ST/ESA/103

Natural Resources/Water Series No. 8

EFFICIENCY AND DISTRIBUTIONAL EQUITY IN THE USE AND TREATMENT OF WATER: GUIDELINES FOR PRICING AND REGULATIONS

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EFFICIENCY AND DISTRIBUTIONAL EQUITY IN THE USE AND TREATMENT OF WATER: GUIDELINES FOR PRICING AND REGULATIONS

prepared jointly by

Department of International Economic and Social Affairs

and

Department of Technical Co-operation for Development

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NOTE

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FOREWORD

The pricing and use of water is about as easy to describe as a rapidly changing sunset. There are clouds, rivers, lakes and oceans of water - all changing and having a different meaning to each beholder. Water is used for many purposes in a variety of situations. Though many methods have been developed to control and manage it, no one method is best for any particular situation. The method of control is dependent upon site-specific situations and factors of a physical and socio-economic nature. In addition to the regional hydrology, physiography and climate, the questions of who is involved and what they are accustomed to doing are of paramount importance. Chances are that the controls and pricing schemes found in any one country are the result of years of compromise but need to be kept under regular review so as to evolve more appropriate and rational methods, bearing in mind that there are many ways to manage water. It is interesting and useful to understand something of the panorama of water-pricing institutions that have evolved, as well as the different situations that call for varying types of controls and institutions.

This study is concerned with efficiency and distributional equity in the use and treatment of water. Its primary purpose is to provide guidelines for using prices and regulations to achieve higher levels of efficiency in the allocation, use and effluent treatment of water, subject to comprimises with distributional equity goals. The essential mandate for preparing the study has been encompassed in the Guidelines for Action in the Development of Natural Resources recommended by the Committee on Natural Resources at its second session in 1972 and approved by the Economic and Social Council in resolution 1673 B (LII). The purpose is to promote improved water resources management and administration and to disseminate related information.

The scope and objectives of this study also fall within those of the United Nations Water Conference, which was held in Mar del Plata, Argentina, in 1977. One of the objectives of the Conference was to improve management in order to achieve higher levels of efficiency in the allocation, distribution and use of water. The Mar del Plata Action Plan (United Nations, 1977) 1/ treats "water use and efficiency" as one of its major subject areas and gives recommendations and resolutions on many related sectoral and general aspects, including (1) instruments to improve efficiency of use; (2) efficiency and efficacy in regulation and distribution; (3) water use for community water supplies and waste disposal; (4) water use for agriculture; and (5) water use for industries. It may also be noted that under the subject area "Policy, Planning and Management", the Conference recommended that countries formulate a national water policy as a framework for developing and implementing specific programmes and achieving greater efficiency in water utilization; define goals and strategies for different sectors of water

1/ Sources are given in full in the reference list for the present report.

use (community supplies, agricultural and industrial); and evaluate water-pricing policies and institute policy instruments in an economically efficient and egalitarian manner. To this effect, the Conference declared that "pricing and other incentives should be used to promote the efficient and equitable use of water". It also urged adoption of the general principle that "as far as possible, direct or indirect costs attributable to pollution should be borne by the polluter" and that legislation should define the rules of public ownership of water and the related rights, obligations and responsibilities.

The present publication deals with pricing and regulations as they pertain to most of the above-mentioned areas. Chapter I explains the rationale behind pricing and its relation to investment decisions. Chapter II offers some suggestions for classifying a variety of situations related to the management of water quantity and quality. Chapter III provides a review of legal instruments used in the allocation of water and touches on laws, types of ownership and regulatory mechanisms. Chapters IV, V and VI discuss prices and regulations as they pertain to agricultural irrigation; water and waste charges to households and industries; and water quality in streams and the role of effluent charges. Some conclusions and suggestions for using pricing in combination with regulations for achieving stated goals of allocative efficiency and distributional equity are also given in each of those chapters. A summary of the main conclusions drawn from the different chapters is presented in Chapter VII. It is hoped that the material presented will prove useful to a wide range of officials, including water-resource planners, policy makers, managers, engineers and administrators, as well as to teachers and students of water management seeking reading and reference material.

The study has been prepared jointly by the Department of International Economic and Social Affairs and the Department of Technical Co-operation for Development of the United Nations Secretariat, with the assistance of James A. Seagraves, Professor of Economics and Business, North Carolina State University at Raleigh. Use was also made of general and case-study material prepared by other consultants, including S. Arlosocroff, Gardner Brown, Steven Hanke and Donald Taylor. In addition, the present study incorporates relevant parts of selected documents submitted to a meeting of the Ad Hoc Group of Experts on the Achievement of Efficiency in the Use and Re-Use of Water, convened by the United Nations in 1974 at the invitation of the Government of Israel (United Nations, 1975).

The study has benefited from reviews and comments by individual experts both within and outside the United Nations. Valuable comments were received from the following noted authorities in the field, who gave freely of their time: Gardner Brown, Professor of Economics, University of Washington at Seattle; K. William Easter, visiting Professor of Agricultural Economics, Tamil Nadu Agricultural University, India; Neil S. Grigg, Director, Water Resources Research Institute, University of North Carolina at Raleigh; Charles C. Howe, Professor of Economics, University of Colorado at Boulder; Gunter Schramm, Professor of Resource Economics, University of Michigan at Ann Arbor; and Robert A. Young, Professor of Economics, Colorado State University at Fort Collins. Detailed and comprehensive comments were also obtained from R.J. Saunders, J.J. Warford and P. Stone, all of the Energy, Water and Telecommunications Department of the World Bank. The United Nations Secretariat expresses its sincere gratitude to them all.

Explanatory notes

The following symbols have been used in the tables throughout the report:

Three dots (...) indicate that data are not available or are not separately reported

A dash (--) indicates that the amount is nil or negligible

A blank indicates that the item is not applicable

A minus sign (-) indicates a deficit or decrease, except as indicated

Details and percentages in tables do not necessarily add to totals, because of rounding.

The following apply throughout the text and tables:

A full stop (.) is used to indicate decimals

A comma (,) is used to distinguish thousands and millions

A slash (/) indicates a crop year or financial year, e.g., 1970/71

A hyphen (-) between dates representing years, e.g., 1971-1973, signifies the full period involved, including the beginning and end years

Reference to "tons" indicates metric tons, and to "dollars" ($) United States dollars, unless otherwise stated

Annual rates of growth or change, unless otherwise stated, refer to annual compound rates.

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Chapter I

BASIC ECONOMIC PRINCIPLES

The conclusions and suggestions presented in this chapter and in chapters III through VI are derived in part from experience and in part from economic theory. The role of prices and the goals of administered pricing are briefly reviewed at the onset of the chapter and definitions of key concepts and terms, such as efficiency, income redistribution, marginal cost pricing, opportunity cost and value, are defined.

A. Introduction

1. Basic economic questions

All economic systems must answer four basic questions: (1) What goods and services should be produced? (2) When should they be produced? (3) How should they be produced and distributed? (4) For whom should they be produced? These questions arise because society has unlimited wants that must be satisfied by scarce resources. In other words, conflicting demands are placed on the limited resources. Economics provides principles, theories and postulates that help to resolve those conflicts and thus help to answer the basic what, when, how and for whom questions.

These questions must also be addressed in developing and managing water resources. A distinction is generally made between stock or non-renewable resources and flow or renewable resources. With a few notable exceptions, water falls within the renewable category. Because water seldom stays in one location for long periods of time, it is also considered a fugitive resource. These categorizations reflect the fact that water is governed by the hydrological cycle, a process involving three phases: gaseous, liquid and solid. In the land portion of the cycle, in the streams, lakes and ground-water aquifers, water displays temporal and spatial scarcity and thus variations in supply in relation to the demand for its use. Our interest is therefore concentrated on the management of surface and ground water resources. In this regard, use of water resources involved withdrawal uses (agricultural, industrial, commercial, municipal, residential) and non-withdrawal uses (navigation, waste disposal, recreation).

Another relevant feature of water as a resource is that it is categorized as a public good because it is consumed collectively by the citizenry. Therefore, decisions related to its allocation and use concern primarily the public sector or the Government, as opposed to the private sector or the individual. Government entities such as water authorities are often assigned the responsibility of providing guidelines and supervision in the allocation and use of water. The present publication is addressed primarily to planners within that context.

2. The role of prices

In answering the basic questions indicated above, prices can serve as important instruments of policy. They help to distrubute limited goods and services to consumers and also to determine the allocation of resources. With varying degrees of decisiveness, prices affect the following economic goals in the development of water and other natural resources:

(a) The efficiency with which resources are used (allocative efficiency);

(b) Distributional equity (income redistribution, capital recovery and the like).

Efficient resource allocation is the use and allocation of resources in such a way as to produce, at the least possible cost, those goods that are wanted most to meet consumer priorities with the least sacrifice of scarce resources. Clearly, this does not mean that maximum equity is necessarily achieved. In fact, the goals of economic efficiency and equity are often in conflict and their simultaneous solution involves compromises or trade-offs among the objectives. That is, efficiency conditions are often traded-off on equity grounds. It should also be borne in mind that prices are important for fiscal and financial analyses.

Efficiency has a greater bearing on price and can be evaluated by considering what to produce and consume, how to produce and when to produce. Water prices have more effect on how to produce the goods and services than on what and when to produce. On the other hand, equity or income redistribution is primarily concerned with and can be evaluated by considering: (a) intersectoral effects, or revenue generation, capital recovery goals and widespread tendencies to subsidize agricultural development, such as by revenues generated from the sale of hydropower; and (b) intrasectoral effects, or redistribution of income within a sector, such as agriculture. When we consider the complex effects of prices and regulations on investments and consumption, we see that they affect the distribution of income, the location of production, what and when is produced, who consumes the products and how things are produced.

The desire of societies to redistribute income in favour of the poor often conflicts with the desire to maximize efficiency. Administrators of public water programmes are often under pressure to redistribute income and at the same time to achieve efficient usage of water. The problem is how to find a reasonably stable (optimal) combination of regulations and prices that will lead to the efficient use of water and equitable redistribution of income as well as to recovery of capital from investment projects. Useful references on this question include the works of Davis and Hanke (1971), [1/] Milliman (1972) and Herfindahl and Kneese (1974).

B. Some useful concepts and terminology

1. Demand

A simple demand curve is shown in figure I. Price, which is usually given as a vertical axis, is common to both the demand and supply sides of the market. A demand curve is a locus of points of maximum prices that will be paid for different quantities of a resource (goods or services) per unit of time. Stated in a different way, the demand for a resource is a schedule of quantities of a product consumers are willing and able to buy at different prices at a particular point in time. The principle of demand postulates that an inverse relationship

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1/ All sources are given in full in the reference list for the present report.

exists between the price of a product and the quantity demanded.

Demand may be classified as either final or derived (intermediate). Final demand occurs when consumers purchase the good or service for final consumption purposes. A demand is derived when the factor, good or service is required as an intermediate input in the production of another marketable product. For example, demands for water for agricultural (irrigation) and industrial purposes can be represented generally as derived or intermediate, since the demands for these uses are derived from the demand for a final product, such as a crop grain or paper pulp. On the other hand, water use for household purposes for example may be represented as a final demand since its utility accrues directly to the consumer and not indirectly through the sale of another good.

2. Price elasticity of demand

The quantity of a product demanded varies in response to a price change. In some cases a small change in price results in a large change in the quantity demanded by consumers, while in other instances quantity demanded is quite unresponsive to a price change. Elasticity of demand is a measure that describes the degree of responsiveness of quantity to price change and is defined as the ratio of the per cent change in quantity divided by the per cent change in price, or

$$e = \frac{\text{per cent change in quantity}}{\text{per cent change in price}} = \frac{\Delta Q/Q}{\Delta P/P}$$

For the single linear demand curve given in figure I, it can be demonstrated that e has a value equal to one (e=1) along a locus of points equidistant from the two axes and exceeds this value on the upper half of the quadrangle, while it diminishes below this value on the lower half. One important inference that can be drawn from the demand curve and associated elasticities is that total revenue is affected in different ways when prices rise. In the inelastic range, total revenue increases with an increase in price; in the elastic range total revenue falls with an increase in price; and when elasticity has a unitary value, total revenue remains constant.

3. Opportunity cost

Opportunity cost is one of the fundamental ideas in the economic theory of production. Production costs denote opportunity codes associated with producing output. Opportunity cost denotes the output sacrificed or foregone when a society uses resources for one product rather than another. Opportunity costs of using a resource are implicit and explicit costs of production paid in the form of wages, rent, interest and profits.

Opportunity costs may not be the same as money outlays or explicit costs, although money outlays expressed in the form of price may in most instances serve as an appropriate measure of opportunity cost, or at least of a major component of it. The value of resources that may not receive explicit monetary payments is an implicit cost of production; that is, there are implied opportunity costs associates with using resources because they have alternative uses.

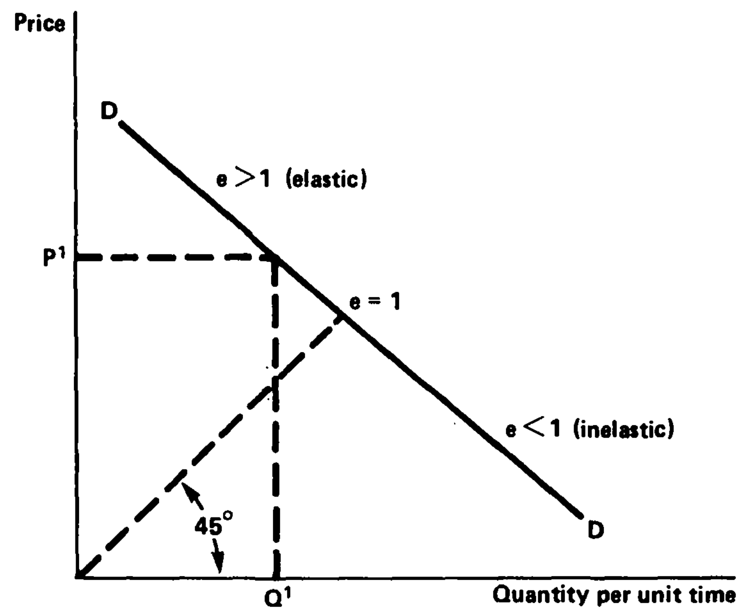

Figure I. Linear demand curve and related elasticity values

4. Social cost

Social costs reflect the full opportunity cost in the production process. Social costs include private costs plus the costs of externalities imposed on society such as the pollution of streams. When an industry discharges wastes into streams it is avoiding private costs and imposing a cost on society.

5. Value and cost

A simplified relation between total cost and total value or revenue is given in figure II. In the short-run, total cost is the sum of variable and fixed costs, while average cost is obtained by dividing total cost by the quantity of total output. The long-run planning horizon occurs when there is a long enough time to vary the proportion of the various inputs, including the size of plants. On the other hand, the short-run is assumed to be a short enough span of time such that some resources are used in fixed quantities.

"Marginal cost" is the change in total cost per unit change in quantity of output. It is the first derivative of the total cost curve. The marginality concept is very important in resource allocation and use. As we will see in the following sections, this concept provides the criteria for defining allocative efficiency in resources use. The total value (or benefit) from a public provision of a good or service is measured by the total willingness to pay for a given level of output at a given point in time. For public goods, willingness to pay can be represented by a demand curve, such as that in figure I. The total value of a good could be approximated by the area under the demand curve.

"Marginal value" is the first derivative of the total value or total revenue curve. It is the change in total value per unit change in quantity of output. As pointed out above and further developed below, knowledge of the marginal value function is as important as knowledge of the marginal cost function in the efficient allocation of resources.

To relate these definitions specifically to water, the cost of water may be regarded as the amount per unit volume that would have to be paid to make it available at a given flow, at a given time and in a given place. Such cost may include capital costs and operation and maintenance costs. Likewise, one way of representing the value of water is by the maximum amount per unit volume of water that society would be willing and able to pay to obtain a given volume of flow at a given time and in a given place. Another way of representing the value of water is by its opportunity cost, which is the minimum amount per unit volume that one would be willing to accept if someone else proposed to take away a unit at a given flow at a given time and in a given place. Implicit in the above definitions is the assumption that water problems are specific to site, time and hydrology.

Water can have value even when a government does not charge for it. If the quantity of water is fixed, then the value of additional water will equal its opportunity cost. If the total quantity can be increased, the value will refer to the marginal net social benefits of providing more water or willingness

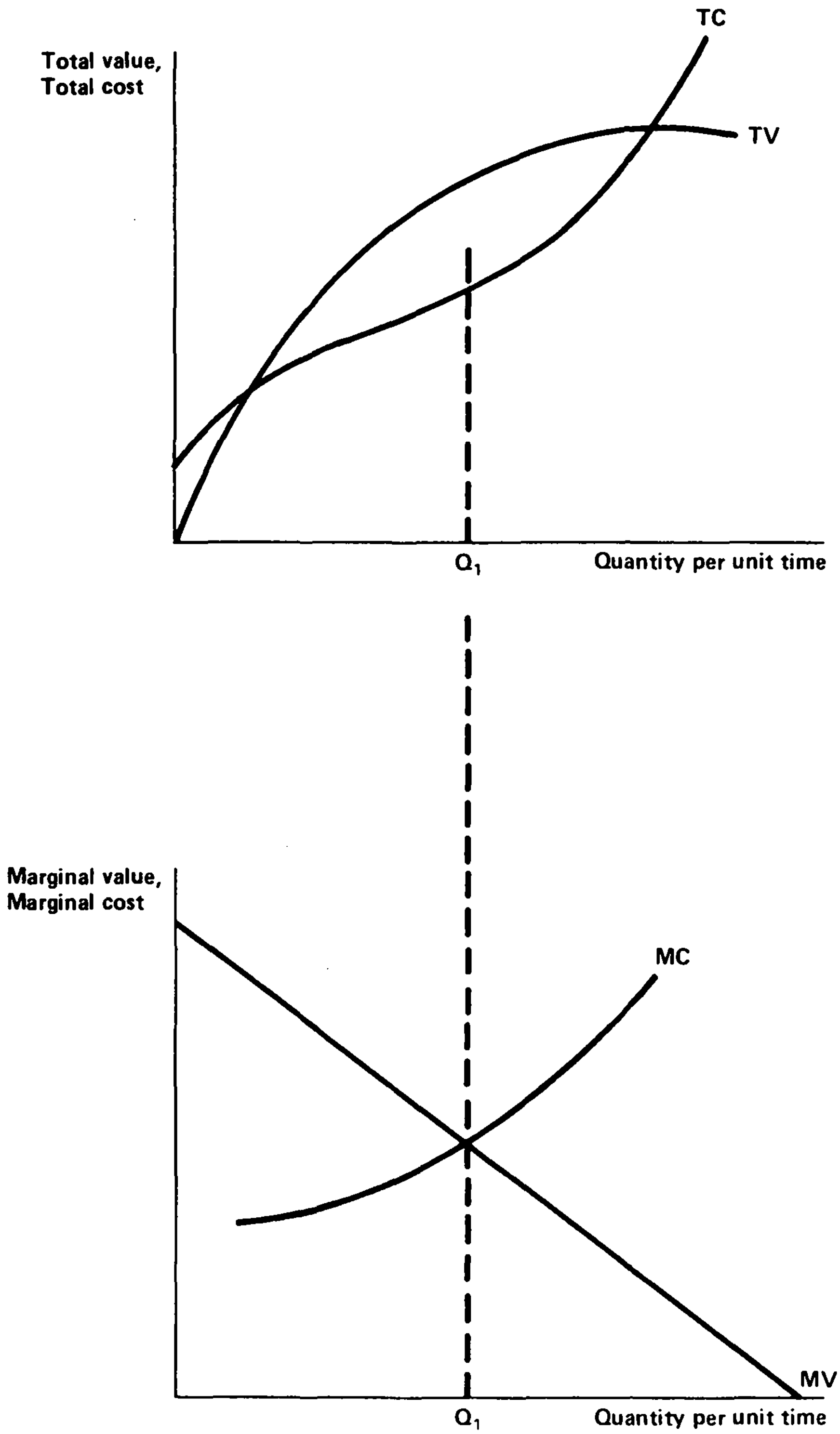

Figure II. Total and marginal costs, values and their relation to pay for it. This could refer to individual producers who have water allocations or to entire valleys with a limited supply.

Resources may be considered distinct from one another if unit values differ or if their values do not move together. Water is quite a different commodity in different places and at different times. Agricultural water is more variable in value than is potable water in cities, owing to sharp variation in seasonal demand and supply and to variations in quality. Prices should take into account seasons of shortage and of excess and arrive at appropriate levels reflecting the long-run and short-run costs. When the transfer is feasible, then the prices set should try to recover long-term marginal costs, not only operation and maintenance in periods of excess supply.

The cost of transporting water is usually high relative to its value, so that often it is not worthwhile to connect areas of surplus with areas of deficit. However, water transfers are becoming more common within countries and small regions. In order for transfers to become feasible, the transfer cost must be less than the differences in the value of water in the two areas under consideration. Most transfer systems involve high proportions of fixed investment costs, as opposed to operating and maintenance (or variable) costs. It would be beneficial to use such facilities as long as the difference in values exceeds variable costs. Canals transferring water from one valley to another can have dramatic equalizing effects on the value of water and the social benefits of such transfers may exceed the total costs. Yet it may be difficult for governments to recover the fixed costs of installations from users, because the optimal size is so large that there is excess capacity most months of the year.

Similar points apply to differences in the value of water over time. It is only worthwhile building storage reservoirs to eliminate differences in seasonal values if the present value of the long-run expected marginal benefits exceeds the marginal costs. It is often difficult for governments to recover the costs of water storage. However, technological change, particularly in earth moving is reducing the relative costs of storage both above and below ground. These cost reductions, plus increasing differences in seasonal values, account for some recent decisions to store more water.

Different water values based on differences in quality can sometimes be encountered. In such cases, differences in price should reflect differences in values and the marginal cost of upgrading the quality. Where the value of polluted water is negative, effluent charges may be logical. Water withdrawals from (and discharges to) streams could logically be assigned a wide range of positive or negative prices depending on time, place and quality. In actual practice, governments often give away use of streams and adopt regulations rather than prices to control usage. The discussions in chapters III through VI can provide further details in this regard.

Many studies have estimated the value of water and the gains that are possible from transfers. Young and Gray (1972) reviewed several empirical studies and argued that the value of water cannot exceed the marginal cost from the least costly source but may in practice fall far short.

C. Efficiency and distributional equity

1. Economic efficiency

Resource allocation is efficient when the marginal value is equal to the marginal cost. This occurs at the point of intersection of the two curves in the bottom curves in figure II. The real significance is that the difference between total value and total cost is maximum when output is at Q_1 level. This will always be true for a competitive or monopolistic system. It is also true for the short-run and long-run provided that the cost and revenue curves are appropriate to the situation.

Now consider the case where the quantity of water is fixed and its quantity is invariant. Efficient use of a given quantity of water under such a situation is to specify that the marginal values (added value to society per added cubic meter) should be the same in all uses. This means that if the marginal value product is higher in one use than in another, then the welfare of society might be enhanced by permitting some water to be reassigned to the usage that returns the higher income or the better opportunity. The maximum benefits foregone are referred to as the "opportunity cost" of the water. In other words, even though the quantity and quality of water at a given point in time and place are assumed to be fixed, a transfer to any other use has a cost: the social value foregone by transferring a unit of water from its best use - that is its opportunity cost. Water should be reallocated among uses until it has the same marginal value product or opportunity costs in each use.

Next, consider the possibility of increasing the water supply. If it is possible to obtain additional water at some marginal social cost that is less than its marginal value product (its opportunity value in the best usage), then units of water should be added. Each addition to supply is assumed to cost more and more(that is the marginal cost function is an increasing function of the quantity supplied). Also, additions to each usage, other things being equal, will cause reductions in marginal benefits that is the demand or the marginal benefits(curve for water is a decreasing function of quantity). New water should be added until the marginal social cost equals the marginal social benefit.

The equality of marginal value to marginal cost implies that the "equilibrium" price and quantity which would be applicable under any economic system of ownership either public or private. Public enterprises, such as water and sewer utilities, should consider setting their administered marginal price equal to marginal social cost of additional water. If the price is set equal to the marginal cost, then users who pay that price will tend to equate their marginal benefits to the marginal social costs. Governments do not have to charge each customer the same price for all the units bought. Where resale is difficult, governments can and do use both increasing and decreasing block rate schedules to achieve objectives other than efficiency. However, efficiency is enhanced if all customers pay the same marginal rate for incremental amounts of water and if this rate is equal to the marginal social cost.

2. Equity and income redistribution

There is a strong tendency to use prices charged by public enterprise to help redistribute income to the poor. Many developing countries are already using "lifeline" rate schedules for water and electricity. These start with low block rates for small users and work up to high marginal or penalty rates for large users. For example, the United Nations Water Conference and Habitat: United Nations Conference on Human Settlements have stressed the concept of potable water as a right, meaning that a certain minimum amount of clean water should be available to everyone everywhere to meet basic human needs. The concept of a "right to potable water" implies that general revenues and/or water rates to paying customers should be used to subsidize the cost of water from public standpipes for the poor.

As elaborated in chapter III, the water laws of many countries emphasize that the role of prices or water fees are to recover operation and maintenance costs and some parts of the capital costs of water projects. Using prices to achieve a desired amount of capital recovery from the users amounts to the same thing as using prices to achieve some income redistribution. These same laws often indicate that regulations or permits will be used to achieve rational or efficient use of water. Presumably, water quotas can be designed to assign to each firm the socially optimal quantity of water. However, it is doubtful if the administrators have the ability to define and order efficient usages. It may be preferable to turn the situation around so that marginal prices are used to achieve efficient usage (equality among the marginal value products) and that regulations or quotas are used to achieve the desired income redustribution.

The main theme of this publication is that if two goals are to be achieved-- efficient usage of water and some level of redistribution of income -- then it will be advantageous to use two instruments: both regulations and prices, dual prices, quotas plus penalties and rebates, or permits plus transferability. Both goals, equity and efficiency, can be incorporated to varying degrees into pricing structures if the marginal prices charged to different users can be set approximately equal to marginal costs. Whenever possible, for example, a country may want to tax small farmers proportionally less than large farmers and also provide incentives for efficient use. Large users could have a schedule of declining block rates while small users have increasing block rates. These rates could be adjusted so that most users ultimately pay about the same marginal rate for incremental quantities of water. Various legal arrangements, including laws, ownership systems and regulations in different countries are reviewed in chapter III. Furthermore, a system of dual prices proposed by Seagraves (1975) is described in the last part of the Peruvian case study in chapter IV. Roberts and Spence (1976) point out that permits plus penalties and rebates are logical in the context of uncertainty about the response of firms to environmental controls and charges.

3. Costs of administration

The goal of minimizing the costs of administering resources often conflicts with the goals of efficiency and income distribution. More efficiency usually involves more precise monitoring, more differentiation of prices according to place, time and quality, and more policing. Adding income redistribution as a goal of water regulations and prices inevitably adds to the cost of transactions. These transaction costs include costs of information, contracting and policing. Administrators should seek to minimize the social costs of transactions and problem-solving. Among the purposes of this publication is one to provide policy makers with guidelines on how to find low-cost solutions to the problems of efficiency and income redistribution related to water.

4. Economic solutions to political problems

If consumers cannot buy water at a reasonable price they often resort to political pressure to correct the problem. One problem could be a shortage because the existing price is set too low and does not allow rationing of the available supply. Another could be that a monopoly is charging more than the marginal cost of producing the water. Many problems that are basically economic in nature are treated on physical or technical grounds and are solved with legal decrees or direct government action, without the necessary economic evaluation. Some commonly encountered problems in the development of water resources include requests for infrastructure without fully considering its returns and costs; over-use (mining) of ground water; drainage and salinity problems; pollution; and over-use of streams. Economic incentives, prices or transferable permits should be given due consideration in solving these problems. The problems arise because no one owns the stream or the aquifer or, even if the government legally owns the water resources, it behaves as if they were free (for more details, see chapter III). Economic aspects should be given proper weight in the process of seeking solutions to these problems, which undoubtedly require interdisciplinary approaches.

Problems that arise in the field of water resources are extremely varied. Not only does the value of water itself vary widely from negative to highly positive, but the value of preserving water quality also varies depending on the levels and locations of demand. This means that institutions that are appropriate in one situation may be completely inappropriate and unnecessary in other situations. Water laws must be designed to be flexible instruments of policy, permitting a variety of site-specific solutions to evolve. The optimal water monitoring and control technologies depend on the circumstances. A recurring theme is that when the value of water is low, people cannot afford to spend much time measuring it and developing institutions to control it. A corollary is that when the value of water is increasing, new institutions will become worthwhile and can be justifiable.

D. Marginal cost pricing

In the real world of administered prices, it is rare that one encounters any reference to marginal cost pricing or economic efficiency as a goal. Administrators must respond to other pressures, such as conflicting demands by social interest groups, on the one hand and demands that pricing be "fair" on the other. Administrators are rarely criticized for setting prices very low, or in such a manner as to contribute to economic inefficiency. There is a tendency to adopt similar rate schedules and minimize revisions of the schedule, based on the view that this system would be simple to operate and would minimize complaints. Seasonal price variations are usually avoided even though they may be needed to solve a problem. Simple rules are adopted for estimating average costs of "fair" prices. Endless "scientific" studies are financed to support any changes that might be controversial.

Obviously, this setting of administrative conservatism and institutional rigidity makes it very difficult to adopt the relevant economic criteria of setting prices equal to marginal costs. Prices should vary according to the incremental cost of adding service at each particular time and place. In addition to the difficulties in applying economic criteria, standards of procedure in estimating the values and costs are frequently rather arbitrary and not rational. While agreeing to the concept, even economists do not agree on the details of practical implementation.

1. Three simple cases

One case in which the principle of marginal cost pricing may be applied is one in which demand is expanding, present facilities are fully utilized year round and new facilities are being added. Then, long-run marginal cost (LRMC) can be recommended as the price. A reasonable estimate of LRMC would be the average total cost of water from the newest project.

A case in which new facilities are used only part of the year and must be expanded to meet peak demand is also often easy to handle. Marginal costs in the peak period should be defined to include all the fixed costs of the new facilities and the operating and maintenance costs. Off-peak marginal costs and prices should reflect the operating costs of offering additional service in slack periods. These simple rules often cause economists to recommend extremely high prices in peak periods and very low prices for the slack periods. The shorter the period of peak usage the greater the disparity. These cases are further elaborated in chapter V.

As explained in chapter V, one must consider the possibility that peak period prices will cause the former off-peak period to become the new peak period. In practical applications of seasonal or time-of-day pricing, administrators must usually soften the economist's recommendation towards smaller differences, fewer customer complaints and recovery of a greater portion of capital from off-peak users. It might seem that administrators would hesitate to recommend higher prices for peak periods because of the implied income redistribution against persons who use the service in these periods. Actually, it is hard to know whether poor or rich customers find it easier to adjust consumption, and there are many reasons to think that price differentiation favours the poor. A more logical reason for administrators to resist using higher prices in peak periods is that higher prices could cause complaints from some users and may be shown in the form of political pressures.

The conflict between economists and administrators is likely to be most severe when there is excess capacity year round, and the economists recommends forgetting the cost of the fixed facilities -- "writing them off". The recommendation to forget about fixed costs is often met with administrative resistance. This is especially true if the demand is inelastic. Then the percentage decrease in price is greater than the percentage increase in quantity, and total revenue falls every time price is reduced.

The argument against ignoring the fixed or sunk costs is based on equity grounds; notably in the case where the cost of the fixed facilities is not yet paid, the marginal costs should include consideration of the unpaid balance of capital costs.

2. "Requirements" versus "demand functions" as guides to investments

A common procedure for deciding the size and the timing of water resource investments is the "requirements" approach. It is based on forecasting requirements or design capacity by summing up the requirements of various users under existing price conditions, and then engineers estimate investments that will meet those requirements at least cost. Generally, little analysis is made of how much beneficiaries should pay in the new situation. The demand and supply approach through pricing has rarely been considered as a means to limit use and influence investment patterns.

Forecasts of water requirements usually assume that the quantity of water demanded will increase proportionally with increase in population and economic activity. One variable that is ignored or kept constant by these forecasts is the price of water and its potential effect upon the quantity of water consumed. By using these requirement forecasts, water managers are assuming that prices will remain constant and are predicting the amount to supply at that price.

In contrast, the demand/supply approach assumed the existence of a demand curve with an inverse functional relation between price and the quantity of water demanded, and that the price should be set equal to the long-run incremental cost of supplying water from the newest project. By considering the fact that higher prices will induce consumers to use less water, and by setting the price equal to LRMC, the optimum size and number of investments can be determined.

However, this standard approach to long-run marginal cost pricing might result in major difficulties and shifts in demand if the last addition to supply is very much more costly than existing supplies - for example, a 5 per cent addition of water from a desalination plant to a ground-water supplied plant with 90 per cent agricultural water use would simply kill off all agricultural use if marginal costs were charged. In a situation like this, additional considerations of willingness to pay by different classes of users must be considered(that is, discriminatory pricing).

It should also be remembered that both the estimation of the demand function and the determination of the optimal size of investments are complex, difficult and costly processes. A graphic illustration of the dynamics of marginal cost pricing is given in annex I of the present report.

3. Why isn't marginal cost pricing more widely used?

Among other reasons, marginal cost pricing is not widely used because (a) the underlying concepts are usually not understood by those involved in policy-making and administration; (b) considerations directed towards minimizing conflicts tend to receive far greater attention than those directed towards maximizing efficiency; (c) estimates of short-run and long-run marginal costs (P_1 and P_3) and opportunity costs (P_2) are often lacking and are not easy to determine; and (d) there are tendencies to make total revenue equal total cost. One easy way this can be done is by making the average price equal the average cost. Society may prohibit such utilities from showing a profit or a loss on the assumption that the users of the service should pay for it.

This section presented the case in favour of using marginal costs, or LRMC, as guides in pricing public services such as water and sewer services. Arguments in favour of average cost pricing will now be reviewed briefly as we describe public utility regulation. As pointed out above, one of the biggest problems in applying marginal cost pricing is the lack of appropriate market prices. One approach to a solution to this problem is the use of shadow pricing.

The discussions on pricing so far have been based on the existence of some measurable market values. However, market values rarely reflect the old value of public goods, such as water resources. Adjustments to market prices are often needed because market values do not represent the real value to society of the inputs going into a project or the outputs produced. The real or intrinsic values of project inputs and outputs are more correctly measured by their "shadow prices", sometimes called "accounting prices". Divergencies between market and shadow prices occur whenever the market departs from the competitive norm or when the government intervenes. In its simplest form, a shadow price is one that comes closer to measuring the real value to society of a good or service than does its market price. According to this concept, the use of shadow prices leads to a higher level of national production or welfare than reliance on market prices. Departures from the competitive norm are caused by the violations in the simplifying assumptions on which the competitive models are based. These assumptions include the following:

(a) Complete and accurate knowledge of future conditions,

(b) Economic rationality of decisions by producers and consumers;

(c) Many buyers and sellers, none of whom can alter market prices by their individual actions;

(d) No spill-over effects on others, such as pollution;

(e) Divisibility of investments;

(f) Resource mobility, including freedom of entry and exit, rarely if ever accurately held.

The market should be relied upon as a reasonable indicator of real values to society to the extent possible. In developing countries departures from the norm tend to be greater and government interference with the market forces more extensive than normal (Gitinger, 1972). Therefore, there is greater need in developing countries for indirect approaches such as shadow pricing. The general approach among practitioners operating in these situations is to apply market prices whenever market forces are believed to be reasonably effective and to rely on shadow prices when they are not. Adjustments to market prices are most frequently required for economic transfers (such as taxes, tariffs and subsidies) input factors (such as unskilled labour, foreign exchange and domestic capital) and outputs when project size is relatively large.

E. Regulation of privately owned utilities

Distribution systems for services such as water and electricity are often described as "natural monopolies" because larger volumes result in lower unit costs: it would be wasteful to have competing systems serving the same customers. There is an extensive economic literature on how society should regulate the prices of such natural monopolies. Much of it emphasizes the negative effects of average cost pricing and advocates marginal cost pricing. The regulators of privately-owned utilities and the administrators of publicly owned services face many of the same problems. Perhaps there are some useful lessons that can be learned from the regulation of private utilities. Private utilities are usually permitted to recover their full costs, meaning necessary operating costs plus a fair return to capital. But, there are problems deciding which costs have been necessary and what a fair return on capital might be. It is virtually impossible to agree on which costs are legitimate. Assuming that public utility regulators can solve these problems, full cost recovery still means that prices are based on historic average total costs rather than on future long-run marginal costs (LRMC).

One reason LRMC are not more widely used as guidelines for utility pricing is that if governments get involved in setting the highest price that can be charged on efficiency grounds, then they also pick up some responsibility to protect the price-controlled firms from periods of deflation, technological change or falling demand. In effect, the lawyer's definition of fairness, which looks backward and protects firms, wins over the economist's definition, which looks ahead and holds private enterprise responsible for its own errors, such as not adopting more efficient technologies. The economist says that he would control an electric utility by estimating the LRMC of producing more electricity and then asking the utility if it wants to keep on supplying power at that price. If not, the utility can sell out and let someone else produce it. The only guarantee that is made is that the government will continue to re-evaluate LRMC in the light of changing technologies and other factors. Most economists would soften this proposal by favouring only gradual re-evaluations of LRMC and changes in highest prices possible.

Chapter II

SUGGESTIONS FOR CLASSIFYING WATER RESOURCES SITUATIONS

A. Problem-solving

A common approach to problem-solving involves a definition of the problem, a statement of objectives, the formulation of possible solutions, and evaluation of the technical, economic and political feasibility of solutions and recommendations. This publication is addressed to a broad set of problems and to administrators who need to anticipate problems that may arise in the future so that they will have time to study alternative solutions. Assuming that objectives are well defined, water resource administrators may find it useful to proceed as follows:

(a) Classify water resource situations;

(b) Identify problems that could arise;

(c) Outline reasonable solutions;

(d) Examine alternative solutions adopted by countries that have already faced these problems; and

(e) Develop a long-range strategy to cope with the problems.

In developing any long-range strategy, it must be recognized that institutions must change and may need to become more sophisticated as problems become more complex. Moreover, becuase it may be just as costly to solve problems too soon as to solve them too late and because different regions within countries often have very different resource situations and problems, it is probably best to think in terms of flexible national water laws that will allow a variety of rules and organizations to evolve in different regions.

B. A classification of water resource situations

Water resource situations are classified according to the following factors:

1. The value of water
2. Seasonal pattern of water values and costs of storage
3. Considerations that make the transfer of water among regions and countries difficult
4. The importance of water quality
5. Flooding and drainage problems
6. Interrelations between surface and ground water.

It is hoped that this classification scheme will help to idenfity water resource problems and point towards some solutions.

1. The value of water

The value of an additional unit of water depends on how scarce it is relative to other resources. This concept of the marginal value or worth of water is defined in chapter I and further examples are given in chapters IV and V. Water deficit regions face the common problem of finding some means of rationing water. This might involve having to measure the water or proportion it. One solution is to assign quotas to each user. Another is to charge a price for the water and make the price high enough so that people will only want to buy the quantity available. The higher the value of the water the more carefully it will be measured and the more attention will be given to the method of rationing.

Water surplus regions do not face the same problem and can often get by without measuring water. For example, it will be noted in the chapters that follow that in Israel, where the value of water is extremely high, it is felt to be important to have separate meters for each apartment. In Bangkok, where the relative cost of water is much less, it is uneconomic to install water meters in many of the homes. Also, water for supplemental irrigation often has such a low value that it does not pay to measure it.

2. The seasonal pattern of water values and the costs of storage

If the costs of storage are high or if storage simply does not exist, then water can have widely different values in different seasons of the year. This might mean that different systems of measuring and rationing water will be appropriate for each season.

If there are unreasonably large differences in values of water, one might anticipate that there will be pressure to build some kind of storage and complaints if high prices or other rationing schemes appropriate to a water-short season are carried over to a season of water surpluses. It may be less expensive for a Government to build large storage reservoirs or develop underground storage than for individuals to store water. Storage reservoirs can be used for a number of different purposes: flood control, irrigation, hydro-power and recreation. It is easy to imagine situations where some of these uses are in conflict.

3. Considerations that make the transfer of water among regions and countries difficult

Situations that make transfer of water difficult can persist for years. Transfer might be expensive for technical reasons or simply difficult for institutional and legal ones. If the value of water differs greatly between two adjacent valleys, then it is easy to imagine recurrent political pressure to "solve the problem". The problem may remain unresolved because there is no way to guarantee that only surplus water will be transferred or there is no way to pay the potential losers.

4. The importance of water quality

The cost of improving water quality can be estimated, just as can the costs of storage or transfer. Water quality problems are likely to be more noticeable in places where the quantity of water is abundant. In fact, quality rather than quantity is the main water problem in vast humid regions of the world.

Sometimes it is easy to predict that there will be increased interest in stream quality. Downstream populations and uses may be growing. Rising standards of living may bring increased interests in recreation and concerns about health. Problems related to water quality include the following:

(a) The water must be reused by persons downstream;

(b) Fish may be killed or contaminated;

(c) The water may be unsafe for bathing and water sports.

It may be less costly to society as a whole to keep toxic substances out of streams than to try to remove them in subsequent treatment of potable water or to suffer the related health problems. Basically, there are three levels at which pollutants may be controlled: (1) in the production process or before wastes are discharged to cities or streams; (2) at the "end of the pipe" or with effluent permits; and (3) in the environment. It is easier to handle some water quality problems at one level and other problems at a different level. Toxic substances may need to be eliminated in the production processes; bio-degradable materials may be regulated or taxed as effluent; and infrequent problems with a variety of causes, such as algae blooms, might be handled by monitoring the environment and simply being ready to apply the most logical solution after the problem occurs. In chapter VI several different approaches to water quality problems will be described.

5. Flooding and drainage problems

Different regions of the world suffer very different problems related to an excess of water. These problems can occur in nature or be aggravated by man. A frequent problem in agriculture is excessive irrigation. If systems are not properly designed, then drainage problems can ruin good soil.

Flooding problems can be aggravated by development in flood plains. Flood control structures (dams and dykes) may be justified in terms of existing usage of land; but once the structures are built, the land in the flood plain may be used more intensively. If such usage is not controlled, then the net effect of flood control structures may be a substitution of less frequent but more costly flooding for the previously more frequent but less costly floods. The net effect on national income could be highly negative.

6. Interrelations between surface and ground water

Where surface water is scarce and being rationed, the question arises as to whether farmers should be encouraged to use ground water. The answer would seem to be "yes" if the level of ground water is constant. However, if the level of the ground water is falling it might be better to discourage its use. In some cases, surface and ground water can be treated as one, and similar pricing schemes developed for both.

Some aquifers have very small water losses such that they make excellent reservoirs for storing water between seasons and even between years. Problems could arise regarding whether or not to encourage the recharge of such aquifers and how to maintain water quality.

This classification of physical situations suggests a variety of water-related problems that may arise and create demands for public programmes. The problems shape the formation of the needed institutions. It is also true that existing institutions, traditional ways of doing things and technical capabilities affect the number of feasible solutions. Water resources administrators in different countries will need to develop their own classification schemes for situations, problems and solutions. This report can only provide some general guidelines.

Chapter III

LEGAL INSTRUMENTS FOR THE ALLOCATION AND USE OF WATER

A. Introduction

Water laws are affected by physical, economic and social factors and government desires to maintain an acceptable balance of efficiency among such conflicting goals as equity, income redistribution and capital recovery from water development projects. Laws, in turn, affect the ways in which users organize themselves and efficiency in managing the water. Most laws affect organizations through the application of regulations but some are so idealistic that they are simply not practicable. Moreover, efforts to devise national legislation often encounter stubborn political and administrative resistance. Many laws delcare that Governments own all the water, but very few Governments actually act as if they own it.

Efficiency in the use of water resources has become an important legislative goal. This emphasis is due, on the one hand, to the growing demand for water for different uses, which makes quantitative and qualitative problems almost ubiquitous, and on the other hand, to advances in technology. It is, therefore, extremely important to set up laws that allow for changes and innovations in water utilization, and there should be provisions for critical evaluation and control of technological development. The establishment of a legislative design conceived within a comprehensive development framework, and the use of a broad and flexible type of legislation leaving a wide discretionary range to the relevant administrative agencies, seems to offer an acceptable and feasible solution for more efficient use of water resources.

The main purpose of this chapter is to provide general background to the chapters that follow. It presents a review of some of the legal instruments for the allocation, use and treatment of water, with emphasis on allocative efficiency. The material has been organized according to the following subheadings: types of water ownership; order of priority among different uses; quantification of water-use rights; water rates and pricing policies; transfer of rights; protection and enforcement of water-use rights; duration and loss of rights; and administrative powers.

B. Types of water ownership

Three alternative classes of ownership can be distinguished, particularly with respect to irrigation, which is the main consumptive user: private water rights, government ownership and common property rights. Efficiency in the use of water for irrigation is the subject of chapter IV, which will provide a fuller understanding of the topic and supplements the discussion presented in this chapter.

1. Private property

Private property rights develop as an institution for resolving differences or conflicts of interest. Knowledge of the amount of water one can count on as a "right" or a certainty is crucial to users, particularly to farmers investing in irrigation systems (and especially for use in orchards). Once farms are developed, owners naturally assume they can transfer well-established water rights with the land. When there is a need to change the ratio of water to land, farmers ask courts and legislatures to establish a system whereby they can transfer water rights separately from the land.

Transferability does not necessarily suggest that large farmers will buy all the water and take it away from small farmers. It merely suggests that users who are making more efficient use of the water will be able to bid it away from those who are making less efficient use. For example, irrigators of high cash crops such as vegetables often have an advantage in such bidding. Of course, those who have established rights will want to preserve a share for the future.

Why are private water rights unpopular politically? The idea that they are unfair to small farmers would not be of concern if water rights were well defined and fairly defended in the courts. However, it is possible that an unfair advantage in favour of large farmers exists in terms of education and greater success in court battles. Water rights may have a worse image than property rights over land because they are hard to define, especially in cases where the flows are subject to great fluctuations and uncertainty. It would be desirable to define several classes of superiority for water rights if these could be made to reflect an optimal solution to the problem of allocation and social goals and objectives. However, experience shows that years after they are established and supposedly understood, superior water rights continue to be attacked as "unfair". The main reason is that the laws may not be flexible enough to allow evolutionary changes corresponding to changes in the goals of efficiency and equity.

Logically, private owners should pay for improvements in their irrigation systems because they are the beneficiaries and in that way they will try to limit themselves to investments that are profitable. Actually, the rationale of letting users pay for improvements in systems is equally valid under both government and private ownership. In either case, charging for improvements and for shares of water prevents users from making unreasonable political demands.

2. Government ownership

A system of government ownership of water suggests that the State will either sell scarce water to the highest bidder, regulate use by establishing cropping patterns and irrigation plans, or distribute to certain farm groups on grounds of equity. Governments could sell rights to use water or a share of the water for a definite period, say 10 years. If the supply is normally abundant, the Government could sell excess rights and then only make additional charges based on volumes requested in times of shortages. The principle of marginal cost pricing given in chapter II and further demonstrated in chapter IV would be appropriate in this regard. This would amount to a two-part tariff, or fixed fee, plus an occasional variable charge. Many water laws decreeing total government ownership also represent a political revolution against the idea of private property and specifically prohibit all forms of transfer of water rights. This makes it difficult to manage the water system efficiently, especially if the Government wants to subsidize irrigation.

Given a typical combination of governmental objectives - (a) to subsidize agriculture, (b) to prohibit private transfers, (c) to encourage efficient usage and (d) to recover capital - a system of dual fees or water rights plus charges (penalties) for water bought in excess of quotas can be recommended as a viable option. It is also logical to pay farmers for the quotas not used (turned back to the State). In the Peruvian case cited in section E of chpater IV such water pricing was recommended precisely because the above constraints existed under the Peruvian Water Law of 1969; the possible advantages and applications of such a pricing system are presented (Seagraves and Ochoa, 1978).

Alternatively, a Government can attempt to ration water on the basis of crops and patterns of cropping. Regulations to this effect can be used to give incentive to growing crops with greater return potential and to ration water more efficiently. However, the ability to determine with an acceptable degree of accuracy the irrigation diversion requirements and the added costs of administration present two major problems. Technically, irrigation diversion requirements must take into account not only the consumptive use but also the distribution and application of water losses that are site specific.

3. Common property rights

Resources that have low values are often owned in common. When they become valuable, governmental ownership or private property rights tend to be established. It is often said that resources that belong to everybody in effect belong to no one and are often inefficiently used, which is only noticed once the resources have become valuable. Air and water are examples of resources that are often owned in common. This simply means that, at a given time and place, problems connected with their usage are not important enough to justify the establishment of rules and property rights regarding their use.

C. Order of priority among different uses and/or users

Almost all water laws create a ranking of priorities among uses, and in some cases also users, establishing a certain order or preference. This ranking represents the community's appraisal of the social and economic values of particular uses at a given time and serves as a guide for the apportionment of water between new applicants. Where improved efficiency is desired, the rating of uses can be either a help or a hindrance, depending on how the preference is expressed in the lists fixing the priority. Unless they are very recent, such lists tend to embody social and economic criteria no longer pertinent to the current situation and may hamper the water administration in promoting efficient use.

The ranking of preferences may, however, permit a new higher use to draw on water already appropriated for an existing lower use. In the State of Wyoming, for example, non-preferred uses can be expropriated for the benefit of preferred uses when there is no unappropriated water to satisfy either (Wyoming Stat. Ann. section 41-3). In time of shortage the uses that are lower in the scale may get no water at all or less water than more privileged uses, as under the Chilean Land Reform Act (Act No. 16640 of 1967, article 107), which gives the President of the Republic power to issue a supreme decree providing for the total or partial extinction of any usage right when water must be supplied for domestic purposes.

As will be seen in chapter V when water is in short supply, domestic purposes invariably head the list of preferred uses. As long as they are confined to satisfying the needs of individuals or households they present relatively few problems, even when they include the irrigation of small pieces of land. Ground water is an exception to this generality: in some places it has been substantially depleted by uncontrolled domestic use.

In many jurisdictions, however, the preference accorded to domestic use extends to municipal and community water supply, which can involve huge amounts of water and considerable waste. This preference is explicitly stated, for instance, in the civil codes of Ecuador (articles 889, 916) and Bolivia (article 382), which prohibit diversions that would imperil the flow in watercourses for municipal and community supply. The preference is also explicit in provisions according municipalities the right of eminent domain, as in the United States of America.

Under the umbrella of municipal water supply, industrial and commercial uses often acquire a preferential status equal to that of domestic use. This is a problem common to all jurisdictions where industry is concentrated in steadily expanding urban areas. Domestic and industrial or commercial uses, taken together, often come into sharp conflict with irrigation through the exercise of the domestic-use preference.

The listing of preferred uses in statutes imposes quite rigid guidelines on the administration, but the concepts of public interest and public policy do provide an escape valve. In all prior appropriation, states within the United States, for instance, even in those with an elaborate list of preferences, the administration may refuse a permit if the proposed use is against the public interest (Utah Code Ann. section 73-3-8 (supplement 1977)). A more elastic way of dealing with the problem is expressed in section 27 of the 1969 General Water Act of Peru, which states that "the executive may vary the order of preference... above, in the light of the following basic criteria: the characteristics of watersheds or systems, availability of water, water management policy, land reform plans, uses conceived in the greater social and public interest and uses in the greater economic interest."

Going a step further, the public interest may be the sole or main criterion in evaluating uses. Thus, article 9 of the Italian Testo Unico of 1933 requires the administration to weigh which concession would better satisfy the public interest, in addition to weighing financial and technical considerations. This may give the administration too much discretion unless it is kept in check by the general supervision of the courts or in the first instance by special water tribunals.

In some jurisdictions, the administration is given virtually carte blanche to set up a system of priorities in times of shortage for any purposes considered vital and all other rights may be revoked or suspended. This may be done by establishing special protected zones or areas. For instance, the 1966 Water Law of Somalia empowers the administration to declare "limited use" areas within which it may impose any limitation on the utilization and distribution of water. A number of the western states of the United States have legislation providing for the establishment of "designated" or "controlled" or "critical" areas of ground-water regulation.

Usually, authorizations revoked in a time of scarcity are restored when the water supply returns to normal and compensation is payable. The Paraguayan Law requires growers of certain crops who have received preferential treatment to compensate farmers whose crops were ruined (Cano, 1956). However, there are instances where no compensation is paid by those who benefit to those who have suffered a loss of right.

The laws of some countries of South and Central America contain provisions giving preference to small farmers, as in the water codes of three Argentine provinces (Salta, 1946, article 21; Jujuy, 1950, article 48; and Santiago del Estero, 1950, article 87) and the Bolivian Decree No. 01264 of 8 July 1948. The Mexican Law of Waters of National Ownership of 30 August 1934 is quite detailed on the subject, giving preference first to holdings of less than 50 hectares, then to zones of colonization and thirdly to land belonging to members of users' associations, before any other users are satisfied (art. 26). In its acreage limitation provisions, the United States Reclamation Act of 1902 (43 U.S.C. 431, 434) also contains such an implicit preference, and so do some recent agrarian and social reform laws that give preference to those who participate in the reform areas, such as Panama's Act No. 37 of 1962 (article 429) and Chile's Land Reform Act of 1967 (Act No. 16.640 article 107).

D. Quantification of water-use rights

Quantification of water-use rights is a key element in the efficient use of water. The extent to which it is carried out by the water administration depends very largely on the over-all amount of water available, the characteristics of its occurrence, the uses to which it is put, the degree to which it can be measured and the cost of administration. (Certain uses in water-rich areas, for example, are not quantified at all, whereas in water-short areas even relatively minor uses may be strictly limited.) Quantification may also be based on factors that have nothing to do with the current availability of water or present demands but relate to past uses, outmoded technologies and rigidities in the legal system.

Keeping an accurate inventory of available water is a desirable prerequisite to quantification. Registration of rights provides an inventory of waters that cannot be used without authorization. Minimum flow requirements are a new feature of the modern management of water resources. These requirements not only inhibit wasteful withdrawal but also act as a means of preserving the quality of waters against various forms of pollution, including sedimentation and salt-water intrusion. Such requirements are part of the 1963 Water Resources Act of England and Wales (section 19) and the French Rural Code (article 97-1, added by Law No. 64-1245 of 1964), which provides for a *débit reservé*, and are also in force in a number of South American jurisdictions (e.g., in the Salta, Argentina Water Code of 1946, articles 44 and 184-189) where they are established as a basis for calculating the apportionment of water between users.

Minimum-flow provisions to protect fresh-water supplies from salt-water intrusion are contained in the Japanese River Law of 1964 (Law No. 167, article 1) and in the United States Federal Water Pollution Control Act Amendments of 1972 (86 Stat. 816, section 102 (b) (2)), which authorizes the Corps of Engineers, the Bureau of Reclamation, and other federal agencies to determine the need for storage to regulate stream flow to that end. The State of Florida defines minimum flow as the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area (Florida Stat. Ann., para. 373.042(1), (1974)).

E. Water rates and pricing policies

Most legal systems set up in greater or less detail the basis for payment for water. Usually only the general principle is given in the statute and the details are left to regulations or by-laws of the organizations supplying water.

In a considerable number of countries, especially in the riparian rights and prior appropriation systems, holders of water rights can draw water directly from the source without charge. Nearly two thirds of the irrigated acreage in the United States of America, for example, is self-supplied and no charge is made for the use of water (United States Water Commission, 1974). No charge is made either in Belgium, Canada, Finland or the Netherlands for water directly abstracted from sources (United Nations Economic Commission for Europe, 1977).

This is also the situation in the USSR where article 15 of the 1970 Principles of Water Law states that water use shall be free of charge and that special water use (that is water used with the application of facilities or technical devices) "may" be subject to a fee. In many Asian countries there is no charge for irrigation water, and in the State of Victoria, Australia, under section 15 of the Water Act of 1958, the riparians retain their right to free water, even when it is supplied from a government waterworks (though it is restricted to a fixed maximum quantity, above which additional water must be purchased) (United Nations, 1967).

The so-called occupiers' rate prevalent in several states of northern India is usually dependent upon the kind and extent of crop grown and does not take into account the cost of supplying water. Before World War I, these rates differed considerably on the various canals and were deliberately fixed below the commercial value of the water. Irrigators are charged lower rates to induce them to enter into long-term leases for water supply (Jacob and Sing, 1972). In the early period of many new irrigation schemes, it is the practice to give concessional rates or even to charge no rate at all for the first year or so. This is the practice in Madhya Pradesh, West Bengal, Mysore and Maharashtra, where the special concession may be continued for as long as seven years. Similarly, in the United States of America the Bureau of Reclamation made long-term contracts for water supply to promote settlement and irrigated agriculture, not economy in water, and charges were based on an estimate of the users' ability to pay (United States Water Commission, 1974).

In relatively few jurisdictions are irrigation charges made solely on a volumetric basis. South Australia is one place where this is done. There, the waterworks commissioner may sell water metered on the consumer's land and payable according to quantity consumed (Waterworks Consolidation Act 19321962, section 82).

F. Transfer of rights

The latitude given to users to transfer water rights is not only an important element of water law but also contributes to efficiency of use. Powerful arguments in favour of according users almost total freedom to transfer rights from one use to another have been brought to bear in the United States of America, based on the view that market forces help to allocate water more efficiently between competing uses (United States National Water Commission, 1974). This is a complex problem, however. It includes transfer from one place to another, as well as the right to dispose of water saved by the diligence of the transferer or transferee.

Perhaps the closest system to free operation of market forces can be found in Chilean law prior to the Land Reform Act of 1967. Prior to that act, a concessionaire of public water could sell the whole amount for which he held a concession or the surplus which he did not need. Through membership in canal-users' associations water and water conduits could not only be sold but also rented or encumbered, as well as transformed through death or by simple conveyance. Water could also be mortgaged separately from the loans as security for obligations assumed, leaving the way open for foreclosure and acquisition by third persons (Chile, Water Code 1951, articles 246-247).

At the other end of the spectrum there are the laws which make water appurtenant to land and prohibit its sale or transfer without the land - the objective being to prevent speculation in situations in which the water is more valuable than the land itself. This is the case with intuitu rei concessions in Argentina, which are automatically transferred on sale of the land and the transfer recorded in the land register.

In Chile, the Land Reform Act of 1967 (Act No. 16640, section 104), proclaiming all waters to be national property, made usage rights non-transferable, as did the Peruvian Land Reform Act of 1964 (Act No. 15037, sections 109 and 113), prohibiting total or partial transfer independently of land, as well as alienation or lease of waters.

Absolute prohibition, however, is the exception rather than the rule. Generally, transfer is permitted with the approval of the water administration in accordance with appropriate procedures. In giving its approval the administration may be more or less circumscribed by law. For example, in the State of Nevada, where water is for all purposes attached to the land, it can be severred and transferred to other land and used only when it becomes impractical to use it beneficially or economically where it was attached (Nevada Rev. Stat., section 533.040).

More flexibility regarding transfer is to be found in those jurisdictions which simply require approval of the administration without specifying the conditions. This is the case in Japan (River Law, Law No. 167 or 1964, article 34).

Approval of transfer in these situations is not wholly at the administration's discretion. There is frequently a proviso in statutes that such change of use cannot be made to the detriment of existing rights (for instance, in the Kenya Water Ordinance of 7 May 1952). This, of course, limits the water agencies' freedom of action and is tantamount to giving a veto to appropriators who are, or think they are, injured by a projected transfer of use.

The rigidities of the law concerning transfer is in some cases relaxed through the medium of users' associations. Colorado law, for example, states clearly that a water district has freedom to appropriate and distribute water within its jurisdiction (Colo. Rev. Stat., section 150-5-13 (10)). Outside a district such transfer may not be permitted.

G. Protection and enforcement of water-use rights

Under this heading two different aspects of the protection of existing water-use rights are discussed: the protection of such rights in the transition from an old to a new legal régime of water utilization, and the judicial and/or administrative enforcement of existing rights.

One of the most serious obstacles to promoting efficiency and savings in water use, and especially to the introduction of new measures, is the existence of prior rights that cannot be abolished without severe technological difficulties and considerable social and economic upheaval. The quest for efficiency and better utilization of scarce water resources may lead to the cancellation of all existing water-use rights in order to begin anew with a system that protects better the public interest. On the other hand, in most legal systems water-use rights are considered to be either property rights or administrative rights entitled to protection. In any case, the use of water very often involves a heavy investment of resources and the sudden abolition of the right of use could cause economic hardship and bring uncertainty into the water economy.

The question then becomes: how should the new evolve from the old? or how much should be introduced that is new and how much retained from the old? Solutions range from leaving the old rights unaffected side by side with the new régime, through assimilation into new ones after a period of grace, to immediate and virtual abolition of pre-existing rights.

Laws that leave pre-existing water-use rights unaffected by a new régime may bring about a complicated - and, from the standpoint of efficiency, undesirable - situation in which different regimes apply to the same source of water.

Until fairly recently it has been a general rule in South American countries that new water laws do not affect rights acquired before the effective date of the legislation. Thus, article 677 of the Colombian Civil Code of 1887, though it declared all surface waters public, left riparians undisturbed in the use of such waters; so did article 539 of the Venezuelan Civil Code of 1942 with regard to the use of non-navigable streams. In Morocco under the Dahir of 1 August 1925 (article 12), pre-existing rights were continued in their existing form and extent, as if there had been no change in the régime.

In some jurisdictions, the possessors of pre-existing rights who are not affected by the change need not submit to any new procedure in order to exercise their rights. In others, a simple declaration or registration suffices to protect the right.

The modern trend in water law is represented by laws that assimilate pre-existing uses into new systems after a period of grace. They give the administration full control while making the transition less painful for users, who, for reasons of economy and efficiency, receive less water or be forced to alter their pattern of use. The State of Mississippi adopted this "conversion method", as it is known, when it replaced its riparian rights system in 1956 by a prior appropriation system (Mississippi Code (1172) Ann. section 51-3-7 (1)). It did not exempt existing riparian rights from the new procedures but gave the riparians priority and first opportunity to perfect their rights. The United Kingdom also adopted the conversion method when it introduced the Water Resources Act of 1963. The grace period was short under the 1963 Water Code of La Rioja Province, Argentina (Decree Law No. 21333 of 27 August 1963, article 296), which gave previous users the right to a new concession but only if they applied within one year. Generally, upon conversion of old rights to new ones, the user is entitled to the same quantity of water as before.

The most radical solution is found in some recent codes that virtually abolish pre-existing uses by making their assimilation into a new permit system mandatory, immediate and subject to conformity with national or regional plans. This gives the administration much more control over water allocation, and in order to further such assimilation it is desirable to protect land reform or the efficiency in water use. However, this approach can be very hard on the users if applied arbitrarily. In Poland, rights acquired before the Water Law of 30 May 1962 retain their validity only if they are in accord with general water plans, which is determined by the administration granting the permit (article 163 (1)). Thus, there is not a straight conversion of old rights into new ones: the old rights need approval in each instance, which almost amounts to abrogation.

The Peruvian Land Reform Act (Act No. 15037 of 1964, article 110) made the recognition of pre-existing rights conditional on their being in harmony with "social interest", meaning that the rights of the community take precedence. This law marked the end of the rather automatic recognition of prior rights in that country and, by giving a flexible yardstick to measure their usefulness, greatly facilitated abolition. Iran's Water Nationalization Law of 18 July 1968 (article 6) authorized holders of pre-existing rights to convert them to permits but left the extent of their use under the permit to be determined by special committees appointed for that purpose. The committees were empowered under the act to take into consideration the quantity of water, amount of land, place of use, efficiency of use and local customs, and the converted use could then be very different from the previous right.

Effective protection of water use rights depends to a large extent on how speedily and inexpensively a decision can be reached on a controversy and how fully it is complied with. From the standpoint of efficiency, a speedy final decision that cannot be challenged in long, drawn-out proceedings may be of great importance and in some instances may even warrant trading off some degree of equity. These aims seem to be well realized where the entire process of protection and enforcement (except perhaps for criminal penalty) is in the hands of the water administration proper. For example, in Poland the agencies that grant a water-use authorization also decide any dispute concerning it (Water Law of 30 May 1962, article 3) and the general courts merely have appeal jurisdiction as to the amount of compensation. Since the Water Resources Act of 1963, England and Wales also follow this system to the extent that all appeal decisions of the appropriate minister are considered final (section 39 of the Act). However, in the general legal system in England there is always recourse to the courts from final administrative decisions, at least for over-stepping the limits of competence, but such recourse ordinarily would not stay a minister's decision.

Leaving the entire decision in the hands of the administration may lead to arbitrariness. This is why in some jurisdictions special courts that combine administrative and judicial features were established. When they function well, such courts provide a judicial counterbalance to administrative arbitrariness and still preserve the desired speed in reaching a decision. In some instances they perform both purely administrative functions, as when they grant authorizations to use water, and judicial functions, as when they exercise civil jurisdiction in disputes. On a somewhat lower level, this is not dissimilar from the functions of the tribunals of water associations in Spain and in Latin American countries. There, however, the tribunals are limited in their judicial role to deciding questions of fact, leaving questions of law, if they occur, to the general courts.

One important feature of the decisions of special tribunals, especially those of lower order, is that recourse from them to other courts does not stay the decision. For example, in Chile the executive board of a canal users' association acts as a tribunal (Water Code of 1951, articles 138 and 141). It follows arbitration procedure and is not bound by the rules of evidence. First, a prima facie case is established and then a decision is given within a month. If there is a delay the judges may be fined. The board may also impose fines and suspend water supply for violations. The legality of a decision can be challenged before an ordinary court, but this does not stay execution. By contrast, in countries where ordinary courts decide disputes, as in the United States of America, under both the prior appropriation and riparian rights systems, administrative decisions are (except in emergency situations) enforceable only through often lengthy procedures.

H. Duration and loss of rights

Another feature of the new water codes that fosters efficient and effective use of water is the limitation of such use to a definite period of time. The length of time is not uniform but perhaps should not be shorter than 25 years, as advocated in some model codes. In this way, past mistakes can be corrected and water uses would fit more easily into the general scheme and be made to correspond to the changing interpretation of social interest.

As noted previously, in many different jurisdictions and under different water-use régimes, the law may tolerate and condone even extremely wasteful practices as long as they conform to prevailing techniques for the particular locality, and when there is no explicit intention to waste water. Failure to use the water is viewed in an entirely different light and is perhaps the most frequent cause of loss of water rights.

Though it is true, as a general proposition that neither abandonment nor forfeiture apply in the riparian rights doctrine, non-use as a cause of loss of right can be found in some riparian jurisdictions, especially in those states located in the western region of the United States of America (Oregon, Washington, South Dakota and Nebraska) with a mixed riparian-prior appropriation system. Non-use of appropriated waters is the most serious of all violations in the prior appropriation system, and courts have unequivocally interpreted it as a tantamount to waste.

The length of time that must elapse before a right can be revoked for non-use is to some extent a measure of the permissiveness of the law as far as efficiency and economy of use are concerned. This varies widely, from two consecutive years under the Chilean Land Reform Act of 1967 (section 109 (la)) to 20 years under the Spanish Civil Code of 1889 (article 441).

An alternative to spelling out in the legislation a precise time-limit for non-use, and which gives the water administration considerably more discretion and flexibility, is to make use of the right within a reasonable period a condition of authorization. Failure to observe the conditions of the concession, license or permit as a ground for revocation of right is already stated as a general proposition in the water legislation of many countries - for example, several of the Argentine provinces, south Australia, Austria, Israel, Japan, Kenya, Paraguay and Spain - and it is left to the water administration to detail specific conditions.

Inefficient use as a specific cause for revoking rights exists in some jurisdictions. It generally involves failure on the part of the user to prepare his land to receive irrigation water, or failure to construct or repair whatever works or parts of works he is responsible for, so that the water goes unused. The laws of the Argentine provinces contain such a provision and so does a Bolivian Decree of 1948, the 1967 Land Reform Act of Chile (article 109 (e)), and the 1931 Rural Code of Paraguay (article 384).

Neglect to maintain works in good working order is a ground for cancellation or suspension of rights in Poland (Water Law of 1962, article 57); Israel (Law No. 5179-1959, section 11); south Australia (Irrigation Act 1930-1946, sections 70 and 72), where the administration may assume control of leased land when the lessee is guilty of neglect; and Panama (Act No. 37 of 1962, article 427).

I. Administrative powers

Traditionally, water laws were dispersed in numerous enactments and were use-oriented - that is, separate laws governed separate uses (United Nations, 1967). A codification process spread at a rather leisurely pace until spurred, after the Second World Water, by demand for water and advances in the hydraulic sciences. The consolidation of water law has been followed by the parallel consolidation of water administration. It is often more effective to have one administrative entity to administer a single body of laws. Not only can contradictions and conflicts be reduced to a considerable extent but national planning is also made easier. This can contribute to the achievement of efficiency in water use.

So far as efficiency in water use is concerned, it is important that allocation and use of water be vested as completely as possible in public administration. This is generally the case in modern codes.

Leaving aside local variations, the model sought in administration is the consolidation of water activities under the direction of regional administrative agencies corresponding to areas as close as possible to drainage basins, with the co-ordinating and policy-making functions entrusted and centralized in one water agency of national scope.

The consolidation on water administration in terms of drainage basins, has been pushed one step further by an emerging awareness of the unitary character of the over-all environment. Under the impact of this idea, water administration has been consolidated or co-ordinated within the administrative framework concerned with the environment as a whole. This has great advantages in promoting an inter-disciplinary approach to the management of the environment in general and of water in particular. It also tends to promote pollution-control measures.

However, emphasis on pollution control and environmental protection may inhibit some developmental aspects of water administration, such as long-distance and inter-basin transfers of water and large storage projects, and may postulate the maintenance of minimum flows and estuarine supplies of fresh water.

Chapter IV

EFFICIENCY IN THE USE OF WATER FOR IRRIGATION AND THE ROLE OF PRICES AND REGULATIONS

A. Introduction

Efficiency in the use of water for irrigation is normally defined in a physical sense - in engineering and agronomic terms; and it is often assumed that higher efficiency is desirable. However, in an economic sense, there is an optimum range in the level of physical efficiency. Normally it can be said that as water values increase, it becomes more rational to increase physical efficiency by selecting and adopting improved methods of controlling, measuring and applying water, and to design systems of pricing and regulations that will promote optimal allocation and efficient use. However, the value of water is often extremely low, in which case there may be little economic incentive from the viewpoint of an individual enterprise to improve physical efficiency unless forced by physical factors that affect production and productivity - such as soil characteristics, water logging or nutrient leaching. Water used for irrigation is free: its value varies from place to place and from season to season. Institutions for the management and administration of water also vary widely and are affected by traditions, regulations, prices and subsidies.

However, from the viewpoint of the public, improvements in efficiency through the introduction of appropriate incentives can have far-reaching implications for increasing production and productivity and for saving water. The water saved can be used extensively (to expand irrigation to new irrigable lands) and intensively (to increase yields from lands already under irrigation).

Price determination is a function of many interrelated site-specific physical and biological factors, such as climate, soils and crops. The combination of regulations and prices also reflect trade-offs in the resolution of the conflicting goals of redistribution of income in favour of agriculture, the recovery of capital and the need to encourage efficient use of water. Regulations and pricing systems also depend on the value of water, the dependability of supplies, systems of delivery and the extent to which flows can be regulated.

Physical efficiency in the use of water for agriculture is generally far below attainable levels. Diversions in excess of actual needs are common, yet most water losses in transit, distribution and application could be reduced significantly through proper planning, design, construction, operation and maintenance of the system. The application of institutional and economic incentives through properly formulated policy instruments can lead to improvements of the physical and also of economic efficiencies.

Concerning policy instruments, it is noteworthy that the United Nations Water Conference (United Nations, 1977) declared that "pricing and other economic incentives be used to promote efficient and equitable use of water". On the subject of water for agriculture, which received great attention, the Conference adopted a phased action programme directed towards increased production and productivity. As this may be of interest to the reader, a brief indication of the trends and momentum resulting from the Conference, including a description of the phased action programme for agriculture, is presented in annex III.

The present chapter is mainly concerned with places where and times when irrigation water has a positive value and with ways of allocating it. It is also concerned with the use of prices and regulations as instruments of policy to encourage economic efficiency, recover costs of irrigation projects and encourage equity. Economic and physical efficiencies and their interrelation are also discussed. 2/ Section B deals with physical and economic efficiency, value and resource combinations. Section C discusses factors affecting prices and regulations for irrigation water. This is followed by a discussion in section D of alternative systems of delivering irrigation water to farms and of ways in which pricing can be adjusted to suit these alternatives. Section E briefly summarizes cases of actual practices in selected countries, including India, Israel, Mexico and Peru. The Peruvian case is relatively more detailed in that it presents a methodology for estimating the value of irrigation water and suggests some alternative pricing schemes. These case studies are preceded by a brief outline of the cost recovery goals of the World Bank. Conclusions and some suggestions for pricing irrigation water are given in section F.

B. Physical and economic efficiency, value and resource combinations

The term "efficiency" is used in a variety of ways to describe performance in relation to the use of water in agriculture. It means different things to economists, engineers and agronomists. Misunderstandings can and do arise occasionally. Accordingly, it is useful to examine such definitions from these various viewpoints.

1. Physical efficiency

In agronomy, the term "water-use efficiency" is used to express yield (usually dry matter), divided by the amount of water consumptively used by a plant during the growing season. It should be noted that water-use efficiency is equivalent to an average crop yield per unit of water, or to an "average product", provided that water use is measured in terms of consumptive use. Water-use efficiency is not a dimensionless index of efficiency.

Irrigation efficiency, by comparison, is an index of the physical performance of a complete irrigation system or components of a system. It is affected by the value of water as well as by physical circumstances and factors. There are unavoidable losses in application, storage and distribution systems, including evaporation and seepage losses from reservoirs and conveyance channels, transpiration by non-beneficial vegetation, deep percolation losses in fields and operational waste (see fig. III). The magnitude of these losses varies widely

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2/ Some of the material in this chapter follows the discussion by Neghassi and Seagraves (1978).

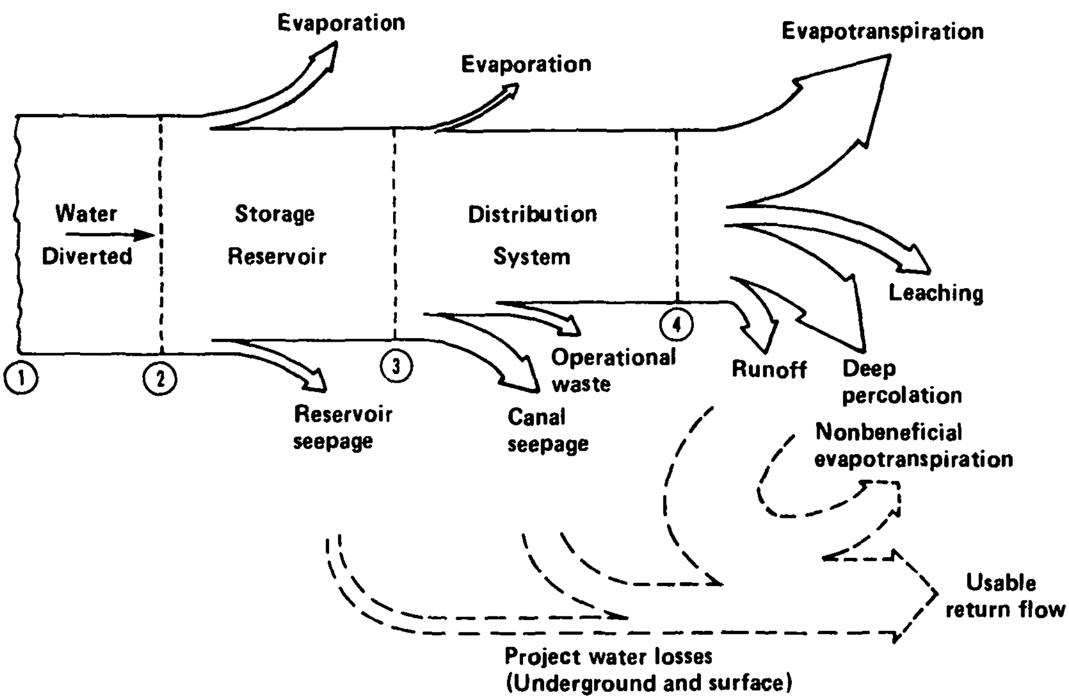

Figure III. Disposition of water diverted for irrigation

Source: M. E. Jensen, "Evaluating irrigation efficiencies," *Journal of Irrigation and Drainage Division* (New York, American Society of Civil Engineers, 1967), 95.

among irrigation projects, owing to differences in physiographic features, water control and conveyance structures, management practices and methods of irrigation. Conveyance, application and over-all irrigation efficiencies are useful concepts in the design of projects, in feasibility studies and in the operation, management and evaluation of irrigation projects.

Application efficiency is usually expressed as a ratio of the volume of irrigation water consumptively used (transpiration by plants and evaporation from the soil and plant surfaces) and of water needed to regulate salt concentration in the soil to the total volume of water diverted for irrigation. In other words, it is the sum of evapotranspiration and leaching requirements divided by the quantity of water diverted to the field (the volume at point 4 in fig. III). Water conveyance efficiency is the ratio of the volume of water delivered to the field (measured at point 4) divided by the total volume of water supplied to distribution systems (measured at point 3). Surface evaporation, operational waste, canal seepage and evapotranspiration are the major components of conveyance losses. Over-all irrigation efficiency is the product of the component efficiency ratios, or the field application efficiency multiplied by conveyance efficiency.

A common misconception about irrigation efficiency is the notion that if efficiency is increased there will be a substantial increase in the water available downstream. Improvements in efficiency result from a decrease in application and delivery losses. However, since much of the excess water may return to the stream, such decreases in upstream deliveries may not result in equal increases in net available water for downstream users.

The method of irrigation is primarily an economic choice. The selection of a particular method is affected by the way in which water reaches farms, the topography, level of technological development, availability of trained manpower, value of water and relative price of labour and capital. When water is more valuable, in general there will be more interest in physical efficiency and systems that lead to economic efficiency.

Table 1 presents several irrigation efficiencies from a global study by Bos and Nugteren (1974). Application efficiencies are higher for sprinkler irrigation as compared with surface methods, which include furrow, basin and flooding. Surface irrigation is, however, by far the most common method in use, and over-all irrigation efficiencies are on the order of 20 to 30 per cent. The study is based on 1,439,300 hectares irrigated as representative of a potentially irrigable area of about 5 million hectares. Average application efficiencies were 53, 32, 60 and 66 per cent for groups I, II, III and IV respectively. Group IV combines countries whose agricultural systems are highly capital intensive and which use sprinklers for supplemental irrigation and probably have low-valued water. Group I represents areas that are generally more labour-intensive and are characterized by small farm holdings and a severe rain deficit.

The definition of application efficiency does not explicitly reflect adequacy or uniformity in the application of irrigation water. Nevertheless these measures

Table 1. Global irrigation efficiencies: conveyance, application and overall efficiency for four global regions grouped by climatic and socio-economic factors a/

Efficiencies								
Conveyance efficiency	Application efficiency as influenced by method of irrigation					Overall average irrigation efficiency	Criteria for grouping	Countries in group
	Average	Furrow	Basin	Borders	Sprinkler			
							GROUP I	
0.40	0.53	0.54	0.66	0.47	...	0.22		
Number of sample areas			28				Severe rain deficit Entirely dependent on irrigation Small farms Cereals grown as main crop	Colombia, Egypt, India, Iran, Israel, Mexico, Zimbabwe-Rhodesia
Irrigable area			6 683 000 hectares					
Irrigated area			1 851 000 hectares					
							GROUP II	
0.65	0.32	...	0.32	...	...	0.21		
Number of sample areas			22				Some rains Supplemented irrigation Main crop rice	Colombia, Guyana, Japan, Democratic People's Republic of Korea, Malaysia, Malawi, Philippines, Thailand
Irrigable area			1 218 000 hectares					
Irrigated area			309 800 hectares					
							GROUP III	
0.51	0.60	0.58	0.59	0.57	0.68	0.31		
Number of sample areas			32				Shorter irrigation season More advanced technologies Cereals, fodder crops, fruit, vegetables	Australia, Cyprus, France, Greece, Italy, Portugal, Spain, Turkey, United States of America
Irrigable area			1 530 000 hectares					
Irrigated area			379 000 hectares					
							GROUP IV	
0.39	0.66	...	...	...	0.66	0.26		
Number of sample areas			10				Cool, temperate climate	Australia, Canada, Federal Republic of Germany, Netherlands, United Kingdom
Irrigable area			359 000 hectares					
Irrigated area			67 200 hectares					

a/ M.G. Bos and J. Nugteren, 1974.

are important and should be considered carefully when interpreting, comparing or using irrigation efficiencies. For example, if water is applied to furrows until an adequate amount is absorbed at the lower end of the field and if the tailwater could not be reused, the application efficiency may be as low as 60 per cent. However, if tailwater could be reused, the efficiency may exceed 90 per cent (Neghassi, 1971).

2. Economic efficiency and marginal cost pricing3/

Economic efficiency refers to the optimal use of water from the standpoint of society. Optimal use is achieved when the welfare of society will not be improved by re-allocating water to other uses. If the quantity of water is fixed, then the marginal social benefits of additional water allocated to each use should be equal. Thus, the value of water corresponds to the marginal social benefits in its best alternative uses and this provides the opportunity cost of water for any other usage. If additional water can be secured at some marginal social cost in terms of other resources, then this cost becomes the marginal value of water. Maximizing social welfare requires that additional water be obtained for each use until the marginal social benefits in each use equal the marginal social cost of acquiring the additional water.

This description of an optimal state - that marginal social benefits equal marginal social costs - does not imply anything about the method of achieving this state. Two different approaches may be taken. Experts can study levels of usage that make the two roughly equal and then influence policy towards allocating water to each use in this manner. This could be called the "mandatory" or "beneficial"use" approach. Alternatively, society can set prices based on the marginal net social costs (which include the marginal costs of producing the water and of important externalities) as a guide in setting prices. These prices, when paid by users, become marginal costs. These can be shadow prices, when direct estimates do not exist. Individual users acting rationally will use more water until their marginal private benefits roughly equal the price. Presumably, this water usage will be equal to that prescribed in a mandatory or beneficial use approach.

3. The relation between the value of water and observed physical efficiencies

There are many ways to combine labour and capital. These resources substitute for one another. The value of all resources, plus the technical possibilities of substitution, determine the optimum combination. The higher the wage rate, the more it pays to save labour and substitute other inputs. The same applies to water. As water values increase, so does use efficiency. A low value for water implies that a low level of irrigation efficiency may be economical, if poor drainage and salt hazards do not arise from excessive application. High values of water imply high levels of efficiency. There is little evidence indicating that field crops respond differently to different irrigation methods under normal growing conditions. However, rational selection of the method is based on the system of economic incentives.

3/ The discussion below is further to that presented in chapter I.

Table 2 presents a hypothetical example of the influence of the value of water and wage rates on the selection of an optimum method.

Table 2. Hypothetical illustration of the effect of wages and the value of water on the selection of optimal (economic) irrigation method and related application efficiency

Value of Water (and application efficiency)	Wage rates	
	Low	High
Low	Wild flooding Border flooding Basin flooding	Border Furrow
Medium	Furrow Subsurface	Portable sprinklers Solid set sprinklers Centre-pivot sprinklers
High	Portable sprinklers	Drip

Of course, the optimum method depends on other factors, such as type of crop and soil, topography and level of technology. When capital is limited in comparison with the availability of labour, low wage rates and traditional methods of irrigation (such as flooding, furrows and portable sprinklers) tend to predominate. These methods are relatively more labour intensive. On the other hand, when wage rates are high, more capital-intensive methods, such as solid set sprinklers, centre-pivot sprinklers and drip irrigation, are optimal. Therefore, low water values are associated with surface irrigation, while high values make sprinkling and drip irrigation economically efficient. It is likely that properly structured economic incentives lead to increasing irrigation efficiency as the value of water increases. Similar conclusions could be reached in reference to application efficiencies (see table 1).

C. Factors affecting prices and regulations for irrigation water

The regulations and prices used to allocate water depend on the value of the water, availability and dependability of supply, the ability to control its flow, the desire to subsidize agriculture, the value of the crop, traditions of ownership, the type and pattern of cropping suited to the location, the value of the crop products and the number of farmers involved. No one system of allocation can apply to all areas. An understanding of systems is needed to improve the efficiency of use in different site-specific circumstances. It may be useful to try to explain factors affecting choices among systems for regulating and charging for water before describing systems that are actually being used.

1. The value of water

If the value of irrigation water is low, as is often the case, it is generally not economical to measure it or levy charges for it. More accurate measurements and more sophisticated systems for allocating water resources could emerge as the value of the resource increases. An allocative scheme involving volumetric measure would be inappropriate if the cost of measuring the water exceeds the value of the water itself. Better measurements and record-keeping schemes would be expected when the cost of measurement and administration falls and the value of the water rises.

Establishing value for irrigation water presents a number of unusual difficulties. Market prices for it are rarely encountered, so estimates of value are based on indirect approaches involving the determination of water production coefficients and economic value of the crops. Accurate measurements of crop water use and yield cannot be made because crop growth is a biological process occurring in an uncontrolled dynamic and stochastic environment affected by climate and soil-water-plan relations. Crop yield is also affected by other inputs and the way in which they are combined with each other and with water. The pattern of cropping and the adopted varieties of each crop respond differently to water applications (see, for example, Young and Gray, 1972; Blaney and Criddle, 1962; FAO, 1977; Neghassi, 1974; Jensen, 1973).

Crop response is inhibited by soil salinity and alkalinity and by the level of salts in the irrigation water. In cases where water is plentiful and applied in excessive quantities, there is the danger of raising the water table with resulting drainage problems. This suggests that even when the value of water is low, farmers should guard against excessive applications of water.

2. Government recovery of capital investments and subsidy

In practice, the scope for efficiency pricing of irrigation water is limited. As can be seen from table 3, which summarizes the practice in selected countries, irrigation projects are generally highly "subsidized", implying that the direct beneficiaries do not pay for the complete cost of irrigation. Since irrigation projects also generate indirect benefits and irrigation is one of several project purposes, it is reasonable that other beneficiaries should bear a share of the costs of the irrigation infrastructure and operation and maintenance. In this sense, repayment commensurate with the benefits realized by other beneficiaries should be deducted from over-all project costs before the extent of subsidy to direct beneficiaries can be inferred.

In many countries efficiency pricing of canal irrigation water does not exist. Instead, irrigation water is subsidized. A recent summary of 17 irrigation projects financed by the World Bank (Duane, 1975) reveals that, on average, 30 per cent of total project costs are recovered. In that study, water charges comprised only 17 per cent of the incremental farm income. Why are irrigation project costs only partially recovered and why do subsidies for irrigation water remain so high? The following points may help explain the situation in part.

Table 3. Level of subsidy of irrigation water in selected countries/regions

Country/Region	Nature and level of subsidy	Reference
Australia	All capital construction costs and part of operation and management costs	Bhagivath (1969)
Canada	More than 50 per cent of capital construction costs	Bhagivath (1969)
China	50 to 70 per cent of capital construction costs	Asian Development Bank (1973)
Democratic Kampuchea	100 per cent of capital and O and M costs	Asian Development Bank (1973)
Democratic People's Republic of Korea	70 per cent of capital construction costs	Asian Development Bank (1973)
Europe	Generally 40 per cent of costs of irrigation	ECE Committee on Water Problems (1976)
India	80 per cent or more of annual equivalent costs of construction (major projects)	Taylor (1971)
Japan	40 to 80 per cent of capital construction, improvement and reclamation costs	Asian Development Bank (1973)
Lao People's Democratic Republic	100 per cent of capital and O and M costs	Asian Development Bank (1973)
Malaysia	100 per cent capital construction and over 50 per cent to O and M costs	Taylor (1975)
Pakistan	In lower Indus region, cost of irrigation is only 10 per cent of the returns to irrigation	Caruthers (1968)
Peru	All capital costs of major irrigation projects	Seagraves (1978)
Philippines	40 per cent of operation and management costs in the Santa Cruz system	Torres (1972)
USSR	100 per cent irrigation infrastructure and operation	Bhagivath (1969)
United Republic of Tanzania	100 per cent of capital and O and M costs	United Nations questionnaire
United States of America	Up to 60 per cent in Burean of Reclamation projects; mostly by other uses, mainly power	Water Resources Council (1968)
Viet Nam	100 per cent of capital and O and M costs	Asian Development Bank (1973)

Following the example of other nations, some countries subsidize agriculture. Just as tariffs can quickly become competitive, so can policies to subsidize agriculture. Subsidy of agricultural projects, including irrigation, is justified on grounds of increasing exports and rural employment, while reducing migration to the cities and domestic food prices. It is frequently difficult to charge farmers for water during the early years of a project, thus making it politically impossible to institute water charges at a later stage.

By the same token, irrigation projects are popular and "safe" ways for politicians to show that they are helping their farm polulation. Politically determined prices are generally inflexible. A higher order of political rigidity often makes it impossible for one water jurisdiction to sell title or rights to another - hence an incentive towards construction and commitment of available supplies. Certain errors in economic reasoning have played a role, such as ignorance of the marginal principle, double counting of benefits and use of inappropriately low discount rates. In the United States, no provision is made for recovering more than 100 per cent of a successful project; in the case of failures, cost recovery is often less than full. But, all projects in an area tend to contribute to recovery at the level of the least profitable project (United States Water Resources Council, 1968). It should also be pointed out that if Governments start charging what water is worth, some farmers may be forced out of business, but others will buy the land at lower prices. One of the long-run effects would be to reduce the market value of land.

3. Number of farmers involved

When the number of farmers sharing an irrigation system is small, personal agreements may be used to resolve differences among them. As the number of users increases, it becomes more logical to adopt formal procedures to allocate water. Price rationing is one of the simplest ways of doing this. Water may not be priced at its value because stream flows not regulated by a reservoir may vary depending on the season, time-of-day and other factors. If the value of water fluctuates a great deal, it may be too difficult to vary the price. Hence, a low price is assigned to encourage full use in periods of abundance. Quotas or regulations are used to allocate water among farmers in times of shortage.

4. Uncertainty and variability in water availability

Uncertainty and variability in the quantity of water makes rate-making difficult. This problem is compounded by the difficulty of estimating water requirements on the basis of specific cropping patterns and delivery systems. For example, there are instances where under-estimation of delivery system losses have resulted in the failure of some projects. With such difficulties in mind, decision makers tend to promise less and deliver less. The success of efficiency pricing of irrigation water depends on measuring water. However, the cost of the measurement is often so high compared to its value that from an over-all social point of view, it is not desirable to measure it. In canal irrigation projects, especially those serving numerous small lots, metered sale of water is costly to implement and administer. It is rarely practised in developing countries.

When flows are variable, it is common to distribute water among farmers according to shares. Each farm receives a proportion of the flow of a river for a certain period of time. Fairness may be more important than measured quantities in such circumstances and farmers may defend their "right" to a certain share of the river flow. Ownership may reside with the Government by law, while, in fact, farmers are accustomed to receiving the water free of charge. The value of such water rights fluctuates over time with agricultural prices and is probably built into the purchase price of the farms. If a Government began charging what the water was worth, it might put many farmers out of business.

Charging the full value of the water under such circumstances would amount to repossession of water "rights".

D. Alternative systems of delivery to the farm and pricing

1. Pricing structures

Different pricing structures (charge schedules) for irrigation water are in force today. Structures differ from country to country and from project to project. Charge schedules are of two general types: (1) flat-rate or fixed charges not related to volume of water schedule; and (2) graduated charges or charges related to volume.

Under the first, the rate is based on area or volume, whereas in the second, some measure of volume is implicit in rate determinations. Variations of both depend on the method of delivery, crop, type, season, application method, soil type and number of irrigations. Some examples from Mexico are given in section E.3 of this chapter. Method of delivery and charge schedules are strongly interdependent, as the following discussion shows.

2. Systems of delivery

The method by which irrigation water is delivered affects irrigation efficiency and affects feasible pricing systems. Four common methods of delivery - continuous flow, rotation, demand and closed pipe - are distinguished below. Seldom, if ever, is all of the irrigation water in a region always delivered by a single method. Modifications or combinations of two or more methods are more commonly used, depending on tradition, physical conditions, and level of water development and control.

(a) The continuous flow system

Under the continuous flow system, water flows through a canal on certain days and each farmer is free to take the quantity he needs. The water itself may be free, even though the delivery system may be costly. In such cases, farmers usually pay annual fees for access to the water or contribute labour towards the maintenance of the canal. It does not make sense to estimate the amount of water used or to charge different rates per hectare for different crops. It might make sense to levy charges per hectare and to vary these charges depending on the cost of storage and delivery to a given point.

(b) The rotation system

In the rotation system, water is delivered to users by turn, according to a prearranged schedule. This makes it difficult for a farmer to delay receipt of his water or to transfer it to someone else along a different canal. But, a flexible schedule also causes problems. Flexibility makes it necessary to inform everyone of the time the water for their farm will arrive. Such systems of rotation are usually based on proportional division of stream flows so that farmers receive shares of an annual flow rather than a known volume. Even though the volumes of water might not be known, shares could be valuable to all users since those shares could be traded or sold. A sensible way to charge farmers on a rotation system might be according to the number of shares or the proportion of water they receive. Farmers often are charged by the hectares served or the hectares of each crop multiplied by a certain volume per hectare. In other words, the water charge is a land tax or a differential land tax for different crops. It is sensible to base water charges on shares received because this relates charges to water usage (demands), enabling administrators and farmers to buy differing numbers of shares.

(c) The demand system

The demand system involves the delivery of water to farms at times and in quantities requested by the water user. It is ideal from the user's point of view because it permits irrigation of crops when needed with the most efficient and economical quantity of water. This system of delivery offers many opportunities to encourage efficient use of water. In open canal systems, such deliveries require an ingenious and flexible operational organization capable of matching daily supply with demands. As the name "demand system" suggests, users are able to request and actually receive the quantity of water they wish. Prices based on volume are both feasible and sensible. This does not suggest that the same price must apply to the whole volume purchased by one user; free quotas plus penalties for exceeding them, or gradually increasing block rates, are also feasible.

(d) The closed pipe system

The closed pipe system is the fourth method of delivery. Under this type of demand system, water is distributed through a system of pipelines over the entire project, and farmers can draw water in accordance with their demands at any given time. Closed pipe systems are generally used in conjunction with overhead sprinkling, drip and subsurface irrigation. When closed pipe and metered systems exist, it is easy to levy charges based on volume or graduated on the basis of water delivered to a farm.

3. The relation between system of delivery and efficiency

The value of water and the ease with which flows can be controlled affect the system of conveyance used, and the systems chosen in turn affect efficiency. For example, Israel has an extremely limited supply of water and most of it is now distributed in a closed pipe system.

Table 4 gives values for average irrigation efficiencies for the four methods described above. It is noteworthy to observe that farm application efficiency increases sharply from about 26 per cent for the continuous flow system to approximately 70 per cent for the closed pipe (sprinkler) system. One explanation of this is the greater use of volumetric water charges in the case of delivery and demand and closed pipe systems, which is made possible by the advanced technical water control facilities. A main reason for the sharply decreasing value of conveyance efficiencies, from 90 per cent for continuous flow to 53 per cent for the demand system is that seepage losses are higher in a non-continuous (rotation and demand) method of delivery. Since total seepage losses are directly related to the length of the conveyance canal, differences in length can affect the conveyance efficiencies. The differences could also be due to other interrelated factors that affect canal seepage (type of surface, wetted area, age and shape of the canal, type of surrounding soil and amount of sediment in the water).

Table 4. Effect of system of delivery on component and overall irrigation efficiencies

System of delivery	Application efficiency	Conveyance efficiency	Over-all efficiency
Continuous flow	0.27	0.91	0.25
Rotation	0.41	0.70	0.29
Demand	0.53	0.53	0.28
Closed pipe	0.70	0.84	0.59

Source: Bos and Nugteren (1974).

Another important point revealed in table 4 is the dependence of the over-all efficiency on the product of the component efficiencies, indicating that improvements in farm application efficiencies and implicit potentials for water saving can be nullified by low conveyance efficiencies. Therefore, programmes to improve over-all efficiencies should be viewed with simultaneous consideration of the components of the total irrigation system.

E. Brief reviews of actual practices

1. The World Bank: cost recovery goals and performance of Bank projects

In general, the farmers who use irrigation projects pay but a small part of the costs of these projects, and the way in which charges are levied does little to encourage efficient use of water. Of course, the farmers are not the main beneficiaries of large projects; rather, the consumers benefit most through lower prices. The basic issues have been stated as follows by Paul Duane (1975):

"In principle, cost recovery issues involve two sets of considerations. The first is concerned with the level and structure of the prices to be charged for the output from a project so as to maximize its net economic benefits to the economy, i.e., with "efficiency" prices. The second set of considerations relates to the desirability of adjusting the efficiency prices, or charging alternative taxes, because of fiscal and financial concerns or on income distribution grounds. Among the questions that arise in this context are: How pressing is the need of the government for additional fiscal resources; what is the current and expected income position of the beneficiaries; how important is financial independence of the project entity; how feasible is it to levy additional charges; and how seriously do they affect the net benefits from the project?

"The scope for efficiency pricing of irrigation water is limited, however. In the case of canal irrigation projects, especially those serving numerous small lots, metered sale of water is costly to implement and administer, and is rarely practiced in developing countries. Nonetheless, the potential advantages of volumetric pricing are great, both for bringing about optimal water use in the command area and for revenue generation.

"The Bank's policy has been to require a recovery of at least the public sector's operation and maintenance (O and M) costs, and up to 100 per cent of all direct public costs of a project, with revenues and costs in future years suitably discounted and adjusted for general inflation and with costs measured at domestic market prices. In practice, negotiated recovery rates in Bank projects have indeed exceeded O and M costs, but have fallen well short of total costs /see table 5/. According to a survey of 17 Bank irrigation projects, anticipated recoveries averaged only 29 per cent of total costs /see table 6/. The policy has therefore allowed wide discretion in setting the level of charges, at least in relation to public costs. Justifications of proposed charges have referred mainly to the need to preserve user incentives.

"There seems to be no obvious, meaningful pattern. Indonesia Rehab. III has the second lowest cost recovery index (10 per cent), but Indonesia Rehab. IV (40 per cent) and II (49 per cent) are in the upper range. India Pochampad has the lowest recovery (8 per cent), but India Kadana is slightly above average at 31 per cent. Both Korean projects are at the low end of the range (14 per cent and 16 per cent). The two Malaysian projects are somewhat above the average (31 per cent and 37 per cent).

"The benefit recovery indexes for the 17 projects (the percentage of incremental farm incomes expected to be recovered by water charges) average 17 per cent and range from 5 per cent to 33 per cent; 60 per cent of the projects are in the 5 to 16 per cent range and the remaining 40 per cent range between 20 and 33 per cent. There seems to be no obvious correlation between the cost recovery index and the benefit recovery index".

Table 5. Sample comparison of estimated level of water charge collections and operation and maintenance costs at full development: 14 projects

Country	Loan credit number	Project	Year signed	Estimated level of annual water charge collection (millions of $)	Estimated level of annual O + M cost	Surplus
China (Taiwan Province)	7-CHA	Ground water	1961	2.31	1.37	0.94
India	13-IN	Shetrunji	1961	0.26	0.10	0.16
Pakistan	11-PAK	Dacca	1961	0.21	0.10	0.11
Mexico	275-ME	Irrig.Rehab.	1961	9.39	5.57	3.82
Pakistan	22-PAK	Khairpur	1962	1.60	1.60	0.00
Pakistan	39-PAK	Brahmaputra	1963	1.06	0.19	0.87
Pakistan	40-PAK	Chandpur	1963	1.02	0.46	0.56
Turkey	38-TU	Seyhan I	1963	1.28	0.64	0.64
Malaysia	434-MA	Muda	1965	1.31	1.00	0.31
Mexico	450-ME	Irrig.Rehab.III	1966	1.74	0.98	0.76
Malaysia	500-MA	Kemubu	1967	0.60	0.33	0.27
Sri Lanka	121-CE	Lift Irrigation	1968	0.15	0.15	0.00
Mexico	527-ME	Rio Colorado	1968	7.02	3.82	3.20

Source: Paul Duane, 1975.

Table 6. Cost recovery index and proportion of water charges to incremental farm income: 17 projects

Name of project	Cost recovery index (percentage)	Water charges as percentage of incremental farm income
India - Pochambad 268-IN	8	10
Indonesia - Rehab. III 220-IND	10	5; 9 a/
Republic of Korea - Yong San Gang	14	13
Republic of Korea - Pyongtaek Kumgang 600-KO	16	31
Philippines - Pampanga 637-PH	20	5
Afghanistan - Khanabad 248-AF	26	11
Madagascar - Lake Alaotra 214-MAG	31	26
Malaysia - Kemubu	31	14;16 b/
India - Kadana 196-IN	31	11
Egypt - Nile Delta 181-UAR	32	21;29 b/
Mali - Mopti Rice	34	33
Iran - Dez 1 594- IRN	34	15
Greece - Ground water 754-GR	35	20
Malaysia - Muda 434-MA	37	7
Indonesia - Rehab IV.	40	7;10 c/
United Republic of Cameroon - Semry Rice	46	23
Indonesia - Rehab. III 195-IND	49	6;20 d/
Average	29	17

Source: World Bank project Reports (various years).
a/ Depending on location.
b/ Tenant and owner, respectively.
c/ Depending on crops.
d/ Depending on other inputs.

Even though we may consider these recovery ratios low, they are probably much higher than the average recovery ratio for comparable projects not financed by the World Bank. That is, pressure from the Bank towards fiscal self-sufficiency of individual projects probably had some effect.

Economists favour fiscal independence for different reasons than does the banker. It contributes to better investment decisions in the future. If users know that they will be paying for a project then they will participate more actively in the decisions regarding that project. Also, if decision makers know that they will be paying for a project then they also will participate more actively in decisions. Also, if decision makers know that users will have to pay for a project then they will study more seriously the actual benefits to the users in order to predict actual usage. More important perhaps is the concern that charges for water be based on the "marginal cost pricing" principle, which requires knowledge of the quantities (volumes or shares) of water actually used.

2. Israel: Moving towards an efficient allocation of water

Water management in Israel provides an example of a situation in which water has high value and useful lessons have been learnt on how to use it efficiently. Most of the material below has been condensed from a paper prepared initially for the meeting of the Ad hoc Group of Experts on the Achievement of Efficiency in the Use and Reuse of Water, held in Israel in 1974, and updated later as a thematic paper for the United Nations Water Conference (Arlosoroff, 1977).

(a) Water pricing

Internal political pressures and a great deal of trial and error have led to the tariff structure described in table 7. Most water is sold under the uniform tariff structure for municipalities given in section A.1 of the table. Increasing block rates are used in which the households have three rates, sharply increasing from $2.46 per m3 under 8 m3 per month to $6.16 per m3 for any amount above 16 m3. Agriculture, industry, hotels and services have two prices: low prices for water within the official allocations and higher prices for any water purchased in excess of these quotas. Hospitals, educational institutions and security installations have about the same penalty (marginal) charge as households, $6.16 per m3.

The rates for exceeding quotas are less for agriculture, public gardens, industry and hotels than for the others listed. Commercial establishments such as laundries and restaurants have flat rates for all the water they use.

There are plans to use more treated waste water from the cities for crop production in the future. There may be a need to establish special incentives to encourage full use of this water by farmers and induce efficiency in the process. Large users could make contracts with cities to manage waste treatment plants and make specific contracts to handle industrial wastes, including provisions for limiting the discharge of toxic substances.

Table 7. Water rates in Israel, effective 1 October 1977

A. Water tariffs for municipalities with own source of supply a/

Types of use	Block rates	Block rates within official allocations	Block rates in excess of allocations	Flat rates applied to commercial firms without allocations
	(dollars per m^3) b/			
Household use per dwelling, per month c/				
Under 8 m 3	2.46			
8 - 16 m 3	3.89			
Above 16 m 3	6.16			
Agriculture, industry, services and public institutions				
Agriculture		0.85	1.80	
Public gardens		1.33	2.28	
Industry		2.32	3.27	
Hotels		2.46	3.32	
Educational institutions		3.14	6.18	
Hospitals		3.15	6.18	
Security installations		3.16	6.19	
Laundries				3.18
Fish mongers				3.19
Swimming pools				3.19
Restaurants				4.46
Construction				5.69
Shops and offices				6.02
Other				4.41

(continued)

Table 7 (continued)

Types of use	B. Water tariffs for users supplied by others d/		
	Tax on low-cost water	Ceiling price = cost plus tax	Minimum price of subsidized water
	(dollars per m^3)		
Agricultural	0.9	0.57	0.95
Industrial	0.28	1.04	1.37
Other	0.43	0.85	0.95

a/ Rates are uniform throughout the entire country for those municipal authorities that have their own sources of supply, except in the desert town of Eliat. When a municipality purchases water, the charges are as follows: for agricultural uses, the cost of purchase plus $0.28 per m 3; for industrial uses, the cost of purchase plus $0.57 per m 3.

b/ Exchange rate: $US1.00 = 1.05 Israeli pound.

c/ Any family of more than four persons occupying a single dwelling unit is entitled to an additional 3m3 per month at the base rate per additional person.

d/ Buyers are taxed is suppliers have low costs and are subsidized if they have high costs.

This tariff structure contributes to the twin goals of redistributing income and promoting efficient use. The most favoured sector is clearly agriculture. The highest rate for agriculture ($0.85) is less than the starting rate for all other users except public gardens. Swimming pools, fish mongers, laundries and industry also receive preferential rates. Greater efficiency in water use could still be encouraged by adopting a uniform penalty rate based on opportunity cost or price rationing to achieve full use of the available water.

(b) Use of water in agriculture

Water allocation for agricultural purposes is based on a system of annual licenses. These are norms and maximum quantities of consumption related to the various agricultural crops. The allocated water quantity is the sum of the appropriate norms times the cultivated areas. The norms are calculated on the basis of economic and efficient use. If the farmer is wasteful he will find himself unable to sustain his whole farm on the annual quantity of water available to him. Thus, the allocation provides the main incentive for efficiency. Over-consumption is also discouraged by payment of a penalty rate.

In addition, the Minister of Agriculture, by power of his legal authority, has issued regulations restricting the use of water in fish ponds, poultry houses and orchards (the largest consumer of water in Israel). The purpose of the regulations concerning water use in orchards, for example, is to encourage and promote efficient methods of water utilization, both in the engineering and economic contexts. A study of water consumption in orchards indicates that the use of various devices has resulted in saving considerable quantities of water. In order to provide the incentive for this form of water saving, the regulations stipulate that water saving achieved through the use of the said methods and devices shall not reduce the right of the consumer to receive the full quantity of water originally allocated to him including use on another site.

The activities of the Water Commission in this programme consist of developing efficient irrigation methods and systems, fostering their introduction by the farmers, granting loans at attractive interest rates, reducing market prices of water saving appliances, and of education projects. The co-operation of the farmer can be best secured by bringing about an increase in his income. However, the farmer must be given guidance and information as well as financial incentives. He must be induced to improve his systems of irrigation and thus save money and labour in addition to water.

Of the 200,000 hectares of land under irrigation in Israel, 90 per cent is irrigated by sprinkler and drip methods. This is the result of deliberate steps taken by the authorities to finance and otherwise encourage the replacement of gravity irrigation by closed-pipe systems over the past two decades. The national water system is capable of supplying water at suitable pressure for sprinkler and drip irrigation without the need for boosting. It is an integrated national system, with farms working to an "on-demand" schedule within a preset over-all water quota. The following considerations influenced the selection of this system:

(a) Sprinkler and drip irrigation systems make it possible to control the rate, amount and timing of water application and improve the over-all uniformity;

(b) The sprinkler and drip systems can be better adapted to the topography of the land and the shape of individual plots, while the irrigation rate can be easily adapted to soil type, climate and crop age at each plot;

(c) Sprinkler and drip systems are easy to operate; this is particularly important when land is being developed and farmers have little experience.

Drip irrigation is widely used for cultivating vegetables and vineyards and has recently been applied in cotton fields. Being stationary, drip irrigation systems lend themselves to the use of automatic water-control devices and a high degree of irrigation efficiency can be achieved.

The inevitable result of labour and/or water shortages, increasing costs, rising food prices and decreasing water quality, is an increasing need for and development of automated irrigation systems.

It is quite simple to set the automatic metering valve to deliver any prescribed volume of water, so there is no fear of excess discharge due to pressure fluctuations or forgetfulness. This device increases irrigation efficiency; and though it does not eliminate manual labour, it does reduce it.

Agriculture can enjoy the benefits of outside initiative in the development of electronic data-processing and control equipment, but most of the sensing devices are specific to agriculture and, apart from any problems regarding the profitability of automation in relation to labour costs and the value of additional production, they must activate and stop irrigation according to sound principles. Fully automated sprinkler and drip irrigation systems are in operation. Water applications are done by computerized scheduling based on considerations of water availability, climatic conditions, soil properties and marketing factors. Among the main problems in this regard are the great efforts needed to develop the data requirements for sound computerized scheduling and the desire to update computer programmes based on experience.

3. Mexico: evidence relating irrigation efficiency to the method of charging

One of the few studies that documents the relation between the method of charging for water and irrigation application efficiency was made by Schramm and Gonzales (1967) in Mexico. The study demonstrates that charges based on volume or the number of irrigations makes farmers more careful in their use of water (thus contributing to application efficiency), whereas flat rate charges per hectare or per season give no incentive to conserve water.

Table 8 shows the great variety of rate schedules in use in Mexico, a situation typical of many countries. The schedules are of three general types: charges related to volume of water use, fixed charges not related to volume of use, and a third type that includes elements of both types.

Table 8. Structure of irrigation water charges in Mexico, 1971/72 a/

Type I. Charges related to volume of water use

Basis of charge	Charge group	Description of structure	Area (hectares)	
Flat rate: primarily volumetric	A	Constant charge per 1 000 m^3, P_v	478 481	
	B	P_v + fixed charges per ha	400 368	
	C	P_v for well water (depending on type of ownership - government or private)	35 890	
	D	P_v based on pumping time	10 733	
		Total: group A - D		925 472
Graduated rate: based on number of irrigations, area irrigated and crop type	E	Constant charge per ha per irrigation, P_i (same for all crops)	92 062	
	F	P_i, with higher charge for first irrigation	164 334	
	G	P_i differentiated by crop	132 128	
		Total: group E - G		388 524
Mixed rate: volume, area, number of irrigations and crop type	H	Fixed charge per ha for a number or irrigations + P_v for additional use	5 457	
	I	As in group H but differentiated by crop	8 387	
		Total: group H and I		13 844
		Total: type I		1 327 840
		Type I as percentage of grand total		55

Type II. Fixed charges not related to volume of water use

Basis of charge	Charge group	Description of structure	Area (hectares)
Flat rate: primarily based on area	J	Fixed charge per ha, P_a	704 161
	K	P_a differentiated by crop	14 501
	L	P_a differentiated by crop and by farm size	9 413
	M	As in group L additionally differentiated by inside and outside district users	108 314

Table 8 (continued)

	N	P_a differentiated by kind of tenancy	7 717	
	O	P_a differentiated for canal and well water	3 500	
	P	P_a differentiated by mode of payment - individual or co-operative	8 216	
		Total group J - P		855 822
Flat rate: seasonal	Q	Fixed charge per ha per cycle, P_{ac}	12 659	
	R	P_{ac} differentiated by crop	16 028	
	S	P_{ac} differentiated by crop and by season	26 646	
		Total group Q - S		53 333
Graduated rate by size of well	T	Charge graduated by size of well and tenancy	188 475	
		Total: group T		188 475
		Total: type II		1,097 630
		Type II as percentage of grand total		45

Type III. Combination of types I and II (A variable within control of us user determines type I (49,021 ha) or type II (31,401 ha)

Fixed rate: primarily based on area	U	P_{ac} if pumped from river, otherwise as in group C	497	
		Total: group U		497
Crop rate	V	Charge structure as in D or K depending on crop	21 253	
	W	Charge structure as in E or K depending on crop	43 506	
	X	Charge structure as in W differentiated by canal or government well	15 166	
		Total: group V - X		79 925
		Total: type III		80 422

a/ Double-cropped areas counted twice.

Under type I, which accounts for 55 per cent of the irrigated land in Mexico, the rate structure depends on (a) a flat rate, primarily based on volume; (b) a graduated rate, based on number of irrigations, area irrigated and crop type; and (c) a mixed rate, based on volume, area, number of irrigations and/or crop types.

Type II covers the balance of the area under irrigation and includes the following variations in its price structure: (a) a flat rate, primarily based on area; (b) a flat rate, based on seasons or crop cycles; and (c) a graduated rate, depending on the size of well and tenancy.

Type III is based on certain combinations of the elements in types I and II and mainly includes fixed charges primarily based on area and crop rates related to various modes of water delivery to the farm.

The study attempted to relate irrigation application efficiencies for 14 irrigation districts to the structure of irrigation water charges (see table 8). The application efficiencies were obtained from an independent study, from computations based on definitions similar to those presented in section 2 above. The 14 districts were grouped according to tariff structures into those with fixed and those with variable charges. In 1971-1972, water application efficiencies in seven districts with fixed water charges ranged from 12 to 82 per cent, with an unweighted average of 51 per cent. The seven districts that charged by the quantity of water used had farm application efficiencies ranging from 45 to 98 per cent, with a simple average of 72 per cent. These may be compared with the values presented in table 1.

These differences suggest that tariff structures and their levels, when related to the volume of water use, have a significant effect on behaviour of farmers and could, therefore, serve as a policy instrument to effect higher irrigation efficiencies. If districts with fixed water charges applied variable rate structures, and if, as a result, irrigation efficiencies in these districts rose to the level of those observed in districts with variable charges, then the resulting water savings would be sufficient to irrigate an additional 523,000 hectares on the basis of the 1971-1972 data.

However, specific conclusions from the above study must be interpreted with some caution. Factors other than differences in tariff structures could explain the differences in efficiencies, such as the existence of effective water rationing systems in water-short districts. Furthermore, water savings or higher water-use efficiencies are of interest only if the water saved has value in alternative uses and excessive irrigation does not pose problems of drainage. This might not apply in districts with high rainfall or ample stream flow. Clearly, the introduction of variable water charges is not costless, since it generally requires the operation, maintenance and administration of measuring devices. Only if the net productive value of the water saved exceeds the additional investment and administrative costs is it worthwhile to introduce more complex tariff systems.

Table 9. Differences in the application efficiencies of districts with fixed and graduated water charges, 1971/72

District	Application efficiency	Average of maximum and minimum annual efficiencies
	Districts with fixed charges per hectare per time period a/ (percentage)	
Rio Blanco, V.P.	12	18
Zamora	28	28
Tepalcatepec	38	68
Tehuantepec	56	66
Cd Delicias	59	59
Valle del Fuerte	80	68
Edo. de Morelos	82	66
Simple average	51	53
	Districts with charges that vary with quantity of water used b/ (percentage)	
Tula	45	60
Santo Domingo	55	54
Rio Colorado	65	68
A.R. Lerma	66	64
Rio Mayo	84	84
Rio Yaqui	89	92
C. de Chapala	98	73
Simple average	72	71

Source: Mexico, Water Resources Secretariat, 1973.

a/ Including those tariffs that vary according to the crop planted.

b/ Including all districts that charge per irrigation per hectare or per unit of water supplied.

Problems of reliability and accuracy in the estimation of water use and diversion requirements also affect these conclusions, since by definition the accuracy of physical efficiencies depends on the accuracy of such estimates. In this particular case, evapotranspiration was estimated by the Blanney-Criddle (1962) method. Because the parameters were calibrated for arid conditions in the western United States, the results may diverge from actual values if the local conditions differ, particularly under humid and tropical climates. There are a number of other methods for estimating evapotranspiration from which a selection can be made (see, for example, Jensen, 1973).

Nevertheless, the findings of this investigation are encouraging and suggest that the use of variable, quantity-related water charges may represent a useful instrument for reducing waste and increasing the effective water supply. Improvements in physical and economic efficiencies in the allocation and use of water have significant potential for saving water, which can be used for additional intensive and extensive irrigation and possibly for transfer to domestic, municipal and industrial uses.

4. India: diverse rate structures and low charges

(a) Significance of irrigation in India

In India rainfall varies greatly from place to place and the distribution pattern is such that 70-90 per cent of the recorded rainfall falls during the monsoon period of three or four months. The total gross area irrigated in India amounts to some 33 million hectares, which is nearly 20 per cent of the world's total irrigated area. The net area under irrigation is likely to increase from about 23 per cent of India's total cultivated area to a maximum of 45 per cent by the end of this century, but the gross irrigated area will increase more spectacularly and raise the intensity of cropping from 130 to 180 per cent (Kanwar, 1973).

Irrigation is used mainly on land used in the production of food grain, which accounts for about 60 per cent or over 26 million hectares of the total irrigated area in the country (see table 10). The predominant crop is rice, followed by wheat and barley. Rice cultivation is a rather water-intensive process involving a large amount of waste.

(b) Integration management

Irrigation has helped increase production and productivity. However, irrigation creates the greatest impact when it is properly combined with other input factors and on-farm water management practices (see table 11).

There are three relevant points to note in table 11. First, consistent with the definition given earlier, water-use efficiency (WUE) is obtained by dividing grain yield in kg/ha (rice in this case) by the amount of seasonal water used in ha-mm/ha. The resultant values of WUE are in kg per mm per ha.

Table 10. Use of irrigation in India, 1967/68

Crop	Gross irrigated area (thousands of hectares)	Percentage of area under crop	Percentage of total irrigated area in the country
Rice	13 861	38.5	41.8
Wheat	6 457	43.5	19.5
Barley	1 509	45.2	4.5
Maize	669	11.9	2.0
Jowar	707	3.9	2.1
Bajra	382	3.0	1.2
Ragi	390	16.1	1.2
Other cereals and small millets	119	2.3	0.4
Gram	1 249	15.6	3.8
Other pulses	761	5.0	
Subtotal (foodgrains)	26 104	21.6	78.8
Sugar-cane	1 530	76.3	4.6
Other food crops	1 792	25.2	5.4
Oil-seeds (including groundnut)	753	5.0	2.3
Cotton	1 285	16.7	3.9
Drugs and narcotics	74	15.7	0.2
Fodder crops	1 275	16.8	3.8
Other non-food crops	319	55.0	1.0
Subtotal (non-foodgrain crops)	7 028	31.4	21.2
Total	33 132	23.7	100.0

Source: India, Ministry of Agriculture, Directorate of Economics and Statistics, 1968.

Table 11. Effect of water management practices on rice production at Central Road Research Institute, Cuttback, India

Mode of water application	Grain yield (kg/ha)	Water used (ha-mm/ha)	Water use efficiency (kg/ha-mm)	Water use index (as percentage of water requirement under continuous submergence)
1. Continuous submergence	7 550 (100%)	2, 566	2.9	100.0
2. Weekly irrigation 8 cm. depth	7 966 (105%)	1,296	6.1	50.5
3. Alternate wetting and drying; 5.8 cm. water applied at flowering	7 780 (103%)	1,619	4.8	63.1
4. Alternate wetting and drying alone	7 730 (102%)	1,287	6.6	50.2
5. Irrigation when soil just started cracking	7 695 (101%)	900	8.6	35.1
6. Irrigation when soil is completely cracked	7 120 (94%)	423	16.8	16.5

Source: J.S. Kanwar, 1973.

Water use efficiency (WUE) as used in agronomy measures the ratio of the yield of a crop produced with a given amount of water consumptively used (evapotranspired). Provided that water use is measured consistently, WUE is equivalent to an average crop yield (average product) as used in economics for seasonal water use, which is total yield divided by total water use.

The second point to note is that the method of delivery or irrigation water and the frequency of irrigation has great effects on yield and on water-use efficiency. The water-use efficiencies increased from 2.9 kg/ha-mm under continuous submergence to 16.8 kg/ha-mm when the irrigation water was applied to soil that was completely cracked. The latter involved 423 mm of water use, compared to 2,566 mm under continuous submergence. The relative consumptions are shown in the last column of table 11. The yields are nearly the same in all cases, but the amount of water use can be reduced significantly, to as low as one sixth of that under continuous submergence. The experimental results show that if the crop is irrigated only when the soil is completely cracked, a yield is obtained that is equivalent to 94 per cent of the water otherwise required under continuous submergence. This amounts to nearly a 600 per cent increase in water-use efficiency in terms of physical savings of water. In fact, all the experiments under the Water Management Project have shown that continuous submergence is essential only at critical stages of growth such as at transplanting and at the reproductive stage.

The third point is that from this data it is not possible to make valid inferences and comparisons regarding the engineering efficiencies and the economic efficiency. Engineering irrigation efficiencies are dimensionless ratios. Economic efficiency, on the other hand, implies comparison of marginal value with marginal cost. In general, a high economic efficiency would imply a high irrigation efficiency. Only under certain conditions can the same be said with regard to agronomic efficiency as defined here.

(c) Irrigation water charges

India has a long history of water charges and associated land taxes on beneficiaries of government-constructed irrigation project. The major objective of these charges has been generation of revenue by the Government. The responsibility for water resource construction and the authority to set and levy water charges reside in the state Government; as a result, rate structures and amounts vary from state to state. In general, charges are levied against individual farmers and/or landowners in amounts established on the advice of their respective state irrigation ministries; water charges are generally collected along with land taxes.

There are a diversity of systems of charging for irrigation water. The list below gives some specific examples of structures still in use in India:

(a) Crop area based - with different rates for different crops recovered from irrigators;

(b) Seasonal rates - charges levied in the form of rate per irrigated area depending on the type of crop, the season of the year and the method of application;

(c) Agreement rate - similar to occupier rate except that a contract is agreed for supply of water for one year or several years; the rate is paid even if water is not actually used;

(d) Block rate - consultant water rate per acre established for an entire cropped area;

(e) Consolidated rate - the water charge is combined with land revenue to form a consolidated rate; this system is suitable only where a single category of crop is grown;

(f) Volumetric rate - generally in vogue in areas with lift irrigation and tubewells; the charge is levied on the basis of measured quantity of water; the quantity is based on an estimate of the crop water requirements;

(g) Occasional rates - charges levied for use of water in an unauthorized manner, or for wastage of water; these charges are recovered as water rates in addition to any penalty incurred on account of such use or wastage;

(h) Percolation rate - in certain parts of India water charges are made on cultivated land within 200 yards of canals that receive by percolation or leakage from such canals an advantage equivalent to that which would be received by a direct supply of canal water for irrigation; such a water rate is even levied for use of percolation water for non-irrigation purposes;

(i) Irrigation cess - levied in respect of land under irrigable command in some cases to cover maintenance costs in addition to water rates or other charges leviable under the provisions of the irrigation acts;

(j) Concessional rates - incentive for rain-fed cultivation to adopt a changing pattern of water supply and to meet expenses on land levelling and the like; free water is allowed the first year after the distributary is open; in the second and third year, the water rate is only one third and two thirds respectively, of normal rate; a full rate is charged from the fourth year onwards.

The most common practice is that based on a combination of the rate structures in the individual states. Often these comprise (a) an occupier's rate, which varies by season and crop and is levied per unit area actually served; (b) a flat charge or irrigation cess per unit area covering all areas serviced by the project, whether or not actually severed during a given season or year; and (c) a betterment levy, applied per unit area served by the project. The first two charges are generally ear-marked to recover operation and maintenance costs. The betterment levy is a one-time payment or a limited number of relatively heavy payments grouped at the beginning of the project life; it is ear-marked for the recovery of a portion of project capital cost.

The pricing of irrigation water has been examined during the past two decades by a number of national and state committees, and the conferences of state Ministers for Irrigation and Power. The National Council of Applied Economic Research suggested that an irrigation rate equal to 20 - 50 per cent of net additional benefit derived from irrigation may be charged. The Maharashtra

Irrigation Commission in 1962 recommended that water rate may be fixed between 6 and 12 per cent of the gross income from various crops. In addition, it recommended a betterment levy of 14 per cent and a depreciation charge of 6 per cent. The Committee of State Irrigation Ministers set up by the central Government in 1964 recommended that wherever the requisite data are available the irrigation rate should be fixed at 25 to 40 per cent of the additional net benefit accruing to the irrigation value of the crop. Where data for estimating additional net benefit are not available, initial rates equal to 5 to 12 per cent of the gross income to the farmer from irrigated crops should be charged. The Irrigation Commission adopted the following guidelines for fixing water rates:

(a) Water rates should be levied on a "crop basis" except in the case of irrigation from tubewells;

(b) The rate should be related to the gross income from the crop and not to the cost of the project; it should range between 5 and 12 per cent of gross income, the upper limit being applicable to cash crops;

(c) The rates should be within the paying capacity of irrigators and should aim at ensuring efficient utilization of available supplies;

(d) Between regions with a similar class of supply, there should be the minimum disparity, if any, in the rates charged;

(e) For fixing rates, irrigation should be divided into A, B and C categories on the basis of the quantity and timeliness of supply;

(f) The general level of rates in a state should be such that, taken as a whole, the irrigation schemes do not impose any burden on the general revenues.

Interdepartmental water rate review boards are being set up in the states with a view not only to revising the water-rate structure but also to modernizing suitably and broadening the data base so that the state government can evolve a rational rate structure and suitably review the rates, as necessary. Where average holdings are small, it is impractical to supply water by measurement to individual farmers who are irrigating a variety of crops on one outlet. Such a system is feasible in a few situations where sizable areas are given over to a single crop, as in sugar-cane blocks in the State of Maharashtra or rice areas where the water is sold to a co-operative of irrigators.

However, volumetric charges have not worked satisfactorily in actual practice. The Maharashtra Commission's report referred to substantial economy in the use of water in sugar-cane blocks that would be possible if charges were made on a volumetric basis. On the recommendation of the Commission, the state government agreed to supply water by measurement to co-operatives where at least 75 per cent of the irrigators agreed to become members. Three co-operative sugar factories on the Pravara Canals undertook to take water by measurement and distribute it to their member-irrigators on crop-area basis, but within a year they found the system unworkable for want of co-operation from the irrigators. The Government of Gujarat also accepted the principle of volumetric supply to co-operatives of irrigators but has not found the system practicable. The Irrigation Commission has recommended that efforts should be made to introduce the system in a few selected areas on a pilot basis and if the experiment is successful it should be extended to other areas.

Though associated with difficulties in actual field application in the case of irrigation from canals, volumetric measurement of water supplies for irrigation from state tubewells has been tried and works well in the States of Gujarat, Madhya Pradesh and Uttar Pradesh. In the States of Haryana and Punjab, the supply of tubewell water is assessed on the basis of electric power consumed in operating the tubewell for each irrigator, the argument being that electric meter reading is more dependable and less costly than assessment on a volumetric basis. This may be true if the vertical lifts (total dynamic heads) are similar over time and among farms, implying relatively flat topography. In other situations volumetric measurement of water in an irrigation system would involve a large investment for installing meters and supervisory staff, which are beyond the country's present resources. When benefits are important in setting rates, it is advisable to price water at full cost, subject to the constraint that the charge should not exceed some appropriate fraction of benefits. If benefits do not exceed costs, a lower price may be justified on the grounds of equity and income redistribution.

5. Peru: estimating the value of irrigation water and some alternative pricing schemes

This section provides a way of thinking about the value of water in terms of relative scarcities and illustrates, with examples, two common methods of estimating values: the residual method and linear programming. The basic framework is presented in annex II. Also, the Peruvian Water Law and pricing practices are explained briefly. Some alternative pricing schemes are defined. One of them, dual fees, makes use of estimated values of water.

(a) The residual method: an application

Budgeted net income per hectare in three distinctly different valleys provides the basis for estimating the residual value of water or land given in table 12 (see annex II for a description of the methodology). The letter (R) after the estimate indicates the factor that is assigned the residual income, while (MC) indicates that marginal cost is being used as a proxy for the value of that resources. One valley in Peru where water is in extremely short supply and good flat land is abundant is Tacna, with an annual rainfall of 12.9 cm. It was estimated that the net income was $192 per hectare per year in 1974 dollars (based on an exchange rate of 50 soles = $US1.00). All of these numbers are based on crop budgets with yields and costs corresponding to average performance with modern technology. It is assumed that many hectares in Tacna could be levelled and provided with roads and irrigation canals at about the same cost, $40 per hectare per year. Subtracting this from the net income of the combined

Table 12. Summary of net incomes and resource values estimated by the residual method and by linear programming

Valley	Annual rainfall (centimeters)	Net income (dollars per hectare per year)	Water used per ha (ha-cm)	Marginal value of resources: Water (dollars per hectare per year)	Marginal value of resources: Land (dollars per hectare per year)
Residual method:					
Tacna	12.9	192	80	1.90 (R)[a]	40 (MC)[b]
Chancay-Lambayeque	57.8	360[c]	80	4.00 (R)[a]	40 (MC)[b]
Cañete	431.1	500	180	0.40 (MC)[b]	428 (R)[a]
Linear programming:					
Cañete		522[d]	177	0.38[e]	455[d]

a/ R = from the residual method.

b/ MC = from marginal costs.

c/ Pertaining to the dry part of the valley and one crop of beans per year. Remarkably similar estimates for resource values would be obtained from assuming sugar-cane and 250 ha-cm per year.

d/ Average values including rent to potatoes and cost of developing the land.

e/ Weighted average of the marginal values of water in the field from table 5, which includes the cost of developing the new water.

resources leaves $152 per hectare per year as the residual net income to the corresponding 80 ha-cm of water used. Dividing by 8 ha-cm per hectare per year gives the estimated value of water of $1.9 per ha-cm (or about $23 per acre-foot). Another water-short valley, Chancay-Lambayeque, is on the northern coast of Peru with a climate ideal for sugar-cane, rice and other crops. The residual net income of water is estimated to be $4.00 per ha-cm (or about $49 per acre-foot).

Cañete, on the other hand, has a relatively abundant supply of water and a shortage of irrigable land (data from a linear programming study of this valley are presented in table 13). The net income is estimated at $500 per hectare per year. Assuming a marginal cost of water of $0.4 per ha-cm and an annual usage of 180 ha-cm, the net income must be reduced by $72 per hectare to obtain an estimate of the annual value of land alone of $428 per hectare per year. It may be noted that the linear programming and the residual method yield comparable results for water and land in Cañete.

(b) Linear programming estimates of water resource values

Method of analysis. A mathematical technique called linear programming was used to determine resource values. Linear programming can be used to determine the optimum allocation of resources (such as capital, raw materials, manpower or facilities) to obtain a particular objective. For example, maximum profit or minimum cost may be the objective when there are alternative uses for the resources. Linear programming is a budgeting tool capable of handling large amounts of data. The results of this technique can provide information on the value of additional resources which are limited in quantity and the effects of given price changes in inputs and products on the profit or loss of a business.

The residual method offers a simple way of separating the value of water from the combined value of land and water. A modification of the residual method illustrated here uses the ratio of water to land to help decide which of these resources would have the more elastic supply. A marginal supply price is then budgeted for that input and the residual income is attributed to the other "fixed" resource. 4/

The intention here is to explain estimates of monthly values of water and land by simultaneously considering demands and supplies of each resource. If the supply of a resource can be expanded at a constant cost then its long-term value can't exceed that marginal cost. If supplies are strictly limited by time or other constraints, then resource values will equal opportunity costs or marginal value products in best uses (demands)as shown in figure XIII. Details of the linear programming model and assumptions are described by Seagraves and Ochoa (1978). The model is used first to analyse land and water values in Cañete

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4/ Prices used were those expected to prevail in Peru in 1974 and were based on past prices inflated forward. Results were later converted to 1974 dollars, using an exchange rate of 50 soles to the dollar.

Table 13. Resource values, optimum crop plans and net incomes in Cañete, with various levels of water and no new investments in land or water

Item	Levels of water that are exceeded the following percentage of the time: a/		
	90	70 (percentage)	50
Quantity of water used (millions of cubic meters per year)	242	252	241 b/
Monthly values of water (dollars per 1 000 m3)			
August	0.76	0.76	0.76
September	0.76	0.76	0.76
October	10.82	0.76	0.76
November	38.02	4.72	1.86
December	11.58	5.16	0.76
January	0.76	24.08	2.62
February	29.08	0.76	0.76
Value of water, August-February (dollars per 1 000 m3) c/	13.10	5.28	1.18
Marginal value of land (dollars per ha per yr)	215.58	307.54	380.82
Crops grown (hectares)			
Corn	3 695	4 976	4 000
Potatoes	4 000	4 000	4 000
Cotton	11 104	10 916	11 241
Number of hectares planted per year d/	18 799	19 892	19 241
Net income of valley (millions of dollars per year) e/	7.66	7.80	7.82

Source: James A. Seagraves and Reman Ochoa, 1978.

a/ The corresponding lists of monthly water supplies are given.

b/ Less water actually is used in this solution, which has the most water available because a better monthly distribution of the larger quantities of water facilitates the planting of more cotton, a crop that requires less water than corn, especially in the later summer months when water is almost always abundant.

c/ Simple averages of marginal values for each month.

d/ Totals reflect double-cropping of 3,600 to 4,000 ha of land.

e/ Values are not comparable to those in table 15 because they do not reflect new investment in water or land.

in the present situation - that is, without additional investments in land and water development. Attention then is turned to opportunities for additional investment in these resources and the implications of these investments for land and water values.

The present situation. Cañete is known as a valley with an abundant supply of water, given the existing canal system and quantity of irrigated land. Even so, the linear programming solutions, assuming no investments in new land, reveal that water can have high values from August to February in years when the supply is less than normal. Resource values assuming different supplies of water are given in table 13. Changes in optimum crop plans and incomes are small as one increases the river flow from that exceeded 90 per cent of the time during each month to that exceeded half of the time, reflecting the fact that in the present situation, the availability of water is not a limiting factor in Cañete. The marginal values of land and water are sharply affected, however, by changes in the amount of water available, the value of water of course increasing and that of land decreasing with smaller amounts of water and a fixed land base. In the condition of greatest water scarcity (that amount exceeded 90 per cent of the time), not quite all the available land is used.

Opportunities for investment in water and land. Table 14 indicates that in Cañete the cheapest source of additional water (up to about 51 million cubic meters) would be to tap 11 lagoons in the upper reaches of the valley. This water actually would be cheaper than that available from existing wells. On the other hand, drillings of new wells would tap the largest single source of water, and the cost would be less than that of building a new reservoir if the wells were used 12 months out of the year. The programming results (discussed below) indicate, however, that the optimum combination of water and land resources in the valley would call for pumping from the wells only a part of the year. Under these circumstances the reservoir is a cheaper source of water than the new wells. In addition, although this is not considered in the model, the quality of the well water would not be as high as that released from the reservoir.

Land development possibilities include drainage of 2,912 hectares formerly in crops near the Pacific. New land that can be brought into production includes 1,110 hectares to the north of the present agricultural area and 19,960 hectares to the south on the pampas of Concon Topara. The area now cultivated in the valley is approximately 22,000 hectares. Of these, some 6,800 hectares in fruits and minor horticultural crops were excluded from the programming analysis. The analysis focuses on 15,241 hectares now in crops, plus approximately 23,982 hectares potentially irrigable with new investments.

Monthly values of land and water with new investment. Table 15 shows the monthly values of land and water in Cañete, assuming the six investment opportunities described above are allowed. The values result from the programming analysis and can be regarded as reflecting the equilibrium between monthly supply and demand curves for a given river flow.

Table 14. Steps on the supply curve for irrigation water in Cañete

Source of water	Volume of water 1000 m3 (10ha-cm) per year a/	Annualized cost of investment (thousands of dollars) b/	Marginal costs (dollars per 1000 m3 or 10ha-cm)
River, now available	515 000		0.76 c/
11 lagoons	51 300	38.08	1.50 d/
Existing wells	6 412		1.88 e/
New wells	168 193	599.62	3.56 f/
New reservoir	76 000	242.88	3.96 d/

a/ Based on monthly flows of the Cañete River expected to be exceeded 75 per cent of the months, monthly canal capacities, lagoon and reservoir capacities, less 5 per cent for evaporation, and year-round pumping from wells.

b/ Based on the assumptions that the real interest rate is 4 per cent. This rate was at the lower end of the range of rates used by the Peruvian Government in project planning. Use of rates up to 12 per cent has little effect on the pattern of land investments in Cañete or on total water use but important effects on the pattern of investments in water and on values of water.

c/ Based on fees of $0.60 per 1 000 m3 or 10 ha-cm now collected in the irrigation district, divided by 0.8 for losses in canals and including 2 per cent interest for 6 months.

d/ Includes costs of transferring water to the field of $0.76 per 1000 m3 (10 ha-cm).

e/ From an analysis of operating and maintenance costs of six existing wells.

f/ Pumping costs of $1.88 per 1 000 m3 plus fixed costs. The fixed cost component here is based on usage 12 months of the year. In the programming results presented in table 15, additional new wells are only used 5 months of the year and the marginal cost is $5.14 per 1 000 m^3 or 10 ha-cm.

Table 15. Implicit values of water and land in the basic solution for Cañete a/

(1974 dollars)

Months	Implicit value of water in the field		
	Implicit value (dollars per 1 000 m3 or 10 ha-cm)	Volume (1 000 m3 or 10ha-cm)	Total value (millions of dollars per year)
October to January	5.15	298 444	1.54
February	7.20	119 633	.86
March, July, September	0.77	260 288	.20
August	1.92	17 000	.03
Total		695 365	2.63

Months	Implicit value of land in the basic solution			
	Classes of soil (number of hectares)			Total value of all hectares (millions of dollars per month)
	1 (28 302)	2 (6 485)	3 (4 436)	(39 223)
August	93.70	45.54	60.66	3.22
September	...	54.84	10.48	0.40
October	...	7.52	4.20	0.07
November	11.26	31.20	48.78	0.74
December	...	...	...	...
January	82.98	5.70	42.86	2.58
February	...	53.70	...	0.35
March	...	...	10.00	0.04
April	13.76	54.48	55.56	0.99
May	13.92	...	10.32	0.44
June	95.90	15.94	102.60	3.27
July	12.48	66.36	...	0.78
Total	324.00	335.28	345.48	12.88

Total value of land and water in millions of dollars per year 15.51

a/ Based on a real rate of interest of 4 per cent, monthly flows of the Cañete River that are to be exceeded 75 per cent of the time, the six investment possibilities described in the text.

The value of water for October-January, $0.52 per ha-cm ($5.15 per 1 000 m3), is the same as the marginal cost of water from an additional well fully used October-February. The option of withdrawing variable amounts of water from the reservoirs in any one of these months accounts for the equalization of the values.

Water is more valuable in February than in October-January because the capacity of the canals is the limiting factor in February, the month in which daily evaporation and agricultural water use are highest. Paradoxically, river flows are normally abundant in February, and the model allocates the surplus water to the reservoirs. Shortage of water in the fields in February leads to a high value, $7.20 per 1000 m3 or $0.72/ha-cm, which is less, however, than the cost of a new well for this month alone.

In August, some of the wells are used and the value of additional water is equal to the variable cost of pumping, $1.92 per 1000 m3. The value of $0.76 per 1000 m3 in the other months is the average cost of maintaining and operating the canal system, including interest.

Seagraves and Ochoa (1978) present optimum solutions and resource values under a different set of prices, and a number of interest rates from 4 to 32 per cent. They also provide an evaluation of the linear programming model.

(c) The Peruvian Water Law and its administration

Article I of the Peruvian Water Law (1969) specifies that all water belongs to the State, that there will be no private property nor any acquired rights in water, and that all authorized uses must be rational and in harmony with the interest of society and the development of the country. Many articles of the law are devoted to specifying procedures for authorizing rational use of water. In effect, all uses must be authorized by the Government and all authorizations must be "rational". Clearly prohibited is any system of granting permanent water rights or the transfer of temporarily assumed rights among users (see chapter III for further examples and general reviews of existing legal instruments). Articles 12 and 18, which pertain to user fees, make no reference to rational use. They specify recovery of the Government's cost of producing and distributing the water based on volumetric measures and fees per unit, which can vary for different uses. Also, the Government can both subsidize and tax the development and use of ground water.

As pointed out in chapter III, water laws are statements of ideals in regulating behaviour in relation to the development and management of water. Many tend to be simplistic. The Peruvian Water Law is no exception. The ideals it establishes are rational use and cost recovery. Both of these goals require measurement of water used and diverted. At the same time the Government wisely permits a variety of systems that fall short of these ideals but which may optimally meet the needs of the individual valleys.

Cost recovery. In Peru, as in most countries, the approach to pricing water simply is that of a service fee or cost recovery. Peru has two types of fees for irrigation water: national tariffs (tarifas) and local fees (cuotas). The tariffs are low and typically cover only the costs of administration, operation and maintenance provided by the Ministry of Agriculture through its irrigation districts (Distritos de Riego). Local fees are levied by the local user committees (Juntas de Usuarios) to pay for their investments, canal cleaning and flood protection projects. As of 1975, the national Government was not trying to recover from the users the capital costs of its large projects, even though this clearly is possible under the law. In 1975 the national tariffs ranged from $0.08 to $0.80 per 1000 m3 or $0.008 to $0.080 per ha-cm.

Estimates of water use and delivery to each farm. The value of water varies a great deal from valley to valley, and careful rationing exists only when and where water is limited and therefore has high value. In most valleys where water is scarce, it is measured by proportional division of variable river flows among canals and the allocation of a certain number of minutes per irrigation cycle to each farm. A few valleys have water flow regulations with storage reservoirs and measuring devices that permit control and determination of flows and volumes. However, according to the national water law, fees must be based on estimates of water delivered in a particular year. Normally, these annual estimates are based on the expected water requirements of each crop and a specific cropping pattern on the number of hectares devoted to each crop that are reported by each farm. That is, the national user fees are normally land taxes that vary from crop to crop.

At this point, it should be added that present engineering practice is to estimate net water requirement (consumptive use plus leading requirements plus miscellaneous requirements minus water stored in the soil minus effective rainfall) on the basis of the procedure referred to in section B of this chapter. Then adjustments are made for conveyance losses and operational losses by applying the appropriate irrigation efficiency term.

Rational use. Methods currently used to bring about rational use of water are not working. Farmers are required to submit to their irrigation district a list of the crops they wish to plant. The district then establishes a crop and irrigation plan for the valley, taking into account (a) farmers' desires, (b) national crop plans and (c) expected water supplies. Where water is abundant, it may be relatively easy to work out a compromise, but, where water is extremely scarce and valuable and land is idle, there are potential conflicts between (a) and (b) and the "rational" allocation is likely to be simply a perpetuation of the status quo. An administrator in such a district must be tough but fair if he wants to keep his job. He will grant to each farmer the water to which he thinks each is entitled and will ask for a crop plan consistent with the farmer's share. In effect, the administrator is saying, "If you are greedy in preparing your crop plan, I will apply my own scissors to it." These irrigation plans are little more than descriptions of the existing situation, and their effect is to discourage sharp changes in the status quo. The Government has neither sufficient competence nor adequate trained manpower to supervise the accurate determination of diversion requirements and of the actual diversion and use also at the farm level as required by the rational use provisions of the law.

Advantages of the present system. The existing system of distributing and charging for water is simple. When there is plenty of water such that it does not become a limiting factor, it is free (toma libre), and little time or money is spent on supervising canals. When the value of water is high and the flows are highly variable and uncertain, it is logical to distribute water among farms as proportions of the total supply at any given time or minutes of flow, rather than to establish set volumes. In most of the valleys this is done by rotation. When the flows are regulated by a dam, farmers can contract for certain volumes of water, and it may be feasible to measure it fairly accurately. In such cases, it may be reasonable to also charge by volume. This will tend to encourage farmers to buy the quantity of water they need. This is being done in some valleys, although the price charged for the water is far less than its value.

The opportunity to use prices to resolve problems. Economic problems related to water are often stated as requests for political action. Some of the problems which appropriate use of prices could help resolve are: (a) requests for investments or more water without considering the costs; (b) reluctance on the part of farmers and cooperatives to use their wells; (c) requests that water be reallocated to small farmers who have had few water rights in the past; (d) drainage and salinity problems resulting from excessive use of water; (e) and falling water tables. An approach to alleviate these problems is in the use of dual water fees such as those outlined below. The question is whether new economic incentives (pricing schemes created to help solve these recurring requests for public action) will provide benefits greater than the costs of installing and operating them.

Costs to be recovered: Cañete. Before discussing pricing schemes it is necessary to define the capital costs to be recovered and an approach to future inflation. According to the water law, full costs should be recovered, but the law says nothing about what rate of interest to charge or how to treat inflation in amortizing the capital costs of investments. An implementing decree for water fees (Article 19 of the Reglamento de Tarifas y Cuotas, Decreto-Supremo No. 683-72-AG, 1972) specifies that no interest will be charged, straight-line depreciation will be used to calculate the annual capital cost, and that these recoverable costs shall be inflated forward each year. Applying this rule in the case of Cañete suggests that water fees, which should be $0.62 per 1000 m3 (10 ha-cm) without any new investments, would need to be raised to $1.02 per 1000 m3 in order to cover the costs of water with the six new investments (see table 16). Alternative fee structures to recover these capital and operating costs will be discussed below.

(d) Alternative pricing schemes

It is possible to design fee structures that are fair and have the ability to recover a target sum of money each year. Often it is suggested that fees should vary according to location and time. In these examples for Cañete, which have been worked out on the bases of the above discussion, time will refer to seasons of the year and location to the old and new sectors of the valley

Table 16. Data and assumptions used in calculating water fees for Cañete

	Volume of water (million m3)			Costs per unit (dollars per 1000 m3 (ha-cm)			Annual costs (thousands of dollars)		
Area	Aug.-Feb.	March-July	Total	Variable costs b/	Fixed costs c/	Average total d/	Variable costs	Fixed and pumping costs	Total
Future whole valley a/	437	259	696	0.60	0.42	1.02	417.60	205.78	713.88
Present old valley	157	93	250	0.60	0.02	0.62	150.00	5.09	155.00
Difference for new area	280	166	446	0.60	0.62	1.24	267.60	290.78	558.08

Note: Fees are based on linear programming solutions using levels of water exceeded 75 per cent of the time.

a/ Assuming the six investment opportunities were taken.

b/ Assuming the variable costs in the future will equal those now being recovered, namely, local fees of $0.48 per 1000 m3 plus a national tariff of $0.12 per 1000 m3.

c/ Fixed costs without interest (straight-line depreciation) for lagoons, a reservoir and 139 wells, based on the costs of these investments plus the extra cost of pumping 51.126 m3 and amortization of past national projects.

d/ Unit cost times the volume of water.

which enjoy different benefits from the proposed investments. Data needed to make various proportional divisions of costs are presented in table 16, and five alternative fees are summarized in table 17. Only one system, the fifth, is based on estimates of the value of water. The others may be thought of as simple cost allocations. All five systems of fees produce the same revenue per year. The five basic alternatives are:

(1) A single fee for the entire valley;

(2) A separate fee for each sector;

(3) A separate seasonal fee for the entire valley;

(4) Separate fees for each sector and each session;

(5) Dual fees.

The advantage of using a single fee for the entire valley ($1.02 per 1000 m3) are that it is simple.

By assigning a separate fee for each sector, the farmers in the old valley would pay $0.62 per 1000 m3 (that is, the old fee including past investments), while farmers in the new sector would pay $1.24 per 1000 m3 (that is, the costs of 446 million m3 of new water). After the new investments, the old valley would receive more water than before and have a slightly better seasonal distribution. However, the assumption here is that the users in this sector should pay no more per unit volume than they did before. Basically, the projects benefit the new sectors, and under this system the new users would have to pay the difference (see table 16) until such time as the investments in water have been repaid. It is assumed that rates to both old and new users would increase with inflation. The advantage of this set of fees is that those who benefit pay. The disadvantage is that newly established farms are likely to be carrying heavier financial obligations than are older farms, and therefore the former will be less able to pay water fees than will the latter.

When a separate fee is charged for each season throughout the entire valley, several methods exist for its application:

(a) The simplest system would be to charge nothing during those months when there is normally plenty of water but to charge enough during the period when the supply is limited to recover the desired amount. Assuming that water in the field would be in short supply during the seven months of August through February, and that the volumes and costs are those depicted in table 17, the fees would be as follows: for the low-valued season, no charge; and for the high-valued season, 713.38/437 = $1.64 per 1000 m3;

(b) Another method would be to assign all the fixed costs to high-valued months. For example, in the low-valued season, variable costs would equal $0.60 per 1000 m3, and during the high-valued season, variable costs plus fixed costs, /437 ($0.60) + $295.78/ ÷ 437 = $1.28 per 1000 m3;

Table 17. Summary of alternative systems of water fees for collecting the same annual sum in the "future" valley of Cañete

(Dollars per 1 000 m^3 (10 ha-cm))

Systems	Low-valued season	High-valued season
Single fee for whole valley	1.02	1.02
Separate fees for each sector		
Old valley	0.62	0.62
New valley	1.24	1.24
Separate fees for each season, based on		
Zero in low-valued season	-	1.64
Fixed costs to high-valued season	0.60	1.28
Using linear programming proportions	0.20	1.52
Separate fees for sectors and seasons		
Old valley	0.12	0.92
New valley	0.26	1.84
Dual fees		
(a) Zero in low-valued season		
Flat charge for all water	-	-
Additional charge above basic allotment a/	-	5.58
(b) Fixed costs to high-valued season		
Flat charge for all water	0.60	0.60
Additional charge above basic allotment a/	-	4.98

Note: Assuming that amount of water is available 75 per cent or more of the time.

a/ The basic allotment is the optimum amount of water used, less the amount on which the marginal value of water is charged. The amount of water diverted times the charge is equal to the total annual cost of water (see discussion of dual fees in the text).

(c) One way to divide costs among seasons would be to use the shares of the total value of water that pertain to each season from the linear programming. The proportion of the value of water that pertains to the seven months, August through February, is 0.925 and that for March through July is 0.075. For example, in the low-valued season, 0.075 (713.38)/259 = $0.20 per 1000 m3; while for the high-valued season, 0.925 (713.38)/437 = $1.52 per 1000 m3).

Seasonal water fees have the economic advantage of encouraging users to save water when it is in short supply, and these simple fees give users in each sector the same impetus to save water.

The simplest proposal, (a), has a seasonal fee of zero when water is abundant and a single charge when it is limited. The zero charge would end the pretense of estimating water volumes during the periods when farmers are actually free to utilize as much water as they want.

In order to calculate separate fees for sectors and seasons we can use the proportions from item (c) for seasons and allocate "present" cost to the old sector and the "difference" to the new sector (see table 16). For the old sector in the low-valued season, 0.075(155.00)/93 = $0.12 per 1000 m3, while in the high-valued season, 0.925(155.00)/157 = $0.92 per 1000 m3. For the new sector in the low-valued season, 0.075(558.38)/166 = $0.26 per 1000 m3; while in the high-valued season, 0.925(558.38)/280 = $1.84 per 1000 m3.

The above fees would be quite simple to calculate and apply. They have certain advantages which are of a political and economic nature. These fees are politically acceptable because of the division of cost among sectors, and economically they stimulate a degree of respect for the higher value of water in the short season.

A system of dual fees would have a low "flat fee" for all water and a seasonally variable "marginal fee" for any water requested in excess of each farmer's "basic allotment" (see table 17). Marginal fees should reflect the marginal value of water. In this case, it was assumed to be equal to the estimate from linear programming for the high-valued season. Two alternative systems of calculating dual fees are illustrated below:

(a) In the first, no flat fee would be charged. The marginal fee in the low-valued season would also be zero and then the marginal fee in the high-valued season would be set at the estimated value of the water, $5.58 per 1000 m3. This estimate is the weighted average value for August through February, taken from the linear programming solution shown in table 15. Simpler estimating procedures could serve just as well. In order to recover only the target sum of $713.38 thousand per year (table 16), this marginal fee should only be applied to a volume of 127 million m3 per year ($713.38 thousand/$5.58 per 1000 m3). This is 29 per cent of the water delivered during the seven high-valued months, indicating that the basic allotment would be 71 per cent of this amount of water, or 311 million m3;

(b) In the second, variable costs, \$0.60 per 1000 m3, would be used as the flat fee for all water in both seasons. When charged against the 696 million m3 used in the entire valley, this fee would cover total variable costs of \$417.60 thousand (table 16). The additional fee in the low-valued season would be zero and in the high-valued season \$4.98 (\$5.58 minus \$0.60) per 1000 m3. Fixed costs (from table 16) are divided by this marginal fee to estimate the quantity of water that would be subject to the marginal fee, \$295.78/\$4.98 = 59 million m3.

If the fixed costs to be recovered in each sector differed, it would be necessary to estimate separate basic allotments for each. If these marginal fees caused sizable reductions in the use of water (that is, below the levels expected), it would be necessary to reduce basic allotments or marginal fees, or both.

Evaluation of dual fees. The main advantage of marginal fees is that they convey a proper message to producers regarding more efficient use of water. Redistribution in favour of particular groups or sectors can be handled through the basic allotments. Systems of dual fees can be used to accomplish the following:

(a) Create a mechanism, for times of extreme shortage, to ration extra water to the farmers with the greatest demands. These demands will be reflected by their willingness to pay for marginal water;

(b) Create a mechanism to restrict excessive use of water where it causes problems of drainage and salinity or where it is clear that excessive use is reducing yields. Studies should be undertaken to determine the social costs of these externalities;

(c) Give the owners of some wells an incentive to use them more through differentiated tariffs for ground and surface sources. Small basic allotments of surface water and high marginal tariffs for additional surface water would be one way to do this;

(d) Give the owners of other wells with falling water tables incentives to use them less. High marginal tariffs, representing the social cost of excessive use, could be charged for water withdrawn in excess of basic ground-water allotments;

(e) Use water saved as a result of the incentives indicated above to irrigate more land.

Factors which could pose problems in the application of dual fees include the following:

(a) The requirement that the Government define rational use of water and assign it to the farmers. Since the water law makes this a public responsibility, many administrators refuse to recognize officially any system that allows the farmer freedom to choose the quantity of water he wants, or simply small changes in the allocation;

(b) Uncertain flows of water. When flows vary greatly and are uncertain there is a tendency to divide the water proportionally in terms of minutes rather than volume and to allocate all the minutes. Assignment of "additional minutes" could be annual, monthly, or per irrigation, depending on the needs of the valley, but in any case it involves setting aside some minutes and then allocating them. It is more complicated than reading a water meter. Giving more water to one farmer probably affects the scheduled time at which all other farmers receive their allotments;

(c) Low values and poor measurements of the water. In many valleys the water is not measured with accuracy simply because it has not been economical to do so.

It might seem that one further disadvantage of dual fees is that they require explicit water allotments and an unlikely degree of vigilance and honesty on the part of the public employees involved.

(e) Conclusions

The Peruvian Water Law declares that all water belongs to the State, that the State is responsible for assigning it rationally to users, and that user fees should be levied on measured volumes of delivered water so as to recover all the costs of water to the Government. The concept of full cost recovery is appreciated in economic analysis. However, as discussed in great detail in this chapter and also in chapter II, the main interest lies in using prices to achieve efficient use. Special pricing schemes, such as seasonal prices, and almost always use of measured volumes, are recommended. In actual practice, irrigation water is highly subsidized, the collection of the fee has little relation to the amount of water used, and it is often uneconomic to measure it volumetrically.

For effective instrumentation, water laws should be based on an economic rationale which, in turn, should be based on the agronomic and engineer factors and constraints. However, applying these complex relations to workable legislation is not a simple matter. First, flows tend to be highly variable and uncertain. The effects of these are reduced by regulatory reservoirs. Such variability in flows lead to the proportional rationing of water when it is scarce rather than promises to deliver certain volumes at specified times. Variable flows also help to explain a tendency to be conservative in assigning prices so as not to discourage use when flows happen to be abundant.

Secondly, most irrigation projects involve large fixed investments with long lives, are associated with the opening up of new land, and tend to be influenced by a variety of political, as opposed to economic, considerations. Finally, subsidies can be explained partly in terms of the multiplicity of interrelated objectives of irrigation projects, which often are resolved on the basis of trade-offs among the economic and political goals.

With respect to Peru, two tentative conclusions can be drawn: (a) it would be worthwhile to begin a modest programme of recovering the capital costs of irrigation projects that actually charge according to the formula specified by current regulations disregarding interest but charging depreciation inflated forward and (b) volumetric measures should be stressed only where water has a high value and flows are metered and where proportional allocations can be accepted as a way to ration water and charge for it where flows are highly variable.

Seasonal fees appear to be warranted in Cañete as well as in many other Peruvian coastal valleys. Estimates of seasonal water values could be useful in setting fees when such estimates exist. In valleys having extremely high values for water and cost recovery rates, dual fees may be applicable. Seasonal fees could provide an easy transition to dual fees in the future. Dual fees have the added advantage of providing a way to recover different proportions of capital cost from different areas.

F. Conclusions and suggestions regarding irrigation water pricing

Regulations and prices of any type, including systems of quotas and marginal prices for irrigation water, reflect conflicting goals: (a) the need to encourage efficient use of water; (b) the desire to redistribute income towards agriculture; (c) the desire to recover capital costs from users; (d) the desire to favour small farmers; and (e) the need to minimize administrative costs. Emphasis has been given to defining the efficiency of irrigation systems and, to a lesser extent, to explaining systems of water rights and government pricing which can be used to redistribute income.

Irrigation efficiency and the combination of regulations and prices used to allocate water depend on the value of water; the dependability of water supplies; systems of delivery to the farms and water-control facilities, and level of on-farm management; desires to subsidize agriculture and needs to recover capital investments from users; and traditions of ownership. Because no one system of allocation can be recommended for all regions or projects within a country, rigid prescription of policies would be inappropriate. Water laws need to allow for a variety of site-specific solutions.

An understanding of systems is needed to spur improvements in net incomes under different circumstances. In general, when the value of water or wage rates are high, irrigation efficiencies are improved and highly structured institutions become worthwhile.

Desires to minimize capital recovery from agriculture or to subsidize it, obscure the possibility of efficiency pricing warranted by the high value of water. One way to combine these dual goals of subsidy and efficiency is to use two or more prices combined in a system of permits or quotas plus "progressive" penalties for exceeding them. Economic efficiency will also be increased if quotas are transferable **or** exchangeable among users or if the State is ready to buy unused quotas.

While numerous variations are possible, two general pricing structures - fixed rate and volumetric rate - are in common practice. Efficient economic allocation requires that the marginal benefits be the same for all users. If efficiency is a goal, administered price systems should assign the same final block rate to all classes of users.

Institutions for the management of water from irrigation canals are affected by the extent to which the flow can be measured and regulated by such means as a reservoir. Since volumetric measurements are costly, they are recommended only when the value of water is high enough and the flow can be regulated.

When flows are highly valuable and uncertain, it would be appropriate to allocate shares of the water rather than volumes to individual farms. A proportion of the river flow is diverted to a canal and a definite share of this diversion is allocated to each farmer. Shares, or the number of minutes that a farmer will receive water may be known very well, while the volume that will arrive remains subject to the variability and uncertainty that pertains to the canal diversion itself. Under such situations, farmers might be permitted to buy shares or minutes of water from one another or from the Government. The allocation of water among users would be efficient under such a system. That is, all farmers could approach the same marginal use value of a share.

"Equity" refers to fair distribution of income among farmers and also between agriculture and other sectors. What is "equitable" depends on who is talking or who is in control. It is possible for Governments that own the water to design prices and regulations which could reflect the desired level of trade-offs between equity and efficiency and thus contribute to both equity and efficiency. Equity may be handled through the assignment of basic water quotas among farmers and by the choice of base fees for these quotas. Efficiency is achieved by charging all the users along a canal the same marginal price for additional water. This is the inverse of the usual situation where prices are used for capital recovery (income redistribution) and regulations are used to mandate efficiency.

Following are some suggestions regarding irrigation water pricing and regulations:

(a) The selection of a system appropriate for regulating and/or pricing irrigation water will depend on a number of its characteristics. At any one site, the job can usually be done by several different methods. Important factors affecting institutional choices include the value of water, the variability and uncertainty of stream flows, the ability to control and ensure flow, the extent to which irrigation is subsidized, the extent to which inefficient use is a problem, the number of farmers, the level of knowledge and experience within a country, present institutional arrangements and the like;

(b) As a general rule, it is desirable to base administered water prices on the marginal cost of acquiring more water, or on its value in alternative uses. However, it is often contended that such prices, based on marginal costs, would lay a heavy burden on the farmers. An alternative system uses low-priced quotas plus high marginal charges for purchasing more than one's quota and rebates for using less than quotas. This may be practical particularly when conjunctive use of surface and ground water is intended;

(c) It often is desirable to increase local and regional responsibility for water resource development, operation and financing. At the same time, it is necessary to understand why national subsidies are common and tend to persist. A variety of water values over time may cause underpricing in some cases;

(d) Seasonal pricing is practical under certain circumstances. High prices could be used to ration water during periods of peak demand;

(e) It may be desirable to use a system of shares, measured as certain proportions of the flow for given time periods, as an alternative to the use of volumetric measures to allocate irrigation water. Volumetric measurements would be feasible when water was limited in availability and had high value. There is little evidence that farmers who have free but limited rights to valuable water will be any more wasteful of their water than will those who pay for water usage. However, optimum allocation by shares or by volumetric measurements among farms will be more likely to result if shares are transferable;

(f) Charges for water can be designed to include the cost of drainage, so as to give farmers an incentive to reduce excessive irrigation and thereby minimizing the risk of water logging and salinity build-up while at the same time improving irrigation efficiency;

(g) Prices and quotas should not only encourage efficient allocation of water over time (by providing incentives for the construction and use of storage) but should also contribute to efficient allocation among farmers, among regions, and between agricultural and non-agricultural uses. As discussed above in section G, in the case of Peru a system of quotas based on extensive margin or on historical usage may be feasible. In order to achieve the desired goals, quotas should be transferable and, conversely, users should be allowed to purchase more than their quota from the irrigation authority.

CHAPTER V

WATER AND WASTE CHARGES TO HOUSEHOLDS AND INDUSTRIES

A. General principles and practices

Households and industries often buy combined water and sewer services from one entity, usually a municipality, a national water company or a privately owned utility. These sellers will be called "cities" for short. Cities usually must break even over time, or set fees so that revenues equal costs. Since it is relatively more expensive and difficult to measure wastes, most cities simply combine charges for sewerage services with the charges for water supply. That is, the structure of the combined water and sewage charges are generally dependent on the structure of the water charges. When charges are volumetric, metering and billing is probably the main joint cost. This is the main reason for the frequent combination of these enterprises in one city department.

Generally speaking, cities adopt extremely simple pricing schemes and are reluctant to make changes. More complex pricing schemes, such as peak demand pricing, interruptable service contracts and waste strength charges are adopted only when the benefits of doing so become obvious. Such schemes tend to be tried first by cities where they are most needed and are applied first to large industrial or institutional customers where the monitoring and administrative costs are small compared to their water and sewer bills. Without repeating the ideas on public utility pricing outlined in chapter I, the basic principles governing different types of water and sewer charges will be reviewed in section A of this chapter. Section B gives a review of actual practices in several countries, including a discussion of (a) water and sewer pricing in the United States of America; (b) the water supply tarrif in Bangkok; and (c) recommendations of the United Nations Habitat and Water Conferences regarding community water supply and sanitation. Section C offers some over-all suggestions regarding water and waste charges to households and industries.

1. Factors affecting urban water use

Water use for households and industries are part of total urban water consumption, which can be considered as the sum of water use in four sectors: residential, industrial, commercial and public. There may be some overlap among these sectors.

Urban water use is influenced by many variables. Table 18 provides a summary of explanatory variables, many of which are considered in the physical design of waterworks, and some, in formulating policy to operate the works. It is most important to note that in terms of policies, usually three of these explanatory variables can be manipulated and used by water authorities to achieve mandated goals, which in present practice, generally include cost recovery, equity and efficiency.

Table 18. Main explanatory and policy variables of water use for each urban sector

Explanatory variable	Sector				Main water policy variables
	Residential	Commercial	Industrial	Public	
Population	x	x		x	
Housing classification	x				
Property values	x				
Technology	x	x	x	x	
Income	x	x			
Economic activity		x	x		
Politics			x	x	
Attitudes (expectations)				x	
Price (revenue)	x	x	x		x
Metering	x	x			x
Restrictions	x	x	x	x	x
Climate	x			x	

Source: D.R. Gallagher and R.W. Robinson, 1977, as modified by the United Nations Secretariat.

The main policy variables include price, metering and regulations. At this point it should be observed that the physical design of the water storage and distribution system should take into account the factors indicated to the extent that their effect can be estimated. At the same time, operating rules based on alternative sets of values of the policy variables should be analysed and incorporated in order to achieve allocative efficiency.

2. Users pay costs of service

Economists who have written about efficient pricing of water are generally optimistic about sales of water to households and industries. Hanke and Davis (1973) identify municipal water service as one of the few promising areas where water resources are or can be priced so as to lead to economic efficiency in water use. The main reason for optimism is that these services have not been heavily subsidized in the past. Since the users are paying for the water, they occasionally exert themselves to keep the system efficient and the charges reasonable. In addition, customers are usually free to buy whatever quantity they want. Persons not willing to pay for the service could more readily be excluded from its benefits.

Some municipalities still have wholly or partially unmetered water systems and charge their consumers a flat rate per month. Under these circumstances the consumers are not given the incentive to balance the value that they derive from incremental water use against its cost. The practice of offering unmetered water should be abandoned in those cases in which transaction costs of metering are less than the possible gains in efficiency, as will be explained in section 4, below.

Where meters exist, average cost pricing is the most widely used policy. As pointed out in section B of chapter II, the shortcoming of this policy is that the average historical costs to which prices are not generally equal to the marginal cost. Prices should be equated to the relevant marginal costs, not the average costs. Ways of approximating prices to marginal costs are stressed here.

The "user pays" idea, which is widely accepted in the production and sale of both electricity and water to metered households and industries, is much more important than whether average (historic) or marginal (present or future) costs are used in calculating the average of all charges that customers pay (Coase, 1970). The fact that users pay, forces both users and administrators to become interested in all of the basic principles that will be defined in this section: 5/

(a) The effect of price on consumption;
(b) The benefits and costs of metering;
(c) Block rates;
(d) Capacity and service charges;
(e) Interruptable service contracts;
(f) Acreage, distance and connexion fees;
(g) Peak-demand pricing; and
(h) Waste strength charges.

3. Prices do have an effect on consumption

Since price is one of the most important policy instruments available to a water authority, knowledge of a demand relationship, the related price elasticity (if site-specific estimates exist) and other similar parameters is highly desirable. The demand curve is an expression of the quantity of water demanded per unit of time in response to the price per unit of water, and other variables such as the price of substitute products, level of income and number of persons per residence. The elementary law of demand indicates that other things held at a constant level, quantity demanded will vary inversely with price. That is to say that a greater quantity will be demanded if the price is low, and vice versa.

5/ See chapter I, above, for discussion of the basic economic rationale.

Other factors kept constant, the presentation in figure IV illustrates the horizontal addition of simple linear individual demand curves, d1, d2 ... to obtain the total curve, D. Besides showing the quantities that will be bought at each price, q1 + q2 + ... = Q, demand curves also show the total marginal benefits consumers would realize if they were given one additional unit when they already had q1, q2 ... . That is, the intercept value of the bars at q1, q2 ... and Q indicate the value of one more unit, say in dollars per unit. In other words, there is a price, P, at which all units of quantity, Q, will be bought, and this price reflects the marginal benefits or value of an additional unit (for additional details see chapter I).

(a) Comparison of per capita consumption in three countries

Studies on the influence of metering on domestic (in-house) use show that substantial reductions in the quantity of water use are possible. Table 19, which presents a summary of data from the western United States, substantiates this position. The table also leads to other inferences with important policy implications for the management and administration of domestic water.

According to the time-series studies carried out in Boulder, Colorado, a reduction of 36 per cent in the average domestic water use was attained when metered rates were used. In this particular case domestic water use was reduced from the very high level of 1,160 litres per day to 748 litres per day. The next set of data in the table from 18 municipalities, all from the western United States, shows a 34 per cent reduction in total domestic uses in metered areas and a 56 per cent reduction in water use for sprinkling. This study did not find differences in household (in-house) uses between the two areas. Similarly, cross-sectional studies made in Toronto and Tel Aviv show that non-metered (flat-rate) use could be about 25 per cent more over a year than use in metered single dwelling units. It should be noted that the latter study is based on the comparison of water use when whole buildings were metered as opposed to installing meters in individual apartments.

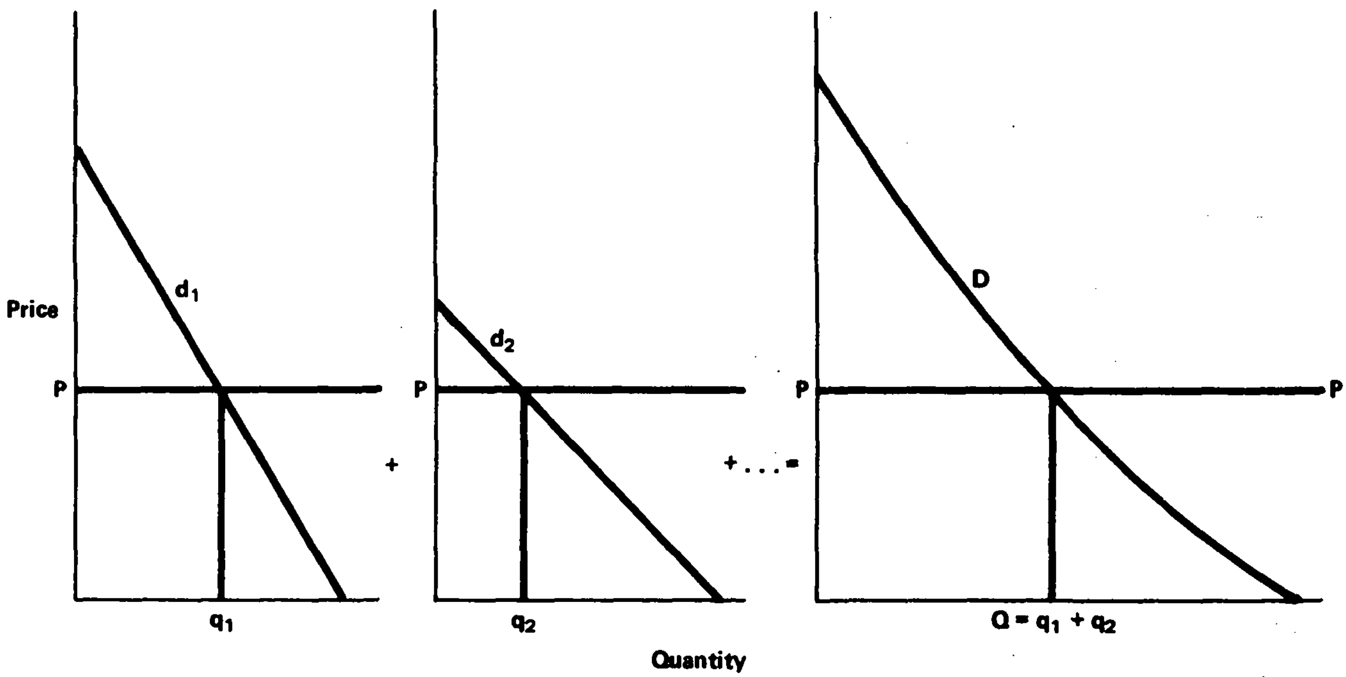

Figure IV. Horizontal summation of individual demand curves and marginal benefits

Table 19. Annual average per capita domestic (in-house) water use for metered rate and non-metered (flat) rate areas

Location	Metered rate (litres per day (gpd)) a/	Non-metered rate (litres per day (gpd)) a/	Per cent differences	Nature of study	Reference
Boulder, Colorado	748 (197)	1,160 (307)	36	Time-series	Hanke (1970)
18 municipal agencies, United States of America					
Leakage and waste	94 (25)	136 (36)	31	Cross-sectional and time-series	Howe and Linaweaver (1967)
Household	937 (247)	892 (236)			
Sprinkling	703 (186)	1588 (420)	56	(10 metered, 8 non-metered municipalities)	
Total	1731 (458)	2616 (692)	34		
Maximum day	3700 (979)	8898 (2,354)	58		
Peak hour	9378 (2,481)	19580 (5170)	52		
Toronto					
Winter	581 (154)	771 (204)	32	Cross-sectional	Grima (1973)
Summer	719 (190)	836 (221)	16		
Average	650 (172)	815 (216)	25		
Tel Aviv	197 (52)	237 (63)	24	Cross-sectional b/	Kamen and Dar (1973)

a/ gpd = gallons per day.

b/ Metering of individual apartments compared to metering whole building.

Another important inference that can be drawn from the table is that there are large differences in the patterns of domestic water use. Even though there may be differences in climate and policy variables in these cases, including housing classifications and residential property values (level of income), it appears that the differences are too large to be explained by such variables. On the average, the quantity of metered water used for household purposes in municipalities in the United States of America and Canada were respectively 4.8 and 3.3 times that used in Tel Aviv.

The application of policy variables, including regulations, in allocation and public education, together with metering and higher levels of pricing was an important factor in explaining the differences in the levels of conservation of water. The water law in Israel specifically prohibits waste by requiring every consumer to install meters. It grants authority to a government agency to set norms of 80 cubic meters per capita per year (220 litres per day (lpd)) for domestic and municipal use. This, in turn, provides the basis for production licenses. Metering is mandatory, and bi-monthly readings give warning of excessive consumption, enabling the Government to achieve close control of water allocation. The law establishes penalties, including cancellation of a license, for waste. The collection of special payments which could be viewed as fines was found more effective than very severe restrictions. The study made in Canada also permits comparison of seasonal differences. Metered dwellings had a modest "peak" between winter average use and summer average use of 24 per cent. The United States study also reveals comparable differences.

Another equally important inference from the study by Howe and Linaweaver (1967) has implications for system design. As can be seen from table 19, average maximum day and peak-hour water demands were reduced from 8,898 lpd to 3,700 lpd and from 19,580 lpd to 9,378 lpd, which represented a 58 and 52 per cent reduction respectively, when metered rates were used. The peak demand values are critical considerations in determining system capacities and, therefore, the size of system investments.

(b) Some observed elasticities

Many studies have confirmed the negative slope of demand curves for residential water and have estimated price and income elasticities, which are percentage changes in quantities consumed divided by percentage changes in price or income. Table 20 lists the authors of 8 recent studies of residential water demand and some of their findings concerning price and income elasticities. All of the elasticities have the expected sign, and in most cases, they are significantly different from zero. In order to apply elasticities estimated in one situation to another situation, a person should understand the two situations and ascertain whether or not they are similar in terms of factors affecting the elasticities. The numbers in the table are intended to serve as examples and should not be adopted unless the above pre-condition is met.

Table 20. Price and income elasticities for household water demand from eight studies

Authors and identification of equation	Price elasticity	Income elasticity a/
Howe and Linaweaver (1967) United States of America:		
Total residential demand	- .40	
Sprinkling demand, east	-1.57	1.45
Sprinkling demand, west	- .70	.43
In-house demand	- .23	.32
North and Ware (1968) Georgia	- .61 to - .67	.36 to .83
Grima (1972) Eastern Canada, summer	-1.07	.51
Wong (1972) Northeastern Illinois:		
Time series	- .02 to - .28	.20 to .26
Cross sectional	- .26 to - .82	.48 to 1.03
Hollman and Primeaux (1973) Mississippi	- .37 to - .45	.24 to .54
Attanassi and others (1975) Puerto Rico	- .81	.15
Danielson (1977) Raleigh, North Carolina:		
Sprinkling demand	-1.67	.37
Winter (household) demand	- .25	.69
Gallagher and Robinson (1977)		
Australia, winter	- .36	.42

a/ Property values were often used as a proxy for family income.

One application of elasticities is predicting the effect of a price change. For example, Howe and Linaweaver's (1976) over-all estimate of -.40 means that a 10 per cent increase in price would be expected to result in a 4 per cent reduction in water use (in average circumstances in the United States of America). One might also use their results to predict effects of price changes for winter and summer, and for the east and the west in summer.

Table 21 indicates that average per capita water use was influenced by marginal prices (compare regions 3, 4 and 5 with regions 1 and 2).

The effect of price rises on the market share of any commodity will depend on the nature of the commodity, the extent of the price rise and the alternatives available to the consumer. In the case of domestic public utilities, such as water, gas and electricity, a rise in price may be followed by (and is often intended to lead to) a decline in consumption of the commodity, with no necessary rise in the consumption of a substitute. This is especially true in the case of utilities, such as water, other than for drinking, where substitutes for most applications are not readily available. On the other hand, after some point the relative absence of substitutes may make the demand for domestic water less responsive to changes in price level.

Table 21. Influence of metering, marginal prices and property value on domestic water use in Canada

Region	Marginal price (cents per 1 000 litres)	Average *per capita* observed daily use		Average of market value of property a/ (dollars)
		Litres	Gallons	
1	10.32	183.7	48.6	24 520
2	10.32	362.3	95.9	117 720
3	18.85	119.1	31.5	27 950
4	18.25	136.4	36.1	63 750
5	21.16	129.6	34.3	354 000

Source: A. P. Grima, 1973.

a/ Proxy for level of *per capita* income.

4. Metering water supplies

(a) Metering and pricing

As pointed out in the preceding section, metering is one of the policy variables a water authority could use. However, it must be recognized that the installation of meters in and of itself does not guarantee efficient use of water. Metering policy must be considered in conjunction with pricing policy. Before recommending metering of any sort, be it partial or universal, studies must be conducted to determine its full impact, including an assessment of the nature and extent of changes in the pricing structure.

As shown in figure V, metering with a per unit pricing on water supplies induces savings in water, which often may lead to economic efficiency in use of water. Another important inference from the time-series analysis is that the influence of metering could be a one-time stepwise lowering of water use. The study by Hanke (1970) substantiated this position in that household demand showed a one-over structural change of a 36 per cent reduction. As shown in the table 22 sprinkler demand also declined with metered rates. The results obtained by Hanke (1970), which have been averaged by Gallagher and Robinson (1977) for purposes of exposition, show a lower intercept value under the meter rate system as compared to the flat-rate system. Note that the slopes are identical (statistically not different). This implies that the growth pattern before and after metering remained unaltered.

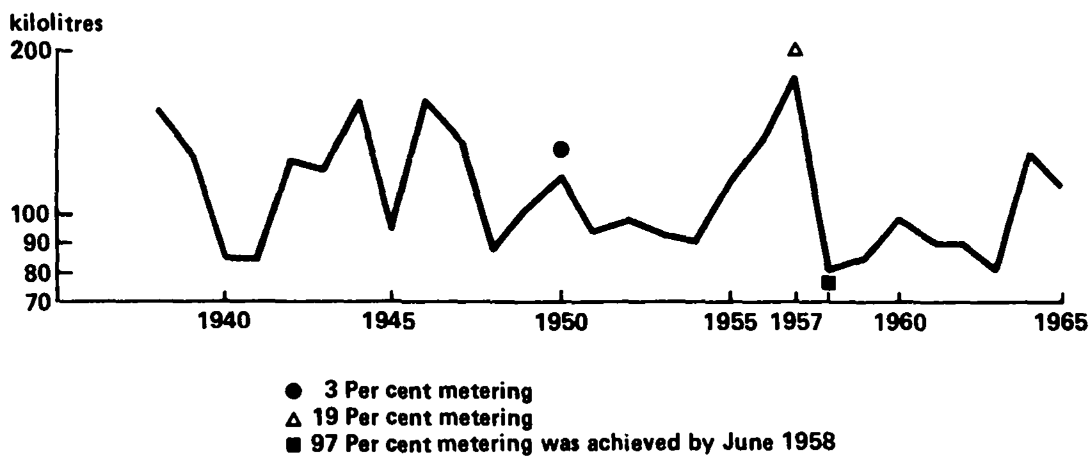

Figure V. Semi log graph of Nowra per capita Non-industrial water consumption

Source: D. R. Gallagher and R. W. Robinson, *Influence of Metering, Pricing Policies and Incentives on Water Use Efficiency,* Australian Water Resources Council Technical Report No. 19 (Canberra, Australian Government Publishing Service, 1977).

Table 22. Comparison of metered and non-metered systems - sprinkling demand

System	Intercept/dwelling unit (thousands of gallons)	Slope coefficient
Flat rate	8.25	0.69
Metered rate	0.99	0.69

Source: S. H. Hanke, 1970.

An examination of non-industrial (household) water use data from Australia also lends support to the fact that metering by itself need not have any effect (see figure V). However, it should be noted that changes in other variables such as population and level of income have a bearing in setting trends. The near universal metering of 97 per cent in 1958 achieved great short-run reductions but consumption rose back up in a relatively short period, resuming the long-run trend.

(b) Evaluation of benefits and costs of metering

The costs of metering are fairly easy to estimate. They include capital costs (interest on investment, depreciation and repairs of the meter) plus operating costs (the cost of reading and maintenance, billing and meter rules). Studies by the World Bank (1974 and 1976) carried out in Lahore (Pakistan) and Bangkok (Thailand) found the costs of metering to be surprisingly high. Methods of estimating benefits are more controversial. The approach used in the Lahore study and recommended here is to estimate the net social benefits of metering. Assume metering is used and that the price per cubic meter of water is set equal to the marginal cost (value of additional water, as in fig. VI). At the price OP, consumers will take the quantity OQ. The benefits of this much water are indicated by the area OTRQ. If metering is not used, the effective cost (price) of additional water to consumers will be zero, and presumably they will use Q*. At this point their total benefits will be represented by the triangular area OTQ*. That is, the benefits of the additional water to the consumers is represented by the area of the triangle QRQ*.

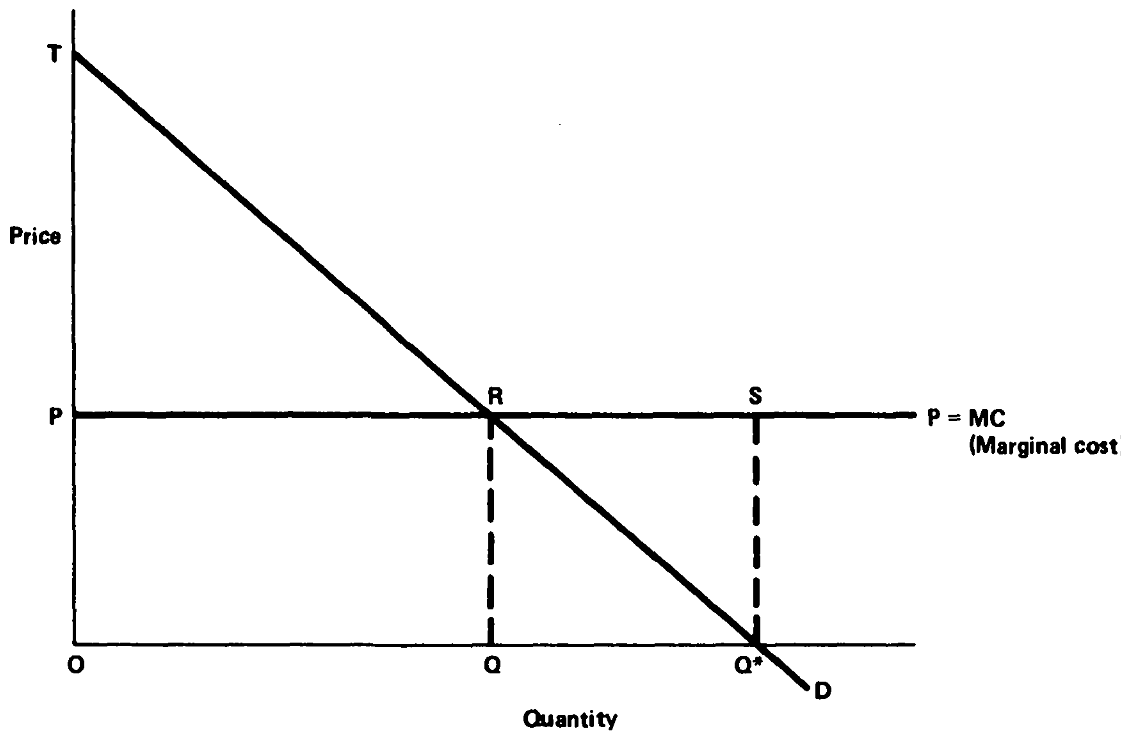

Figure VI. Social benefits from metering and volumetric charges

What then are the benefits of metering? Metering and billing for water at a price OP reduces consumption (and production) from Q* to Q. If OP represents the marginal cost of this reduced consumption or the value of the water elsewhere, then metering and billing can be said to have two effects: (1) it saves resources worth Q*ARS; and (2) it reduces the benefits of consumers by an amount represented by the area Q*QR. The net saving is represented by the social cost triangle, RSQ*. Thus, the net benefits from metering and charging what water is worth are approximately equal to one half of the value of the water saved by instituting volumetric charges.

One can also add a third point: metering could allow reduction in investment costs because its installation and operation are essential to peak demand pricing, which would make possible the reduction in peaks or design capacities.

There are some minor benefits and costs which are harder to quantify. The predicted consumption of a given geographic area may be less with metering than without. This means smaller pipes may be used to distribute water to that area. Also, metering will reduce careless wastage of water. Table 19 and the Boulder, Colorado study cited therein documented a large amount of needless irrigation by unmetered residential customers. More rapid detection of leaks in the distribution system and less costly repair might be another benefit of metering. Still another is the matter of fairness to all customers, large or small, when metering is feasible. One cost of metering which is sometimes overlooked is the extra pumping cost associated with loss in head due to the meters.

5. Price policy alternatives

There is a wide range of price structures from which choices can be made. Block rates (declining and increasing); capacity and service charges; interruptible service charges; size, distance and connexion fees; and peak demand pricing are discussed below. These measures and the principles underlying them are applicable to industrial, household, commercial and public uses.

(a) Block rates

Block rates apply only to the quantity within a range. For example, one rate might apply to the block from 0-10 m^3 per month; another rate applies to the next block - for example, 10-50 m^3; and still another rate to the next - for example, greater than 50 m^3. If one wants to increase or decrease rates with volume sold per customer, then this is a natural way to do it (see figures VII and VIII). Block rates are marginal rates. They cause less distortion in consumption than average rates, quantity discounts, or schedules that lower the rate for all units after consumption exceeds a certain level.

Most water and sewer services are sold on block-rate schedules. In the developing countries, increasing or progressive block rates are common. Increasing block tariffs have been adopted by 21 of the 36 developing countries in the studies that have been borrowed from the World Bank on water supply (see for example, the suggested rate schedules for Bangkok given in section 2 below). In Peru both water and electricity are sold on this basis. Small customers are favoured and the rationale is clearly income redistribution. Declining block rate schedules have been common in the United States of America. As an example, the schedule for Raleigh, North Carolina is presented in table 23.

To a great extent, the developing countries have been receptive to the use of increasing block rates, a practice that could be useful to the larger cities in industrialized countries. Three factors have helped shape the rate-making philosophy of water utilities in developing countries: the narrow revenue base, the rapidly growing demand and the resulting necessity to explore alternative service levels. Finance is normally the primary concern, but extension of service to the poor and avoidance of wasteful consumption tend to command a greater priority than in more affluent societies. The authors note that water-rate policy in the developed countries might follow the example set in the developing world.

The use of increasing block tariffs does not by itself imply anything about marginal costs. In some countries even the highest consumption block is priced well below incremental supply costs. In addition, public water authorities generally do not permit pricing distinctions between consumers on the basis of incremental costs for which they are responsible. The failure to recognize the burden placed on system costs by peak season water consumption is an example.

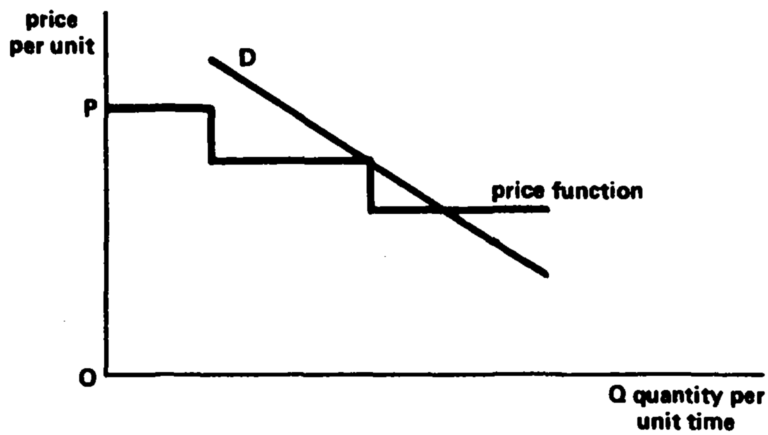

Figure VII. Declining block pricing

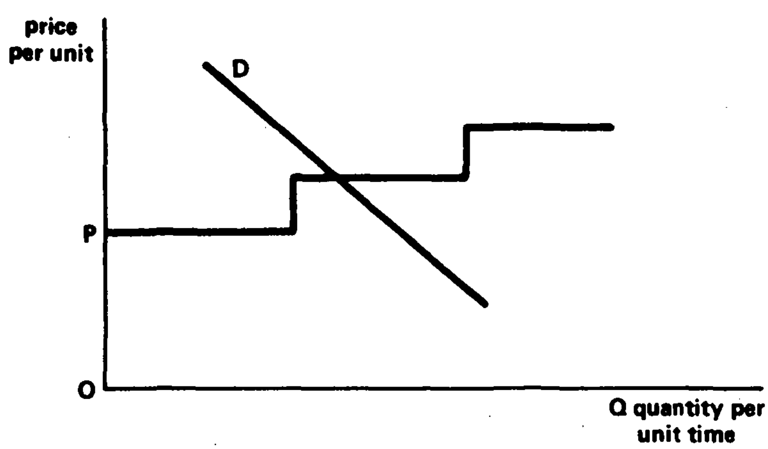

Figure VIII. Incremental block pricing

(b) Capacity and service charges

Many water utilities levy a fixed charge which is determined by the size of the pipe or the water meter. The reasoning behind these charges is that the capacity of the system is rarely used and extremely costly. Users could pay for system capacity in proportion to the capacity of the system used in delivering water to them. A fixed capacity charge would have little effect on actual water usage during periods of peak demand. For this reason economists often prefer peak-demand charges to capacity charges. Peak demand charges have the effect of limiting usage at critical times and hence cause a larger reduction in the required capacity than do capacity charges.

Apart from the capacity to deliver water, it will often be appropriate to levy fixed fees per month to cover the costs of reading meters and billing. These costs are virtually constant regardless of the size of the meter or the quantity of water consumed. However, if certain users demonstrate a stable usage pattern, then longer periods between meter readings and lower flat-rate charges are practical and may be justified. Fixed charges per month for service also may be rational when there is no metering and the water itself is practically free.

A capacity charge need not be the same as a minimum charge per month based on meter sizes. An example of the latter is given in table 23 for Raleigh, North Carolina. Such minimum charges per month permit additional water to be provided free of charge to those who are paying the minimum. A fixed capacity charge could accompany a set of volumetric charges based on the entire metered amount. One way of viewing Raleigh's water rates is that the minimum charge represents both a constant cost per month for meter reading and billing plus a capacity charge. Then the volumetric charges are zero up to the minimum, thereby giving the small customers a small advantage.

(c) Interruptable service contracts

Some electric utilities make concessions to large customers who agree to a termination over a specified time period or to a reduction of service during crises. In return the utility reduces the rates to be paid. It would be practical to write such contracts in the case of water and sewer services as well. If cities use these contracts they can reduce reserve capacity for emergencies. Since such contracts reduce capacity requirements, it would be logical to reduce any capacity charges paid by those who sign them. Users electing to sign interruptable service contracts would be those who are least inconvenienced by such reductions in service. Presumably they are the same customers who would make the largest reductions if peak-demand rates were applied. Thus economists view peak-demand rate structures as an alternative to interruptable service contracts. Contracts have the advantage of reducing demand by a definite amount, while peak-demand prices provide added revenue and a clearer indication of how much customers value extra capacity.

Table 23. Water rates for the City of Raleigh, North Carolina, effective 1 July 1977 a/

Volumetric charges		Minimum monthly bills	
Monthly Consumption blocks ($100 ft^3$)	Block rates (dollars per $100 ft^3$)	Meter size (inches)	Minimum charge (dollars per month)
0 - 32	.6369	5/8	$ 2.55
33 - 65	.5968	3/4	5.10
66 - 130	.5431	1	10.19
131 - 265	.4894	1 1/2	25.15
266 - 465	.4157	2	59.08
Over 465	.3821	3	99.84
		4	180.93
		6	306.73
		8	505.42
		10	811.10

a/ Other features of the system:

(1) Advance deposits are required equal to twice the monthly minimum charge for each meter size;

(2) Water users that are also connected to the City sewer system pay the above rate plus a sewer charge of 73 per cent of entire water bill;

(3) Customers using the city sewer system only pay at the rate of $55.80 per year and make an advance deposit of the same amount;

(4) Customers residing outside the corporate limits of the city pay double the above rates. Industrial users of water from the City's water system who reside outside the corporate limits of the City and use more than 250,000 cubic feet of water per month shall be charged at the outside user rates for the first 250,000 cubic feet and shall be charged at the rate of one and one half (1 1/2) the inside rate for all over 250,000;

(5) Industrial users of the City sewer system also pay an industrial waste surcharge for any pounds of BOD and suspended solids in excess of 300 mg/liter at the rate of $0.0741 per lb of BOD and $0.0943 per lb of suspended solids;

(6) At the time water or sewer lines are installed on a street property owners are assessed a charge of $6.02 per front foot for water lines and $5.02 per foot for sewer lines, whether or not they connect to said service;

(7) At the time customers connect to these services they are charged according to lot size, $350 per acre for water and $250 per acre for sewerage; and connection fees of $267 for a 3/4-inch water line and $267 for a 4-inch sewer or $387, if both are done at once.

(d) Lot size, distance and connexion fees

The length of water and sewer main lines to local neighbourhoods is influenced by the size of the lot and its topography and layout. That is, the smaller the lot, the smaller will be the cost of major trunk lines. One-time only fees based on the size of the lot are sometimes charged when people connect to the water and sewer system. Also, cities frequently charge for the linear distance across the front of the lot and charge a connexion or "tap-on" fee. Distance fees represent the cost of local service lines and connexion fees represent the cost of the meter plus the labour and equipment for making the connexion. Distance charges should be assessed against properties even if the owners of those properties do not request water service properties. The rationale is that property owners should pay for the availability of service.

Note that, as indicated in table 23, Raleigh, North Carolina, uses front footage, lot size and connexion fees in addition to industrial waste strength charges, declining block rates and minimum monthly charges. Raleigh does not use distance charges except in the sense that customers outside the city limit pay twice as much for service as those inside. Neither does Raleigh use interruptable service contracts or peak-demand schedules. It is likely that Raleigh could have enjoyed a sizeable saving in the cost of water supply reservoirs in the past if it had used drought pricing, as explained in section (e), below.

It would also be practical to charge larger marginal rates for customers located farther from pumping stations or the center of the city. Such distance or zonal charges could be added to service connexion fees to cover added fixed costs of main lines and to volumetric water and sewer rates in order to recover the extra costs of pumping and maintaining longer lines. Hanke and Davis (1973) offer a number of references to and arguments for such rates. However, constant rates are simpler, and one might find that inner city dwellers are not close to load centres. Also, it is frequently cheaper to run pipe and make connexions for new users in suburban areas than for those in the inner city. Additionally, repairs in the inner city can be much more costly.

(e) Peak-demand pricing

In chapter I, we compared the "requirements" and the demand/supply approaches to water planning. The conventional approach involves extrapolating water storage capacities based on past consumption trends and does not explicitly take price into account. Furthermore, critical periods of demand are used as a basis to estimate the design capacities of the water-supply system. Safety factors are considered in determining the final value of the design capacity. This approach can lead to building reservoirs that are fully used only in extreme droughts since the reservoirs are designed for a single purpose (water supply). Because so little of the water from these reservoirs is used during normal years, they may be an extremely expensive form of insurance. Two ways to estimate the potential savings from using peak-demand pricing are illustrated below. One method was described very well by Hanke and Davis (1971) as follows:

> "The efficient allocation of resources that would be obtained in an open-market competitive economy can be approximated by water utilities if water managers will broaden their range of choice to include ... pricing. The rules are clear: (1) if capacity is not fully utilized, the price should reflect operating costs with no contribution to capacity costs; and (2) if demands exceeds capacity at this price, the price should be adjusted upward to restrain demand to the capacity level. This is to say, if the same type of capacity serves all users, capacity charges should be levied only when capacity is fully utilized, so that these peak users bear the responsibility for defraying capacity costs. When the capacity charges exceed the incremental costs of capacity, investments in capacity are justified, whereas the reverse case would indicate that existing capacity is excessive.
>
> "The application of these rules for a hypothetical utility is illustrated in figure (IX). Curves D1D1' and D2D2' each last for six months and represent off-peak and peak demands, respectively. The constant average cost (AC) pricing line implies that capacity costs are distributed evenly throughout the year. This assumption is consistent with an average cost-pricing policy. The average variable costs (AVC) are assumed to be constant and equal to marginal costs. The incremental costs of expansion are depicted by a proxy, average variable costs plus historical capacity costs distributed over six months.
>
> "First, the economic optimum will be illustrated. Pricing water efficiently, in accordance with the peak responsibility rules, yields a peak period price of Pp and an off-peak price of Po. These prices produce peak and off-peak demands of QP and Qo, respectively. The capacity is optimally set at Qp as the costs of augmenting capacity (AVC + capacity cost) exceed the values to the peak uses (D2D2') of the additional units of capacity to the right of Qp. Resources have not been wasted by overinvesting in needlessly large systems nor have prices needlessly constrained the use of existing capacity. The relevant marginal values have been balanced against marginal costs.

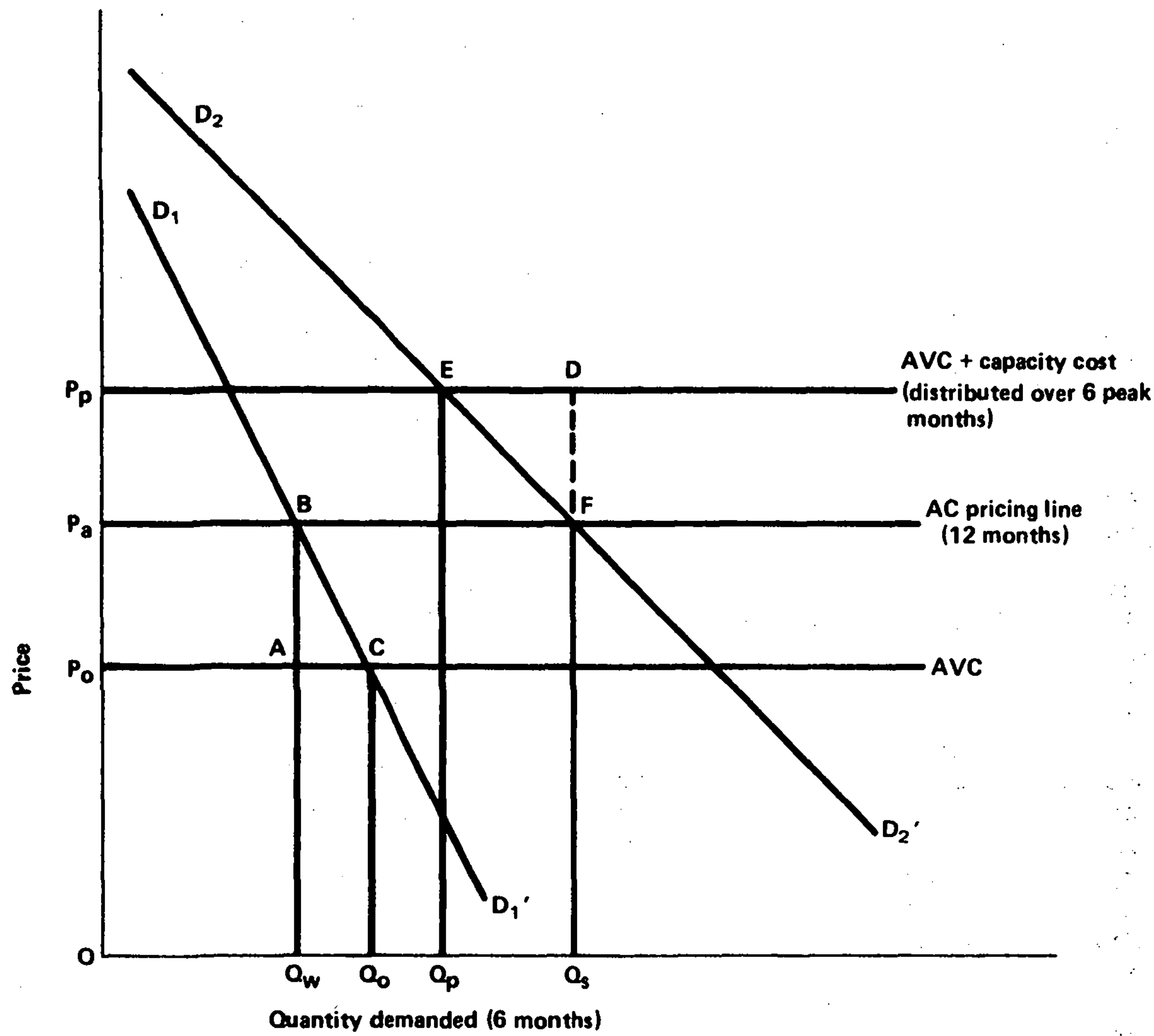

Figure IX. Peak responsibility pricing

"Generally, water utilities impose uniform average prices over time. If prices are set according to this rule the price will be Pa throughout the year. This average cost price will lead to a winter demand of Qw and a summer demand of Qs, which result in large inefficiencies. The use of water in the winter is needlessly stinted as the value of water in the relevant range (Qw - Qo) of D1D1' exceeds the relevant costs (AVC) in that same range. Use in the winter should be allowed to expand until the relevant incremental costs are equated to incremental value; this occurs at output Qo. By allowing this expansion in off-peak use there would be an efficiency gain, represented by the triangle ABC.

"Uniform average prices will also result in inefficiencies during the period of peak demands. The required capacity to serve peak demands will be needlessly excessive. The cost of providing the additional capacity to peak (EDQsQp) exceeds the value (EFQsQp) of that capacity. The efficiency loss generated by increasing capacity from Qp to Qs is represented by the triangle EDF. By utilizing peak responsibility pricing and allocating costs to those consumers who are responsible for them, significant efficiency gains can be realized." 6/

An alternate way to calculate the savings from peak-demand or drought pricing is to estimate the number of years that the construction of facilities can be delayed and the savings in interest that results from delaying these expenditures. This method is illustrated with a hypothetical example in table 24. The middle column shows the years when new reservoirs would be built if a constant price equal to average cost were charged throughout each year. Under average-cost pricing, the third reservoir is scheduled for 1980. With peak-season pricing, where the price is allowed to go up each summer, the third reservoir might be delayed until 1989. At 6 per cent interest, there is a savings of $12 million associated with the construction of reservoirs that will be needed before the year 2015. For purposes of comparison, each of these pricing and investment plans is assumed to have the same safety factor or risk of running out of water. Note that the main purpose of peak-season pricing may be to delay other investments dealing with water purification and delivery, and that reducing seasonal demands may only incidently reduce the need for water-storage reservoirs.

Drought-supply pricing is based on the idea of using extra price increases during droughts to ration scarce water. When the reservoirs begin to be needed during a drought, the idea is to raise the price of water to cover the costs of the next reservoir. Drought-supply prices could be much higher than seasonal prices. For example, if a drought persists until only one month's supply of water is left, then the price might be raised again to cover the cost of bringing in water by truck or emergency pipeline. Use of price rationing during droughts might mean that the third reservoir could be postponed for example, until after the year 2012. At 6 per cent interest, the savings on all reservoirs needed until then would be $13 million over peak-season pricing, and $25 million over average-cost pricing. This is only a hypothetical example but it suggests a method that can be used to estimate savings from drought pricing.

6/ Modifications **underlined** and in the figure were approved by Hanke.

Table 24. Hypothetical example showing years additional reservoirs will be needed and total costs under three pricing schemes

Reservoir Number	Cost of each reservoir (millions of 1978 dollars)	Average cost scheme	Peak season scheme	Drought scheme
		Year reservoir will be built		
1	10	1972	1975	1980
2	10	1976	1980	1995
3	5	1980	1989	2012
4	5	1985	1998	-
5	8	1995	2015	-
6	8	2008	-	-
Total costs discounted to 1978 at 6 per cent		$ 38 million	$ 26 million	$ 13 million

Several additional considerations need to be mentioned with respect to peak-demand pricing. First, during periods of drought pricing, it is not necessary to raise minimum monthly charges which apply to the smallest and presumably the poorest customers. The main argument raised against price rationing is that it will affect the poor more than the rich. This is not necessarily true if the richer customers have the larger gardens and sprinkling demands. Secondly, the useful life of the system of reservoirs may be longer if construction can be delayed because reservoirs which are constructed and filled before municipal growth occurs may be rapidly filled with sediment caused by that very growth. If drought pricing could be used to delay actual construction of reservoirs, if land could be purchased and set aside for future reservoirs, and if developers could be required to build in a way that reduces the amount of sediment entering reservoirs, then the cost of water storage should be appreciably reduced. Thirdly, peak-demand pricing has been recommended a great deal by economists for the sale of both electricity and water, although it has been tried in extremely few places. Time-of-day rates are widely used in the pricing of long-distance telephone calls. However, part of the problem in the case of electricity is that special meters would be required and, in the case of drought pricing of water, special meter readings and calculations would be needed. Fourthly, the question of "shifting peaks" and long-term demand adjustments should be considered. If people know that peak rates are going to apply at some future time, they may go to considerable expense to store water or heat. Thus, the net benefits to the system are not as large as one might expect. Nevertheless, an understanding of peak-demand pricing and how to estimate its benefits could be important to water resources administrators in any region which occasionally suffers a water shortage.

6. Summary and conclusions regarding prices

The preceding sections of this chapter dealt with water and waste charges to households and industries. Pricing is an instrument of policy in this regard. It can be used to achieve higher levels of economic efficiency in the use of water increase, recovery costs and also redistribute income. The final solutions in setting prices are often arrived at on the basis of trade-offs among these conflicting goals.

Howe (1971) prepared a summary of the role of pricing in which he emphasises (a) full cost recovery to the extent possible (b) recovering added capital costs of systems and lines from developers, and (c) using increasing block rates to recover the full marginal costs of new sources of water. Howe's summary was found appropriate to the present discussion and the material below has been reproduced with the permission of the publisher, the American Geophysical Union: *

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* Charles W. Howe, Benefit Cost Analysis for Water Systems Planning, Water Resources Monograph No. 2, pp. 95-99, 1971, copyrighted by American Geophysical Union.

"The particular scheme of charges made against the customer is an extremely important aspect of water management. The pricing scheme will substantially affect the total quantities of water use, the temporal pattern of water use, the distribution of net benefits from provision of water or other outputs, the demands for different water qualities, and the financial receipts of the water agency.

"Placing a price on water guarantees that only those who value additional water in excess of the price will use it, whereas those to whom it is of lower value will conserve its use. If other means of rationing the available quantity are used, it could very well be that persons to whom additional water has very low value would be granted the available water and would commit it to uses of very low value. This situation is precisely what happens to large quantities of irrigation water.

"A similar argument can be made with respect to placing a price or tax on the discharges of pollutants to streams. These prices are referred to as "effluent charges", and they have the effect of discouraging the discharge of pollutants the abatement of which would cost the discharger less than the level of the charge. Thus only those waste dischargers who value the assimilative capabilities of the stream at higher values than the effluent charge will use the stream.

"Appropriate prices must be related to appropriate measures of cost.... In the usual water supply case, there are source costs; transmission costs; treatment, local distribution, and storage costs. Further, there are some costs related just to the heavy peak demands placed on water supply systems. Sometimes one component of the system will have excess capacity; at another time some other component will have excess capacity. There are also economies of scale in most components of water supply systems that cause costs to depend on the sizes of system additions and their intensity of use.

"These are all reasons why it is difficult to be very precise in specifying just how water supply and other services should be priced. The major point to be remembered, however, is that the method of pricing will affect the quantity demanded and this quantity should influence the design of additions to the supply system.

"A second point to be remembered is that the costs of new source development are going up everywhere, not just in arid areas, quite aside from inflation. The more any customer uses, the sooner the supply system will be forced to tap new, higher-cost sources. Thus the only sensible pattern of variable charges (sometimes called commodity charges) to levy against the customer is one that increases with the quantity used each billing period. This pattern of charges is contrary to many existing (decreasing block rate) pricing patterns and public attitudes but is strongly called for by the increasing scarcity of water of good quality.

"A third point to be remembered in connexion with pricing is that the existence of strong peak demands, both seasonal and daily, means that a large part of the local distribution and storage capacity stands idle a good bit of the time. The costs of this capacity are appropriately covered by minimum charges, front-footage charges, or other charges not related to the total quantity used but correlated with the magnitude of the peak demand. An even more desirable method of relating this readiness to serve peak demands to the pricing of water would be to have a peak period pricing scheme that would charge peak users more than it would charge off-peak users.

"From a practical viewpoint, a highly desirable method of pricing urban water services would involve the following cost distinctions: (1) the capital costs of developing new supply capacity, aside from the costs of new source development; (2) the costs of new source development; (3) the current system operation, maintenance, and replacements costs; and (4) the administrative overhead costs. The costs of item 1, computed for reasonably sized additions to the components of the system would be spread over new additions to the system in the form of plant investments fees (PIF) paid by the developer of the new or expanded services. There should be a graduation of the PIF related to the peak demands that the particular customer will place on the system. For residential areas, a good surrogate for peak demands is likely to be the irrigable area of the lawn and garden. Another measure would be the value of the residence. For commercial and industrial users, an appropriate surrogate for peak demands might be size of service, or perhaps forecasts of peak rates of use based on actual customer plant design.

"For pricing purposes, new source development costs should be used as the measure of source costs for all water provided by the system, regardless of actual historical costs of earlier source developments. This point is always difficult to understand, but the increasing uses of water by established customers just as much as the arrival of new customers force the system to acquire or develop new sources. These marginal (incremental) source development costs should be reflected in the rate schedule of all customers, new or old, and regardless of whether or not the water actually comes from the new sources. Thus each customer's decision to use more water will be based on a comparison of the value of the water to him with the costs he is causing the water system to incur.

"Current system operation, maintenance and replacement costs should also be recovered through the commodity charge. Finally, it is probably desirable to cover the administrative overhead costs of the system through the imposition of a fixed charge per billing period.

"In summary, the pricing structure of a water supply utility should consist of (1) a plant investment fee for all new or improved services sufficient to cover all nonsource-related capital costs of providing the new services and graduated upward in relation to the peak demands to be placed on the system; (2) a structure of commodity charges for all customers sufficient to cover marginal source costs plus all OM and R costs, the structure being of an increasing block nature related to total quantity used;

and (3) a fixed fee per billing periods sufficient to cover administrative costs of the system.

> "Pricing water services to recover all costs from users has two further, indirect, but highly important functions: (1) to facilitate economically rational decision-making where alternative systems must be compared and (2) to avoid the buildup of political pressure to perpetuate highly subsidized water services".

It can also be added that pricing can also serve (3) to generate funds for investment.

In summary, it is recommended that the charges based on volume reflect the marginal costs of obtaining water from new sources plus the costs of operating, maintaining and replacing the system. If it is politically impossible to charge this same price for the entire volume each customer buys, then some system of quotas with lower prices for the allotted amounts and a higher price equal to marginal cost for any water purchased in excess of the quotas is recommended. The key element for efficiency is that all users, regardless of size, would pay about the same volumetric rate for additional water. Then every consumer will have the same incentive to conserve water. Howe also recommends that plant investment fees be charged at the time new water and sewer service are provided. This extends the idea of acreage, frontage and top-on fees to include the capital cost of new water purification and waste treatment plants. Howe's basic idea is that in rapidly developing cities, the full capital cost of new systems, but not the new sources of water, should be paid in advance by the beneficiaries.

B. Review of actual practices

1. Water and sewer pricing in the United States of America

(a) Goals and costs

Cost recovery is the main goal of water and sewer pricing by cities in the United States of America. Treating different classes of users fairly is second. Less important is the goal of some smaller cities to attract industry. The goal of efficiency is mentioned rarely as an explicit objective; however, the constraints of fairness and cost recovery make most pricing systems based on metered water reasonably efficient. The main inefficiencies are associated with different users paying different marginal rates for water that has essentially the same opportunity cost, and with the failure to use peak-demand and drought supply pricing..

There is some evidence that large cities have less costly water than small cities. Seidel and Cleasby (1966) found that large cities over 75,600 m^3 per day (20 mgd) were charging about 69 per cent as much as small cities under 7,560 m^3 per day (2 mgd) in 1960. Table 25 shows costs by city size for 1972 and essentially the same ratio, 0.71, between the average total costs of the largest and smallest groups. However, these figures reflect an average of historic costs and it is very possible that the larger cities have older systems for which more of the capital costs have already been recovered. It is also possible that the larger cities enjoy greater economies of scale. The marginal costs of additional water probably are higher in larger cities than in smaller ones because the larger cities will have used more of the low-cost, nearby sources than the smaller cities. Failure to charge the marginal costs of future water could lead to excessive growth of cities, and the use of average-cost pricing could be a more serious source of inefficiency in some large cities than in smaller ones.

(b) Common pricing policy alternatives

Declining block rates have been common in the past in the United States of America but are now receiving a good deal of criticism. For example, table 23, giving water rates for Raleigh, North Carolina, reveals that the smallest customers paid 1.67 times as much as the largest for additional water in 1977. Seidel and Cleasby (1966) found that in 1960 smaller cities were discriminating in favour of large customers more than were larger cities. The ratio of prices paid by the smallest to that paid by the largest customers was 2.46 for the cities selling less than 7,560 m^3 per day (2 mgd), while it was 2.03 for the largest cities, those selling over 75,600 m^3 per day (20 mgd).

Table 25. Costs of water by city size, United States of America, 1972 [a/]

Range of population	Number of utilities surveyed	Total cost (dollars per 1000 m^3)
50,000	20	96
50,000 - 100,000	20	84
100,000 - 500,000	44	77
500,000 - 1,000,000	17	70
Over 1 million	14	68
	115	79

Source: F. W. Montanari and David E. Mattern, 1976, pp. 251 - 254.

a/ Including all costs of obtaining and delivering potable water to the consumer: administration and engineering, operation and maintenance, raw water, treatment, debt service and other costs.

Development of declining block-rate structures may be explained in part by competition among cities for industry. Industries have more alternatives and more elastic demands for water than do households. Smaller cities are often more anxious to attract new industries than are larger cities. Local political leaders may be under considerable pressure to attract industry, and the extension of water and sewer lines plus granting favourable water and sewer rates may be their way of doing it. Lower charges to large customers are rationalized and defended in the courts on the basis of greater economies of scale and lower costs of metering, billing and transporting water to them. As an alternative, fixed monthly service charges based on meter size could be used to reflect economics of size in delivering. Also, a high initial capital charge, representing the additional cost of capacity, could be levied at the time users tap onto the system. This would make new users pay more than old users in a city that has increasing marginal costs.

(c) Sewer service charges 7/

Most of the refinements in water billing that we have mentioned in the preceding section of this chapter and earlier in chapter I involve customers paying according to the way their usage imposes extra costs on the system. Most of these refinements - capacity charges, interruptible service contracts, distance fees, connexion fees and peak-demand pricing - apply just as well to sewer systems. It is also possible that the unusual strength or nature of some industrial wastes will impose extra costs on a system. When this is true, cities may decide that both fairness and efficiency considerations require that they charge industries for waste treatment based on estimated pounds of waste material treated - for example, BOD (biochemical oxygen demand) or suspended solids - as well as for the volume of water that carries these wastes.

Waste strength charges would be especially appropriate if a city is approaching a limit in its waste treatment capacity or it is being forced to adopt new, higher levels of treatment. Also, if a city is having to pay effluent charges, then it will naturally consider passing these charges on to major contributing industries.

Sewer service charges are normally based on water volume and calculated as a certain percentage added onto the water bill. The main objective of this practice is cost recovery; and the main reason for using this approach is that different users impose costs on the waste treatment system proportional to water purchased. Fairness is also important. When users supplement city water with water from their own wells, cities often levy extra sewer charges or require additional metering. Users who do not return to the city much of the water they purchase for waste treatment are also given special consideration.

7/ The discussion in the present section is primarily an attempt to relate the question of sewer service charges to the question of water bills for industries and households. For further discussion and examples of sewer service charges, see chapter VI.

Waste strength charges for industry are becoming more common. They are inspired by motives of fairness and efficiency more than cost recovery. When industries have widely different waste strengths and impose very different costs on the system, then fairness requires that different charges be levied. If waste treatment costs are high or are about to rise because a new treatment plant might be needed, then efficiency also requires that industries be monitored and charged based on the weight of waste material as well as on the volume of water treated. The problem is that monitoring waste strengths is costly and it becomes self-supporting only if waste treatment costs are high. However, monitoring is necessary even if costs are low, because one of its purposes is to create incentives for maintaining acceptable quality standards.

Table 26 provides a summary of waste strength charges used by 49 cities in the United States of America in 1976. The average charge was $93 per 1000 pounds of BOD plus suspended solids. It can be noted that the eight cities that charged for BOD alone charged about the same total amount as those that charged for both BOD and suspended solids.

(d) Effects of waste strength charges

Elasticities from four different studies of the effects of water and waste charges on industrial water and waste are summarized in table 27. Elasticities are expected percentage changes in quantities (FLOW and BOD) divided by percentage changes in prices. Looking only at the results from the most recent study by McLamb (1978), a 1 per cent increase in the surcharge (SURCH) can be viewed as having two effects: (1) a 0.59 per cent reduction in total pounds of BOD that industries send to a city for waste treatment; and (2) a 0.27 per cent reduction in water purchased from the city. Since both water and water-carried wastes change together, they are viewed as complements. The effects of changes in the price of water, NPFLOW, appear to be larger than the effects of changes in the waste strength charges. These elasticities, -0.7 and -0.38 mean that a 10 per cent increase in the marginal price of water is expected to cause a 7 per cent decrease in water consumption and a 3.8 per cent decrease in water-carried industrial BOD sent to a city. Under certain circumstances, one may expect that an increase in the price of water will cause a larger reduction in water usage than in wastes, which may result in an increase in the concentration of wastes in the water.

The parentheses under the elasticities indicate estimates of elasticities at the 95 per cent confidence intervals. For example, the elasticity of BOD with respect to SURCH, 0.59, could really be anywhere between -0.32 and -0.86. The estimates made by Elliott (1972) of elasticity of BOD with respect to surcharge (-0.60) and by Hanemann (1978) for fruit and vegetable processing (pBOD) (-0.80) fall within the range. Confidence intervals indicate that these estimates are not exact. However, the table gives some evidence that price increases will cause reductions in industrial demands for these services.

Table 26. Summary of waste strength charges in 49 cities in the United States of America, 1976

	Number of cities respond-ing	Average charges (and standard deviations) for		
		Biochemical oxygen demand, BOD	Suspended solids, SS	Total: BOD plus SS charges a/
		(dollars per 1000 pounds)		
Cities with charges on BOD and SS	41	$ 52 (50)	$ 41 (25)	$ 93 (67)
Cities with charges on BOD only	8	$ 92 (40)		$ 92 (40)

Source: McLamb, 1978.

a/ Charges for BOD and SS are added together only to facilitate comparison of cities. In reality there is no basis for adding these two charges together for an individual firm.

Table 27. Industrial response to water and waste-strength charges, elasticities for the United States of America

Author and industry or data	Elasticities of FLOW with respect to these prices a/	Elasticities of BOD with respect to these prices a/
Ethridge (1970)		
Poultry processing	GPFLOW = -0.63 PBOD = -0.44	GPFLOW = 1.45 PBOD = -0.20
Hanemann (1978)[b/]		
Fruits and vegetables	NPFLOW = -2.20	NPFLOW = -2.20 PBOD = -0.80
Meat products	NPFLOW = -1.00	NPFLOW = -1.00 PBOD = -0.05
Elliott (1972)		
All monitored industries	NPFLOW = -1.00	GPFLOW = -0.70
35 cities	SURCH = -0.80	SURCH = -0.60
McLamb (1978)[c/]		
All monitored industries	NPFLOW = -0.70	NPFLOW = -0.38
65 cities	(-1.18 to -0.22)	(-0.74 to -0.02)
	SURCH = -0.27	SURCH = -0.59
	(0.51 to -0.03)	(-0.86 to -0.32)

a/ FLOW and BOD stand for water consumption and monitored BOD in kilograms. GPFLOW and NPFLOW stand for the gross and net price of water, respectively, when the net price is obtained by subtracting the value of the free wastes obtained per unit of added water which results from the defined normal levels in the waste-strength charges. PBOD stands for the surcharge per 1000 pounds of BOD, and SURCH stands for an index of the combined surcharges on BOD and suspended solids.

b/ Hanemann (1978) also obtained observations for suspended solids and fit systems of three equations using seemingly unrelated regressions, SUR, and imposed constraints to make pains of the cross-price deviations equal.

c/ McLamb (1978) also used SUR and constrained the derivatives of FLOW and BOD with respect to the price of the other to be equal. Parentheses indicate 95 per cent confidence intervals for the elasticities.

(e) Financial irresponsibility

One source of the low level of efficiency in the supply of sewer services in the United States of America are federal and state grants which pay most of the capital costs of municipal waste-treatment plants. The subsidies cause cities to choose capital-intensive waste-treatment technologies and to ignore options such as land application and energy recovery. One of the reasons that the federal Government began offering subsidies is that it also has been insisting that all cities should have sewerage systems and secondary treatment. The cost of such systems in small towns where households now have individual septic tanks can exceed the property value of the whole town. So, if it were not for the subsidies, there would be considerable local political resistance to the waste treatment goals. It is difficult for national legislatures to consider local needs. There is a tendency to impose the same simple solution on all.

Another problem of cities in the United States is minimization of the costs of reserve water supplies. In particular, cities seem reluctant to try peak-demand or drought-supply pricing schemes, as discussed earlier, as ways of reducing the amount of water that they feel is necessary to store.

2. The water-supply tariff in Bangkok

The following discussion is adapted from a study made by the World Bank (1976) on the tariff structures of water supply in Bangkok and is presented here with the Bank's permission. The conclusions of this study, which would seem to be of particular interest to developing countries and which, to a certain extent, reflect the policy of the World Bank, include the findings that (a) even where labour costs are low, the annual costs of maintaining and reading water meters may be too high to justify installing them for the smaller customers; (b) poor families are assumed to have a right to have potable water piped into their homes, with both the connexion fee and the water fee being subsidized; and (c) public standpipes should be provided for families that cannot afford to have water piped into their homes.

A proper water supply tariff schedule should help the Bangkok Metropolitan Water Works Authority (MWWA) fulfil its financial objectives of providing a cash flow adequate to cover all operation and maintenance expenses, interest repayment of debt, and a portion of the system investment needs. A proper tariff schedule should also assist in fulfilling the basic economic objectives of (a) encouraging the efficient allocation of the limited resources available to the Government of Thailand; and (b) attempting to insure that low-income groups are not prevented from oonsuming the necessary minimum amount of water to sustain a healthful and productive existence.

If one of the objectives of the Government of Thailand is to efficiently allocate the real resources available to the country and to MWWA, it is important that the price paid for water by all consumers of potable water in the Bangkok municipal area should reflect the value of the resources used in producing that water. Estimates of the average incremental costs of producing water b (based on November 1975 projections at 1975 price levels) in the MWWA service area range roughly from $0.15 to $0.20 per m^3 (3.00 baht and 4.00 baht per m^3). As a result, if efficient resource allocation is a goal, and if water wastage and the overpumping of ground water is to be reduced, all consumers of ground and surface water (which is made suitable for human consumption) should be charged approximately $0.18 (B3.5) per m^3 (at 1975 price levels) for all water which they consume. The existing average charge is approximately $0.007 (B1.40) per m^3. The current MWWA tariff schedule, which has been in effect since 1 July 1972, is as follows:

Cubic meters per month	Dollars per m^3	Baht per m^3
0-6	0	0
7-12	0.025	0.50
13-25	0.050	1.00
26-50	0.075	1.50
51-200	0.100	2.00
201-up	0.125	2.50

There is also a monthly meter rent, which varies according to the size of the meter.

To enforce this area-wide charge, which is an incremental block strucutre for water, ground-water legislation would have to be enacted to control ground-water pumping by private consumers in the MWWA service area. Preferably, in the MWWA service area, existing private wells could be metered and charges could be imposed for the private pumping of public ground-water resources, or yearly or quarterly licenses could be issued as a basis for levying pumping fees according to well capacity and perhaps average pumping time. These metered charges or periodic fees should gradually be increased until they reach the equivalent of B3.50 per m^3 in 1975 prices. New wells could either be prohibited or charged the same as existing wells. It is not clear whether there are valid reasons to tax private pumping. If the water table is falling, that is a valid reason; however, taxing ground water simply to force people to buy from MWWA is not.

For both economic and financial reasons, the costs of metering for different areas of the city, different categories of small consumers, and different conditions of use should be examined in detail and compared with the value of the benefits (production cost savings) that are realized through metering. Preliminary calculations indicate that, on the average, water supply metering (even for half-inch connexions) is justified in Bangkok, the costs of metering small consumers in different types or locations undoubtedly vary throughout the system, and until additional progress is made in meter maintenance and billing, the costs of metering in some areas or for some categories of consumers may be significantly greater than the benefits derived from metering the water used by those consumers.

The study includes estimates of the average incremental cost of water, B 3.50 per m^3 and the monthly cost of metering water, B 13.5 for half-inch meters. Evidently, keeping small meters repaired has been a major problem. What volume of water would have to be saved by metering to justify the cost? About half of the gross value of the water saved through metering and billing is offset by the loss in utility to the customers who have metered services. Assuming a straight-line demand curve, as in figure VI given earlier, the net benefit of metering is represented by the social-cost triangle, Q*RS. If the area of the triangle is to equal the cost of metering, B 13.5 per month, and the height, Q*S, equals B 3.50 per m^3, then the base of this right triangle, RS, would equal 7.8 m^3 per month. Following this method, if metering results in a savings of more than 7.8 cubic meters of water per month, then it is worthwhile. With modal consumption at about 31 m^3 per month and with decreases in water consumption due to metering estimated at 30 per cent, the meters seem to be justified, at least for more than half of the households. Similar conclusions were obtained from a study made by the World Bank of metering in Lahore, Pakistan (1974).

Given the objective of making MWWA water accessible to all at a price which is "reasonable" relative to consumer income, it would seem to be necessary that (a) minimum consumption levels should be subsidized at a price considerably below the B 3.50 per m^3 economic efficiency price; (b) charges levied for connecting to the MWWA system should be low enough so as not to preclude most low-income families from connecting; and (c) ground-water legislation should be passed so that large consumers will not (while increasing the supply costs to small consumers) be able to consume ground-water at a price lower than the approximate economic efficiency price of B 3.50 per m^3 in 1975 prices.

With regard to the point that minimum consumption should be subsidized, it is possible to conceive of many alternative tariff schedules in which efficiency conditions are traded-off on equity grounds. For example, a tariff schedule similar to the following (at 1975 price levels) would not seem unreasonable:

Monthly consumption per connexion (m^3)	Dollars per m^3	Baht per m^3
0 - 6	0.05	1.00
7 and greater	0.18	3.50

Using the above tariff schedule, only 3 to 5 per cent of the households would pay more than 5 per cent of their yearly income for water (assuming a family size of 6 and consumption of 13.7 m^3 per month). If consumption for these low-income families is estimated at only 9.0 m^3 per month, then only 1 to 2 per cent of all households would have to spend more than 5 per cent of their income on water. According to a 1972 government expenditure survey, these lowest-income families in the Bangkok-Thunburi area on the average spend between 5 and 8 per cent of their income on tobacco and alcoholic beverages. Also, a comparison with 12 other cities (see table 28) reveals that Bangkok's present rates are relatively progressive and low. Only four cities (Mexico City, Seoul, Bogotá and Cartagena) appear to have lower rates than those of Bangkok. And, only the two cities in Colombia, plus Kingston and Ahmedabad, appear to have rate structures as progressive as that of Bangkok. These comparisons are used to justify the proposed rate increase, including the modest increase in charges for the smallest customers.

With regard to water supply connexion charges, it can be argued that existing charges are prohibitively high for low-income households. The average cost in 1975 to the consumer with a single connexion in the MWA service area was B 2,697. In 1972 such a charge would have amounted to over 25 per cent of the total yearly income for at least the 11 per cent of the population in the bottom income bracket. It is recommended that when tariffs are increased to approximately B 3.50 per m^3, that some revenue from water charges be used to cross subsidize connexion and standpoint expenditures for selected new groups of consumers.

Provisions for selecting which new connexions are eligible for the subsidy could include such considerations as the following:

(a) Subsidized connexions cannot have a service line exceeding three eighths of an inch;

(b) Subsidized connexions can only be made to property with dwellings with an official assessed value of less than a certain (relatively low) amount;

(c) Subsidized connexions can only be made to dwellings that will have only one tap(when more than one tap is installed the full cost of connexion will have to be paid with interest).

The objective of such provisions would be to relieve MWA of the burden of having to make somewhat arbitrary judgments about which households should be defined as low income, and therefore be eligible for subsidy.

Table 28. Estimated water charges as a percentage of estimated monthly income in 12 selected cities a/

City	Income group: Lower 20 per cent	Second 20 per cent	Third 20 per cent	Fourth 20 per cent	Upper 20 per cent
	(Water consumption category m^3 per month)				
Bangkok	0.49	1.12	2.19	2.02	0.86
Mexico City	0.41	0.33	0.38	0.29	0.17
Seoul	0.36	0.32	0.55	0.61	0.49
Bogotá	0.67	0.70	1.04	0.83	1.51
Cartagena	0.97	0.83	1.23	1.25	0.62
Kingston	1.76	3.04	6.05	3.75	0.81
Lima	4.96	2.34	1.25	1.41	0.56
Sao Paulo	4.71	2.28	3.35	2.85	0.90
Nairobi	6.80	5.51	6.00	3.93	1.88
Manila	9.27	1.67	1.65	1.50	0.72
Addis Ababa	8.70	7.89	7.70	6.17	2.46
Ahmedabad	4.25	4.28	10.53	11.70	2.72

Source: Computed from survey data by the staff of the Development Economics Department, World Bank.

a/ Water charges are estimated from tariff schedules and estimated average water consumption figures for households in the individual cities. Income is the estimated monthly income of households.

Metering offers the administrative simplicity of treating everyone alike, but the question of whom to subsidize would not be solved by metering. A combination of subsidized connexions and unmetered water for the poor would cause an increase in the number of connexions and, therefore, increase the costs while decreasing the revenues of MWWA. Maybe it would be better to let the social welfare agency of the Government administer a water subsidy. Following this approach, the MWWA would want to minimize the number of connexions by continuing to charge a monthly fee based on the size of the connexion. This fee could equal the full cost of the meter and all the fixed costs of servicing an account. In addition, there would be a charge at the time of connexion, part of which the customers would be allowed to finance in their monthly bills.

MWWA should consider installing and maintaining a carefully selected number of public standposts in areas where low-income population cannot be served with house connexions, or where population density is too low to justify the extension of service lines to private dwellings. An appropriate government social welfare agency should consider reimbursing MWWA for all water dispensed through such public standposts.

3. Community water supplies

(a) Recommendations made by Habitat and the United Nations Water Conference

Habitat: United Nations Conference on Human Settlements held at Vancouver in 1976, and the United Nations Water Conference, held at Mar del Plata in 1977, promoted the idea that an adequate water supply and basic sanitary facilities are a matter of human rights. The main recommendations and analysis to emerge from these conferences are presented in annex IV, below.

Saunders and Warford (1976), in the summary of their book, Village Water Supply: Economics and Policy in the Developing World, note that "vast numbers of people in the developing world, most of them living in rural areas, do not have access to a safe and convenient source of water, and where they do, they normally lack satisfactory sewage disposal facilities". As indicated in annex IV, below, only 77 per cent of the urban population and 22 per cent of the rural population in the developing countries were said to have access to reasonable water supplies. Saunders and Warford point out that although the relative mixture of rural and urban supplies differs among regions of the world, rural water supply programmes lag behind urban programmes in all parts of the developing world, with the percentage lag greatest in the two regions least able to meet their urban water supply needs, Africa and Southeast Asia. Yet water supply is only one segment of the problem, for water, once used, for this purpose, becomes waste-water or sewage.

(b) Benefits are difficult to quantify

The sewage disposal problem is related to the fact that many human enteric parasites are transmitted through fecal contamination of water. This perpetuates many of the health problems so prevalent in the developing world. Safe drinking water and safe waste disposal are necessary prerequisites to the eradication of water-borne diseases. Benefits are often observed after the fact: for example, providing a safe water supply has sometimes generated new industry in an area, which further improved the quality of life in the area. Predicting the benefits from a safe water supply, however, is somewhat more difficult, for with a more adequate supply of water, fewer people may migrate from rural to urban areas, and it is hard to obtain agreement on the benefits of slowing down such migration.

White and others (1972), report that improved water supply results in significant savings of human time and energy and in significantly improved public health conditions. Here it is necessary to make a distinction between the development of urban and rural water supplies. In urban areas, society could not function without some centrally operated water system, while in many rural areas with no industry or commerce the agrarian life can and does continue to produce without such a water system. Furthermore, if an epidemic of a water-borne disease were to occur in an urban area, many would be affected; while in a rural area, fewer people may be affected. Hence, the justification for public water supplies in urban areas appears to be more pressing.

The main issue, from an economic viewpoint, is to know the effects of the accessibility, quantity and quality of water on health. White found for East Africa that "diseases potentially related to water supply" account directly for 11.26 per cent of the deaths (for which causes have been attributed), 11.8 per cent of all in-patient diagnoses, and 20.9 per cent of all out-patient diagnoses. Working from much more detailed data, White concludes that the expected reductions in these precentages which could be achieved through "greatly improved supplies" are 5.6 per cent, 6.1 per cent and 10.9 per cent. How "greatly improved supplies" are defined is not made clear.

With respect to water quantity, White (1977) concludes . . . "We can be confident that increasing supply by half a liter for those consuming 3 liters a day will have some effect .... There is a point - we would guess somewhere in the 20 to 80 liters per person range - where health benefits of increasing water (quantity) begin to level out .... The common delusion that everything useful or important is already known about infections and water-borne disease is clearly far from true."

(c) Policy recommendations

With regard to water supply systems, Saunders and Warford (1976) recommend that "the technology should be kept as simple as possible so that local personnel will be able to operate and maintain the system for long periods of time in the absence of a qualified engineer". They further observe the following:

"The major problem associated with provision of water supplies in rural areas of developing countries relates to the operation and maintenance of systems. It is difficult to find villages in which the systems are working precisely as planned, both technically and financially, and it is common to find even relatively new systems that are not functioning at all. There is some evidence that villages tend to value their water systems more highly, make better use of the systems, and operate and maintain them more efficiently when they have contributed resources - labor or money - to help cover construction costs and are paying user fees that cover at least operation and maintenance expenses....

"The level of education and skills existing among the rural population is one of the principal factors to consider in determing whether the operation and maintenance phase of the program should have a national, regional, or local administrative base. When village systems are turned over to low-income, relatively uneducated local authorities to operate, the probability of system failure is high. Many failures, however, have been accompanied by a reluctance on the part of central water authorities to use their best men for the training of village operation personnel. In cases where it is decided that system operation and maintenance must be handled on a highly centralized basis, it is desirable at least to set up local village advisory committees so that local populations can feel that the water systems are their own and can take pride in seeing the systems operate properly....

"The principle, therefore, should be that those who can afford to pay the full (marginal) cost of water supply and sanitation facilities should be asked to do so. For water supply this rule typically will mean that house connexions should be provided only to those who pay for the full cost of both connexion and water actually consumed. Where house connexions exist and metering is in force it may be desirable, however, to modify the principle so that an initial supply, the minimum for basic health needs, is provided at a low, subsidized rate. Similarly, it may be desirable to finance standpost supply so that consumption is not reduced to an extent detrimental to public health. Where metering is not used, it is important that any flat-rate charge for water supply or sanitation facilities should be known as such, so that the principle of payment is established in the consumer's mind. A policy of full payment for all but the minimum basic supply is essential if the expansion of rural water supply and sanitation programmes is not to produce an overwhelming fiscal burden on poor countries."

(d) The development of rural water supplies in the United Republic of Tanzania 8/

The United Republic of Tanzania provides a case study of a developing country that has put considerable emphasis on the development of water supplies for rural communities. The country covers an area of 937,062 km^2, including 53,483 km^2 of water area. The population of the mainland is estimated at nearly 15 million, with a growth rate of 2.7 to 3 per cent. Systematic development of water resources was started after the attainment of independence in 1961. Generally speaking, the settlement pattern of the United Republic of Tanzania still follows the availability of natural surface-water supplies.

Most of the projects are designed and executed by the regions. The regions are responsible for deciding their own development projects and priorities through the Regional Development Committees (RDC). After a water project has been approved by the RDC, the Regional Water Engineer is then responsible for its survey, design, construction, operation and maintenance. If the project is relatively large, the region applies for the project to be taken up as a national project, the responsibility for which rests with the Ministry of Water Development, Energy and Minerals.

In order to carry out these programmes, the Government has procured 22 fast drilling (rotary) rigs and 18 percussion drill rigs. It also has 10 pilcon rigs and 2 diamond drill rigs for exploratory work. Until June 1974, all the drilling work was done by contractors. Now the Government is doing most of the drilling.

The Government has also procured earth-moving equipment for the construction of dams and water holes. Six earth moving teams have been formed, each team consisting of two scrappers and a dozer, a grader and a compactor. Each team can construct at least 2 small dams of 17,000 cubic meters annually or 3 dams of 13,000 m^3. These small dams are designed and executed by the regional authorities. The small dams and charcos supply water for domestic purposes as well as for the use of livestock. On an average, the small dams constructed by the 6 teams would be able to supply water to about 94,000 people or 54 villages in a year. The Government is trying to increase the number of such teams of 24 in order to accelerate this part of the programme.

The success of rural water supplies hinges not only on setting up water supplies in the rural areas but on ensuring that they are fully operational and properly operated and maintained. This calls not only for sufficient funds for operation and maintenance but also for a permanent team of skilled operators and mechanics in the rural areas. To alleviate the present and anticipated future shortage of qualified maintenance technicians, the Government has embarked on a training programme. At every regional maintenance workshop, on-the-job training has been started for pump attendants, mechanics, pipe fitters and electricians. At a later date this training programme will also be extended to the district level.

8/ The discussion presented in this section is a condensation of reports presented at the United Nations Water Conference, held at Mar del Plata in March 1977 (see United Republid of Tanzania (E/CONF.70/AB/151 and E/CONF.70/AB/153)).

In order to have continuous and uninterrupted service of water supplies in the rural areas, participation by the beneficiaries is absolutely essential. It is important that the people look on the water supply as their own and not the property of the Government, even though the latter might have been instrumental in setting up these water supplies and providing facilities to keep them operational in the initial states. At present, the supplies and facilities are not being maintained well, since villagers do not regard them as their own responsibility. The Government has, therefore, formed Water Supply Committees at every level, from the village to the region, to ensure proper operation and maintenance.

C. Suggestions regarding charges to households and industry

If water and waste treatment are not costly, then metering water consumption probably is not practical. This might be true, for example, for a city located on a large river with a low-cost supply of potable water. However, a small annual fee for service might be desirable in accordance with the principle that users ought to pay for systems (For further discussion on this point, see chapter VI). If either water or waste treatment is costly, however, then it is probably justifiable and expedient to install water meters as a basis for volumetric charges.

Frequently water supplies and basic sanitary facilities are regarded as a basic human right. Of course, this philosophy does not apply wherever a person may choose to live. What it means is that poor people in established communities are entitled to a minimum amount of free potable water, either obtained from public standpipes or delivered by truck. Many such communities may have relatively high-cost water and sewer services. They will want to charge users who have water piped into their houses and to begin with meters for each household.

If municipal waste treatment costs are high or increasing and if there are some major industries discharging wastes to a city, then the city should consider levying waste-strength charges on those industries in addition to charging them for the volume of their effluents. Such strength charges may be based on a few key indicators that are easy to measure, such as BOD, COD, suspended solids or chlorine demand. Strength charges will cause industries to reduce their water-carried wastes. The introduction of strength charges should be gradual, announced well in advance of initiation and accompanied with offers to help individual industries with waste-reduction programs.

Different countries and cities have widely different objectives regarding the revenue they wish to collect from water users. Frequent changes in rate schedules and contracts to serve households and industries are inadvisable. However, schedules can have built-in flexibility for emergencies such as drought pricing and interruptable service contracts with some industries.

Rate schedules can provide for automatic increases in periods of peak demand or low water supply. Increasing prices during these periods will make it possible for cities to ration water automatically and also to defer capital expenditures on new water purification and storage facilities.

When peak-demand or drought-supply pricing schedules, which reflect large increases in the marginal cost of water for these periods, are used to conserve scarce water, it is not necessary to change the minimum monthly charges that apply to the smallest and presumably the poorest customers.

Chapter VI

WATER QUALITY MANAGEMENT IN STREAMS AND THE ROLE OF EFFLUENT CHARGES

A. Water pollution problems and alternative solutions

Water quality is determined by many factors, including nutrients, toxics, biochemical oxygen demand (BOD), coliform bacteria, sediment, turbidity and temperature. Increases in most of these are considered undesirable and are characterized as "pollution", "minuses" or diseconomies. However, in certain circumstances, some such increases are considered "pluses" or economies. Thus, the various "pollutants" call for different solutions, depending on the circumstances.

Commonly mentioned pollution problems include fish kills (resulting from toxic materials or a lack of dissolved oxygen, DO) and high levels of toxic materials, such as PCBs or mercury, in seafood and water that is thereby unsafe for drinking, bathing and other domestic uses. Other problems include conflicts between communities - as, for example, when a downstream community must reuse some of the water discharged by an upstream community. Obviously, such diverse problems call for a variety of solutions, which generally are site-specific. In managing water quality, certain logical steps must be taken:

(a) Classification of streams based on intended uses, this is often done in public hearings;

(b) Definition of water quality standards (dimensions and measurements) needed to protect designated uses; these include setting minimum levels of dissolved oxygen in the water and maximum levels of fecal coliform bacteria, chemicals and toxic materials;

(c) Selection of the best combination of regulations, subsidies and charges to achieve water quality standards.

In reality, of course, economic decisions affecting the quality of water in streams will be influenced a great deal by political considerations.

1. Alternative solutions

Alternative solutions to problems of water quality can be viewed as either physical or economic. Physical solutions refer to waste treatment technologies, new production technologies, reduction of wastes at sources, residuals management, flow augmentation, storage of waste water, land application and in-stream aeration. Engineers are more inclined to think in terms of regulations that specify technologies or specific installations that they know will work. Economists are more comfortable thinking in terms of incentives. If societies provide the correct incentives, then cities and industries will find the least costly physical solutions.

Regulations, taxes and subsidies, or some combination of these, provide incentives to correct pollution problems. Regulations can be set at one of three levels:

(a) Equipment of production processes (e.g., secondary treatment);

(b) Effluents (maximum permitted levels); or

(c) Environmental quality (e.g., minimum dissolved oxygen).

The most efficient level for regulation depends in part on the costs of monitoring. If monitoring costs are high, it may be least expensive to specify the type of equipment that must be used. If the equipment performs satisfactorily as expected, then monitoring effluents will not be necessary. Correcting environmental problems involves both private and public expenditures for information, contracting and policing. These are sometimes called "transaction costs". Economists tend to favour decentralized systems, which give individuals an incentive to do the right thing and which concurrently minimize the cost of transactions.

Governmental insistance that industries or cities should adopt particular types of waste treatment are often accompanied by equipment subsidies applied uniformly at the national level. However, such regulations may not be efficient for the following reasons:

(a) Treatment techniques do not need to be the same nationwide;

(b) Specifying equipment discourages the development of new and cost effect technologies; and

(c) Subsidies tend to reduce the price of products that create pollution.

Effluent permits are a common form of regulation. In the case of BOD, maximum permitted discharges might be defined in terms of concentration in mg per liter, or in terms of weight in kilos per day. One of the main problems with effluent permits is setting standards for allocating them fairly among waste dischargers; another is the high cost of monitoring. Although cities and firms obtaining permits might be required to do most of the monitoring and reporting, costs will remain for such functions as supervision, inspection and spot-checking.

Specification of ambient quality is sometimes more feasible than regulation through effluent permits or specification of equipment. If there is only one discharger and if the waste assimilative capacities of a stream vary seasonally and annually, then it may be best to require that the discharger be responsible for maintaining the desired water quality. For example, the Government might specify that the dissolved oxygen level at the most critical point on a stream during a critical level of flow should be greater than a certain amount. The discharger would be permitted to use any of a large number of methods approved by a public agency to ensure this result. The combined costs of waste treatment, regulation and monitoring could be minimal under such a policy. However, regulations based on ambient quality obviously would not work for toxic substances

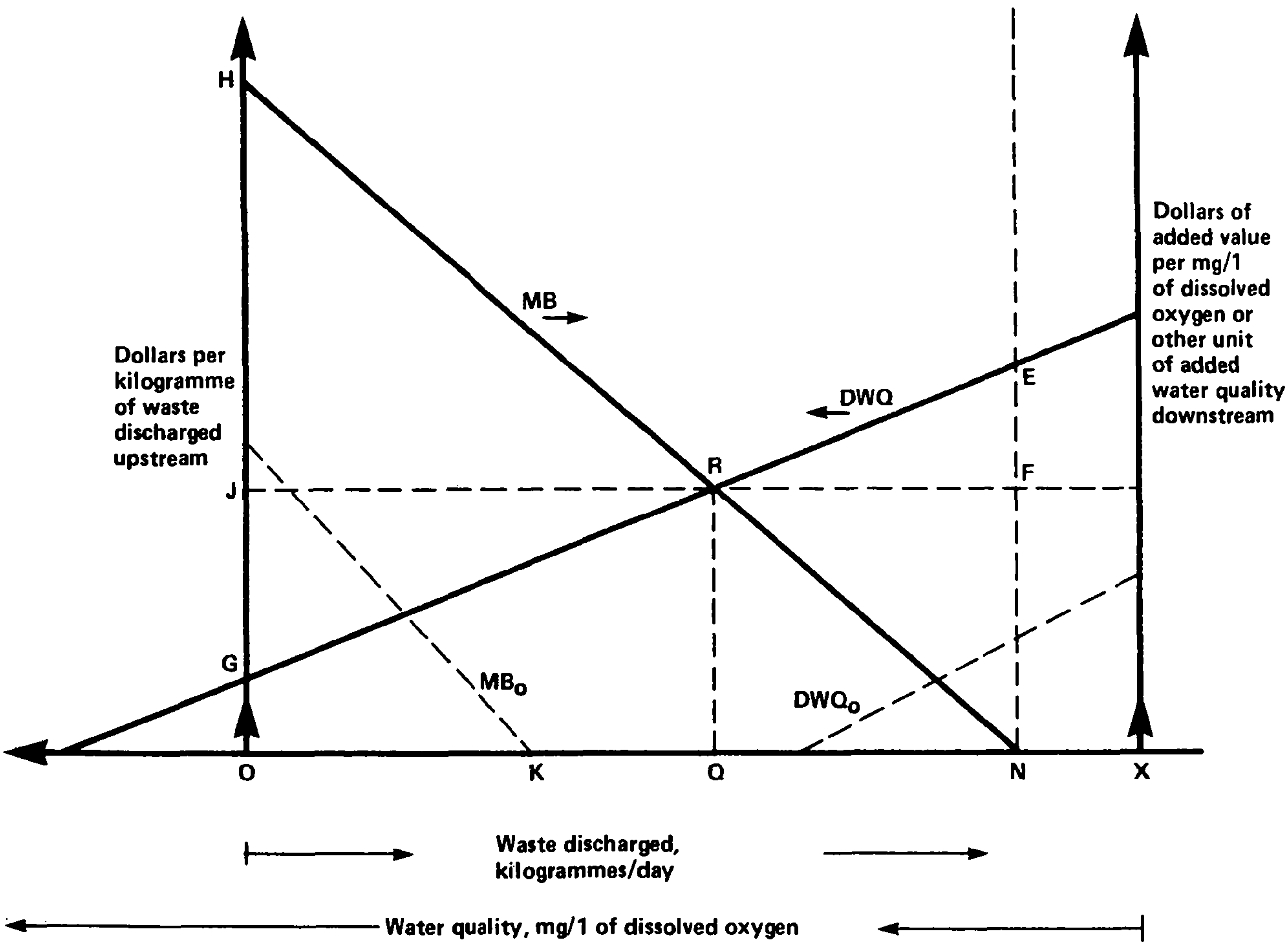

Figure X. Simple illustration of optimum use of a small section of a stream that are hard to detect. In such cases a combination of regulations, subsidies and charges may be used. The methods chosen will depend on the nature and concentration of the pollutants, the number of dischargers and the monitoring costs.

2. Optimum pollution levels

It is useful to define a level of pollution which is acceptable from the standpoint of both the polluter and the public interest. This permissible level is somewhere between zero discharge and the level that firms and cities would choose to discharge in the absence of controls. A simple case can be illustrated by defining optimum dissolved oxygen (DO) in a given section of a stream. The capacity of a stream to assimilate biodegradable material may be viewed as a resource, as the waste-assimilative capacity (WAC) of the stream. If the value of WAC is high, it would mean that there is a surplus of DO in the stream. Dissolved oxygen may be temporarily depleted by dumping wastes in a river; that is, the biochemical oxygen demand (BOD) component of wastes uses up oxygen in the water, which is later replenished. If BOD loadings (wastes) are increased at any one point, which implies an increased demand for WAC, the resource will become more valuable. Once the resource has become valuable, then charges could be made for its use, of people could be assigned maximum permitted shares of the resource. It should be realized that this is a simplified illustration and that complex standards and sophisticated approaches would be needed in arriving at an acceptable level of pollution, particularly when multiple polluters and point and non-point sources are involved.

The optimum pollution levels according to the above interpretation are illustrated in figure X, where competing demands are shown to be increasing over time. Demands of upstream industries on the waste-assimilative capacity of a river are shown on the left ordinate with 0 as the origin, while the competing demand from the right ordinate represents the sum of downstream requirements for water quality, with X as an origin. The upstream demand, MB, can be expressed in terms of pounds of wastes discharged and can be thought of as the horizontal sum of the marginal benefit curve of individual industries and cities. A certain functional relationship between wastes discharged (BOD) upstream and water quality downstream is assumed. Water quality downstream could be measured in terms of DO or other criteria. Assuming that water quality may be partially a public good, the demands for each discharge could be added vertically to get the demand curve for water quality, DWQ, shown on the right in figure X. The two demand curves intersect at R, where 0Q represents the optimum amount of waste discharges and NQ the optimum increase in water quality. The implicit value of the environmental resource is initiated by QR, which could be expressed in either upstream or downstream units. In some earlier period, the two demand curves were much lower, as indicated by the dashed lines MB_0 and DWQ_0 and the value of the resource was zero.

The following sequence of events in a history of pollution of a stream can be postulated. At some past time, the waste assimilative capacity of the stream was ample (its value was zero) and cities and industries discharged an acceptable amount of waste. Then, population increased, industries expanded, wages increased relative to the cost of water and the value of by-products and the use of water to carry away wastes and by-products increased. Today, demands for waste discharges have grown to MB instead of MB_0, and wastes discharged are now ON. Downstream demands for the use of the river for swimming, fishing, boating and water supplies also increased from DWQ_0 to DWQ. Even though the value of the waste assimilative capacity of the stream measured on either axis has increased to QR, the stream is still treated as a common property resource, or as if it were free. However, recreational users begin to call for water-quality improvements. Specifically, if wastes were reduced from ON to OQ, downstream users could benefit in the amount represented by RENQ dollars per year. It would only cost industry RNQ to make this reduction of NQ pounds per year, and the net benefit to society as a whole could be represented by the triangle REN.

Typically, Governments will respond to such inefficiencies with some sort of regulation. Governments often declare themselves to be the owner of the resource and they often ration out use rights, prohibit private transfers and continue to treat the resource as if it were free, which leads to inefficient usage.

3. Fairness of national regulations

There is a tendency to assume that environmental regulations must be the same nationwide in order to be "fair" - that is, "fair" to firms that compete with one another. If one firm must pay the cost of regulations, then all should. However, when deciding where to locate a plant, firms balance a number of factors such as labour and transportation costs and waste treatment requirements. If the Government then changes the rules such that all waste-treatment costs must be equal or that affluent charges must be identical, such action will especially be a burden to firms that had purposely located themselves where little waste treatment would be necessary.

The preceding section makes it clear that optimum water quality and the value of WAC's could vary a great deal along any one stream. Different climates and flows relative to waste loads and downstream use make it logical to assign quite different BOD permits at different places. Homogeneous requirements actually would not be fair or efficient. They would be inefficient because improvements in environmental quality have widely different pay-offs or values at different places and times.

In the United States of America, the same minimum treatment standard is being imposed on cities nationwide, regardless of whether it is needed or not. Also, all firms within an industry must meet the same minimum effluent standards based on levels attained by the most advanced firms. There is no basis for assuming that waste-treatment requirements should be the same everywhere, and there is even less basis for assuming that the value of WACs is the same or that effluent charges should be homogeneous.

4. Effluent charges versus permits

Economists often recommend effluent charges in preference to effluent permits. That is, they recommend setting prices rather than quantities. In terms of figure X, the amount of waste discharged into one small stretch of a river that society considers desirable might be OQ. Two ways of achieving this desirable level are to assign effluent permits which sum to OQ, or to charge a price on all wastes discharged which is sufficiently high to give producers an incentive to reduce voluntarily the wastes they want to discharge from ON to OQ.

Under certain circumstances charges (or taxes) are preferable to permits. First, charges (or taxes) provide a continual incentive for all parties to reduce discharges when there is little uncertainty. An industry that recovers many by-products and is far below permitted levels would have an incentive to reduce wastes all the way to zero.

Secondly, the incentive per unit is the same for all dischargers so that they will automatically achieve waste reduction in the least costly manner. Minimum total cost or maximum efficiency is defined in terms of each discharger having the same marginal benefits of an additional unit of discharge. All dischargers would have an incentive to stop at a point where their marginal benefits equal the price of additional units discharged. It would not be profitable for all firms and cities to make the same percentage reductions nor to end up with the same BOD levels.

Another advantage of effluent charges may be that permit applications and the ensuing approval and appeal procedures are eliminated. In other words, administrative costs could be less under a charge system than under a permit system. Of course, a system of charges could be based on applications to discharge up to a certain amount of BOD at a certain price, so that authorities would have a chance to renegotiate if waste loads were excessive.

One case in which effluent charges are preferred to permits is where either of the demand curves in figure X (MB or DWQ) are almost horizontal. Then the price may be set at this level. If both curves are fairly horizontal, it suggests that the optimum quantity could fluctuate greatly, or that society would be substantially indifferent over a wide range of water qualities. Of course, monitoring would still be required.

A system of effluent charges is an example of the popular idea that "users pay". Upstream dischargers pay society as a whole for damages to downstream usages. Two cases should be distinguished:

(1) If effluent charges apply only to one plant in a competitive industry, then the profits of that plant will suffer: that firm will "pay";

(2) If such charges apply nationwide to all plants in an industry, then the main effect of the charges will be a small increase in the price of the product whose manufacture causes the pollution. Profit rates will not be affected unless there is foreign competition. In this second case, "users pay" refers to the users of the final product.

If the water quality level is extremely critical, or either of the demand curves in figure X is almost vertical, then an assignment of permits may be the logical instrument and may be preferable to charges. Also, if one or both of the curves are vertical, then there is little reason to seek information on them.

The process of holding hearings and choosing target water quality implies knowledge of one or both of the curves in figure X, even though the information may never be expressed in those terms.

Effluent permits would also be preferred where waste dischargers have historically had the right to discharge material into a stream and there is no desire to take this right away from them. The reason is simply that permits imply that cities and industries possess a right or a license to discharge the permitted amounts, whereas new effluent charges imply that former users no longer have rights to discharge wastes without paying. Any rights (licenses) they want must be purchased from the Government at the effluent charge. It is erroneous to think of charges as "licenses to pollute". Charges require users to pay for licenses that would be free under a system of effluent permits. One should expect political opposition to effluent charges from those who will suffer the losses in income.

If the main goal is to improve the quality of a stream quickly, then it might be more advisable to start the process by granting effluent permits rather than by instituting effluent charges. Effluent permits could be granted to cities and industries for a specified period, say 10 years. If permits were auctioned after this period, then users would start paying the Government what these permits were worth. This amounts to the same thing as an effluent charge. Granting free permits during the first period and selling them afterwards amounts to a gradual take-over of the right to discharge certain wastes. Gradual change may be more acceptable than sudden introduction of new charges.

Perhaps the most appropriate approach would be to combine the good features of both permits and charges in one system. One reason to favour permits over charges is that permits do not involve automatic take-over of the assumed property rights of dischargers. Charges, on the other hand, are more desirable because they allow some flexibility and different responses from different firms and cities. A logical combination of both would be a system of free permits plus flexible charges for exceeding permitted levels. It would also be appropriate to pay a rebate to industries that do not need their entire permit, so as to encourage them to sell part of it back to the water management agency. The same result could be achieved by granting permits and then permitting transfer among users. A system of permits plus penalties and rebates would allow administrators to recognize the value of waste-assimilative capacities. This knowledge could help in the evaluation of projects to enhance WACs.

5. Not all problems are worth solving

It is clear that there are many alternative solutions to water quality problems and that it is not feasible to try to solve all of them. Developing countries should not infer from the preoccupation with the environment that exists in many "over-developed" areas that they need similar programmes. Nevertheless, it is good to anticipate problems that will arise and to plan ahead in order to minimize the cost of facilities that may be needed in the future. Effluent charges as they are applied in Europe are briefly described in the following section.

B. An evaluation of effluent charges in four European countries

The material below contains summary descriptions of effluent charges and permits in a number of countries, and a comparison of effluent charges in four European countries: France, the Federal Republic of Germany, Hungary and the Netherlands.

1. Comparison of actual systems

(a) Use of permits

All countries or regions that use an effluent charge system also use a discharge permit system or a set of effluent standards. While some countries rely solely on some sort of legal restrictions or standards regarding permissible waste discharge, no country relies solely on effluent charges to regulate the quality of receiving waters.

(b) Actual effluent charges and damages

While some may believe that effluent charges should be set to reflect damages caused by poor water quality, present knowledge is inadequate for the task. Very little is known about the physical relations between changes in water quality and changes in other natural resources with economic value. For example, the short - and long-range impact of changes in water quality on anadromous fisheries is very poorly understood. Even if physical scientists had defined these relations, the economic value of environmental amenities would be known only imperfectly under the best of circumstances. Most goods and services affected by changes in environmental quality are not exchanged in the market. Without market prices or close substitutes for them, it is difficult to determine the economic value of changes in water quality.

(c) Subsidized costs of waste treatment

In all four countries - France, the Federal Republic of Germany, Hungary and the Netherlands - subsidies are available to pay some of the costs of waste treatment facilities. The subsidy averages about 12 per cent of the investment cost of waste facilities in the case of Hungary, but is as high as 25 per cent of those costs in some instances. The subsidies are as high as 80 per cent in some cases in France, but the average is closer to 60 per cent of the investment cost. The subvention programme in the countries studied differ in several important respects. They usually but not always cover both firms and municipalities. In all countries the central Government is the source of some subsidies, but only in some countries, such as France, are subsidies provided by regional agencies or provincial governments. Some countries, such as France, subsidize operation and maintenance expenses as well. Others, including the Netherlands, subsidize changes in the methods of production designed to reduce the waste per unit of output. Finally, subsidies are usually available only to those who discharged waste into the streams before the enactment of recent major environmental quality legislation.

(d) Relation of effluent charge systems to the form of national economic system, per capita income or severity of waste problems

It might be thought that capitalistic countries would be more likely to choose effluent charges over permits because of the importance those countries attribute to the use of the price system as an allocator of resources. In fact, it is more nearly the other way around. East European countries with centrally planned economies, such as Czechoslovakia, the German Democratic Republic and Hungary, use effluent charges; while free market economies such as Great Britain and the United States of America rely almost completey on regulations. The levels of charges are not directly related to per capita income. Hungary and the Netherlands use effluent charge systems but differ greatly in their per capita income. Great Britain, Italy, Sweden and the United States of America all use effluent permits, and they too differ greatly in per capita income.

Whether effluent charges are used or not does depend on the date when serious efforts were commenced to control water pollution. Water-quality management associations in North Rhine-Westphalia have used effluent charges for about half a century, but in Czechoslovakia, France, the German Democratic Republic, the Netherlands and Hungary, the effluent charge policy is less than a decade old. Great Britain's standards are half a century old, but restrictive effluent standards designed to improve water quality in both Sweden and the United States have been promulgated only within the past decade.

(e) Measures of pollutants as basis for effluent charges

In Czechoslovakia and the Netherlands only two measures of pollutants are used to determine the level of effluent charges. Chemical oxygen demand (COD) and suspended solids were used in Czechoslovakia, while COD and nitrogen were used in the Netherlands. The proposed system in the Federal Republic of Germany calls for three measures of pollutants - COD, suspended solids and toxicity. Until recently, France basically measured three pollutants (BOD, COD and suspended matter) for the purpose of determining the charges, although in a limited number of cases a fourth measure, salinity, has been considered. Now a measure for toxicity has been added and there are plans to introduce thermal pollution when a suitable determination and standard can be found.

In the Ruhr region of the Federal Republic of Germany, the formula for determining the charge is based on four standards (suspended materials, BOD, potassium permanganate and toxicity), but there is some question about whether the toxicity variable is always monitored. Finally, Hungary is the major exception to the principle of simplicity, since its charge is based on 31 measures of pollutants. However, it should be emphasized that perhaps 30 per cent or more of the fines or charges were collected on the basis of only three measures - COD, oils and fats, and sodium. Thus, determination of actual charges is mainly a function of a few measureable pollutants.

In summary, BOD or COD forms a basis for the charge in all countries, and all except the Netherlands use suspended solids. Nitrogen plays a key role only in the Netherlands and toxicity and salinity enter the calculations in a few instances.

(f) Variations in waste discharge fees

There are two basic approaches by which effluent discharge for a city or a firm is determined in practice. The first approach is by actually monitoring the discharge of the city or firm. This approach is said to be in use in Hungary. The second procedure, in use in France, the Ruhr region of the Federal Republic of Germany and the Netherlands, relies not directly on actual discharge but on average discharge per capita per unit of output per employee or per unit of input for firms in given industries. These industrial coefficients are difficult to compare across countries but one can make a comparison of the amounts that similar polluters in different countries pay.

Looking now at some specific industries, the pollution charge for pig slaughtering in the Ruhr region of the Federal Republic of Germany in 1975 was about $1.26 per metric ton and at least twice that level in the Netherlands (national waters), while it was only $0.50 per metric ton in the Seine-Normandy region of France. The charge associated with milk production in the Ruhr region is perhaps 1.5 times that in the Seine-Normandy basin of France ($0.60 per hundred hectoliters). The charge in the Netherlands is at least twice as great as that for the Ruhr when comparing such products as butter, milk, paper products and sauerkraut.

In the Netherlands, annual charges in 1973 varied from about $2.04 to $6.12 per population equivalent, depending on the water board. The uniform charges per population equivalent discharged into the state waters of the Netherlands were: $0.68 in 1971, $1.70 in 1972, $2.72 in 1973 and $3.74 in 1974, all expressed in 1973 dollars.

In France, the charges vary within zones in a basin and from basin to basin. The range was $0.68 to $2.38 per population equivalent in 1970. Charges increase with the size of the population in towns and cities. For example, the charge per person in a town larger than 50,000 people is 20 per cent more than in a town of 5,000 people. The per capita effluent charge in France is less than 10 per cent of the total annualized cost for secondary treatment services for cities of a representative size.

A charge of about $20 per year per population equivalent once proposed by the Federal Republic of Germany represents the estimated cost of sewerage services plus secondary treatment. At present, the charge in the Ruhr is about $5.80 per population equivalent. In the Federal Republic of Germany charges decrease sharply with the size of population.

To summarize, in all countries for which data are available, effluent charges are but a small fraction of the total cost of waste treatment. In order of decreasing levels of actual charges, the countries studied can be ranked as follows: the Netherlands, the Federal Republic of Germany (RUHR) France and Hungary. The fact that charges for residual wastes which are discharged to streams after treatment are but a fraction of the average total cost of waste treatment implies that requirements and standards rather than economic incentives or charges are used in determining the actual levels of treatment.

2. Criteria for evaluating actual effluent charge policies

An effluent charge is efficient if it reflects the opportunity cost of water quality to downstream users and a polluter pays a corresponding rate for each unit of residual discharge. However, damage functions are too costly to estimate and opportunity costs can only be inferred from downstream complaints.

Tables of pollution coefficients used by France, the Netherlands and the Ruhr region (and proposed for all of the Federal Republic of Germany), which assume that every firm in each industry is alike in waste production, reduce the individual incentive aspect of the charge system. Many firms whose pollution per unit of output is less than the norm do not exercise their right to have effluents sampled and charges adjusted.

The fact that the introduction of a charge system is followed by a major investment in treatment systems, or by a decline in pollution levels, does not establish any firm conclusions about the efficiency of the charge system. In every case where this phenomenon has occurred, other policy instruments accompanied the introduction of the charge system, and it is not possible to separate the cause and effects of each element. Perhaps accelerated investments in treatment facilities in France and Hungary were due to the subsidy system introduced at the same time. It is certainly true that the same charge system would have been an unqualified failure without the accompanying subsidy programme in the case of France.

Strictly speaking, no conclusion can be drawn just from the fact that water quality has improved with the introduction of an effluent charge. One needs to know what would have happened had there been no charge, or what would have happened had an effluent standard system been introduced. Reference to the past will not suffice unless one wants to argue that no other influential element in the environment has changed. By way of illustration, under the system of the new effluent standards in Sweden, the pulp and paper companies, which used to account for 90 per cent of all BOD discharge, have dramatically cut back their air and water pollution loads. The large plants have cut BOD levels by as much as 84 per cent at real cost. Maybe a charge system would have produced results judged to be better in some sense, but that is difficult to ascertain.

Although a complete evaluation in terms of efficiency is out of the question, it is possible to evaluate actual charge policies in terms of these simple partial criteria:

(a) Two firms at the same location, producing the same output, should pay different total effluent charges if they use dissimilar production techniques that produce different levels and types of residuals;

(b) Two firms, identical except for location, should pay different unit charges if the necessary amount of treatment in each region varies, or if the damage caused by discharge varies;

(c) Large firms, small firms and municipalities should pay the same unit charge if the opportunity cost or damage to the environment of their residual discharge is the same. The size of an organization should not, by itself, be the basis for imposing different levels of charges for the same pollutant. Location in the public or private sector also is not a relevant distinction;

(d) Charges ought to vary through time if the opportunity cost of pollution changes. Presumably the opportunity value of cleaner environments has increased.

3. Application of these criteria

(a) France

France, like the Ruhr region in the Federal Republic of Germany (see section (b) below), uses a table of pollution coefficients which associates a given amount of pollution with a given amount of production in each industrial sector, as measured by output, input or employees. This table does not vary across a basin or region. As in the case of the Ruhr, a firm can request that its effluent be tested. The results of the sampling are used in computing the charge if it is in the firm's interest. The firm pays for the test if the test is inconclusive. The basin agency also can sample the discharge from individual firms and charge according to sample results. In an idealized setting, all firms discharging less than the amount stated in the table would request a test and would then pay according to the individual results. The actual setting is more complex. There is not a great amount of sampling, and yet there is accumulated evidence that the rate of effluent produced varies greatly across firms in the same industry. It therefore seems reasonable to conclude that criterion (a), above, is not frequently met in France. Firms with different rates of pollution, but alike in other respects, pay the same charge. However, firms can and do receive credit for special facilities and waste reductions.

The unit pollution charge varies across basin agencies and varies within a basin agency depending upon the zone of priority. This variation in charge, which is due to location, satisfies criterion (b), above. Some of the variation seems to be due to justifiable differences in water quality demand. For example, high water quality objectives are established in certain zones that supply water for drinking. Charges accordingly are high in order to achieve those goals.

The charge per kilogram for residual pollution is the same for all firms in the same location, regardless of size and goods or services produced. Moreover, the charge per kilogram of pollution is the same for inhabitants as it is for firms. Thus, conditions set in (c) above are fulfilled. Finally, condition (d) is met in the sense that charges for domestic and industrial waste were scheduled to change several times during the 1970s decade and have done so.

(b) Federal Republic of Germany, Ruhr region

In the Ruhr region, each firm in an industry is assumed to produce the same amount of waste per unit of production (per unit of designated input or per employee) unless it can and does prove otherwise. On the assumption that this challenge is not often initiated by a firm, the charge policy fails to satisfy the provisions established in (a) and (b) above.

(c) Hungary

The Hungarian pricing policy is based on the monitored wastes of each firm or municipality so that condition (a) is satisfied. The charge is insensitive to regional distinctions; thus, condition (b) probably is not met. Since charges are reckoned on the amount of waste discharged rather than on firm size, condition (c) is also met. For a number of years the unit charge for pollution has not changed. Therefore, condition (d) is not met.

(d) The Netherlands

Water policies under national and local jurisdictions are somewhat different, so that no single evaluation is possible. Condition (a), recognizing waste reduction efforts of individual firms, is satisfied by the local boards but not by national policy. Condition (b), recognizing locational distinctions, is not met by the national Government since the charge is independent of location, but it is satisfied elsewhere because charges vary among water boards. Condition (c), ostensibly is met in national jurisdictions because a common formula is used which does not discriminate between firms of different sizes, but it is not known whether this also applies to the local boards. Condition (d), recognizing a temporal variation, is met by the water board and by the national Government.

(e) Summary of evaluation

A summary of this evaluation is provided in table 29. First, it must be noted that the comparisons are relative and qualitative. If effluent charges were used throughout the Federal Republic of Germany, there would be variations by geographic region just as there are in France. Also, looking at only one region in the Federal Republic of Germany produces negative results for criterion (b). Even if these criteria and the results of their application are accepted, they are not decisive. If, for example, each criterion is given equal weight, France performs better than the Ruhr because it meets three of them while the Ruhr region only satisfies two. Yet, those who believe that the polluter ought to pay probably would rank the Ruhr above France because the level of charges is higher and the rate of subsidy is lower in the Ruhr. Advocates of the "polluter pays" principle would rank the Netherlands far above France and well above the Ruhr since effluent charges in the Netherlands are very much above the level in France and greater than in the Ruhr. Thus, magnitude is an important consideration, as is qualitative consistency of policy with economic principles.

4. Desirable components of an effluent charge system

An effluent charge system is not simply a price but rather a complex set of policies and procedures with price as the figurative instrument. It is hoped that by embedding economizing tendencies in the major components of the charge policy, the final result will be a price that encourages efficient use and improves quality of water resources. The following are some suggestions for an effluent charge system:

Table 29. Evaluation of effluent charge policies

Criterion	France	Germany, Federal Republic of (Ruhr)	Hungary	Netherlands National	Netherlands Waterboards
(a) Non-uniform treatment of firms in same industry producing different levels of waste	No	No	Yes	No	Yes
(b) Locational distinctions recognized	Yes	No	No	No	Yes
(c) No economically arbitrary discrimination by size	Yes	Yes	Yes	Yes	?
(d) Intertemporal variation acknowledged	Yes	Yes	No	Yes	Yes

(a) When an effluent charge system is introduced, initially low rates may be established, with a clear indication of the amount and timing of rate increases. This is illustrated by the experience in France, Hungary and the Netherlands. A graduated charge system at the time of implementation decreases the cost of adjusting to the new circumstances;

(b) The charges should be based on pollution coefficients that are comparatively easy to measure by techniques that yield consistent results. Effluent permits can be relied on to protect the water bodies from quality degradation due to pollutants which do not enter in the determination of the effluent charge;

(c) The table of pollution coefficients establishing levels of pollution per unit of output (input) or per population equivalent for the industrial sectors and municipalities greatly simplifies the administration of an effluent charge system. In order to maintain individual incentives to reduce pollution, the table of pollution coefficients must be revised periodically, and there must be a reasonable provision for either the managing agency or the polluter to sample effluents and establish payments according to the actual damage caused by the discharge of pollutants;

(d) Effluent charges will perform best in an institutional structure that encourages co-operation to achieve economies of size from large-scale waste-treatment facilities. This seems to be best exemplified by the water quality management association in the Ruhr region of the Federal Republic of Germany. It is also well illustrated by the pronounced trend towards comprehensive management in Western Europe, which features the consolidation of water organizations;

(e) An effluent charge system should emphasize regional differences. It is very likely that charges should be set high for polluters located among streams that are subsequently used for potable water or swimming. There may also be rivers for which the marginal value of added water quality is significantly lower, and charges can be set relatively lower to reflect this fact;

(f) As a practical matter, standards can be used to ensure that water quality is maintained in a certain acceptable range of predetermined levels and that charges can be varied until this range is achieved. Moreover, effluent charges should be established in such a way that they can become more differentiated as time passes.

These are the major considerations that can be recommended to guide the establishment of a practical effluent charge system. Other considerations include providing extra charges for discharge rates that coincide with treatment system peaks, or setting charges that vary to account for different seasonal damage levels. Seasonal variations are taken into consideration with computation of pollution loads in both France and in the Ruhr region of the Federal Republic of Germany.

5. Additional observations

Other general observations resulting from this study of water quality management in Europe include the following:

(a) It cannot be concluded that the charge systems actually being used are superior to the systems based solely on effluent permits;

(b) Greater efforts at pollution abatement and higher quality water are associated with higher social gains from improved quality and, in particular, with needs to reuse rivers for potable water supplies, as in the case of the Thames, above London, and the Ruhr;

(c) Subsidies are an important aspect of pollution abatement, and countries that are serious about water quality improvement must, for political reasons, subsidize activities that aim to achieve this goal;

(d) Subsidies can be made more effective if they are tied to performance and are available equally for operating, maintenance and capital costs and if they do not discourage cities and industries from taking advantages of economies of size in waste treatment.

C. Comparative analysis of methods for defining standards of water quality in the ECE region: results of a recent study

Based on a six-question questionnaire, adopted by the ECE Committee on Water Problems, a study was conducted on the comparison and analysis of methods of defining standards of water quality in the ECE region (United Nations Economic Commission for Europe, 1978). It is felt that replies to the questionnaire would be of general interest to many developing countries. Accordingly the results have been reproduced in annex V below.

Based on the replies, the following conclusions were drawn by the Hungarian Government, which assumed the responsibility for the analysis:

(a) Asked whether they considered it expedient to set up a task force to prepare a basis for co-ordination and harmonization, the majority of countries considered harmonization of water quality standards in the ECE member countries necessary. Such harmonization should be prepared by a working group;

(b) The classification of water resources according to quality is expedient for the following reasons:

(i) Limit values should be determined for the most important physical chemical and micro-biological parameters and, as for the "black" and "grey" lists, limit values should be determined for toxic substances;

(ii) Limit values with regard to the demands of specific water users should also be determined;

Harmonization of water quality standards start with the most frequently applied parameters, as shown in table 32;

(c) In the case of effluent standards, limit values for components characteristic of pollutants and applied by classifying surface waters according to quality should be determined;

(d) Requirements for effluent backfilling into subsurface layers are not defined in most countries; therefore it would be expedient for the working group to deal with this question;

(e) Drinking water standards in most countries are either based on the instructions of WHO or on European and International Standards for Drinking Water; therefore harmonization of drinking water standards is not timely.

D. Suggestions regarding water quality management in streams and the role of effluent charges

1. Approaches to water quality management depend on the waste material involved, the severity of the problem and the costs of monitoring. Some substances are difficult to monitor in effluent streams and even more difficult to detect once they are in the environment. In such cases it may be most practical to control the technology that is used to recover these substances within plants, or to prohibit completely their use or discharge.

2. When many water quality problems are first noticed, it is not practical to do anything about them. Solutions to problems involve private and public costs for information, monitoring, contracting and enforcement. It is not economical to begin the implementation of solutions until the social benefits from correcting the problem exceed all the costs of carrying out the new policy. Initial solutions may take the form of moral suasion; after that, regulations may be needed; and then, serious misallocations of resources may require some combination of permits and charges. Once it is economically feasible to monitor a few key pollutants, such as BOD and suspended solids, which are discharged along a stream, then it is reasonable to consider a system of effluent charges, transferable permits or a combination of permits plus charges.

3. Effluent charges should be implemented gradually: alternatives should be discussed with those affected, a generous amount of time should be allowed before charges begin, and rates should increase on a gradual schedule.

4. Effluent charge schemes may be designed to collect a wide range of target revenues by combining such schemes with permits. One obvious scheme for balancing a budget is to charge penalties for wastes in excess of permitted levels and offer rebates to those who use less than their permitted amount.

5. When effluent permits are used and when the wastes discharged by several entities within reaches of streams have essentially the same effects downstream, then Governments should facilitate the transfer of permits among users. Such Governments or river authorities should also facilitate a process whereby users in downstream reaches can purchase permits and not use them, or negotiate improvements in water quality in other ways with upstream users.

6. If the waste-assimilative capacity of a stream varies a great deal by season and place, then so will the optimum amount of waste discharged. Permits and charges should be flexible and should depend on the value of added water quality. They need not be the same for each reach of a river and each season.

7. As a practical matter, effluent permits can be set with certain water quality standards as a goal, followed by subsequent adjustments in the permits and penalties to achieve the desired standards.

8. A table of typical pollution levels per unit of output of various industries can be used as a basis for monitoring, and hence the administration of effluent charges. There should be a provision for the polluter to change his in-plant waste management technologies and then establish, through sampling, new base levels for his plant. Typical base levels for different industries also could be used to establish effluent permits

9. If there is only one discharger, or if it is feasible to designate one responsible agency per reach of the stream, then it may be more reasonable to define the responsibilities of that agency in terms of environmental quality (minimum permitted levels) rather than in terms of the maximum level of certain effluents.

10. As time passes, it may be logical to extend effluent charges to a number of waste characteristics and to provide for additional charges on wastes emitted at periods when water quality is dangerously low. Contracts that provide for interruption of service or storage of wastes may also be practical.

Chapter VII

SUMMARY OF CONCLUSIONS

While the findings of the present study may be universally valid, the report has been prepared with particular consideration to the needs of developing countries. It is hoped that the study will prove generally useful to water-resource planners, policy makers, managers, engineers and administrators.

In the preceding chapters guidelines have been provided for the use of prices and regulations to improve economic efficiency in the allocation, use and treatment of water. It is important to bear in mind that efficiency conditions are generally traded off or compromised on grounds of distributional equity. Prices are important instruments of policy in providing economic solutions for the allocation of scarce resources.

The systems for allocating the resources that exist in most countries have developed slowly and represent years of compromise among conflicting interests. It is assumed that the effectiveness of existing institutions can be continually improved through evolutionary change in response to modern needs and technological advances. However, before adopting a new institution for managing water, it is desirable to study the expected impacts and to examine alternative arrangements.

With respect to pricing, including systems of permits plus penalties, the approaches selected will have effects on both the distribution of income and the allocation of resources. These goals are sometimes called "capital recovery" and "economic efficiency". Subsidized water rates are often used to redistribute income to particular groups. They have been used as a policy instrument to attract industry to selected localities and to provide potable water of acceptable quality to poor communities. One way to combine these dual goals of subsidization and efficiency is to use two or more prices that might be combined in a system of permits or quotas, plus "progressive" penalties for exceeding them. Resource efficiency will also be increased if quotas are transferrable among users or if the State stands ready to buy unused quotas and has alternative uses for them.

Whenever possible, the price assigned to final incremental units should be the marginal net social cost or the value of the resource incrementally added at that time and place. This will ensure the necessary condition for economic efficiency - that is, price equal to marginal cost. Producers will tend to buy more water as long as the price per added cubic meter is less than their marginal private benefits. Efficient allocation requires that the marginal benefits be the same to all users. If efficiency is a goal, then administered prices must assign the same final block rate to all classes of users. Examples can be found in chapters III - VI and the basic principles have been set out in chapter I.

Pricing policies for water and effluent disposal charges should be considered early in the investment planning process since prices will influence total usage and hence will affect the appropriate level of investment. The benefits and costs of alternative pricing policies should be evaluated and decisions about pricing should be made before investments are undertaken. Once the projects become operational, the actual rates can be adjusted. Similarly, in the management of existing projects it is important to recognize that pricing policies need to change over time.

One of the main points that has been made in this study is that in order to subsidize particular sectors certain trade-offs are required in efficiency conditions, but this need not preclude the possibility of using efficient pricing at the margin of permitting marginal transfers. We can anticipate greater usage of "progressive" block rates or systems with low-priced quotas and progressive penalties for using more than one's quota.

As can be seen in chapter I, water-resource planners have frequently followed the "requirements" approach in issuing a single value projection of water use to decide the size and timing of future investments under the continuation of present policies. This has generally led to large estimates of future water requirements and to the provision of larger facilities and investments than may actually be needed. The amount of water that is actually used in future will depend in large measure on pricing and other public policies that are adopted. While some water "requirements" can be identified with relative accuracy - for example, the relatively small amounts required for drinking, cleaning and fire-fighting in municipalities, as well as other similar essential social needs, in most instances water use is characterized by water "demands". This suggests that higher prices would induce consumers to use less water. The implicit idea is that if price were equated with average marginal cost, the number and size of investments would tend to be more consistent with the goals of economic efficiency.

Agriculture

The above conclusions apply to all sectors, and to certain resources other than water. Chapter IV offers some specific ideas regarding irrigation water for agriculture. The following conclusions and suggestions from that chapter are stressed again:

(a) The prices and regulatory mechanisms set up to administer irrigation water depend on a number of physical, social and economic factors, including the value of water, variability over time and place, systems of delivery and control, level of on-farm management, subsidization and nature of ownership; therefore, no one system of allocation can be universally recommended;

(b) For a number of reasons, national subsidies are common and tend to persist;

(c) Two general pricing structures often practised in irrigation are fixed-rate and volumetric-rate pricing, and numerous variations of these are common;

(d) Since volumetric measurements are costly, they are often recommended for cases where the value of water is high and the flow can be regulated; in this case, of course, water must be a scarce resource;

(e) When flows are variable and uncertain, it is appropriate to consider allocating water to individual farmers on the basis of shares rather than volume;

(f) Systems of quotas and dual prices can be used to combine the dual goals of efficiency and subsidy. Quotas may be based on historic usage or adjusted to represent the quantity of water per hectare, which maximizes the net income per cubic meter.

Households and industry

The following ideas from chapter V should be re-emphasized:

(a) Since municipal and industrial water supplies have not traditionally been heavily subsidized, pricing on the basis of the "users pay cost of service" principle would be more applicable to these sectors, with greater possibility of inducing economic efficiency;

(b) When water is in scarce supply, metering policy coupled with effective pricing policy can conserve water and improve efficiency in use. Cross-sectional and time-series studies in different countries show that substantial reductions (up to 30 per cent or more) in the quantity of water use are possible when metering is introduced: equally important is an observation that metering together with appropriate pricing structure reduces by 50 per cent or more the average maximum day or peak-hour water demands; this implies reduction in system-design capacities, which in turn would reduce the size of the investment in facilities;

(c) Peak-demand and drought-supply pricing may be used as instruments in determining the optimum size water storage and transmission facilities and provide the possibility of reducing capital costs for water storage; legislation authorizing such price increases would be more effective if enacted before droughts actually occurred; it is not necessary to raise the minimum charges that apply to those who buy the smallest amounts of water whenever seasonal adjustments are made in volumetric rates;

(d) If waste treatment costs are high or subject to increase, municipalities might wish to begin levying charges based on the characteristics of industrial wastes;

(e) Again, dual prices provide a way of redistributing income in favour of certain groups, necessarily implying a trade-off with the efficiency objective; the latter is achieved by charging all customers the same marginal rate; increasing block rates are common in many countries, but as yet there is little tendency to manage them so that households and industries end up by paying the same marginal rate on their highest blocks.

Management of water quality in streams

With regard to the management of water quality in streams and effluent charge practices dealt with in chapter VI, it should be mentioned that chapter VI draws upon experiences in Europe and the United States of America, where quality management has been a policy issue for a long period of time. Developing countries might benefit from those experiences. Some of the main points from that chapter deserve to be re-emphasized:

(a) Classification and standardization of water resources according to quality is expedient before regulatory and control activities can be undertaken; classification and standardization must take into account the most important physical, chemical and microbiological parameters;

(b) Regulations, subsidies and effluent charges must be carefully combined to achieve the desired level of water quality standards;

(c) When pollutants are relatively easy to measure, effluent charges may be combined with effluent permits to control them;

(d) Institutional approaches to the control of different pollutants will vary depending on the cost of monitoring the natural severity of the damages, variability in the waste assimilative capacity of the stream and the number of parties involved;

(e) Regulations may be imposed and enforced at any one of three levels: production or waste treatment technologies, effluents and ambient conditions; subsidies are often tied to the adoption of approved technologies; effluent permits lend themselves to the addition of charges that introduce some needed flexibility; when there is only one major discharger and waste assimilative capacities vary, it may be logical for the discharger to be assigned responsibility for specified ambient conditions and to be allowed to take care of the environment in the least expensive way possible.

A N N E X E S

Annex I

AN ILLUSTRATION OF MARGINAL COST PRICING

The dynamics of marginal cost pricing will be illustrated with the aid of Figure XI. Demand grows from D_1 to D_3; prices are equated to marginal costs. The short-run marginal cost function, SRMC, is assumed to be constant (P_1AB) until capacity is reached at B, when it becomes vertical. The long-run or marginal cost function, LRMC, is displayed as P_3DF. It includes the marginal capacity costs, expressed as amortized annual amounts per unit, plus marginal operating costs. If the initial demand is D_1, then the optimum price would be P_1, which would cover only operating costs and allow nothing for capacity costs. Only part of the capacity, OQ_1 of OQ_2, is being used. As long as there is excess capacity, the marginal cost pricing rule would not include any charge for capacity. As the demand grows to D_2, it is optimal to raise the price to P_2. At this price, operating costs are being covered and there is some contribution towards covering capacity costs (the rectangle P_1BCP_2). As the demand grows, it continues to be optimal to raise the price along the vertical segment of the SRMC function until price equals the long-run incremental costs - that is, until consumers are willing to pay an amount equal to operating costs plus the capital costs of new investments. As demand grows beyond this point, additional investments in capacity should be made. For example, if the demand shifts to D_3, it will be efficient to make an investment in new capacity of Q_2Q_3. During the construction of new facilities it would be logical to charge a higher price, OP_4, in order to ration the limited supply, OQ_2. Once the new facilities are built and OQ_3 is being produced, the value (benefits) of the additional capacity may be represented by Q_2EFQ_3. The net benefit is therefore represented by the triangle DEF. Note that if the same price, OP_3, is charged for all units, total revenue, OP_3FQ_3, could exceed or fall short of covering the fixed costs of past investments. Although this example is highly simplified, it displays the basic fundamentals of marginal cost pricing and investment decisions too often ignored by water utilities.

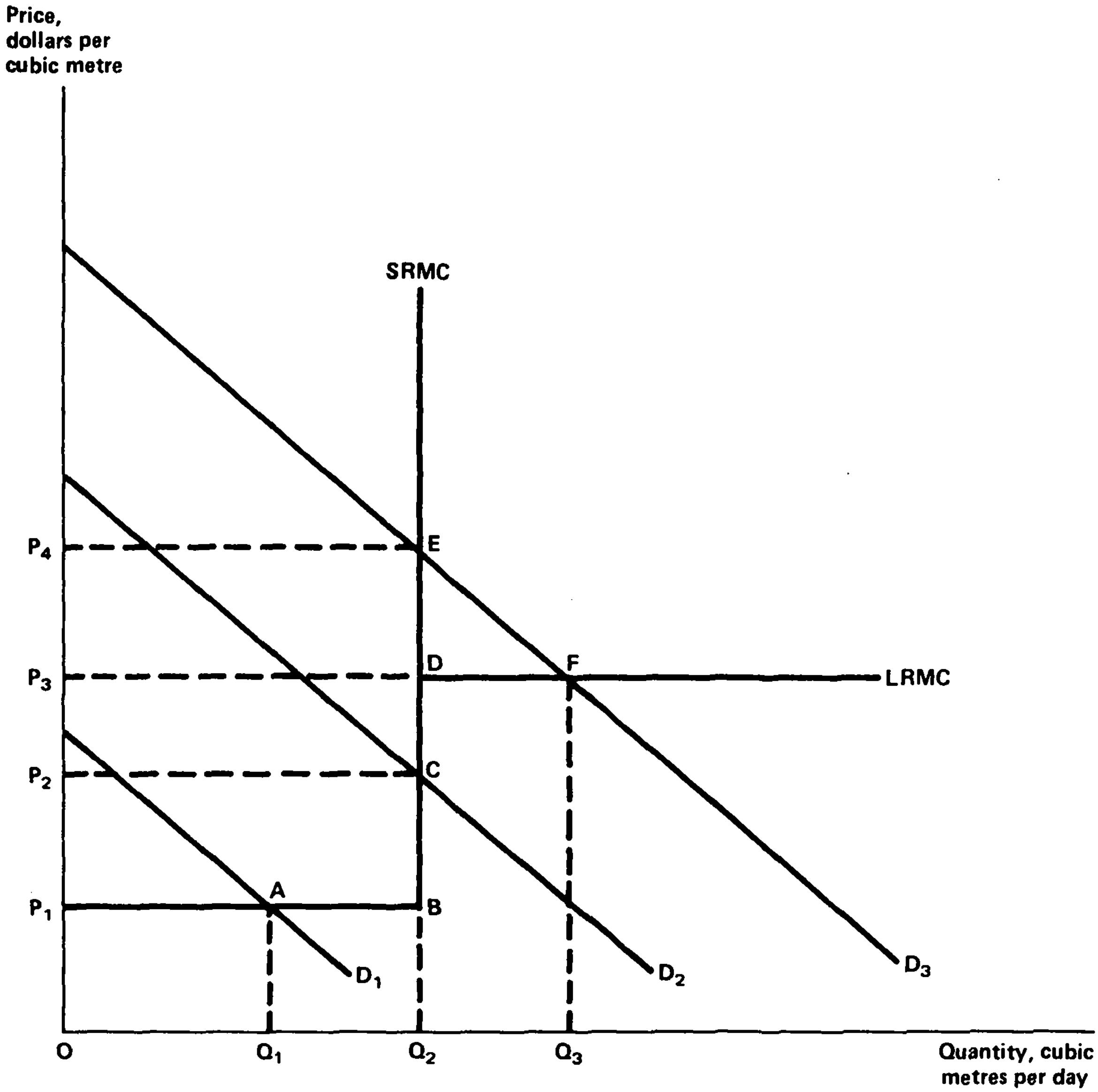

Figure XI. Illustrating the dynamics of marginal cost pricing

Annex II

A FRAMEWORK FOR THINKING ABOUT RESOURCE VALUES

The intended use for the values of water estimated above in section E.5 of chapter IV is to provide guidelines for setting administered prices of water with particular reference to a valley in Peru. Hence, crop budgets are based on the prices farmers actually are expected to receive and pay. On the other hand, for the purpose of public investment decisions, it would be better to use shadow prices to reflect social values when market prices and exchange rates are not in equilibrium.

The basic idea of dividing net income per hectare between income to water and to land is illustrated in figure XII. As more water is available per hectare so that water becomes non-limiting to crop growth, then net income can increase to point I. Net income per cubic meter or the average product is maximum at E and this indicates the optimum amount of water to use in valleys that have an abundance of free land and a shortage of water. Points E and L may be associated with extensive use of land, while points I and W imply intensive use of land and water-extensive technologies. At W all of the net marginal income can be assigned to land since the value of more water is zero. Similarly, at point L the value of more land is zero. (Strictly speaking, this requires an assumption of constant returns to scale throughout this range). The implicit value of the land increases from zero at E to its maximum value at the intensive margin, I, and the net income attributable to a unit volume of water per hectare falls from its maximum value near E to zero at W. In other words, the curve from E to W in figure 31 represents a division of net income per hectare into the implicit values of water and land. Now it is necessary to discuss the marginal cost of additional water and the socially optimum point between L and W.

The socially optimum point between the extensive and intensive margin must be explained in terms of the supply and demand for both land and water. One problem is that water and land have distinctive values in different months or seasons. The supply and demand for water in February depends heavily on the amounts used in January and March, and the same goes for land. There is really an equilibrium among all of the "resources" (months and inputs) which have distinct values, but it is useful to focus on the relations between the supply and demand for one "resource" in order to comprehend the whole. A given supply of other resources implies a given total demand curve for water in any one period. The total demand for water is simply the horizontal sum of the marginal value product curves of the various hectares. Two different demand curves, D_1 and D_2, are used in figure XIII to represent the sum of the marginal value products while the marginal cost of additional water is represented by the supply curve, SS'. D_1 could represent low prices for agricultural products while D_2 represents favourable prices; or these curves could represent smaller and larger numbers of hectares served by the same quantity of water, when the margin value product of water is falling. With D_2, it is socially optimal to develop a greater supply of water, C_2. Also, the value of water, MVP_2, is slightly higher with D_2 than with D_1. Equilibria such as D_1 and D_2 in figure XIII are associated with specific distributions of net income or with points on the curve between E and W in figure XII. These figures not only provide a theory of resource values, they also suggest the following practical extension of the residual method, explained further below.

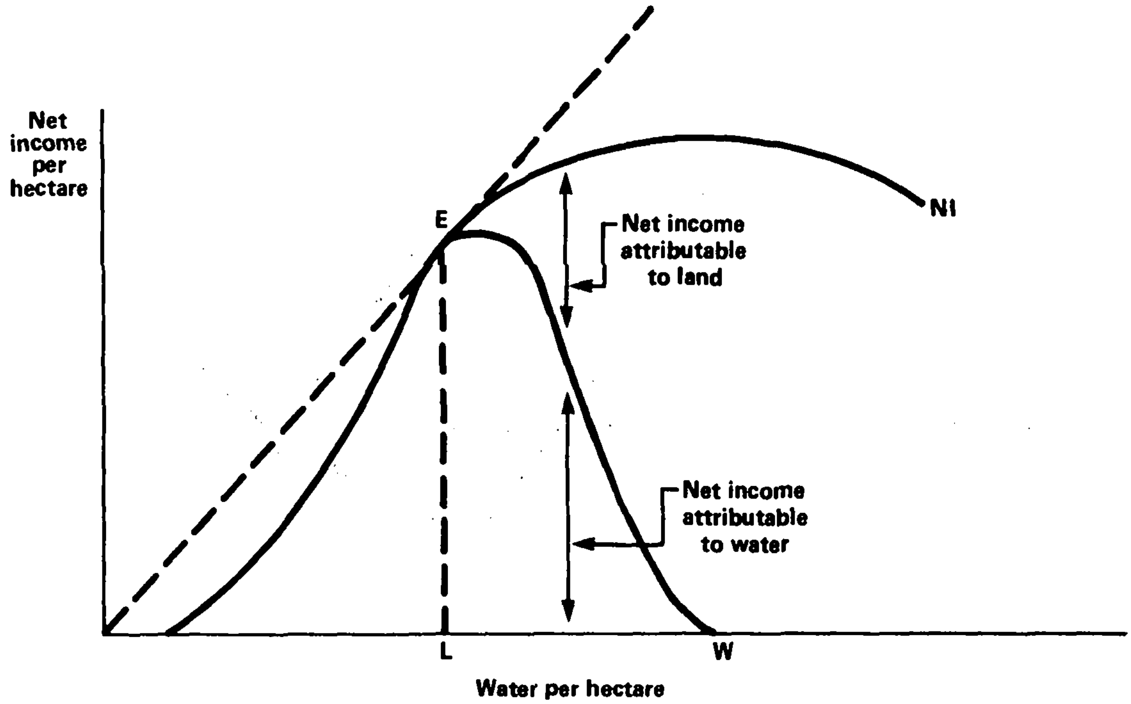

Figure XII. An illustration of the division of net income per hectare between water and land

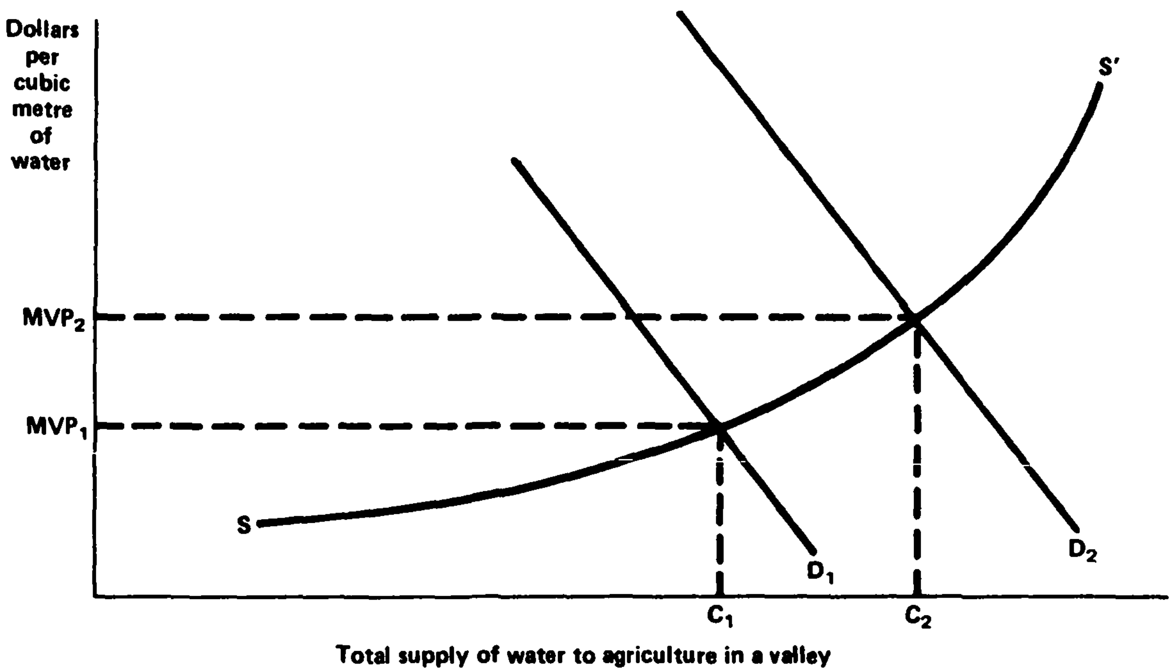

Figure XIII. Supply and demand curves for water

An assumption about the shape of the supply curves could help one obtain separate estimates of the values of land and water. Assume that the supply curves for these resources are first flat (elastic) and then rise steeply (become inelastic, as at S' in figure XIII.

The inelastic portion may be due to exhaustion of the easily available resource in a region and period. If it is unlikely that both resources become "exhausted" at the same time, which seems reasonable, then it is likely that the demand curves intersect their respective supply curves either in the more-or-less flat (elastic) or in the vertical (inelastic) portions. This is where knowledge of resource ratios might help. Resources ratios refer to the rate at which water is combined with other inputs. There is an optimum level at which input resources are combined, which gives maximum returns.

Annex III

TRENDS AND MOMENTUM RESULTING FROM THE UNITED NATIONS WATER CONFERENCE

The Declaration

The following declaration, adopted by the United Nations Water Conference, held in March 1977 at Mar del Plata, Argentina, gives an indication of the magnitude of action needed in the development and management of water for agriculture:

"THE INCREASE OF AGRICULTURAL PRODUCTION AND PRODUCTIVITY SHOULD BE AIMED AT ACHIEVING OPTIMUM YIELD IN FOOD PRODUCTION BY A DEFINITE DATE, AND AT A SIGNIFICANT IMPROVEMENT IN TOTAL AGRICULTURAL PRODUCTION AS EARLY AS POSSIBLE. MEASURES TO ATTAIN THESE OBJECTIVES SHOULD RECEIVE THE APPROPRIATE HIGH PRIORITY. PARTICULAR ATTENTION SHOULD BE GIVEN TO LAND AND WATER MANAGEMENT BOTH UNDER IRRIGATED AND RAINFED CULTIVATION, WITH DUE REGARD TO LONG-TERM AS WELL AS SHORT-TERM PRODUCTIVITY. NATIONAL LEGISLATION AND POLICIES SHOULD PROVIDE FOR THE PROPERLY INTEGRATED MANAGEMENT OF LAND AND WATER RESOURCES. COUNTRIES SHOULD, WHEN REVIEWING NATIONAL POLICIES, INSTITUTIONS AND LEGISLATION, ENSURE THE CO-ORDINATION OF ACTIVITIES AND SERVICES INVOLVED IN IRRIGATION AND DRAINAGE DEVELOPMENT AND MANAGEMENT. IT IS NECESSARY TO EXPAND THE USE OF WATER FOR AGRICULTURE TOGETHER WITH AN IMPROVEMENT IN EFFICIENCY OF USE. THIS SHOULD BE ACHIEVED THROUGH FUNDING, PROVIDING THE NECESSARY INFRASTRUCTURE AND REDUCING LOSSES IN TRANSIT, IN DISTRIBUTION AND ON THE FARM, AND AVOIDING THE USE OF WASTEFUL IRRIGATION PRACTICES, TO THE EXTENT POSSIBLE. EACH COUNTRY SHOULD APPLY KNOWN TECHNIQUES FOR THE PREVENTION AND CONTROL OF LAND AND WATER DEGRADATION RESULTING FROM IMPROPER MANAGEMENT. COUNTRIES SHOULD GIVE EARLY ATTENTION TO THE IMPROVEMENT OF EXISTING IRRIGATION AND DRAINAGE PROJECTS". (United Nations, 1977, para.18)

Studies carried out in relation to the United Nations Water Conference (United Nations, 1977, para. 18) show that underdevelopment is the prime problem in the field of water resources and is particularly serious in the developing countries. For example, in the African region, not more than 2 per cent of potential water resources have at present been developed. The corresponding figure for South America is 3 per cent. Globally, man controls only 5 to 6 per cent of the volume of water that is considered potentially controllable by him. Even allowing for the variations in temporal and spatial distribution, this figure gives a bleak picture of the present situation in water resources development. Coupled with underdevelopment is the fact that efficiencies in the use of water in irrigated agriculture are far below attainable levels.

Phased action programmes

The Water Conference has recommended that national action, with the support of the international community, be directed to formulating phased action programmes for the development and use of water for agriculture and that action be taken on such a basis.

The essential elements of the programme are:

(a) Analysing and assessing the problem and its magnitude and also the potential for development;

(b) Planning for integrated development;

(c) Financing and identifying national capabilities and the need for external aid;

(d) Building up national advisory services;

(e) Strengthening training, extension services, research and formal education;

(f) Establishing and improving institutional frameworks for management, administration and legislative support.

The Water Conference Action Plan calls for increased production and productivity. Two approaches in this regard are:

(a) Bringing new, potentially irrigable land under irrigation (irrigation development); and

(b) Improving the efficiency of use on existing and new irrigations.

Development of irrigation should be made with proper consideration of land and water resources and of long- and short-term productivity. Equally important is the improvement of efficiency in water use through such measures as better on-farm management, reduction of transit and storage losses and adoption of technology packages. Technology packages in turn deal with manpower training, research on soil-water-plant relations and extension services, mechanization, proper design, construction and operation and maintenance.

As shown in table 30, between 1975 and 1990, globally there is scope for bringing an additional 45 million hectares of land under irrigation and for improving 86 million hectares of land already under irrigation. In the developing countries of Africa, Latin America and Asia, the total includes 22 million hectares of new land to be irrigated, compared with 45 million hectares to be improved. These figures indicate that the development targets in general give considerable emphasis to improvement of existing irrigation. Africa south of the Sahara is an exception. Because of the relatively small irrigated area that has existed up to now, new developments are projected to predominate. The programme in developing countries would require the development of additional water on the order of 440 billion cubic meters, and 78 million hectares to be equipped with drainage facilities. It has been estimated that an investment of nearly $100 billion would be required for infrastructure related to the new and improved irrigation in developing countries.

This does not include investments in manpower training. Manpower requirements related to the projected new irrigation developments in the developing countries have been estimated to involve nearly 11 million farmers, labourers and manual workers; 175,000 skilled workers; 30,310 technicians; 20,450 extension workers and 5,540 professional staff. It is estimated that a total of $470 million in investments would be needed to develop the manpower needed: $90 million for technicians; $155 million for professionals; $100 million for extension workers for new irrigation; and $225 million for extension training in areas to be rehabilitated.

Table 30: Irrigation and drainage targets, 1975-1990

(Summary table)

Region[a/]	New irrigation[b/] Area[b/] (1000 ha)	New irrigation[b/] Cost (millions of dollars)	Improvement of existing irrigation (1000 ha)	Improvement of existing irrigation (millions of dollars)	Increased irrigated cropped area (1000 ha)	Water demand (m^3 $x10^9$)	Drainage Area (1000 ha)	Drainage Cost (millions of dollars)
Africa (excluding North-East Africa)								
North of Sahara	240	600	222	126	326	2.58	1 565	118
South of Sahara	720	2 016	561	318	1 200	18.00	4 335	338
Total	960	2 616	783	444	1 526	20.58	5 900	456
Latin America								
Central America and Mexico	1 000	2 400	1 600	880	1 328	9.30	4 365	270
Caribbean	240	576	324	179	310	2.17	388	39
South America	1 861	3 536	2 774	1 047	1 927	21.20	14 492	1 157
Total	3 101	6 512	4 698	2 106	3 565	32.67	19 245	1 466
Near East								
North East Africa	1 560	4 836	2 370	1 564	2 290	16.03	2 406	846
Middle East	2 735	7 111	7 419	4 699	4 031	28.22	7 237	2 430
Total	4 295	11 947	9 789	6 263	6 321	44.25	9 643	3 276
Asia								
South Asia	9 894	28 692	24 833	11 423	18 472	203.19	29 135	5 648
South East and Far East	3 954	11 862	4 885	2 333	9 163	137.45	14 261	2 813
Total	13 848	40 554	29 718	13 756	27 635	340.64	43 396	8 466
Subtotal	22 204	61 629	44 988	22 569	39 047	438.14	78 184	13 659
Asia Centrally Planned (incl. Asian part of USSR)	10 690		23 535		41 702	458.70		
USSR and Eastern Europe	9 845		3 031		4 845	33.90		
Subtotal	20 535		26 566		46 547	492.60		
Western Europe	1 361		2 759		1 361	9.53		
North Americas	684		8 846		684	4.79		
Oceania, Japan and others	500		3 090		500	5.50		
Subtotal	2 545		14 695		2 545	19.82		
World total	45 284		86 249		88 139	950.56		

a/ Regions in accordance with FAO classification.

b/ Including drainage provision.
In the case of multipurpose water developments, only those costs apportioned to irrigation have been incorporated.

Annex IV

DRINKING WATER SUPPLY AND SANITATION: RECOMMENDATIONS OF HABITAT AND THE UN WATER CONFERENCE

Recommendations

Habitat: the United Nations Conference on Human Settlements (United Nations 1976) held at Vancouver, Canada, from 31 May to 11 June 1976, in its recommendation C.12, stated that:

(a) In the less developed countries, nearly two thirds of the population do not have reasonable access to safe and ample water supply, and even a greater proportion lack the means for hygienic waste disposal;

(b) Safe water supply and hygienic waste disposal should receive priority, with a view to achieving measurable qualitative and quantitative targets serving all the population by a certain date; targets should be established by all nations and should be considered by the forthcoming United Nations Conference on Water."

In the same recommendation, Habitat also pointed out that in most countries urgent action was necessary to "adopt programmes with realistic standards for quality and quantity to provide water for urban and rural areas by 1990, if possible" and to "adopt and accelerate programmes for the sanitary disposal of excreta and waste water in urban and rural areas".

Building on the Habitat Conference, the United Nations Water Conference, held at Mar del Plata, Argentina, from 14 to 25 March 1977 adopted a long resolution and recommended a detailed plan of action on community water supply and sanitation. That these goals should be viewed as a basic human right and that strategies and targets toward meeting these goals should be designed can be seen from the following declaration of the Water Conference:

"IN ORDER TO IMPLEMENT RECOMMENDATION C.12 OF HABITAT: UNITED NATIONS CONFERENCE ON HUMAN SETTLEMENTS, THE DECADE 1980-1990 SHOULD BE DESIGNATED THE INTERNATIONAL DRINKING WATER SUPPLY AND SANITATION DECADE AND SHOULD BE DEVOTED TO IMPLEMENTING THE NATIONAL PLANS FOR DRINKING WATER SUPPLY AND SANITATION IN ACCORDANCE WITH THE PLAN OF ACTION CONTAINED IN (CONFERENCE) RESOLUTION II....THIS IMPLEMENTATION WILL REQUIRE A CONCERTED EFFORT BY COUNTRIES AND THE INTERNATIONAL COMMUNITY TO ENSURE A RELIABLE DRINKING WATER SUPPLY AND PROVIDE BASIC SANITARY FACILITIES TO ALL URBAN AND RURAL COMMUNITIES ON THE BASIS OF SPECIFIC TARGETS TO BE SET UP BY EACH COUNTRY, TAKING INTO ACCOUNT ITS SANITARY, SOCIAL AND ECONOMIC CONDITIONS" b/(United Nations, 1977, para. 15).

In resolution II of the Action Plan, the Water Conference recommended that Governments reaffirm their commitments made at Habitat to "adopt programmes with realistic standards for quality and quantity to provide water for urban and rural areas by 1990, if possible" (United Nations, 1977, chap. I). The Plan of Action set forth in that resolution specifies that the following measures should be given priority:

(a) Promotion of (i) an increased awareness of the problem; (ii) commitments by national Governments to provide all people with water of safe quality and adequate quantity and basic sanitary facilities by 1990, according priority to the poor and less privileged and to water-scarce areas; (iii) a larger allocation of resources to this sector;

(b) Expansion of manpower training at all levels;

(c) Enlargement of flows of national, international and bilateral funds on more favourable terms and conditions;

(d) Increasing public participation, training and education in relation to domestic hygiene, and involvement in the planning, construction, operation and maintenance of facilities.

An analysis of the Habitat target

Analysis of some of the implications of Habitat recommendation C.12 and related aspects were made in the report on community water supplies (E/CONF.70/14), one of the basic documents considered by the Water Conference. Some of the results and data from that study are presented in table 31, which gives an indication of the population served in developing countries (excluding China), population to be served and investments required if the Habitat targets are to be met. The following observations are based on data presented in the table:

(a) At present, only 38 per cent (weighed average of 77 per cent urban, 22 per cent rural) of the 2 billion inhabitants of the developing countries (excluding China) have access to reasonable supplies and only 33 per cent (weighed average of 75 per cent urban and 15 per cent rural) have sanitary facilities. A further impression of the magnitude of the problem can be obtained when projections are made taking population increases into account. Assuming present rates of consumption and rates of population growth, the demand by 1990 for community water supply will increase three to five times the present level;

(b) The figures on investment requirements and population to be served were obtained under the following assumptions: that 100 per cent of the rural population will have water and sanitary facilities by 1990 and that a percentage of the urban population not less than the 1975 percentage will have house connexions;

(c) Given these assumptions, an investment of $140 billion (1977 dollars) is needed to meet the targets. A doubling of the present levels of annual investment is implied in the disposition of the investments.

Table 31. Community water supplies and sanitation: population served and to be served (Habitat target) and investment requirements

	Community water supply (CWS) a/				Sanitation (SAN) a/			
	Urban			Rural	Urban			Rural
	hc b/	sp c/	Total		hc b/	hs d/	Total	
Percentage of population served in 1975	57	20	77	22	25	50	75	15
Assumed 1990 Habitat targets (percentage of population served)	57	43	100	100	25	75	100	100
1990 population (millions)			1 088	1 882			1 088	1 882
Population served in 1990 if Habitat targets reached (millions)	620	468	1 088	1 882	272	816	1 088	1 882
Population served in 1975 (millions)	335	115	450	313	148	289	437	209
Additional population to be served to reach Habitat targets (millions)	285	353	638	1 569	124	527	651	1 673
Unit cost per capita (1977 dollars)	121	48	-	26	112	35	-	5
Investment required to meet Habitat targets (millions of 1977 dollars)	34 500	16 900	51 400	40 800	13 900	18 440 e/	32 340	8 400
Investment required per annum to meet Habitat targets (millions of 1977 dollars)	2 300	1 130	3 430	2 720	930	1 230	2 160	560
Investments estimated made per annum during 1971-1975 (millions of 1977 dollars)	2 450	310	2 760	690	490	550	1 040	140
Required Habitat target investment rate as multiple of that in 1971-1975	1.0	3.6	1.2	3.9	1.9	2.2	2.1	4.0
Intrasectoral distribution of investment (row total = 100 per cent) 1971-1975	(53)	(7)	60	15	(10)	(12)	22	3
) 1976-1990	(26)	(13)	39	31	(10)	(14)	24	6

Required annual investment increase for CWS from $3 450 million to $6 150 million; that is: 1.8 times

Required annual investment increase for SAN from $1 180 million to $2 720 million; that is: 2.3 times

Required annual investment increase for CWS and SAN from $4 630 million to $8 870; that is 1.9 times.

Footnotes to table 31

Source: "Report on community water supplies" (E/CONF.70/14).

a/ Urban: (i) Percentage of house connexions (CWS and SAN), not less than percentage in 1975.
(ii) Percentage of street standposts (CWS) or household systems (SAN) in 1990 = [100 - (i)] per cent

Rural: (iii) Percentage served (CWS and SAN) in 1990 = 100

b/ hc = house connexion

c/ sp = street standpost

d/ hs = household system

e/ 80 per cent of this cost likely borne by property owners.

Annex V

COMPARISON AND ANALYSIS OF METHODS FOR DEFINING STANDARDS OF WATER QUALITY: REPLIES RECEIVED FROM EUROPEAN COUNTRIES IN RESPONSE TO A QUESTIONNAIRE (UN ECE, 1978)

A. Are water resources in your country classified according to quality?

Among the 20 countries that replied to the questionnaire, 11 generally use a water-quality classification of one form or another.

In Austria, classification into four classes is made first with regard to biological aspects, according to the Kolkwitz-Marsson-Liebmann saprode system.

In Bulgaria, Czechoslovakia, Hungary and Poland, classification takes into account the physical, chemical, micro-biological, radiological and hydrobiological features of the respective water resources. In Bulgaria and Poland, three water-quality classes are applied, while in Czechoslovakia five and in Hungary four classes are distinguished. These classes take into consideration the recommendations of the "Principles of water quality criteria, standards and classification within the Council for Mutual Economic Assistance (CMEA)". Among the countries mentioned, water-quality criteria are standardized only in Czechoslovakia.

In the Byelorussian Soviet Socialist Republic and the Union of Soviet Socialist Republics, water resources are divided into four categories with regard to their use. Classification into categories for drinking water, domestic uses, recreation and fish hatcheries (two categories) has been taken into consideration.

Classification into five classes of water quality in the United Kingdom and the Netherlands is based on the BOD_5, the dissolved oxygen content, or on the oxygen saturation and NH_3 content respectively from among the parameters characteristic of the oxygen content. The aim of the classification is to give an overall picture of the pollution rate of the water resources and, if necessary, to provide information on the possibility of utilization as drinking water. If the water resource can be taken into account for water supply purposes, the United Kingdom also applies EEC principles of classification.

In Finland five classes of water quality are used; in addition water resources are evaluated on the basis of significant parameters for the type of water uses concerned. In Spain, three classes of water quality have been accepted, based on their physical, chemical, micro-biological and radioactive properties, utilization for water supply being predominant.

According to the principles of EEC, accepted in 1975, surface water resources are divided into three categories (A_1, A_2, A_3) with regard to health, ecological and social considerations. Forty-six physical, chemical and microbiological parameters are applied in the classification. Two limit values are given to each water quality category: under the so-called safety limit, humans and other living organisms (flora and fauna) are not exposed to danger; if the more stringent regulations are applied, no damage can occur. Proper treatment techologies are suggested for the different categories when used for drinking water purposes.

In Belgium, water resources are not classified according to quality, but the maximum permissible limits are given for the most important chemical parameters and organic and inorganic pollutants, based on ecological considerations. In Italy water resources are not ranged according to quality either. In the past, attempts have been made to range waters into classes according to quality; these endeavours have not, however, resulted in creating general rules. Limit values are fixed to classify surface waters utilizable as potable water.

In Romania the quality of surface water resources is characterized by limit values for the different components. In Canada, because of the wide range of the quality of natural water resources, water-quality limit values are determined separately for each catchment area, apart from the demands of water uses most sensitive to pollution. In addition to the general parameters, limit values are fixed for the most toxic inorganic substances, while limit values regarding organic matters are being reconsidered.

No water quality-limit values are applied in Cyprus, France, Norway, Sweden and Turkey. Emission standards of an informative character will possibly be accepted in Sweden in the future; in this respect four component groups (materials causing eutrophication, organic matters, metals, some toxic materials) can be distinguished.

B. Are effluent standards in use in your country?

In Austria, Bulgaria, Cyprus and Turkey no water-quality standards are used. In Austria and Turkey, however, they are under elaboration; in Austria, effluent standards covering altogether 50 parameters will be introduced in the near future and will consider the quality of the recipient, the demand for water uses and economic aspects.

No effluent standards are used in Sweden; the best treatment technologies available are imposed instead.

The effluent standard in force in Poland contains the maximum permissible values for the parameters of effluents discharged into the recipient.

In the other 13 countries replying, the quality and quantity of the effluents dischargeable into the recipients are determined individually, for specific branches of industry, taking into account the features, conditions and capacity for assimilation of the receiving water, the demands of water users and economic considerations.

C. Are drinking water standards in use in your country?

No legally accepted drinking water standards are in use in Belgium, Canada, Cyprus or the United Kingdom. Canada applies the WHO International and European Standards for Drinking Water and the drinking water standards of the United States as terms of reference, while Cyprus and the United Kingdom use the WHO European Drinking Water Standard.

Drinking water standards in 12 countries (Austria; Bulgaria; Czechoslovakia; Finland; Germany, Federal Republic of; Hungary; Italy; Poland; Romania; Sweden; Switzerland; and Turkey) are based on the WHO European Drinking Water Standard, with lesser or greater differences related to the special features of the respective countries.

The drinking water standards of the Byelorussian SSR and the USSR differ from the WHO standards in many parameters.

D. Would you agree with the harmonization of standards to a certain extent in ECE countries?

Ten countries (Austria, Byelorussian SSR, Canada, Czechoslovakia, Hungary, Italy, Netherlands, Poland, USSR and United Kingdom) agree with harmonization of all standards in question, to a certain extent. Canada thinks it expedient to co-ordinate standards related to water quality per catchment areas.

Finland wishes to participate in harmonizing water resources and drinking water standards but is not able to comment on effluent standards, owing to lack of knowledge of the official standpoint.

Hungary considers the harmonization of water resources and effluent standards necessary but not in the case of drinking water standards.

Bulgaria looks upon the norms related to the quality of internal water resources as national matters; however, in the case of international rivers and catchment areas it is willing to co-operate with the countries concerned. Romania believes that it is not possible, nor even necessary, to co-ordinate the standards in question.

E. Comparison of water-quality parameters employed in ten European countries

Based on the replies to the questionnaire, certain tabulations concerning the water-quality parameters employed in 10 European countries are set out in table 32.

Table 32 Parameters taken into consideration when classifying water quality in 10 countries [a]

Frequency of application	Water-quality parameter	Unit	Limit values	
			Best	Worst
10	Dissolved oxygen	mg/l	7	1
9	Biological oxygen demand	mg/l	1	30
8	Ammonium	mg/l	0.005	10
	Iron (total)	mg/l	0.1	5
	Phenols	mg/l	0.001	0.5

(continued)

Table 32 (continued)

Frequency of application	Water-quality parameter	Unit	Limit values	
			Best	Worst
	Coli index		1000	1 million
7	pH	-	6.5-8.0	6.0 and 10
	Cl^-	mg/l	50	400
	SO^2	mg/l	80	500
	NO^-	mg/l	5	200
	Total hardness	0	10	40
	Mercury	mg/l	0.001	0.02
	Arsenic	mg/l	0.05	4.0
	Copper	mg/l	0.01	3.0
	Lead	mg/l	0.05	0.5
6	ANA detergents	mg/l	0.5	3.0
	Petroleum derivatives	mg/l	0.05	0.3
	Total dissolved solids	mg/l	300	1500
	Total suspended solids	mg/l	20	100
	COD perm.	mg/l	2	200
	Sulphide	mg/l	not detectable	0.1
	Cadmium	mg/l	0.005	0.01
	Chromium III	mg/l	0.05	0.5
	Chromium IV	mg/l	0.05	0.2
	Zinc	mg/l	0.01	15
	Manganese	mg/l	0.05	0.8
	Fluorides	mg/l	1.0	
5	Easily liberated cyanides	mg/l	0.01	0.1
	Total cyanides	mg/l	0.05	0.1
4	Cobalt	mg/l	0.01	5.0
	Nickel	mg/l	0.01	1.0

a/ Bulgaria, Byelorussian Soviet Socialist Republic, Czechoslovakia, Finland, Hungary, Netherlands, Poland, Spain, Union of Soviet Socialist Republics, United Kingdom of Great Britain and Northern Ireland.

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