water sale is a profit-making business and they sell at high prices to maximize profits.

The cost of pumping is, of course, one of several factors that influence prices. In some areas prices are high because good groundwater is scarce. In villages around Delhi, groundwater is scarce and its price is Rs 10 per hour compared with Rs 5 in Haryana villages. Secondly, the price of water from diesel-powered lifts is often nearly double that of water from electric lifts. For example, the prices per hour for groundwater in Haryana villages around Delhi are about Rs 10 per hour from diesel-powered lifts and Rs 5 from electrically operated lifts. NABARD (1987) and other studies show a similar picture of prices of water from diesel- and electric-powered lifts. Higher prices for water from diesel-powered lifts arise primarily from higher fuel costs. Most areas have a flat-rate electrical tariff, and the incremental cost of pumping by electric-powered lifts is nil.

Third, in most areas prices of groundwater are generally the same within a village. However, Shah has found price variation within villages, arising out of variation in pumping costs and the extent of monopoly power enjoyed by lift owners. In both villages covered in his study, average pumping costs decline with rising capacity utilization of lifts. In the Andhra Pradesh village lift ownership is widely distributed among farmers of all size groups, and some of the benefits of higher-capacity lift use are passed on to buyers in the form of lower prices. Prices per hour vary from Rs 4.53 for lifts of less than 1,000 hours of annual use to Rs 2.55 for lifts having annual use of 3,000 hours or more. In contrast, in Gujarat village lift ownership is restricted to medium and large farmers, and buyers do not have the advantage of higher-capacity use of lifts. As a result, water prices are high and vary within a narrow range, Rs 24.5 to Rs 26.5 per hour.

The study of tubewells in Punjab (mentioned above) does not present details of variations in water prices across districts but shows only average prices by farm size. The average water price per hour in 1979 varied between Rs 3.92 for small farmers to Rs 5.49 for large-scale farmers. As noted earlier, water sales are largely confined to about 2 percent of tubewell owners with large, higher-cost lifts. The study does not give reasons for the differential water charges across farm size, but the higher price charged by larger farmers appears to arise from their monopoly power.

Fourth, prices of groundwater vary across regions. Shah's study, noted above, shows large variations in prices between the two villages. The regional variations in water prices are largely explained by the variations in the cost of pumping and the supply of groundwater in relation to market demand. Available evidence shows the following pattern: the sale price of water is higher in areas having deep tubewells. Water prices are also higher in areas with a pro rata electricity tariff compared to those with a flat-rate tariff. Water prices also increase in areas with fewer groundwater lifts.

Shah has constructed a theoretical framework for measuring the monopoly power of water sellers. A profit-maximizing water seller will sell water at a price "w" such that w = (e/e-1)c, where "e" is the price elasticity of demand for water and "c" is the incremental pumping cost. Monopoly power is expressed by (e/e-1). Water prices and pumping costs can be estimated, but available data do not permit estimation of price elasticity of demand for water, especially according to segments of groundwater markets. Shah has estimated e for the Gujarat village to be around 1.8, but he gives no details of how this estimate was arrived at. In view of the complexity of estimating price elasticity, one has to consider simpler measures of monopoly power. As noted earlier, groundwater markets are often fragmented into several segments within a village. A lift owner might have a monopoly only in his segment. Furthermore, monopoly power depends on the number of buyers, excess capacity of the seller's lift, and availability of water from other sellers. Measurement of monopoly power in groundwater markets is complex and requires detailed analysis of individual segments.

Impacts

Groundwater markets play three roles in the development and utilization of groundwater resources. First, they enable marginal and small farmers to enjoy the benefit of (capital-intensive) groundwater lifts and thereby help enhance their incomes. Second, groundwater markets help owners to improve the economic viability of their lifts by increasing capacity utilization. Third, these markets help the society by minimizing investment in groundwater lifts. Although the benefits of groundwater markets are known, they are difficult to quantify.

For owners of lifts, water sales increase their capacity utilization and economic viability. Additional income from water sales varies considerably between villages and among farmers within a village. Shah's study shows that an average lift owner in the Andhra village earned about Rs 1,370 per annum. In contrast the average income from sales of water in the Gujarat village was up to Rs 30,000 per year, enough to repay the original investment in three to four years.

Studies by NABARD (1987, 1988a and 1988b) show that income from water sales depends upon the power source of the lift

Table 6.8: Details of sample tubewells in Muzaffar Nagar, Uttar Pradesh

	Electrical tubewells			Diesel tubewells		
	Small	Other	Total	Small	Other	Total
Number in sample	17	25	42	25	20	45
Average farm size (acres)	5.2	13.4	10.1	5.3	12.6	8.5
Net sown area (percent)	90	69	74	94	70	78
Use of tubewell (hours/year)						
Own-farm irrigation	462	870	705	539	789	648
Water sale	194	106	142	152	68	115
Thresher power, etc.	196	181	187	10	30	21
Total	852	1157	1034	701	887	784
Owners reporting sales (percent)	76	40	55	76	50	64
Annual value of sales (Rs)	776	424	568	1216	544	920
O&M cost per hour of operation (Rs/h)	1.7	1.4	1.5	4.5	4.7	4.7
Water charges (Rs/h)	4.0	4.0	4.0	8.0	8.0	8.0
Incremental income (Rs/y)	1908	7055	4971	1659	4302	2835
Incremental employment (worker-days)	224	322	281	265	282	271

Source: NABARD 1987

(diesel or electric) and size of the farm. In Allahabad owners of diesel-powered lifts earned more than owners of electrically powered lifts, but the opposite was true in the Muzafarnagar district. In both districts, small farmers earned more from water sales than others. Significantly, in both the districts income from water sales was about 30 percent of the net incremental farm income resulting from investment in groundwater lifts. On the other hand, NABARD's study of the arid districts of Haryana shows that only 10 percent of lift owners reported sales of water and, that was only on a small scale, around Rs 150 per annum per owner. The study explained that marginal water sales in this region are the result of apprehension of borehole failure from excess draft of water from tubewells and erratic electrical supply.

Shah's study describes the impact of groundwater markets on farm incomes and employment. In the Andhra Pradesh village buyers and sellers of water had similar crop patterns, input use, crop yields, and gross value of output per acre. The benefit of groundwater irrigation increased considerably with the 1982 change to a flat rate tariff. The reduction in pumping costs caused water sales, area devoted to water-intensive crops, and demand for hired labor to increase.

In the Andhra village the groundwater market increased the intensity of irrigation. In the Gujarat village, where the cost of groundwater was much higher, the cost of purchased water contributed about 28 percent of gross value of crops of water buyers compared to only 2.5 percent in the Andhra Pradesh village. The per-acre gross value of output in the Gujarat village was about half that of the Andhra Pradesh village. Further, in the Gujarat village continuous increases in pro rata tariffs raised water prices considerably and caused a decrease in the area under lucrative but labor-intensive crops.

The detailed study of tubewells in Punjab mentioned above does not assess the impact of tubewell irrigation. The study indicates that sale of groundwater was confined to only 2 percent of farmers who earned Rs 1,177 per year per farm from water sales.

The evaluative studies of tubewells by NABARD (1987) provide little information about groundwater markets. A few give details about the impact of groundwater irrigation on the area irrigated. For instance, the report for Muzafarnagar in Uttar Pradesh shows that the impact of groundwater irrigation depended upon the type of irrigation available before investment in tubewells. The impact was highest when tubewell irrigation was provided on rainfed areas (table 6.8), and electric pumps produced higher incremental income than diesel pumps. Per acre incremental income is shown in table 6.9.

POLICY IMPLICATIONS

The growth of groundwater markets has helped large numbers of marginal and small farmers to share the benefits of capital-intensive ground-

Table 6:9. Incremental income generated by electric pump and diesel pump

	Incremental income in Rp/acre	
Type of shift in irrigation	*A*	*B*
From rainfed to		
Electric pump	883	1188
Diesel pump	627	707
From canal irrigation to		
Electric pump	631	749
Diesel pump	370	472

A = Includes value of both family and hired labor
B = Includes value of hired labor only
Source: NABARD 1987.

water lifts. In addition, groundwater markets benefit owners by improving the capacity utilization and economic viability of lifts. According to Shah and Raju (1988), groundwater markets "can become powerful instrument[s] for efficient and equitable groundwater development" because they are amenable to certain policy interventions, especially changes in electricity tariffs. He cites the example of Gujarat, where the shift from a pro rata to a progressive, flat-rate tariff caused groundwater prices to decrease by 25-60 percent. However, it may be noted that, given the high subsidy on electricity in most states, the cost of power is a very small part of total pumping costs. Therefore, there is little scope for lowering groundwater prices through adjustment in electricity tariffs.

Another policy option is to encourage investment in groundwater lifts by marginal and small farmers whose land is suitably located to provide water sales to small and marginal farmers. For these farmers water sales could become an important source of additional income, and their presence in the market could help curb the monopoly power of large lift-owning farmers and ensure availability of groundwater to marginal and small farmers at reasonable prices.

Another important option is to reduce pumping cost through promotion of energy conserving measures. Most pumps in India do not meet the Indian Specifications (IS) and are low-efficiency and have high operating costs. The sale of pumps not satisfying minimum efficiency standards should not be permitted, and concessionary financing and/or subsidies should be available only for pumps that meet the specifications.

SUMMARY

Groundwater is currently used to irrigate 28 million hectares of land in India, and 70-80 million ha may be exploitable from this source. Groundwater potential can be developed for the benefit of poorer farmers by installing public or community tubewells. Alternatively, water markets can be further encouraged to enable the efficient disposal of water from existing or planned private tubewells. About 95 percent of the area served by groundwater in India is supplied by privately owned modern wells.

Well-developed water markets have existed in Gujarat for 70-80 years. Technology has increased the supply of water in excess of the needs of well owners and stimulated growth of water markets. Farmers with fragmented land holdings are often both buyers and sellers of water. As much as half the area irrigated by modern private wells may be supplied by water purchased through water banks. Farmers on land irrigated by canals often supplement that water from their own or other ground sources.

The productivity of water purchased through markets tends to be high, since buyers can get it when they need it. Buyers are often small, poor farmers who purchase small but crucial quantities of water when investment in a modern well is not viable or not affordable. There is empirical evidence from India, Pakistan, and Bangladesh that water obtained from private (either owned or purchased) sources is more productively employed than that from state tubewell schemes. Private supplies are usually more efficiently run, more reliable, unbureaucratic, and offer flexibility of payment.

The degree to which water markets are developed in specific situations is influenced by five main factors.

- *Nature of transactions*. The most favorable situation is the widespread use of cash, the sale of water per hour of pumping, and the use of standardized lease contracts. Markets tend to be less developed where in-kind payment predominates and where leases vary greatly in form. For instance, in one part of Andhra Pradesh three types of lease contracts exist: (i) a labor contract based on the exchange of labor and draft power for water; (ii) crop sharing; and (iii) crop and input sharing. As markets develop, the multiplicity of in-kind contracts gives way to cash payment.
- *Portion of output sold*. Water markets are

more highly developed where a relatively high percentage (typically 40-90 percent) of owners' water is sold. The two features reinforce each other: an active and efficient market induces sellers to offer more of their water. That increases the size of the market, and so on.

• *Homogeneity of operations.* Relatively uniform cropping patterns, input use, and technology are conducive to efficient markets and, vice versa, where there are large differences between well owners and others.

• *Portion of buyer land irrigated with purchased water.* The larger the percentage, the better-developed the water markets.

• *Objectives and motives of well owners.* Markets tend to be more highly developed when owners, in addition to meeting their own irrigation needs, aim to maximize their returns from the sale of water. In certain cases, this return may be the owner's primary concern. In Gujarat, selling water is a highly developed commercial business, whereas in Punjab farmers are more typically concerned to secure their own water needs and are less interested in selling surpluses (A. Bottrall, personal communication). Underlying these factors are more general explanations. One is social attitudes towards the sale of water: in some areas farmers have deep misgivings about selling surplus water. The development of water markets is, in general, greatest in areas where modern crop production methods are widely practiced and the full economic potential of irrigated farming is recognized. Other key factors are the extent of rural electrification and the predominance of modern wells. The cost of installing modern wells is an additional determinant: in some areas the cost is so low that virtually every farmer has a well.

In Eastern India, there is great scope for development of water markets that will benefit the poor. Both demand and supply have produced only limited development of water markets. Modern seed and fertilizer technology has spread slowly, land is not, in general, used intensively, and there is a semi-feudal social structure. Power supply is inadequate and unreliable.

It is evident that the development of water markets in the Indian context is not primarily a device for reallocating a given quantum of water from less-efficient to more efficient uses. In most cases, the ability to sell water will result in more pumping. In some instances, probably the minority, well owners may decide that selling water is more profitable than using it on their own crops, in which case the process is one of pure reallocation. But this study does not indicate how common this case is. In the long term, on a scenario where the potential for groundwater development is largely taken up, the development of water markets will, of course, result in a more productive use of the resource and, in this sense, reallocation occurs.

However, the growth of groundwater markets may risk over-exploitation of the resource, especially in areas of low groundwater potential and high utilization. The main thrust of the research is in devising electric power charges that encourage development of water for sale and reduce the monopoly power of well owners. Flat rate tariffs–a uniform monthly rate based on pump capacity–would encourage a greater output and sale of water than one based on actual consumption of power. A flat rate system would also discourage oligopolistic behavior and benefit poor water buyers, but could cause inefficient use of power and water.

In peripheral irrigation command areas, the growth of groundwater markets has on occasion increased the depletion of aquifers that lack any recharge except rainfall. In such a situation the encouragement of groundwater irrigation in core command areas would both improve drainage and release more canal water to recharge aquifers in the peripheral areas.

REFERENCES

1. This study was initiated in response to the need of staff in SODs to document cases where policy instruments were successfully used for water demand management.

2. For a discussion of the economic value of water in alternative uses see Young (1986) and Gibbons (1986).

3. In the case of irrigation, receipts in may developing countries were less than 10 percent of the full costs of irrigation services in 1984. In the case of water supply, data from urban water supply projects initiated between 1966 and 1981 shaw that the realized effective price was slightly over $0.17 per cubic meter or about one third of the incremental cost. For details, see reference Bhatia and Falkernmark (1992).

4. Costs are given in constant 1989 dollars.

5. US Army Corps of Engineers Report prepared in 1984 lists various studies of residential water use based on data from developed countries. The reported water price elacticities rank from -0.15 to -1.09. Also, the range of the most likely long-run elasticities is from -0.20 to -0.40 [US Army Corps of Engineers 1984].

6. Water price elacticity ranges for the residential and industrial sectors are derived from table 2.1 and table 2.2. Estimates of price elacticity of demand for irrigation water are derived from six Californian case studies [Fredrick 1992].

7. In theory, two approaches can be used to address excessive water quality degradation caused by the absence of a market for clean water: the "consumer-pays" principle, by which the government forces payments from the people who enjoy improvements in water quality, and the "polluter-pays" principle by which the government demands a compensation from the polluters who degrade the resource. The second approach transfers the burden of remedying water pollution damage from the public sector to the private sector. Each approach has its own impacts in terms of distribution, implementation, and collected revenue.

8. Losses, in this case, refer to leakages, evaporation, percolation or any other avoidable wastages in the production or the utilization of water resources.

9. See references INDEC et al (1987) and IWACO-WASECO (1989a, 1989b, 1990).

10. Maximum consumption was fixed at 30 cubic meters per month. The surplus was to be used to supply water to people waiting for a connection.

11. It is worth noting that a proper tariff structure must be designed in accordance with two basic economic objectives: (a) to encourage the efficient allocation of limited resources available; and (b) to ensure that the low-income population consumes the minimum volume necessary for their basic needs.

12. The incremental cost of a scheme with capacity to satisfy 45 m^3 per household per month is estimated at Rp 440/m^3. Assuming that 10 per cent increase in output is obtained with about 7 per cent increase in cost, i.e., an economy of scale parameter of 0.67, the related unit cost for an output of 160m^3 will be Rp. 1120/m^3.

13. The estimated cost to repair leaks amounts to Rp. 101,241. Thus, assuming that the repair will have a life of at least 18 months and a discount cost of 10%, the equivalent monthly cost is about Rp. 6,080 [IWACO-WASECO 1989a].

14. Only 66% of the total reduction of 35m^3 per month, from 160 to 125, is considered to be the shift in demand which entails "useful" consumption forgone. The 34% left, reduction of leaks, does not involve any loss.

15. Based on references Martin and Kulakowski (1991), Martin and Ingram (1988) and El-Asry and Gibbons (1986).

16. Based on references EBMUD (1985) and Gilbert et al. (1990).

17. Under this approach, incremental block rates are applied to the quantity within a specific range.

18. Under this approach, a "base" volume of water is allocated to each group. The base volume is obtained by applying the conservation targets shown in Figure 5-10. Any consumption in excess of the base volume is subject to an increasing block rate structure, e.g., a customer who consumes 140% of the volume allocated to him or her would have to pay 6 times more than a customer who consumes 100%.

19. They contained water-saving devices, such as low-flow shower heads and toilets tank inserts.

20. Based on reference Hanke (1982).

21. The average price elasticity of demand was estimated to be -0.24 (-0.29 in summer and -0.1 in winter).

22. The impact of restrictions was estimated from multiple regression analysis of time series data for a 30-year period, during which time summer water use restrictions were operative for 13 of these years.

23. Based on Duncan (1991) .

24. In Australia, a partially effective integration in water resources management has been achieved by the creation of the Department of Water Resources. Even though this department has increased the significance of regionalization of water resources management, there is still a lack of a basin-wide use of the price mechanism, especially in the irrigation sector.

25. This section is based on a paper prepared by Devandra B. Gupta, Institute of Economic Growth, Delhi, India.

26. Based on Bhatia et. al. (1994).

27. This section is based on a note prepared by Manu (1991) after a field visit to these industries in the Manali Industrial Park near Madras.

28. This section is based on a report prepared by Oscar Cordeiro-Netto during a summer internship at the World Bank 1991.

29. It was assumed that the firm bought 60 percent of its water from SABESP.

30. The Water Law of China stipulates that the "State shall exercise a unified administration system on water resources in association with administration at various levels by departments." The State Council has established the National Leading Group for Water Resources and Soil Conservation to reinforce the leadership on the integrated administration and protection of the national water resources.

31. In Beijing, consumers who exceed their water allocation have to pay between 10 and 50 times the normal charge. Those who consume from 1-10 percent above their quota pay 10 times the regular price; from 11-20 percent, 20 times; from 21-30 percent, 30 times; from 31-40 percent, 40 times; and above 41,50 times.

32. Cooling accounts for from 70% to 80% of the water use in fertilizer production.

33. The proportion of the investment related to water savings are determined by the following formula: (total annual cost-annual benefits other than water saving)/total annual costs.

34. Based on "Policies for Water Demand Management and Pollution Control in the Industrial and Household Sectors in the Jabotabek Region, Indonesia," by R. Cestti, R. Bhatia, and C van der Berg (draft) 1993.

35. This section is based on a paper prepared by Mr. Basawan Sinha 1991, Metaplanners and Management Consultants, Patna, India.

36. Based on reference ADB (1998).

37. Based on reference Triche (1990).

38. Based on Howe et. al (1986).

39. Based on Vaux (1991).

40. Based on Kennedy (1991) and Vaux (1991).

41. Farmers with established surface water rights.

42. Farmers with overlying rights to groundwater.

43. Based on Siman and Anderson (1990).

44. This section is based on a paper prepared by Rishi sharma of Agricultural Economics Research Center, University of Delhi, India.

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