Chapter 11

WATER DEMAND MANAGEMENT AND LOSS CONTROL

11.1 Introduction

Water demand management (WDM), arose from the key principles of the Dublin Statement, which were restated at the Second World Water Forum held at The Hague in 2000. Water demand management, sometimes referred to as demand-side management, uses a range of tools such as conservation, pricing, water-efficient technologies and public education in conjunction with existing water supply infrastructure (i.e. supply-side management) to address the problems of dwindling water supplies and escalating water demand. The shortfall between supply and demand is a worldwide problem that is being exacerbated in many areas by climate change. Although applicable to all water users including industry and the biggest user agriculture, the section below deals only with drinking water supplies. Water demand management has been pioneered in Canada through the POLIS water sustainability project (POLIS 2005) and in Australia, where the first water use efficiency labelling scheme has recently been introduced (Government 2005). Specific actions may include the integrated use of conservation measures, metering, charging, building regulations incorporating water use minimization, and the increased water use efficiency of appliances and fixtures. To be successful, WDM also requires the development of new management techniques and structures, the use of decentralized technologies, and a change in user attitudes and behaviour.

Water demand management has identified the need to move away from expensive, unrestrained and ecologically damaging infrastructural development associated with continually increasing water production. Rather it aims to replace traditional engineered solutions with a more sustainable approach where existing resources are used more effectively so there is no longer a need to exploit new surface or ground water resources, or damage existing resources further by increasing abstraction or by the construction of impounding reservoirs. The POLIS project has proposed ten key actions to achieve a more sustainable use of water resources (Table 11.1) (Brandes 2006). All had to meet the basic criteria of being technically feasible, broadly applicable, socially acceptable and cost effective compared to normal infrastructural development. These are considered below in detail.

11.1 Controlling water use

Although there are theoretically water resources sufficient to meet world requirements now and for the foreseeable future, the increasing distances

Table 11.1: The ten key steps identified by the POLIS project to achieve water sustainability.

Priority area	Actions
Leakage control	Locate and repair leaks: Distribution network Supply pipes Household leaks
Water-efficient appliances and fixtures	Replace the following with water efficient models: Toilet Showerhead Taps/faucets Washing-machine (laundry) Dishwasher
Implementation of water demand management (WDM)	Creation of permanent WDM staff Integration with existing supply-side management Sufficient financial support Long-term commitment to WDM
Linking water conservation and development	Make water infrastructural funding dependent on WDM Capping local water use so that further development is dependent on offsetting new demand through conservation
Conservation-orientated pricing	Universal metering Volume-based pricing
Planning sustainable	Long-term strategic planning Soft-path approach to planning
Rainwater harvesting	Promote decentralized infrastructure New buildings to rely on rainwater as primary water source Develop new gardening methods
Water reuse	Promote decentralized infrastructure Develop high-profile demonstration projects to build community support
Water-sensitive urban design	Integrate land use decisions and planning with catchment management and water conservation
Education	Development of a water ethic Identify and target high-water-use groups Promote community involvement Promote practical advice and solutions

Source: adapted from Brandes (2006)

required to pump water, and the storage required to meet droughts, make the cost of exploiting new sources higher and higher. The price of further water is therefore likely to increase. In addition, the expected increasing living standard of many of the population will mean that greater volumes of water will be sought, even thought consumption may start at a minimal level. Resources are being depleted or polluted. This affects not only availability for human consumption but also the amount of water in rivers and new supplies. Sustainability of resources is also threatened and decreased yields may occur reduce requirements for raw water. All this cannot be achieved except by considering marginal costs and increasing tariffs. The occasions when water tariffs need to be considered will also affect the instrument used to control usage. During crises (e.g. drought), short-term tariff increases may be applied, whereas in the long-term, the average tariff will depend on historical costs and the cost of new sources.

Water consumption can be limited by physical, sociological or economic means (instruments). Physical means include cut-offs or pressure control by reduced pumping or constrictions in pipes. e.g. orifices or washers. The latter costs money in waste of energy and cost of installations. On the other hand, it may even out the water drawoff variations by making consumers take water uniformly over more hours per day and provide in-house storage to meet peak consumption. The former (curtailing supply over periods of hours), could result in higher peaks when supply is resumed, but this will in turn reduce pressure and therefore peak drawoff. Demand control by pressure reduction could result in different drawoff patterns. Roof tanks could be tilled at night. This will save distribution pipe costs but not necessarily reduce total volume of use. It may also be possible to reduce supplies to uneconomical, no longer valued consumers with compensation. in preference to newer consumers. In the long- term, water-saving plumbing devices could be installed or retro-fitted. These include small and double action cisterns, low-volume showers, and automatic tap closers. Invention of water savings devices such as reuse of basin water for toilet flushing, not only saves water in that situation, hut they make people aware of water scarcity.

Water savings devices: The use of water savings plumbing systems can do a lot to save water in the household. Their efficiency depends on the design and cost effectiveness will be a function of the value of water saved. In the case of metered connections, these savings directly benefit the consumer. Such devices include:

- Aerators on taps and low flow taps/showers
- Automatic tap closures
- Dual flush toilets
- Low flush toilets (down to 5 l for faeces. 2 l for urine)
- Low water consumption gardens

- Diversion of grey water to gardens
- Diversion of hand basin water to toilet flushing

In industry, the savings and value of reclaiming and recycling is largely one of economics. On the public side, other possibilities arise, such as use of urinals with low intermediate flushing, and replacing night street flushing by sweeping.

A distinction should be made between water used and water consumed. Used water returned to sewers is largely a quality and treatment problem. Water lost by evaporation is irretrievable and should be costed at the top marginal cost.

A wastewater tariff based on the concentration of pollutants in effluent could cause industry to dilute its wastewater. Hut tariffs based on the volume of wastewater could enforce industries to evaporate wastewater, to avoid this, high water tariffs are effective, plus a tariff based on the total pollution load in wastewater.

Sociological methods include appeals, way of living or legal action. Appeals, through the media or on monthly accounts, rarely last long before consumers forget the urgency. Long-term changes in ways of life to reduce water consumption will generally be caused by increasing water costs, together with public relations campaigns. Legal enforcement of water restrictions, in associated with fines, can be effective but costly to apply. It may mean inspectors checking consumers, or relying on spying neighbours. Then fines would have to be imposed by courts unless incorporated in water accounts. Such methods include prohibiting use of water on gardens on specified days, banning filling swimming pools or use of hosepipes for flushing drives. Consumer awareness can encourage local reuse of grey water, e.g. wash-water for gardening, or toilet flushing.

Economic methods include water tariffs, metering or charges on discharges. Theoretically, the best system would be to charge prices which reduce the usage to meet availability. This is, however, an unknown equation since the true value of water may not be known to the supplier or even the consumer. It may also involve tiered tariffs. That is, successively increasing consumption will be charged at higher rates so that the basic requirements of consumers, particularly domestic consumers, are met and more luxurious uses are charged at higher rates. This assumes there will be no trading between consumers. It may also encourage consumers to seek alternative sources which, although they may be more costly in total supply, may be cheaper to individual consumers. Apart from the socio-economic objectives of providing water, there is a longterm value of water. If the world population and standards of living continue to increase, water will become scarcer. It may also occur that climatic change requires more careful use of water owing to reduced availability or greater variability in rainfall. The traditional approach to supply management is to meet demands with successively more expensive schemes until the demand balances the supply. However, unless marginal pricing is applied, the average supply cost will always be less than the marginal additional cost of water, so that the demand will continue to increase asymptomatically.

11.2 Economic theory of supply and demand

A fundamental concept in economics is the law of supply and demand. Figure 11.1 shows theoretical supply and demand for water. At higher prices, producers would be willing to supply more but consumer demand would decrease: at lower prices, consumers would demand more but producers would cut back on supply. Figure 11.1 shows the theoretical equilibrium condition between the price and the quantity supplied and demanded for average costing and marginal costing.

With increasing price, the reduction decreases because further reductions may require changes in behaviour that are inconvenient or contrary to personal or social norms. And at even higher prices, there will be no reduction at all if it means cutting into essential uses like cooking and waste disposal. On Figure 11.2 this relationship is shown by an increasingly steep demand curve as prices increase on the left side of the graph. At lower prices, people will buy and use more water, but there is a limit on how much water anyone can use, even if it is free. So again as price falls, demand eventually drops off as well.

The rate at which demand changes as price changes is called the *price elasticity of demand*. (Similarly, there is a *price elasticity of supply*.) Conceptually, when demand changes a great deal for a given change in price demand is said to be *elastic*. When demand does not change very much compared to the change in price, demand is said to be *inelastic*. Economist calculate the elasticity of demand e as:

$$e = \frac{dQ/Q}{dP/P} \qquad 11.1$$

Where P is price and Q is quantity.

As new water schemes are commissioned, the average cost per unit (long-run

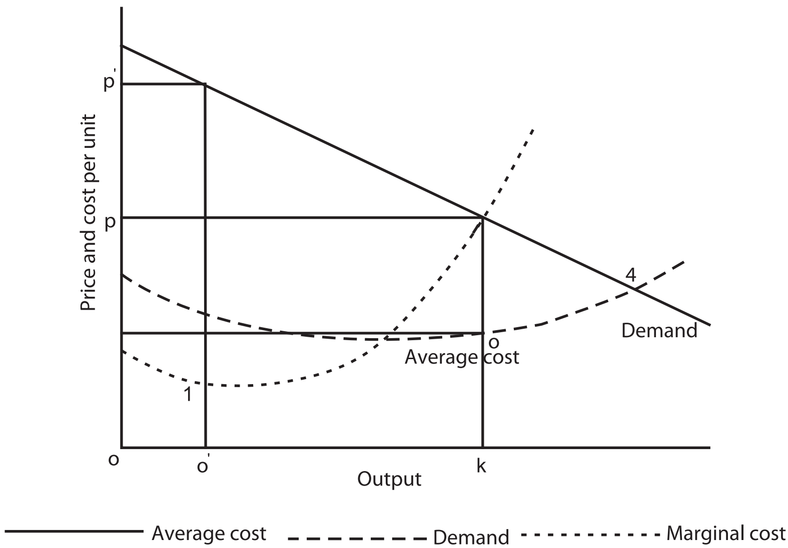

Figure11.1: **Supply and demand with different price structures**

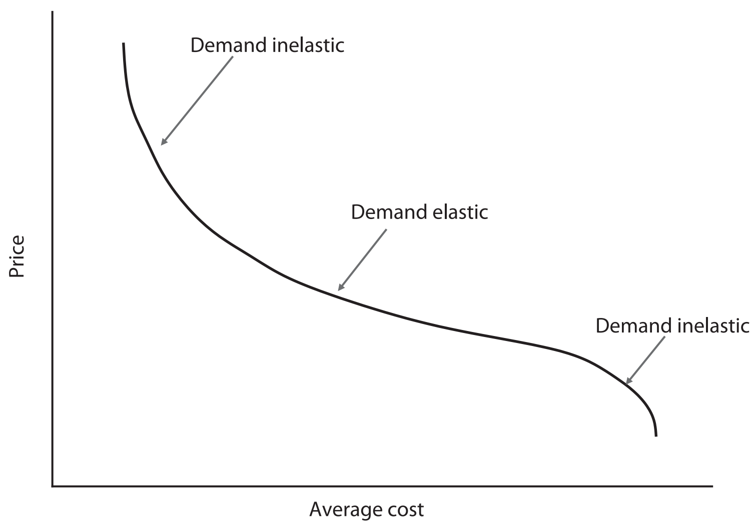

Figure11.2: **Showing how elasticity changes at different points along the water demand curve.**

cage cost or LRAC) is likely to increase due to more expensive projects succeeding cheaper projects. On the other hand, over the life-span of each project the short-run average costs (SRAC) may reduce as consumption 'eases and more efficient use of facilities occurs (Figure 11.3).

The short run cost changes are due to construction of new schemes or abnormal one-off costs. For example when a new project such as a dam is constructed it may be able to meet demands for another twenty years but initially the cost (probably annual interest and loan redemption) have to be met.

Without a balancing fund this may result in a price hike for the water. This could in fact be a compound effect, for the increase in cost of water could reduce demand temporally, resulting in a further price increase.

A water company should anticipate these reactions to smooth to price increases. And new schemes could be delayed by applying restrictions for a few years to reduce costs and enable the new project to come in at a higher demand base. If there is more than one source of water the short term cost in Figure 11.3 may not rise to the marginal cost as Costs could be averaged over old and new schemes.

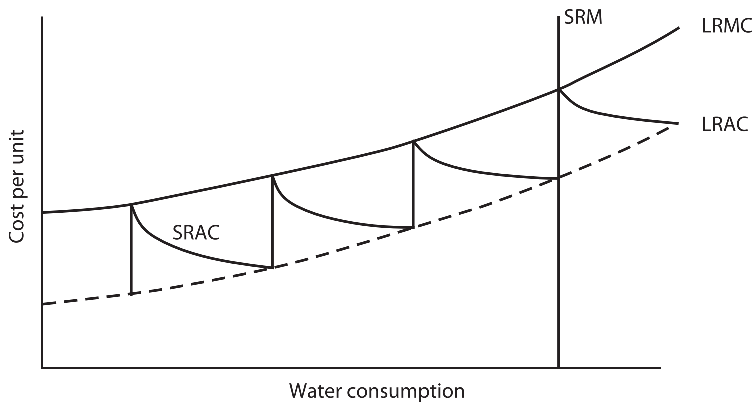

Figure11.3: **Short-run average costs of water supply. SRM = short range marginal, LRMC = long range marginal cost, LRAC = long range average cost.**

11.2.1 Metering of water

Water metering is the process of measuring water use through water meters (Figure 11.4). Water metering is common for residential and commercial drinking water supply in many countries, as well as for industrial self-supply with water. However, it is less common in irrigated agriculture, which is the major water user worldwide. Water metering is also uncommon for piped drinking water supply in rural areas and small towns, although there are examples of successful metering in rural areas in developing countries, such as in El Salvador.

Figure 11.4: **Water metering**

Metering of water supplied by utilities to residential, commercial and industrial users is common in most developed countries, except for the United Kingdom where only about 30% of users are metered. In some developing countries metering is very high, such as in Chile where it stands at 96%, while in others it still remains low, such as in Argentina.

The share of residential water metering in selected cities in developing countries is as follows:

- 99% in Santiago de Chile (1998)
- 96% in Abidjan, Côte d'Ivoire (1987)
- 62% in cities in Guatemala (2000)
- 30% in Lima, Peru (1991)
- 28% in Kathmandu, Nepal (2001)
- 5% in Conakry, Guinea (1984)
- 2% in Buenos Aires, Argentina (1992)

Benefits: The benefits of metering are that:

- in conjunction with volumetric pricing it provides an incentive for water conservation,

- it helps to detect water leaks in the distribution network, thus providing a basis for the reduction of Non-revenue water;
- it is a precondition for quantity-targeting of water subsidies to the poor.

Costs: The costs of metering include

- the investment costs to purchase and to install meters, as well as
- the recurrent costs to read meters and to issue bills based on consumption instead of bills based on monthly flat fees.

Those consumers who pay average cost will tend to use more than those paying higher marginal cost. If the water is metered, it is the (long range) marginal cost to the consumer which influences the consumption (Figure 11.5) since the supplier can observe who is using water excessively and charge them a higher marginal tariff If it is unmetered, only public responsibility, which is related to LRAC, controls consumption (Q_1), or the water company can only charge an average tariff which will encourage greater use.

The marginal cost of not metering is area ABQ_1Q_2. This may be compared with the cost of metering. Actually, the marginal cost varies slightly with metering, so the comparison is a bit more complicated (see Henderson Sellers, 1979).

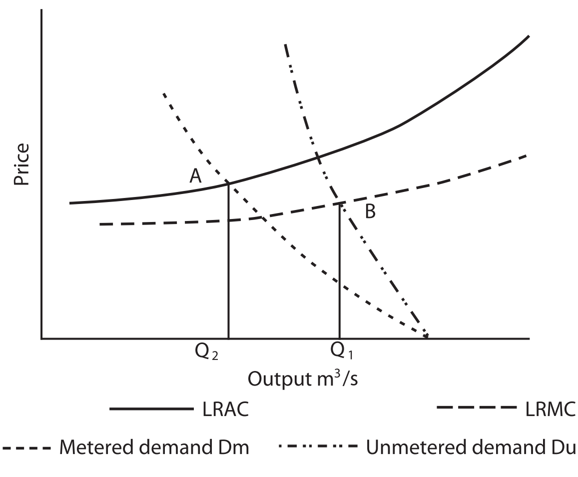

Figure 11.5: Demand curves with and without metering

Problems: Problems associated with metering arise particularly in the case of intermittent supply, which is common in many developing countries. Sudden changes in pressure can damage meters, so that many meters in cities in developing countries are not functional. Also, some types of meters become less accurate as they age and under register consumption thus leading to lower revenues, unless they are being replaced regularly. Many types of meters also register air flows, which can lead to over registration of consumption, especially in systems with intermittent supply, when water supply is re-established and the incoming water pushes air through the meters.

11.2.2 Management by use of tariffs

If the true value of water to consumers could be assessed, it may be possible to charge a limiting tariff. This method could be applied on a long-term basis or less effectively for short-term (crisis) demand reduction. However, one must be careful of applying crisis criteria persistently. Some consumers may locate their organization based on indicate water tariffs but the use of variable tariffs to manage water during drought, for example, must be explained and incorporated within the overall tariff system.

The level of consumption could be decided at the planning stage, if the cost of assured water is balanced against the Cost to the economy of rationing. However, the operational basis will be from a different perspective.

Unfortunately, a uniform tariff cannot be applied in this way to restrict the use of water, for the poorest sectors of the economy may not be able to meet the miffs which would be imposed on industry in order to force them to restrict water. Therefore, a percentage reduction, or a differential tariff or shadow value may have to be incorporated. The shadow value may not be paid by the poorer sectors but it should be added onto the cost of water to others. The alternative would be to charge a tiered tariff, i.e. the first volume would be at the original tariff and above a lifeline supply rate the tariff would be successively increased a function of the percent of the lifeline supply rate. In this way, poorer consumers will only pay marginally more for excess consumption, whereas richer or industrial consumers would pay considerably more. The tariffs would have to be based on the economic value to all consumers. Burlingame (2002) indicate increased tariffs reduce consumption but to a limit.

Hong Kong's experience with tiered tariffs is that the resulting demand management is limited. But they were limited by having to keep charge levels within inflation. Their most successful experiment in saving water was to use sea-water for flushing. Tucson's experiments with block rates also failed due to the politicians' control on maxima, but their summer rate differential reduced consumption. Australia is also experimenting with demand management.

In fact, water pricing experiences throughout the world show that external objectives of politicians or administrators can destroy the efficiency of water use control through tariffs. Increasing prices can instead be intended for many purposes. e.g. financing new schemes, becoming financially self- sufficient or cross-subsidization.

In the long run, it may also be that the consumer could find alternatives to being restricted in water usage or paying higher tariffs. He may seek alternative sources such as groundwater. These sources may have a higher operating cost but as they are intermittent it may not be as severe as long-term usage. This results in efficient conjunctive use of alternative resources.

Consumers may also elect to reuse water and if necessary purify the effluent reused. Again this may be a higher operating cost alternative but, owing to the limited duration effect, could be ameliorated.

The effectiveness of economic methods to control use will vary with the consumer. Industry may be most sensitive to price increases, whereas poor people will hardly be able to adjust their consumption even though they may find it difficult to pay. The richer domestic consumer is likely to have most elasticity in demand, but this is likely to constitute a decreasing proportion of the total.

In order to put objectiveness into water tariffs, (Burlingame 2002) suggest a five-part tariff based on:

Variable costs:	Consumption
	Maintenance
Fixed costs:	Connection
	Development
	Upgrading

The above basis is, however, not sufficiently detailed to control use or obtain a method of cost allocation. There are other factors which affect water tariffs. e.g.:

- Capital and operating costs
- Opportunity cost
- Time-of-use or peak-load basis
- Size of property
- Size of connection
- Zoning of district or purpose of use
- Timing of application

- Investment reserve
- Conservation
- Environmental
- Foundation consumers
- Insurance to ensure continuity during shortfalls
- Capacity allocation
- Tiered
- Cross-subsidization of income groups
- Location

11.2.3 Effect on consumption

There is disagreement as to the effect of metering and water pricing on water consumption. The price elasticity of metered water demand varies greatly depending on local conditions. The effect of volumetric water pricing on consumption tends to be higher if the water bill represents a significant share in household expenditures. There is evidence from the UK that there is an instant drop in consumption of some 10% when meters are being installed. In Hamburg, Germany, domestic water consumption for metered apartments (112 liter/capita/day) was 18% lower than for unmetered apartments (137 liter/capita/day) in 1992. The municipal utility Hamburger Wasserwerke GmbH had installed more than 40,000 water meters in individual apartments of older houses since 1985. All new apartments had to be metered by law. Previously there had been only a single meter for the entire house in multi apartment houses. In every new building must have the water meter by law by DWASA, but unfortunately , many illigal connections make the water supply system difficult.

11.3 Timing

There are three stages during which the tariff for water needs consideration. (Table 11.2 summarizes which methods of demand management are applicable to which occasion.)

11.3.1 Long-term (planning and design)

Before a water scheme is constructed, the capital cost of the project is likely to be the most serious economic consideration. Average running costs will be added to

Table 11.2: **Demand management methods and their use**

Method	Crisis management (Drought, non-payment)	Operational time-frame	long-term (Planning and design)
Technical	Pressure reduction Scheduled supply Valve closure	Flow control Orifices Legislation Cross subsidies	Metering Loss control Plumbing devices
Social	Appeal Social persuasion Advertisements	Differential tariffs Trade	Consumer awarencess Education
Economic	Fines Punitive measures		Supply and demand economics Marginal prices

discounted capital cost of dams and conduits for alternative schemes in order to select the most economical alternative. If rationing is to be considered at this stage as an alternative to larger resource schemes, the true economic cost to the consumers due to shortfall also needs to be included. (This is not the same as the income to the water supplier which may even increase due to punitive tariffs during shortfall.)

When new water schemes are being considered, the cost of the scheme and consequently the average cost of water to consumers is the prime criterion. Alternative sources and levels of assuredness will be compared. This section is concerned with the reliability of supply during drought, and typically the more reliable the surface source, the greater the cost will be (Figure 11.6).

11.3.2 Operational time-frame

Once the scheme (e.g. darn and waterworks) is built, its cost does not feature in operational optimization. The object of the new optimization exercise is to minimize economic loss due to restrictions. This may mean shuffling the available water around to minimize total economic loss. The result will be an operating policy for a reservoir.

After water scheme is commissioned, the perspective changes and day-to-day, as well as annual, supply rates change. Each year, the tariff may be revised as the supply rate increases, and hence the tariff could be reduced if it were solely to meet fixed repayment costs. However, funds for future more expensive schemes

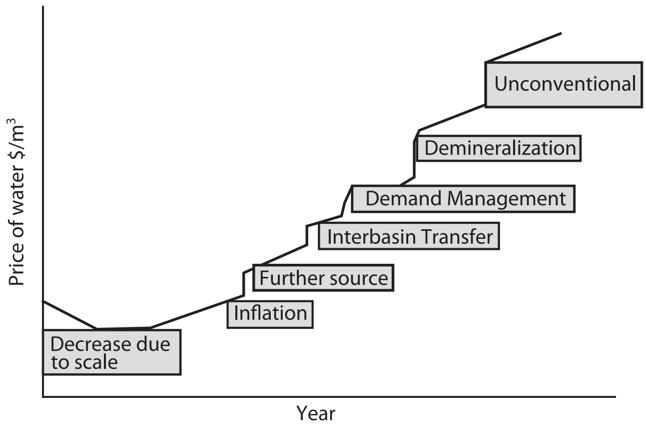

Figure 11.6: Short term and long term trends in water cost

also have to be raised so it rarely happens that the tariff drops over the years. An operational policy for reservoirs may be designed to enable water to be conserved during drought. The control of usage could be by tariffs. The tariff may be consumer orientated, i.e. lower tariffs for the poor, higher for the rich, or industry. A tiered or sliding tariff structure generally results. (Figure 11.7 shows the resulting effect on consumption).

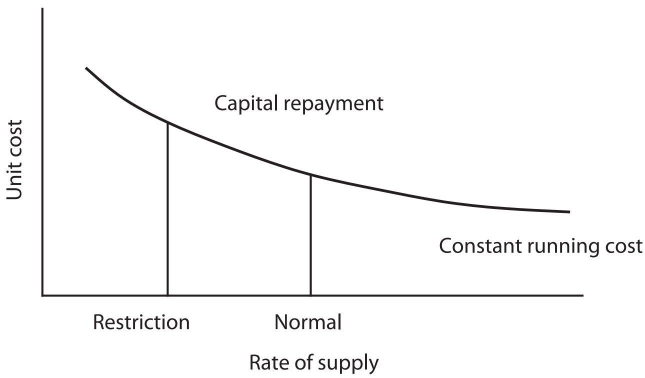

Figure 11.7: Effect of tariff on consumption

The objective of the water works should be to cover costs. They should not unduly be enriched, by charging marginal costs or basing tariffs on what the market will pay. There may also be a planning component and a stabilizing component in the tariff.

The consumer on the other hand is entitled to minimize his costs. He may seek alternative sources of water, or insure himself against shortfalls. Industry and agriculture would suffer real losses if water was restricted or charged at an uneconomic rate. He may store water, or trade it, or purify and reuse wastewater.

The trading or reselling or buying water could affect the water works efforts in the short term so the supplier needs to think of similar saving measures. Generally an operating cost intensive source will be retained as a standby, as the costs may not be incurred. Such schemes could include recycling or boreholes.

Capacity allocation is not a tariff-based method of controlling water usage provided there is sonic other way of controlling the volumes used. There are a number of other methods for controlling water use during periods of shortfall or crisis. For example, public appeal has been resorted to with limited success. There are also methods of physically restricting supply of water by control valves, orifices and pressure reduction. The latter have been employed with roof tanks so that consumers can draw at peak rates while inflow is restricted. It may also be that the consumer could find alternatives to restrictions or paying higher tariffs. Lie may seek alternatives such as groundwater. These sources may have a higher operating cost, but as they are intermittent it may not be a severe penalty. This is efficient conjunctive use of alternative resources.

11.3.3 Crisis management

When there is a shortage at the source. e.g. during a drought, then there could be rationing of water, but at the same time the authorities have to meet fixed costs. The tariff may have to be increased (see Figure 11.8).

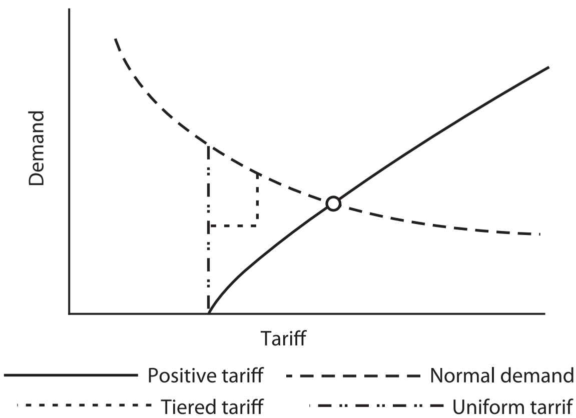

Figure 11.8: Effect of restrictions on cost of water supply

Assuming that an emergency has arisen in the way of drought or some oilier reason for inability to supply water, then the method of restricting water consumption could be based on an economic system as follows:

- **Penalties or punitive tariffs:** Higher tariffs could be charged for total consumption if consumption is above a set figure. Alternatively, a marginal penalty could be applied for consumption above a certain figure. This method is not guaranteed to reduce consumption correctly because the supplier has not necessarily estimated the value of water to the consumer.
- **Purchase system:** If there were a free market, then consumers could bargain amongst themselves to purchase different allocations of water.
- **Shortfall surcharge:** Due to lower sales figures by the water authority, they may have to increase tariffs in some way to meet their costs which cannot all be reduced in proportion to the amount supplied.

The problem of time lag arises with crisis management by means of tariffs. Following the establishment and promulgation of punitive tiered tariffs to meet a certain requirement, it may be months before the tariff is charged, detected and evaluated by a consumer. He will then change his consumption, but possibly not by the amount desired by the biller. So the process may be iterative.

11.3.4 Notes on management by use of tariffs

If the true value of water to consumers could be assessed, there is likely to be a wide range of tariffs and the supplier may unduly benefit from overcharging. One must be careful of applying long-term criteria during crisis. Some consumers may locate their organization based on indicated water tariffs, but the use of variable tariffs to manage water during drought must be explained and incorporated within the overall tariff system. The level of rationing can be decided at planning stage if the cost of assured water is balanced against the cost to the economy of rationing. However, the operational basis during drought will be from a different perspective.

A drought would be identified if the water level in the reservoir is low arid the probability of refilling the reservoir during the current operational season is remote. The objective is to minimize the probable economic damage by applying water restrictions. The fact that water restrictions may be implemented by use of tariff is incidental, but it has the advantage that the tariff can be more easily decided if the level at which the tariff will influence the consumption is known. i.e. the economic value of water to the consumer is known. Unfortunately, this may result in recuperation of excess income or possibly under-recovery of income by the water supply authority and therefore a balancing fund would have to be built up by the water supply authority to ensure he does not make a profit or loss, if it is an autonomous non-profit-making organization. After ranking all consumers, a relationship between minimum damage and level of restriction could be established. Then the objective would be to minimize the probable damage or economic loss due to restrictions. In order to apply the restrictions, the cost of water must be increased to its perceived economic value.

There is some optimum tariff which may he charged for water at which a compromise between consumer and supplier satisfaction is achieved. 'This level may never he achieved, because of conflicting objectives, political intervention or the complexity in achieving it. Political objectives could be towards achieving socially acceptable levels of supply.

11.4 The Cost of Water

To control use of water by means of tariffs requires estimating the marginal value of water as well as the marginal cost. The components which make up the supply cost of water include (see also Table 11.3):

- Capital costs
- Operating costs
- Quality control, purification, pressure maintenance, supply rate including backup for droughts
- Funding of indirect projects such as redistribution of wealth or national improvement in health and economy
- Deterrents for conserving resources such as a premium to reduce usage of water
- Components to pay for environmental protection or reclamation
- Community funding including training
- Reserves for future expansion and to ensure continuity of supply or jobs
- To cross-fund. e.g. other department's shortfalls, or redistribution of charges.

The historical basis on which tariffs are calculated is generally the cost of supplying the water. However, there is the possibility of charging for water before it has been controlled or tapped by man. This is a form of funding as the real cost is zero, seeing it is a renewable source. If the resource is mined, such as the use of groundwater at a rate greater than the natural replenishment rate, then there may be a long-term cost to the environment.

The historical cost has been the one most commonly used for establishing water tariffs. The income from water tariffs is used to meet the costs of repaying loans, operation, maintenance, fuel, management and often a fund for future expansion. Based on average cost, the water authority will charge a tariff which could be the total expenditure divided by the total sales of water.

A deviation from this method of costing is the marginal cost basis. Based on the fact that additional augmentation costs more than the original source of water, new users may have to pay more. Alternatively, all users may have to meet the additional cost. An alternative marginal effect may be the reduced cost due to bulk supply since the cost per unit delivered from a source decreases the larger the pipeline or the supply system.

If the total income from tariff is only to meet average costs, then it is purely a financial calculation. However, there are invariably economic components which make the historical or average cost basis rather academic. For example, the nontechnical components described above may be added onto the total cost.

The cost of water is not static even though historical costs may be constant, until the loans are repaid. Invariably, there is no reduction in average tariffs when costs are paid off, since expansion increases expenditure faster than the reduction in loan repayments over years.

Costs increase because supplies have to be augmented and these augmentation schemes are invariably from more and more costly sources. There is also inflation of prices causing the unit cost to increase. Policy factors may also cause increasing cost to some of the consumers.

For example, subsidization or redistribution of resources may mean more acceptable costs to some, but others will have to pay more to meet total costs. There may also be cost increases of a temporary nature due to limited sales, for example during drought, which means that the unit price must be increased to meet certain fixed costs.

Historical water costs vary enormously throughout the world, and it is difficult to compare them internationally. They depend on the cost of installations at the time, inflation since then, the standards of supply and the ability of the consumer and government or authority to meet costs.

The cost of municipal water in Europe and North America is of the order of US$5/$m^3$. In South Africa, it is less than US$0.50/$m^3$, and in some regions in Africa, it is sometimes free. An affordability of 1% to 2% of income is a yardstick in developed countries, but in some developing communities they may pay up to 10% of their income.

The methods developed for justifying water resource projects, particularly in the United States, in the mid-20th century, were based on comparing benefits and costs of projects before ranking them, or deciding on the scale or priority of development. Whether these techniques can be applied to water supply is doubtful. In particular, the evaluation of benefits which cannot be cashed in could distort the market. It could result in over-expenditure or power-building in government centers which fund water supply projects. At the most for water supply, it should be used for ranking projects hut the social impact needs to be evaluated for inclusion in the decision-making process.

When trying to assess the value of water to a user with regard to curtailing supply, the true long-term value may not be the applicable figure. The user will only consider his operating benefits minus costs, since capital expenses cannot be avoided. He will also consider primarily cash benefits, since intangible benefits. e.g. education, are long term. So, it is important to distinguish between long-term and short-term benefits as well as tariffs.

The principles of economics, however, should be used for comparing projects and optimizing supplies. Thus the possibility of alternative sources or inter-basin transfers may have to be compared in some fashion.

The benefits and Costs of water supply are not easy to evaluate. Tables 11.3 and 11.4 list some of these. The costs can vary not only for the direct installation costs but also the social impact costs. These could be as obscure as changing social customs due to different methods of water collection. There are also changing population demographics which are difficult to evaluate and the interruption of the economy by providing temporary construction employment. The river patterns may change if the water is dammed. This may affect agriculture. The environment is affected whether it is due to burying pipelines or construction of structures. More particularly, it is affected by the change in hydrology if the demand is for surface water. Groundwater is also obviously affected and the effects are not as readily seen in the short-term, but in the long-term, it could have severe environmental implications.

Table 11.3: **Factors affecting water prices**

	Charges	Controls
Direct:	Sale of nature resource for	Differential tariffs
Dams	income	Subsidization
Pumping	Prevention of	▪ communities
Pipelines	overexploitation	▪ localities
Reservoirs	Cost of alternative sources	▪ relocation
Purification	Cost of depletion	▪ use type
Administration	Fines	▪ higher marginal cost
Upgrading	Pollution – cost of	Drought rationing
Land	purification	
Indirect:	Environmental restitution	
Financing	Control of usage	
Risk minimization	Economic benefits	
Standby equipment	▪ health	
Monitoring	▪ time	
Future more expensive	▪ education	
sources	▪ commercial	
Commissions	Taxes	
Mismanagement	Affordability	
Inefficiency	Permits	
Hidden (not charged):	Willingness	
Labour distribution during	Bearability	
construction		
Rerouting communications		
Loss of land surface		
Loss of future potential		
Alternative uses of water		
Environmental impact		
Wastewater disposal		
Siltation		

There are also opportunities lost as the water cannot be used for other purposes and also future planning will change owing to the lesser availability of water. Costs of planning also need to be considered in the total system cost, and if all direct, indirect and hidden costs were included, it is likely that the level of water supply would be reduced in many countries.

Table 11.4: The benefits of water supply

Benefits of water supply
Incomes
Health
Improved quality of life
Time for
▪ education
▪ leisure
▪ economically productive
Commercial and industrial development
Agricultural
Power generation
Environmental

On the other hand, the benefits of providing water are many. Not only are they those listed below but also they have a multiplying effect in parallel with many services. That is money is injected into the economy, the level of development increases, standards of living increase, expectations increase and therefore the entire economy is provided with an injection. Of course, there is also the effect of increasing price leading to lower consumption.

The human rights issue means that if water is to be provided to all, then it must be marketed at affordable rates, which vary considerably. It therefore appears that some form of differential tariff system would be required whereby the richer subsidized the poor. This could be disguised in various ways. For example, incremental water consumption would be charged at a higher and higher tariff. This assumes that the full cost is to be recovered by the water supplier. Subsidization by the government could further complicate the issue. This in fact may be necessary if the policy is set by the government.

An alternative to the cost recovery pricing system would be the production cost pricing system. This would imply that prices were pushed up to reflect the value of water to the consumer, whereas the price may not be pushed to the limit of affordability, it would reflect some value to the consumer. The third alternative is the water scarcity pricing system whereby the price of water is increased to reflect its value. This may be on a permanent basis or temporarily during drought. Unless a thorough understanding of the affordability of water is obtained then the price to limit consumption during scarcity may be a matter of trial and error.

The problems of setting affordable tariffs, particularly to poorer communities, will draw in the following considerations:

- Adequate quality of service that is pressure and flow
- The possibility of upgrading the system as living standards or affordability improve
- Labour-orientated construction to inject money into the community
- Flexibility to ensure that various levels of demand are satisfied to their standard
- Charging for services to recover what is possible, but also to instill a sense of value
- This may involve prepayment systems or flat rate systems to simplify collection of rates
- Speed of delivery which is a function of financial resources and technical resources

The problem of non-payment for water complicates the issues — the cost must be borne by others until pressure is sufficient to right the problems causing nonpayment. Methods of subsidizing water costs vary. If the subsidizer does not want to become involved in the politics, he may subsidize the water supplier and this could be by means of direct payments or reducing taxes or cost of raw water. The alternative of payment to the consumer is complicated not only by administration or the need to appear equitable and just, but also in the method of payment. It would appear more logical to subsidize indirectly, that is by reducing taxes or providing other services to reduce expenditure. Donors often subsidize the capital Cost of the system, particularly rural water supply schemes.

It is also not easy to decide how to discriminate between recipients subject to different levels of subsidization. In many cases, abuse of the systems needs consideration (misappropriation or resale).

The value of water to a consumer is influenced by risk. If there are frequent interruptions (due to breakdowns) or lengthy rationing (drought) or pressure drops or pollution, or high tariff increases, the value is diminished. Unfortunately, supply authorities generally give no indication of these or the associated probability of occurrence. Some are catered for, e.g. emergency storage, and others may be completely unknown, e.g. future price increases.

11.4.1 Future trends

The future is likely to see increasing water costs. This will automatically reduce consumption. The theoretical correct way to control consumption would be to charge marginal costs on the top consumption, but the administration and lifeline requirements make this difficult.

Conflicting objectives make economic methods impractical for accurate day-to-day control, but economics can be used in the longer term.

Physical ways of limiting consumption (pressure reduction, cutoff) are only applicable in periods of crisis, and long-term education of consumers is seen as a necessary.

11.5 Value of Water

Whether water is a 'free good' or an 'economic good' is a paradox which has been the subject of much debate. The International Conference on Water and Environment in Dublin. 1992, listed the following guiding principles:

- Water has an economic value in all its competing uses.
- There is a basic right of all human beings to have access to water and sanitation, at an affordable price.
- Managing water as an economic good is an important way of achieving efficient and equitable use and of encouraging conservation and protection of water resources.
- The value of water can be measured in terms of:
    - its utility, which results in an economic benefit.
    - its exchange value.
    - its scarcity. The scarcer the resource, the greater its value.

The price is not the same as the value of water. Public organizations use one or more of three prices:

- The market value based on supply and demand.
- The administered price based on cost recovery or political decisions.
- The accounting price, which could be the shadow value of the water, or marginal value.

The shadow value is a function of the value in alternatives uses. For example it could be the replacement value (not possible for domestic use). or the value for alternative consumers.

11.6 Loss Control

Losses of water can be up to 50% in older reticulation pipe systems (Figure 11.9). And in irrigation systems it can be equally alarming bearing in mind the large quantities used. Many cities quote losses of 20 to 30% but the figures are seldom less than 15%. The losses may not only be the fault of the supply system, there may be consumer plumbing leaks or requirement of water which cannot be charged for. This is not strictly water lost, but could result in a loss of revenue. (Table 11.5)

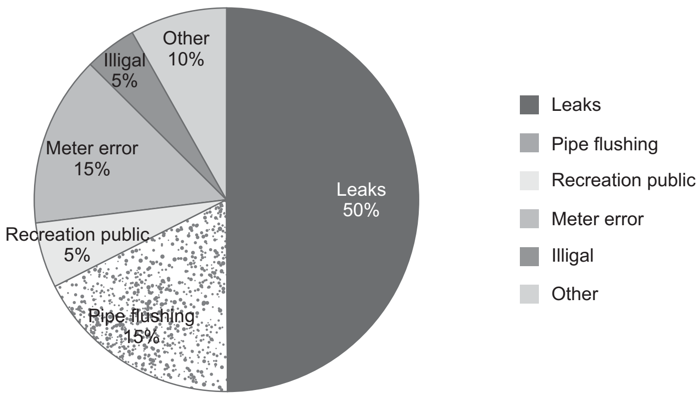

Figure 11.9: Components of water loss in reticulation systems

Table 11.5: Type of losses in water supply

Loss of:	Water	Revenue	Other
To Supplier	Leaks, Bursts Flushing streets Reservoirs Backwash filters	Non metering, Meter slip Illegal connections Public use, Fire fighting Shortage of water	Pilfering Office inefficiency Energy, Friction Data
To Consumer	Demand management Stolen Leaking fittings Wastage	Plumbing leaks Meter misreading Corruption Ineptitude	Confidence in supplier Pressure Damage to property Water quality

The term unaccounted for water is also used; hut some losses can be measured but not avoided e.g. flushing out pipelines or reservoirs, or water used for Street washing. If a proper interdepartmental charging system could be developed it may reduce some of these losses. And it is not only water which is lost. It could be revenue, or energy or customer relations which is lost, all of which represent financial loss to the water company.

Whereas in the past losses used to be taken for granted, with improvement in business sense the cost of losses, as well as the waste of resources is realized and appropriate steps are taken to minimize losses. The following methods are used to reduce losses of water:

- Passive maintenance (repairs when notified of leaks)
- Active maintenance (vigilant inspection programme)
- Water audits
- Monitoring
- Zoning to limit maximum pressures
- Pressure reduction by valves
- Metering
- Targets, e.g. 5 l/hs/hr or 500 f/km/hr
- Education of consumers

The Figure 11.10 also shows the location of losses in water supply system.

Apart from the inertia of supply organizations, there are physical factors affecting the loss rate. The following factors affect losses:

- Pipe age
- Pipe material
- Corrosion protection, internal and external
- Wall thickness, pressure class, and standard
- Jointing system
- Changes in pressure
- Soil type, moisture
- External damage
- Number of consumers, connections
- Maintenance

Many water supply companies now take active steps to find losses and reduce them. The following leak detection methods are applied:

- Night flow measurement

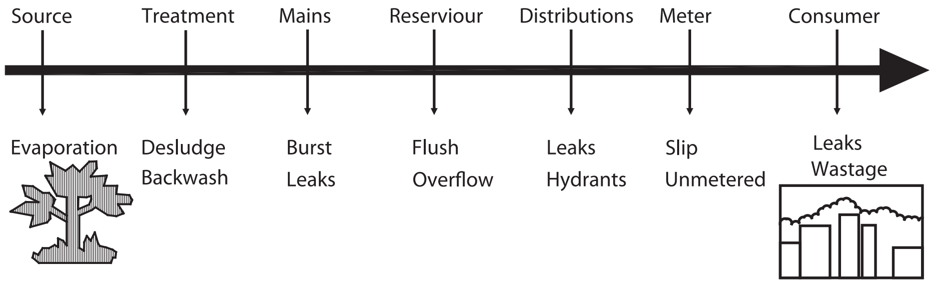

Figure 11.10: **Location of losses in a water supply system**

- Step pressure/flow measurement
- Remote sensing using infra red waves
- Visual inspection
- Gas/tracer injection and detection
- Seismic refraction
- Resistivity surveys
- Noise frequency detection
- Noise correlation

In all cases cost effective loss control should be aimed at. That implies careful management to ensure the correct level of maintenance. Apart from revenue loss the supplier should conserve resources as they are a national asset and of latent value in their natural State. In fact national monitoring of resources and if necessary imposition of control measures from the resource and pollution point of view are desirable.

Loss reduction improves the economics of supply as the costs are reduced. This assumes cost effective loss control. But there are also hidden benefits. Less resources arc consumed. Older systems can have their life prolonged. Structural damage at leaks is minimized. And if losses are due to theft, better consumer response is achieved. Rehabilitation of pipelines and reservoirs is a specialized task which has benefits beyond the saving in water. Relaying of pipes by plastic sleeves or in-situ applied mortar reduces friction and energy losses. The capacity of pipes is increased. So the pipes may supply more consumers and disruption of roadways by new pipes is avoided.

11.7 Auditing of Water

11.7.1 Leak Reduction in water mains

All water distribution systems suffer from leaks, with the degree of loss related to the age of the pipework. So as systems age more water is lost requiring ever increasing investment to mend leaks. In Canada 13% of the total volume of treated water is lost via leaks, while in the UK it is about 24%. It is relatively easy to save between 5% and 10% by having a dedicated leak detection and repair service. However, in the UK, the national leakage rate has remained at approximately the same level for a decade even though increasing effort is spent in leak detection and repair each year (Figure 11.11).

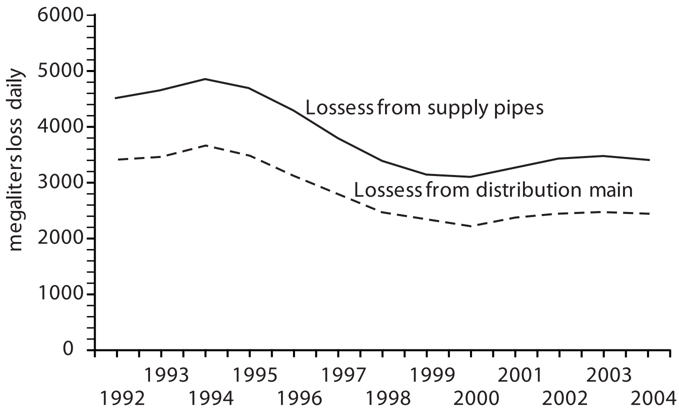

Figure 11.11: Water leakage reported in England and Wales during the period

There are a number of ways in which leaks can be detected in water networks: water audits, sonic leak detection and passive detection. Water audits compare the amount supplied to the amount consumed using water meters at the supply and householders ends of the distribution network (i.e. integrated metering). The International Water Association (IWA) and the American Water Works Association (AWWA) have jointly developed a sophisticated water audit system that takes into account system-specific features such as pressure and length of pipework. The code of AWWA is presented at the end of this chapter. This model allows whole sections of the water supply network to be checked at the same time allowing a water balance to be drawn up so that all water can be accounted for and losses can be identified as either apparent or real (Table 11.6, Figure 11.12). The model adopts a theoretical reference value, the unavoidable annual real loss (UARL) that represents the lowest level of leakage that can be realistically achieved if all of today's best technology could be successfully applied.

Therefore, $UARL = (5.41L_m + 0.14N_c + 7.5L_p) \times P\,(\text{gallon per day})$ 11.2

where L_m is the length of water mains in miles, N_c the number of service connections, L_p the total length of private (i.e. supply) pipe in miles calculated as N_c the average distance from curb stop to customer meter, and P the average pressure in the system in psi. The *UARL* gives the level of leakage control that utilities should strive to reach.

Table 11.6: Components and definitions of the water balance used in the IWA/AWWA leakage model.

Water balance component	Definition
System Input Volume	The annual volume input to the watersupply system
Authorized Consumption	The annual volume of metered and/or unmetered water taken by registered customers, the water supplier and others who are authorized to do so
Water Losses	The difference between System Input Volume and Authorized Consumption, consisting of Apparent Losses plus Real Losses
Apparent Losses	Unauthorized Consumption, all types of metering inaccuracies and data handling errors
Real Losses	The annual volumes lost through all types of leaks, breaks and overflows on mains, service reservoirs and service connections, up to the point of customer metering
Revenue Water	Those components of System Input Volume that are billed and produce Revenue
Non-Revenue Water (NRW)	The difference between System Input Volume and billed Authorized Consumption (i.e. Revenue Water)

Alternatively the distribution pipe work can be tested manually from the surface using a sonic leak detector. A number of water utilities, such as the Las Vegas Valley Water District, use fixed underground noise detection systems that allows subsurface leaks to be rapidly identified and located. This is a proactive approach where leaks can be detected early before the losses become too severe.

<table>
<tr><td rowspan="10">System Input Volume (Corrected for known errors)</td><td rowspan="4">Authorized Consumption</td><td rowspan="2">Billed Authorized Consumer</td><td>Billed Metered Consumption (Including water expected)</td><td rowspan="2">Revenue Water</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumer</td><td>Unbilled Metered Consumption</td><td rowspan="8">Non-Revenue Water (NRW)</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="6">Water Losses</td><td rowspan="3">Apparent Losses</td><td>Unauthorized Consumption</td></tr>
<tr><td>Customer Metering Inaccurancies</td></tr>
<tr><td>Data-Handling Errors</td></tr>
<tr><td rowspan="3">Real Losses</td><td>Leakage on Transmission and Distribution Mains</td></tr>
<tr><td>Leakage and Overflows at Utility's Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections up to point of Customer metering</td></tr>
</table>

Figure 11.12: The IWA/AWWA Water Balance model used to determine leaks and loss of water from the distribution system

It also allows the integrity of the pipes to be quantified so that replacement of distribution mains can be prioritized more effectively. However, where water meters are not installed then leaks may only be detected when water is seen on the surface or enters the basement of buildings. This reactive approach is known as passive detection and results in greater water loss and is more expensive as reactive repairs cannot be managed or anticipated to any great extent. Leakage detection and repairs to the distribution system do not involve customers and so are relatively straightforward; leaks in the customer's supply pipe linking the water main, after the meter, to the house are the responsibility of the householder. For example in the UK 1024 Mld^{-1} is lost from leaking supply pipes after the company meter, and so are not picked up by normal water audits.

Detection of these leaks requires the involvement of the customer with household and business audits saving customers 5% on average on their bills. The POLIS project recommends that utilities adopt a comprehensive leak detection and system maintenance programme; and adopt integrated metering. This will need a large financial investment by companies and may need to be included into existing regulations or legislation. Leaks also occur within households through poor maintenance or damage to household plumbing systems. While only metered customers will be paying for this wasted water, it is creating unnecessary demand. Leaking taps and cisterns are not always obvious but can waste significant volumes of water, while it will be even less likely that the householder will realize whether the supply pipe connecting the house to the mains is leaking. If a water meter is installed and accessible then the simplest way to check for leaks is to ensure that all the taps are turned off and that no water-using appliances are running. The meter is then read and again after an hour. If the reading has increased then there is a leaking supply pipe, dripping tap or faulty toilet cistern. If the household is not metered the only alternative is to inspect all the taps and appliances for leaks or check for the sound of water movement in the pipe work when all appliances are turned off and taps are fully closed. Modern toilet cisterns rarely have external overflows with excess water discharged into the bowl, so householders are rarely aware if the cistern is overflowing. Toilets can be checked for leaks by putting a little food colouring into the cistern. If the colouring begins to appear in the bowl without flushing, then the ballcock in the cistern needs to be either adjusted or replaced. A leaking toilet can waste more than 60 000 litres of water per year while each dripping tap can waste between 30 and 200 litres of water each day.

11.7.2 Efficient water-using appliances and fixtures

Residential water use has been rising steadily and has been associated with greater ownership and use of certain household appliances. However, mainly as a response to the need to reduce energy usage, these appliances have become increasingly water efficient. So a key area where water demand could be reduced without compromising current standards of living could be through the adoption of water-efficient appliances and fixtures.

Apart from water-efficient equipment, the better design of plumbing systems can also contribute to water conservation. For example, using small-bore pipework and reducing the distance between the hot-water cylinder and the most frequently used taps, usually the kitchen, reduces the volume of cold water that must be drawn off each time the hot-water tap is used. Conservation measures can be classified as either structural, which involves an investment in water-efficient technology, or behavioural, which involves a change in daily habits. Almost all water utilities offer conservation advice to consumers, and although there are local and regional variations in the advice offered there are a number of key actions that are universally recommended. Whatever conservation techniques are adopted, hygiene and public health must not be compromised. What is important, however, is for families to develop a philosophy about the importance of water conservation and to maintain good habits not just at home but also at work, school and on holiday.

11.7.3 Adoption of water demand management

The importance of including WDM as part of the overall water supply management programme is crucial. In the past, water engineers have been reluctant to incorporate WDM solutions into long-term planning, preferring to rely on traditional infrastructural solutions, but this is slowly changing. There are three important aspects to the successful implementation of water conservation programmes: appropriate staffing, sufficient financial resources and sufficient time to achieve results. It is important that suitably trained permanent staff are appointed, and this will include those with an understanding of economics, psychology and education. Success of WDM depends on bringing all stakeholders on board and in particular gaining the support of consumers. Apart from the financial cost of specialist staff, it will also be necessary to fund incentive programmes and to offer financial assistance where required. Timescale is also important and water conservation programmes normally take up to ten years before significant results are achieved, but far less time than required bringing a new reservoir on stream from scratch.

11.7.4 Water charging and levies

Flat-rate charges provide no incentive to conserve water and indeed encourage a wasteful approach to use. In contrast metering can reduce water consumption by between 20% and 45% overall and is seen by the Organisation for Economic Co-operation and Development (OECD) as the single most effective measure to encourage efficiency and reduce water use (OECD 1987) . The full price for water is paid either directly through an annual charge levied by the company, or indirectly through taxation. Indirect funding does nothing to instil either the importance or the value of water and so does not promote its conservation. It is important that the full cost of water is levied directly to customers with incentives that will encourage them to reduce their usage and thereby save money. Pricing must achieve two things, reflect the full cost of supplying water and penalize excessive consumption. To achieve this, all supplies must be metered.

A range of pricing options can be adopted and these are summarized in Table 11.7, although a tiered charging system based on actual volume used appears to be the most effective in reducing water use. In order for access to water to be equitable and to ensure that all basic human water needs are met, a fixed but sufficient volume of water for the size of the household should preferably be provided at either low or no cost to the customer, and subsequent water usage charged at increasingly higher rates as various volume barriers are past. However, installing meters is relatively expensive and requires more staff to administer the new system of charging. Also, unlike flat-rate charges, revenue from meters is less

Table 11.7: **The various options for pricing metered water.**

Charging system	How it works	Expected impact on demand
Uniform rates	Price per unit volume is constant	Reduces average demand
Increasing block rates	Price per block (i.e. set volume) increases as consumption increase	Reduces both average and peak demand, by providing increasing incentives to reduce waste
Seasonal (drought) rates	Prices during peak periods (e.g. summer) are higher	Sends a stronger signal during periods of high demand or water scarcity
Excess-use rates	Prices significantly higher for above average use	Targets excessive users thus reducing peak demands
Indoor/outdoor rates	Prices for indoor uses are lower than prices for outdoor uses	Reduces seasonal peak demand, which is mainly from outdoor use, and is considered more responsive to price changes
Feebacks	High water users pay a premium that is distributed to those who use less	Promotes revenue neutrality and provides incentives by penalizing heavy users and rewarding low users

predictable making financial management more problematic. However, putting consumers in control of their own water usage through volume-based charging will drive demand for more efficient appliances and encourage conservation-based behaviour.

11.7.5 Planning sustainably

In the past, water conservation has been seen as a short term mechanism to overcome temporary periods of water scarcity or to allow enough time for further expansion of water supplies to meet the deficit between supply and demand. So conservation programmes are normally designed with a terminal life-expectancy of 2–5 years. In contrast, WDM requires a strategic planning approach for the water supply chain that looks at least 20–30 years ahead or more preferably 50 years into the future. Conventional water planning has largely isolated the engineer and planner from the other stakeholders, including the consumer, creating a spiral of increasing demand. The objective is to avoid further infrastructural expansion by making demand-side management as important as supply-side management. Sustainable planning is designed to ensure utilities are able to meet the future demands for water as well as mitigate the effects of climate change and so protect ecological health of resources through the adoption of a more integrated approach using the tools of WDM. This can only be achieved by creating community-based partnerships with utilities and increased stakeholder involvement. An effective water conservation programme should result in water savings as high as 50% of current usage and in theory could even be higher.

A key tool in sustainable planning is soft-path planning. Whereas conventional planning treats water solely as an end-product, soft path identifies water as a means to accomplish certain tasks, thus focussing on demand rather than supplying water simply to satisfy demand. So conventional planning uses traditional forecasting to extrapolate future demand from past use, linked to factors such as population trends and economic growth. Incorporating standard conservation measures simply reduces demand by a fixed percentage and so reduces the slope of the predicted demand on the forecast chart (Figure 11.13). However, in both cases demand continues to rise steadily. In contrast, soft path relies on backcasting, the starting point of which is the desired future end-point in terms of human need and ecological limits. So a future limit is placed on water use based on the potential resources available and on a rate of withdraws that are both ecologically and socially acceptable. The planners then work backwards to find feasible paths to meet long-term social and economic needs (Figure 11.13).

The core principles in soft-path water planning are: containing water demand within local eco-hydrological limits; providing services rather than water per se; maximizing productivity of water withdraws; matching quality of water supplied to quality required by end user; open, democratic and participatory planning; and finally, planning backwards to connect a desired future state to present conditions (i.e. backcasting).

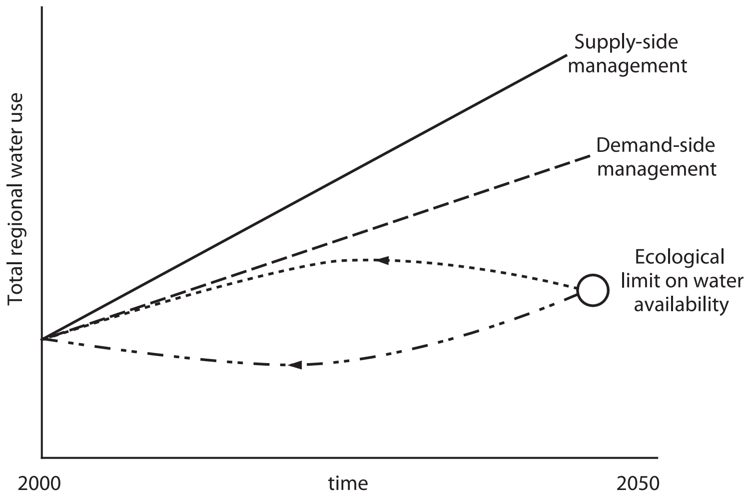

Figure 11.13: **Comparison of traditional forecasting using both supply- and demand-side management approaches with soft-path backcasting**

11.7.6 Rainwater harvesting

One of the most effective water conservation measures that can be undertaken is the collection and storage of rainwater for use inside the home for toilet flushing and washing clothes and for outside use such as watering the garden. Estimate s in both the UK and Canada has shown that 45 –50% of water used in the home could potentially be replaced by rainwater. This is not a new idea, as many Islands such as Bermuda have relied on rainwater collection systems as the primary source of water in the home for centuries. It is also feasible that rainwater could be used for drinking purposes, but in Europe this would normally require a point-of-use treatment system in order to meet drinking water standards and general quality expectations. The key benefits of using rainwater include enhanced local water security; reduced environmental impacts due to reduced demands on central water resources; improved urban stormwater control; and reduced centralized infrastructure needs for water supply, wastewater and stormwater treatment (Brandes 2006) .

11.7.7 Water reuse

A major flaw in our water supply chain is that all water that is supplied must be of drinking water standard, yet less than a third needs to be of this quality. Up to 30% is used to flush toilets and in the summer months large quantities of highquality water are used to water gardens with only about 5% used for drinking and cooking. The concept of dual water systems, one high quality and one only partially treated has been muted for decades, and in the 1970s many new buildings were constructed with dual plumbing systems to facilitate this futuristic idea. However, the excessive cost of providing two distribution networks and concerns associated with the misuse of microbially unsafe water led to this early initiative being abandoned. The reality is now, as we approach almost universal water scarcity in our cities, that reusing or recycling water for toilet flushing and outdoor irrigation could save up to 50% of supplies during periods of high demand in the summer. The idea of double use is an attractive one as it does not require a second set of water mains supplying partially treated water as was proposed in the 1970s and also prevents open access to the used water. In several southern states in the USA reclaimed water is supplied for outdoor use on a local basis via a separate distribution system, the so-called purple mains. There are three options in relation to 'double use' of drinking water. Reclamation is the direct use of treated wastewater effluents. The use of these effluents is dependent on the degree of treatment given, and while they can be used in theory to flush toilets, they are mostly used for irrigation of municipal parks and golf courses where the added nutrients are considered beneficial. The use of stormwater and surface runoff after simple filtration is also increasingly common. Reuse is the recovery of water within the home that is then reused without treatment. A typical example is the collection of bath, shower and laundry water for toilet flushing. Recycling is where water is used again for the same purpose and is normally associated with industrial processes. So in domestic situations drinking water can only be reused. Domestic wastewater can be separated into a number of different waste streams that offer a range of reuse opportunities. These are summarized in Table 11.8.

Reusing used water reduces the amount of water withdrawn by the household from the mains and also the volume of wastewater generated and subsequently needing treatment. Public concerns over health are currently a major limitation

Table 11.8: Different components of domestic wastewater that can be separated and the potential for reuse

Type	Content	Potential use
Black water	Urine and faeces	None
Brown water	Faeces only	None unless dry composted over several years
Yellow water	Urine only	Can be used as fertilizer in garden
Grey water	Washing water	Flushing toilets
White water	Runoff	Unfiltered: flushing toilets Filtered: laundry, hot water

on the wide scale use of used water by householders, although it is becoming increasingly common practice in industry and new commercial buildings. The low cost of treated water is also a constraint on its use, being reflected in new homes rarely incorporating the necessary infrastructure, this having to be retrofitted at many times the cost.

Garden use currently represents 6% of average water use in the UK. This has increased tenfold in just 30 years and is predicted to double by 2025. In actual per capita terms it does not appear to be significant; however, use in the garden is restricted to periods of greatest overall demand when supplies are at their lowest. As the summers become warmer, then traditional gardens need more frequent watering. This can be offset by reusing grey water from the house or collecting rainwater. Alternatively gardens could be designed to better match the climate, by using drought-resistant plants, creating more shade and replacing lawns with paved areas.

11.7.8 Water-sensitive urban design

The introduction of the Water Framework Directive in Europe was a measure to integrate all activities within catchments to protect the ecological quality of all water resources. This approach will need the support of planners if water conservation is to be fully implemented in the design of houses, businesses and communities. Key issues include high water demand associated with excessive outdoor water use, lack of opportunity to reuse grey and white water, or harvest rainwater due to poor building design, reduced groundwater recharge by stormwater unable to percolate back into the ground due to widespread impermeable surfaces, and finally erosion and flooding due to inadequate stormwater management. Water sustainability is only possible by ensuring that all land use and planning decisions are assessed for impacts on the catchment and water supplies (USEPA 2006).

11.7.9 Education

The success of water conservation relies very heavily on the public understanding the problems, accepting the need for conservation and actively participating. So education must not only inform it must also inspire and achieve a permanent change in behaviour and a willingness to invest in structural solutions. Education must be supported by realistic technology and a reward system. The POLIS project lists the main benefits of a good education programme as (1) instilling conservation habits; (2) increasing public awareness to the point where other measures such as volume-based pricing are accepted, (3) changing personal attitudes towards water use, creating a lifelong water ethic; and (4) creating a proactive attitude towards water conservation leading to making water sustainability a political issue (Brandes 2006).

11.7.10 Potential for water conservation in the home

It is generally accepted that only 50–80 litres per capita of high-purity water is required each day to maintain the current standard of living. Through simple conservation measures it is possible to reduce this even further. For example, the indoor water usage in the USA for a typical single family home is 69.3 gallons (262 litres) per capita (Table 11.9). The percentage breakdown is similar to that for the UK, except the volume used by the US family is almost double. Vickers (2001) has studied water use in the USA and estimates that households could reduce their daily per capita water usage by about 35% to just 45.2 gallons (171 litres) per day by installing more efficient water fixtures and regularly checking for leaks. The average US household uses 350 gallons (1325 litres) per day, which is equivalent to 127 400 gallons (482 260 litres) per year. The adoption of water conservation measures up to 1998 saved 44 million gallons (166.6 Ml) of water each day. It is estimated that if all US households installed water-saving features, water use would decrease by 30% overall, saving an estimated 5.4 billion gallons (20 400 Ml) per day. According to Vickers (2001) this would result in dollar-volume savings of $11.3 million per day or more than $4 billion per year.

Throughout the developed world pressure on water supplies is expected to increase due to rising population, new housing development and reducing household size. Increasing migration within countries, for example increasing population trends in south-east England and Ireland, is leading to serious demand–supply shortfalls. The effects of climate change are predicted to produce more-extreme weather patterns. In the south-east of England, for example, a reduction in summer rainfall of between 30% and 40% is expected, resulting in more frequent exceptionally dry summers. So the long-term forecast is for a reduction in water resources and an increase in demand, a situation that is clearly not sustainable. Considerable efforts have been made to educate consumers in their water use, and there is now a plethora of good advice widely available to consumers worldwide. Some countries have made significant efforts to reduce water usage, such as the introduction of mandatory water labelling scheme in Australia for a range of appliances, or setting maximum flush volumes for toilets and the use of banning orders for the use of hosepipes in gardens during droughts in the UK. Metering has been shown to significantly reduce water usage, while the incorporation of new water efficiency targets for water appliances in National Building Regulations (i.e. low and dual flush toilets, water-efficient heating and plumbing systems) in new houses is also making a significant impact on demand. While simple conservation measures can reduce household water usage by up to 40%, water recycling and rainwater harvesting have huge potentials for saving water. Although extremely costly to retrofit in existing homes, they are easily incorporated into new houses. For most homes in the UK rainwater harvesting could supply enough water for toilet flushing, washing clothes and watering the garden, which represents currently half the water used by most households. Just reusing grey water, collected from the shower, bath and washbasins, to flush the toilet in the home could save up to 18 000 litres per household each year, equivalent to a third of the household water demand.

Table 11.9: **Breakdown of water usage for an average US family**

Use	Gallons per Capita	Litres per capita	Per cent of total use
Showers	11.6	43.9	16.8
Clothes Washers	15.0	56.8	21.7
Dishwashers	1.0	3.8	1.4
Toilets	18.5	70.0	26.7
Baths	1.2	4.5	1.7
Leaks	9.5	36.0	13.7
Faucets	10.9	41.3	15.7
Other Domestic Uses	1.6	6.1	2.2

For all water utilities leakage control is an on-going and costly battle. Although many have already reached their calculated economic level of leakage (i.e. the level of leakage where it is cheaper to develop new sources of water than to reduce leakage), it is clear that much more could be done to reduce leakage. For example, currently the life-expectancy of distribution pipes is approximately 100 years; however, accelerating the replacement programme would significantly reduce the occurrence of leaks (EPA 1999).

The table 11.10 represent the codes of the AWWA related to water works.

Table 11.10: **Code of American Water Work Association (AWWA)**

C 101	Thickness design of cast iron pipe
C 150	Thickness design of ductile iron pipe
C 200	Steel water pipe 6 inches and larger
C 203	Coal tar protective coatings and lining for steel water pipelines enamel and tape Hot applied
C 205	Cement mortar protective lining and coating for steel water pipe 4 inch and larger shop applied
C 209	Cold applied tape coatings for special sections, connections, and fittings for steel water pipelines
C 300	Reinforced concrete pressure pipe, steel cylinder type for water and other liquids
C 301	Prestressed concrete pressure pipe, steel cylinder type for water and other liquids
C 302	Reinforced concrete pressure pipe non cylinder type for water and other liquids
C 401	Selection of asbestos cement distribution pipe, 4 inch through 16 inch for water and other liquids
C 403	Selection of asbestos cement transmission and feeder main pipe
C 500	Gate valves 3 in. Through 48 inch for water and other liquids
C 502	Dry barrel fire hydrants
C 503	Wet barrel fire hydrants
C 504	Rubber seated butterfly valves
C 506	Backflow prevention devices reduced pressure principal and double check valve types
C 507	Ball valves shaft or trunnion mounted 6 in. Through 48 inch for water pressure up to 300 psi
C 601	Disinfection water mains

C 602	Cement mortar lining of water pipelines 4 in. And larger in place
C 603	Installation of asbestos cement pipe
C 900	Polyvinyl chlorine (PVC) pressure pipe 4 in. Through 12 inch for water
C 650	Glass fiber reinforced thermosetting resin pressure pipe

11.8 Conclusion

It is evident from the above discussion that the water loss from a water distribution system is a significant factor affecting water delivery to customers. Water loss can be either: (a) the apparent losses due to meter inaccuracies or unauthorized consumption, or (b) real losses due to leakage at water service lines, breaks or leakage on mains and hydrants/laterals or at storage facilities. A municipality applying the strategies and activities mentioned in this chapter will benefit through reduced water loss and reduced costs to the utility. And therefore the municipality will not only increase revenues, but will also benefit through the extension of sustainable water supplies, reduced operating costs, improved system hydraulics and utility efficiency, and improved environmental stewardship. The next chapter describes physical integrity of distribution system so that due to external and internal stresses, physical material of the distribution system will not fail.

References

Brandes, O. M. (2006). Thinking Beyond Pipes and Pumps, POLIS Project of Ecological Governance, University of Victoria.

Burlingame, G. A., J. Rahman, E. Navera, and J. E. Durrant. (2002). Assessing the Future: Water Utility Infrastructure Management. Denver, AWWA.

EPA. (1999). "Uncovered Finished Water Reservoirs Guidance Manual." from www.epa.gov/safewater/mdbp/pdf/uncover/ufw8p.pdf.

Government, A. (2005). Water Efficiency Labelling and Standards Act 2005, Attorney-General's Department.

OECD (1987). Pricing of Water Services, OECD

POLIS (2005). At a Watershed, Project of Ecological Governance, University of Victoria.

USEPA (2006). Growing Toward More Efficient Water Use: Linking Development, Infrastructure, and Drinking Water Policies. Washington DC, US Environmental Protection Agency.