Market forces and the management of water for the environment

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Abstract

Development and the environment are no longer considered mutually exclusive, and economic and social considerations are included in the allocation and management of resources such as water and air. As water resources grow more scarce in South Africa, more efficient methods of water allocation for all sectors need to be investigated. An important sector that requires consideration is the natural environment. In 1970 the Department of Environment Affairs recognised the need for the allocation of water for the maintenance of water ecosystems. Of particular interest in this paper is the allocation of water to river ecosystems. At the moment much research is being done on the water requirements of river ecosystems in South Africa, although there is still insufficient information to ensure good management. Theoretically two mechanisms are available for the allocation of water resources: government control and a free-market system. In reality there is a gradation between the two that includes various levels of mixed economies. The present system relies heavily on government control, although in the long run it may be more beneficial for the environment if water markets are set up in South Africa. This would also promote the sustainable development of water resources. The problems that are faced in setting up water markets include the allocation of property rights and initial pricing of water so as to benefit the environment, as well as the requirements of the poor, especially those in rural areas. All these need to be taken into consideration, and further research needs to be carried out on various aspects of water markets and water requirements of river ecosystems. This paper discusses aspects of water management for environmental conservation with particular reference to allocation strategies using market forces and pricing mechanisms. Special emphasis is given to river ecosystems, due to their value as water sources and the critical relationship between catchment processes, land use and these systems.

Introduction

Environmental issues and the management of the earth's natural resources have attained increased priority status throughout the world (World Commission on Environment and Development, 1987). There has been a fundamental change in the way in which governments and development agencies think about development and the natural environment (Munasinghe, 1993). The two are no longer regarded as mutually exclusive, and it is now recognised that a thriving environment is essential to sustainable development and a healthy economy in the long run (Munasinghe, 1993). This has resulted in governments and resource management agencies actively promoting sustainability of the environment and developing policies which reflect a more balanced approach to the use of resources. Thus, economic considerations have been included in the allocation and management of natural resources such as air and water, to ensure that these resources are properly conserved.

One of the key concerns of resource managers is the availability and utilisation of water resources. It is recognised that there is a growing scarcity of water, as surface supplies in Africa, America and Australia approach full utilisation (Brown et al., 1990; Colby, 1990; Martin and Kulakowski, 1991; Pigram and Hooper, 1992; Thomas and Howlett, 1993). Certainly in South Africa, which is semi-arid and hydrologically variable, major water supply problems have been created by a rapidly growing human population and a relatively well-developed economy (Davies and Day, 1986; Ferrar et al., 1988; King and O'Keeffe, 1989; O'Keeffe et al., 1989a). Additionally the water allocation policy of the last 40 years, which has given 50% of the utilisable surface water to irrigators at a highly subsidised price, has exacerbated the situation. With the recognised need for further rapid economic development in South Africa, the sustainable use of water resources is essential. Thusfar, developments to provide water of sufficient quality and quantity such as the impoundment of rivers and inter-basin transfer schemes have largely undermined the ecological integrity of ecosystems and contributed to environmental degradation (Petitjean and Davies, 1988; Walmsley and Davies, 1991).

In 1970 it was recognised that water should also be allocated to the natural environment for conservation purposes (Roberts, 1983; Department of Water Affairs, 1986; Walmsley and Davies, 1991). However, the Department of Water Affairs and Forestry (DWAF) has only recently seriously considered the problem of water allocation for the maintenance of ecosystem functioning and taken steps towards developing and implementing a policy for this (Roberts, 1983; Department of Water Affairs, 1986; Department of Water Affairs and Forestry, 1991; Walmsley and Davies, 1991). Serious problems remain in the implementation of allocation policies to provide for environmental water needs. Significant trade-offs may be involved and economic and social costs could be incurred in the integration of competing and conflicting demands for water (Pigram, 1992). Different institutional arrangements and regulatory mechanisms will be required to address the constraints which arise in optimising in-stream and off-stream water uses (Pigram, 1992).

One approach to the allocation of water that would ensure sustainable development could be the use of market mechanisms. Opportunities undoubtedly exist for the wider application of market forces in the acquisition of water for the conservation of the environmental (Pigram, 1992). Already in Australia and the American West water markets, linked to property rights of water, are in existence and regulate the use of water adequately (Gardner

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and Miller, 1983; Willey, 1992; Colby, 1990; Simon and Anderson, 1991; Martin and Kulakowski, 1991). Pigram (1992) has suggested that the establishment of water markets could permit the allocation and transfer of water for a range of environmental purposes, such as:

- maintenance of streamflows for ensuring sustainability of aquatic ecosystems and other instream values;
- use of dilution flows for the enhancement of water quality;
- management of water pollution through a system of tradeable emissions in conjunction with capacity sharing storage; and
- management of groundwater resources through manipulation of depths to the water table.

This paper discusses aspects of water management for environmental conservation with particular reference to allocation strategies using market forces and pricing mechanisms. Special emphasis is given to river ecosystems, due to their value as water sources and the critical relationship between catchment processes, land use and these systems. Included in the discussion are:

- the concepts of sustainable development and "water for the environment";
- river ecosystems and their water requirements, including instream flow assessment methodologies;
- mechanisms for the allocation of water resources to the environment, in particular the use of market forces and pricing mechanisms; and
- future research needs.

The concepts of sustainable development and "water for the environment"

The concept of sustainable development is an all-encompassing concept that is loosely defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987). The aim of sustainable development is to ensure economic efficiency and to uphold social objectives without compromising environmental quality (Munasinghe, 1993). Thus, there are three objectives to sustainable development (Fig. 1; Munasinghe, 1993):

1. **An economic objective**, based on the concept of the maximum flow of income that could be generated while at least maintaining the stock of assets that yield this benefit. There is an underlying concept of optimality and economic efficiency applied to the use of scarce resources.

2. **An ecological objective**, focusing on the stability of biological and physical systems. These systems may include all aspects of the biosphere, including man-made environments. The emphasis is on preserving the resilience and dynamic ability of such systems to adapt to change, rather than the preservation of some "ideal" static state.

3. **A socio-cultural objective**, which seeks to maintain the stability of social and cultural systems. Both intragenerational equity (elimination of poverty) and intergenerational equity (involving the rights of future generations), have to be taken into account if welfare distribution is to be effective.

The reasons behind allocating water for environmental purposes are incorporated mainly in the ecological objectives of sustainable development, although it has both social and economic impacts (Fig. 1). Walmsley and Davies (1991) have interpreted it to mean "water which is released in order to maintain a multitude of ecological functioning within habitats such as wetlands, estuaries, reservoirs, river channels and riparian zones". Implicit in the term is also the quantity (for both spatial and temporal considerations) of water which is required for consumptive and non-consumptive purposes, including evaporation demand of estuaries and lakes, flushing flows and flooding requirements of estuaries and floodplains, and drinking water for wildlife (Walmsley 1992; Walmsley and Davies 1991). The Department of Water Affairs also interpret that domestic water for visitors to conservation areas is included, as well as that for water-related recreation (Department of Water Affairs, 1986; Walmsley, 1992). However, these two are essentially human needs and are derived from water which has already been provided for the maintenance of the environment itself.

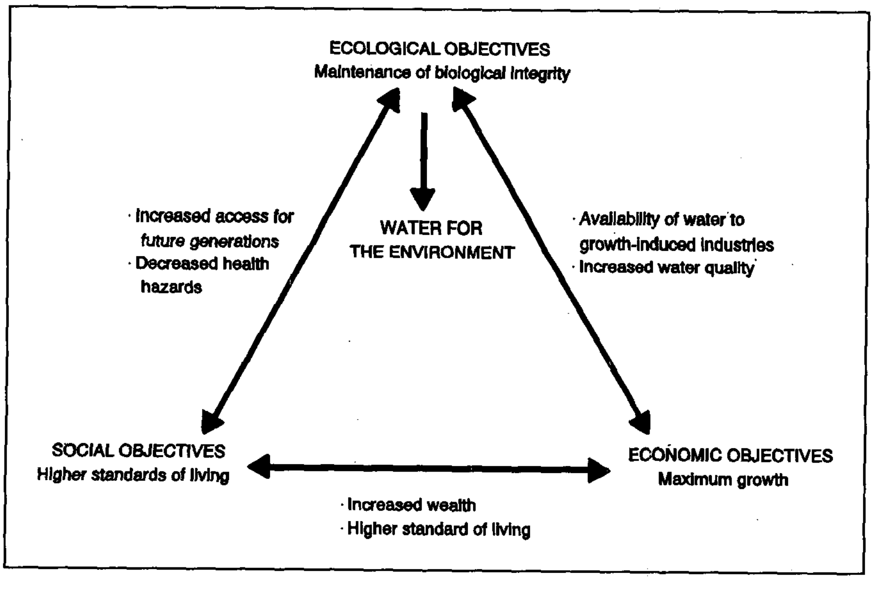

Figure 1 *Relationship between the three objectives of sustainable development, with special reference to water for the environment (adapted from Munasinghe, 1993)*

South African river ecosystems and their water requirements

The South African landscape contains several types of aquatic ecosystems which require environmental water allocations. However, river ecosystems act as transport systems and thus encompass most other water resources ecosystem types such as reservoirs, estuaries, wetlands and coastal lakes. It is fairly safe, therefore, to assume that rivers are the most representative ecosystems to study in terms of water allocation.

South Africa has 22 principal drainage systems, each containing rivers of various length, order and mean annual runoff (MAR). Despite the high ecological and recreational value of rivers, the major concern of water resource managers has been to satisfy the growing demand for water in the various sectors (Department of Water Affairs, 1986; Walmsley, 1992). Urbanisation and industrialisation have led to several major user sectors in South Africa whose demands include: municipal (12%), industrial (7.6%), mining (2.1%), power generation (2.3%), irrigation (50.9%), stock watering (1.5%), forestry (7.5%) and environmental management (15.5%) (Department of Water Affairs, 1986; Walmsley, 1992). The major goal of the water resource managers over the last four decades has been to develop utilisable surface water resources in order to make water available to these major sectors, mainly through the impoundment and regulation of rivers and inter-basin transfer schemes. Consequently river systems have become the primary source of water for these sectors and over 50% of South Africa's total river runoff and 85% of the utilisable MAR has been impounded, giving a total reservoir capacity of about 24.24 x 10^9 m^3 (Walmsley, 1992). The level of development and high percentage of utilisable water already captured explains the growing concern of resource managers and ecologists with regard to water resource allocation to the environment.

The characteristics and conservation status of South African rivers have been reviewed in several publications (Noble and Hemens, 1978; O'Keeffe, 1986a,b; Allanson et al., 1990). River ecologists have made a valuable contribution to the knowledge base on South African rivers, and have clarified to a large extent why rivers need an environmental water allocation and what the likely impacts of inadequate quantity and quality are (Bruwer, 1991; Moore et al., 1991; Walmsley, 1992). Environmental water is needed in rivers for numerous reasons (Walmsley, 1992), some of which are:

- to maintain the biological integrity of the ecosystem, where biological integrity is defined as "the ability to support and maintain a balanced, integrative, adaptive community of organisms having a species composition, diversity and functional organisation comparable to that of the natural habitat of that region" (Hart and Campbell 1992);
- to maintain breeding and life cycle habitats for aquatic organisms;
- to cater for losses due to evaporation and evapotranspiration;
- to provide drinking water for wildlife;
- to provide flushing to remove sediment and debris that obstructs channels; and
- to improve the water quality conditions.

One of the main difficulties in allocating water to the environment and to river systems in particular is to know how much is required to maintain the biotic integrity of a system. Various methods have been developed to determine water quantity requirements of river ecosystems. These methods range from regional estimates of flow needs based on national supply and demand; subjective estimates of habitat availability; and more detailed calculations of wetted perimeters and requirements for different life cycle stages of specific species (O'Keeffe et al., 1989b).

Methods of determining flow requirements of rivers

The Tennant (or Montana) method uses a fixed percentage of the mean annual flow (MAF) as a guideline for the quality of the stream as an aquatic habitat. A flow of 10% of MAF was regarded as an absolute minimum below which only short-term survival of aquatic life could be expected; 30% of MAF would sustain good survival conditions for most organisms, and 60% of MAF would provide excellent habitat conditions (O'Keeffe et al., 1989b).

Cross-section computer methods utilise cross-sectional dimensions and hydraulic parameters gathered at one or more stream cross-sections to predict hydraulic conditions at selected but unobserved flows (O'Keeffe et al., 1989b). The rate of degradation of a river can then be linked to hydraulic properties.

Some methodologies include biological data. The most advanced method of instream flow assessment incorporating biological parameters is the instream flow incremental methodology (IFIM), a documentation and computer program system developed in the United States, by the US Fish and Wildlife Service (Bovee, 1982). The IFIM combines hydraulic and hydrological information on the flow within selected river reaches using the physical-habitat requirements of riverine organisms as indicators of ecosystem integrity (Gore and King, 1989). South African researchers have recently done an in depth assessment of the IFIM, using the Olifants River in the W. Cape as a case study (King and Tharme, 1993). They found that, although it is visionary in many respects and is an outstanding tool for creating a framework for studying catchments, river flow, water quality, biotopes and species, the methodology is mainly theoretical and often incomplete (King and Tharme, 1993). It has been suggested that other methods would be more appropriate for use on South African rivers.

Other methods used in South Africa are the flow record simulation approach and the Skukuza method (King and O'Keeffe, 1989; O'Keeffe and Davies, 1991; Bruwer, 1991). The flow record simulation approach makes use of historical flow records kept by the local authorities for the unregulated river (King and O'Keeffe, 1989). For each month the data on daily flow are plotted and the minimum and maximum flows that occur regularly are identified. These flows then become the limits within which discharges must be held each year. Maintenance flows are then identified within these limits. Although this method is flexible and practical, it only works if records have been kept of river flow prior to impoundment. The Skukuza method is a flexible and comprehensive approach which can be used to give a first estimate or a more detailed calculation of the ecological flow requirements of rivers. It relies on the identification of important consumptive and non-consumptive water requirements and a quantification of these requirements for each use by making use of "best guesses" by the relevant specialists. Water is then allocated for each season as well as for increased and flushing flows (King and O'Keeffe, 1989).

These two approaches have been used as the basis for what is termed the "building block methodology" (King and Tharme, 1993). This methodology is presently being developed and is based on the assumption that riverine species can cope with baseflow conditions that naturally occur in the river, as well as higher flow conditions at certain times (e.g. floods) (King and Tharme, 1993). It is assumed that identifying such flow conditions and incorporating them as part of the modified flow régime will allow the functioning of the river to be maintained physically, biologically and chemically. It is also assumed that certain flows influence the channel morphology more than others and should be incorporated into the modified flow régime to aid the maintenance of the natural channel structure. The recommended flow régime should thus adhere to the natural limits of magnitude, duration and time.

Many of these methods are undergoing investigation in South Africa, although not many absolute answers have evolved. Roberts (1983) recommended that water allocation for environmental conservation should be in the region of 11% of the MAR for South Africa. On a national basis this was estimated as 182 x 10^6 m^3 of water allocated to nature conservation in 1990 (Walmsley, 1992). Using the Skukuza method and the flow record simulation approach, O'Keeffe and Davies (1991) have suggested that a minimum water requirement for both the Sabie and Levuvhu Rivers running through the Kruger National Park would be at least 24% of MAR to maintain them. It is evident from the range of these figures that the understanding of ecological water requirements of South African rivers is insufficient for management and allocation purposes.

Water allocation mechanisms

Once the amount of water required by river ecosystems to function is adequately assessed, a decision on the allocation of water using various methods is required. In theory there are two mechanisms by which this may be achieved: government control, and a free-market system. In reality, however, there is a continuum between the two (Fig. 2); it is very rare for any commodity market to exhibit only the characteristics of a free-market or only those of a government-controlled market.

Traditionally in South Africa, the government has controlled the water resources. In the past water resources were developed by the DWAF largely on an *ad hoc* basis - projects were designed and executed to meet clearly established immediate needs, but with an inadequate rational basis for the determination of priorities, and sustainable requirements (Department of Water Affairs, 1986). Often water development projects have been initiated and conducted with alternative political agendas in mind, rather than the sustainable use of the resource. However, this does not mean that there are no free-market characteristics in the water use sectors in South Africa. Water allocation to most users (e.g. municipalities, mining and industries) has some free-market characteristics (Fig. 2). One of the most important characteristics is that water in these sectors has prices allocated to it (although the new government policy is that domestic water should be provided free-of-charge). Although present prices are below the market equilibrium price (the price at which demand equals supply), the concept of trading water is already in place. The agricultural sector relies largely on government control, with permits for water extraction available at relatively low prices. The low prices charged for agricultural water and the possibility of free domestic water does little to promote a free-market system. Water for the environment and water for domestic use in rural areas is totally under the control of the DWAF, and is available to these sectors as a free resource (Fig. 2).

As water has become more scarce in certain areas, it has become obvious that the traditional approach of water allocation does not work, and better-planned strategies are required for future development. If water resources are to be allocated to ensure sustainable development there should be a move towards a free-market system in all sectors (Fig. 2). There are several ways in which water marketing can benefit water resources, including river ecosystems (Willey, 1992):

- Transactions can shift water from existing uses to new, growth-induced uses (free of political agendas), thereby avoiding the need for new surface supply and diversion projects that have negative environmental effects.
- Direct acquisition of water supplies in sufficient quantity for environmental purposes, and in particular the maintenance of river ecosystems, will be possible.
- Water marketing can be an important component of incentive-based efforts to control water pollution by leading to reduced water use, conservation investments, waste-water recycling etc., which may have positive economic and social effects.

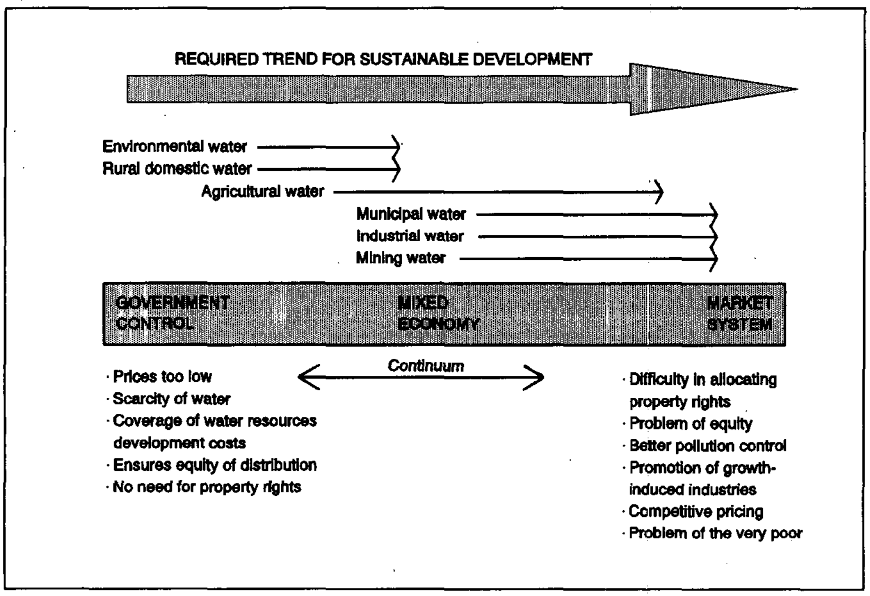

Figure 2
Schematic diagram showing the continuum from government-controlled economies to free market systems with regard to water allocation, and the characteristics of each. Where each water use sector fits in on the continuum is also indicated

However, some authors suggest that a market failure, which may lead to inequitable or non-sustainable allocation, is inevitable if water is provided privately, due to the naturally monopolistic nature of the water industry (Hirshleifer et al., 1969; Willey, 1992). In the presence of these natural monopolies, competition cannot provide protection for the consumer under unrestricted private enterprise. However, unrestricted government may lead to a similar situation. Another reason given for public concern on the field of water resources is that the most efficient use of resources often requires projects of enormous costs, with the result that only governments can supply the capital, and in fact in developing countries even this is sometimes a problem (Warford, 1989). The counter-argument of this is that business corporations are more often than not very efficient at raising capital if the nett benefits are sufficient. Another reason for government intervention is the need to develop resources in a particular region. Often economic development of a region is given as the main reason for this, although whether the provision of water resources to a region encourages economic growth is debatable (Cox et al., 1971; Cicchetti et al., 1975; Cordell et al., 1990).

Two areas need to be taken into consideration in the allocation of water for the environment using market forces: property rights and pricing mechanisms.

Property rights

One of the major failures in water markets, and one that is also apparent in environmental resource markets of any kind (including rivers), is the allocation of property rights. Thirty years ago Garret Hardin coined the term "tragedy of the commons" (Blankley and Siegfried, 1992). This appertains to common resources such as river ecosystems, and reasons that it is clearly to an individual's advantage to exploit a common resource which has open access (no property rights allocated) as thoroughly as possible. Common property with some rights of exclusion attached (limited access) is only effective if the rules governing the commons do not break down. Another problem facing management of water resources is that of the "free rider". River ecosystems and the water provided by them are essentially public goods, which are those goods that cannot be provided for one person without also being provided for others, and once they are provided for one person can be provided for others at zero cost. Thus, attaching prices to such goods is extremely difficult.

The concept of public goods contains few absolutes. Most public goods do have some characteristics of private goods in that property rights can be allocated. River ecosystems provide examples of situations where improved definition of property rights might be helpful in overcoming important problems of resource scarcity and their allocation (Musgrave and Kaine, 1992). The question of property rights in river ecosystems tends to be more readily solved than the atmosphere for instance, due to the fact that we are used to water being owned to a certain extent, although at this stage it may be rather vague and unsatisfactory (Musgrave and Kaine, 1992). Riverine resources have not traditionally been thought of as objects for trade and so property rights which are adequate for the emergence of markets have not been deemed necessary.

Water itself has characteristics that make definition and quantification of appropriate property rights difficult. Not only has it many characteristics of a public good, but it is also a heterogeneous item that serves different needs and uses, and is of both a flow and stock nature (Hirshleifer et al., 1969). Water supplies are stochastic, especially in South Africa with the hydrological uncertainty experienced here, and can usually only be controlled to a limited degree. Furthermore, it is available without cost or at low cost in some locations, but rather expensive in others.

Musgrave and Kaine (1992) emphasise that if markets for water resources are to be set up effectively and work efficiently, property rights are essential. Ownership of a resource must satisfy certain conditions, including (Colby, 1990; Musgrave and Kaine, 1992):

- its recognition by the state through its legal system;
- the owner must have exclusive right to the use of that resource, and be able to determine who can use it, and, in the case of water, it must be distinct from the value of the land and improvements;
- transfer of ownership from one party to another must be voluntary, and transfer rights must be legal;
- access to and use of the resource must be measurable;
- the price and other terms of transfer are negotiable by the buyer and the seller, and are not constrained to be "not for profit" or "at cost".

Additionally, if markets are to work, a market transaction must be attractive relative to other processes by which buyers could achieve their water supply objectives (Colby, 1990). Thus, the cost of a market acquisition, including political and legal costs, must be less than the cost of the alternative means of obtaining water (i.e. transaction costs must be less than the potential benefits).

Pricing mechanisms

In the management of river ecosystems, managers face the dilemma of certain trade-offs between providing water for offstream uses, such as industry, agriculture and domestic uses, and retaining water instream to support recreation, power generation, water quality and conservation of riverine ecosystems. However, scarcity has become the key to economic trade-offs between instream and offstream uses (Colby, 1990). Economists define a resource as scarce when there is not enough of it available to satisfy existing and potential demand (Colby, 1990). Implicit in economic scarcity is the notion that individuals will be willing to pay for the use of a scarce resource based on the value attributed to that resource.

River ecosystems and water are two resources that are inextricably interlinked. Water, in this case, may be considered as a scarce resource, although without good management of river ecosystems this resource will become more scarce as both the quality and quantity of water are degraded. It is very difficult to put a value on river ecosystems, although methodologies such as contingent valuation and travel-cost valuation do exist to determine some value. It is easier to put a value on water in the form of a pricing system within a market than to value river ecosystems. Once prices for water have been set, the right of conservation bodies to buy water allocations for the maintenance of ecosystems will exist, and the costs and benefits inherent in the maintenance of these ecosystems evaluated. This may be considered by some as morally reprehensible, because it is river ecosystems that make the water available in the first place. However, it is a practical solution that has been shown to work in the western states of the United States of America (Gardner and Miller, 1983; Willey, 1992; Colby, 1990; Martin and Kulakowsky, 1991), as well as in Australia (Simon and Anderson, 1990). In these regions property rights have been allocated, pricing mechanisms determined and water markets set up.

Pricing of water depends on the supply and demand for the resource (Fig. 3). If the price for the resource is set at a level lower than the equilibrium price, then a shortage of water will occur. If the price is set at a higher level then a surplus would occur. At the moment in South Africa the price of water, particularly on government schemes, is kept at an artificially low level (Department of Water Affairs, 1986). This in itself, without the added problem of drought, would certainly create a shortage in South Africa.

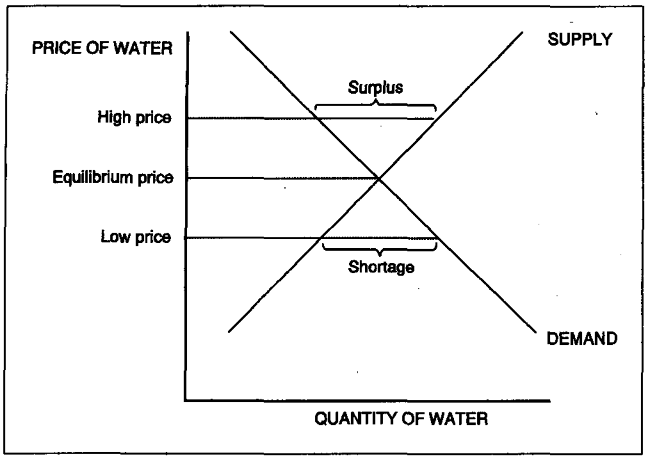

Figure 3
Hypothetical graph showing basic supply and demand curves for any commodity. The equilibrium price of a commodity is the price at which the quantity available is equal to the quantity demanded.

Although demand for water is considered by some authors as inelastic (Howe and Linaweaver, 1967; De Rooy, 1974; Williams and Suh, 1986; Thomas and Syme, 1988), it is believed by others that increasing the water price would still have a considerable effect on offstream demands (Hirshleifer et al., 1969), which would thus make more water available for environmental purposes. There are two options available to resource managers regarding pricing of water. Either the price can be set at the equilibrium level, in which case conservation bodies would be required to purchase water rights to ensure that they receive sufficient water; or the price of water is set above the equilibrium price, and the surplus is automatically allocated to the environment free-of-charge. In the first instance, externalities (where the price of water does not reflect the impact on the environment) are not internalised, while in the second instance the price of water incorporates the cost of maintaining the ecosystem. It may be argued that, for a market to be efficient, externalities must be internalised - if the producer of water has to pay for the production of water then it is inefficient, and consumers access positive externalities that are not reflected in the market price of the water. However, although the second option would possibly be the most acceptable, there is a practical problem in determining the price so that the surplus is equal to the requirements of the ecosystem.

Additionally, pricing of resources must ensure social equity. In the United States the price of water has sky-rocketed, especially in the more arid regions (Gardner and Miller, 1983). The majority of people in South Africa certainly could not afford the expense for what they traditionally consider to be a free resource. This problem may be overcome to a certain extent in the rural areas where there is more direct access to river water once it has already been allocated for environmental purposes. Thus, allocation of water for the environment would have to take the demand of direct water use by the rural populations into account.

Future research needs

It is obvious from the preceding discussion that the management of river ecosystems using market forces and pricing mechanisms is possible as a method for allocating water to the environment. However, the present policies of river management and the maintenance of instream flows still rely heavily on government intervention and control. According to the Department of Environment Affairs (1993), if South Africa is to develop in a sustainable fashion, free-market economic theories will have to be incorporated into resource and river ecosystem management in the future. However, if South Africa were to develop an effective water market, and use this for maintaining the ecological integrity of river ecosystems, much preliminary research would have to be undertaken on various aspects of river ecosystems, water markets and water allocation to the environment. The following are some of the aspects that would require understanding.

- Property rights for water require definition. An understanding of economic characteristics of individual river ecosystems is required if property rights are to be adequately defined.
- The correct legal structures should be in place if water rights are to be defined. The legislative structures that have been set up elsewhere in the world should be studied.
- Valuation techniques for river ecosystems require development. Most valuation techniques, such as contingent valuation, travel-cost valuation and dynamic opportunity cost valuation, value societies' utilisation of the resource, and are only considered valid in a well-informed and homogeneous society. Techniques have not yet been developed for dualistic economies with differing value systems. Once valuation techniques have been established cost-benefit analyses could be successfully undertaken where water resources developments (e.g. impoundments and water transfers) are proposed.
- Policy concerning instream flow requirements requires clarification, and instream flow methodologies need to be perfected and standardised. Instream flow standards for each catchment can then be determined and the cost associated with it calculated.
- Various pricing mechanisms require investigation. Determination of water prices and their effect on river catchment management, and water allocation policies would be a valuable management tool.
- Trade-offs and the cost of trade-offs between various instream and offstream users would require investigation. In particular the effect of various water prices on catchment land-use practices requires evaluation.
- There would be extensive regional variations in prices and the allocation of water. These would require clarification.
- The impact of pricing on communities lacking market power (i.e. rural communities) requires investigation.
- The impact of pricing on water producers is uncertain and requires research input.
- The dilemma of water producers whose water production benefits users further down-stream in a dislocated economic system (e.g. Kruger National Park and Mozambique) needs to be solved.

Conclusion

Various aspects of water allocation to the environment and the problems associated with it were discussed in depth at an international workshop held in 1991 in Armidale, Australia (Pigram and Hooper, 1992). Although many varied viewpoints were expressed, and a variety of issues addressed, there was acknowledgement of certain points in common, all of which apply to South Africa. Some of these were (Pigram and Hooper, 1992):

- Water allocation for the environment should be managed in ways that maintain or restore or enhance natural processes for riverine ecosystems, using a combination of flow management, structural works and other techniques.
- Reallocation of water to maintain natural ecosystem processes should be on the basis of determined environmental requirements, within the context of catchment management objectives, and should take into account national, state, and regional policies for ecologically sustainable development.
- It will be difficult, in the immediate future, to change existing uses for which water allocations have been made, and a transition period will be needed. Initially, unallocated, unregulated flows should be recognised as available for environmental purposes.
- Further division of unregulated flows, from regulated or unregulated streams, should only be on the basis that the ecological sustainability of riverine ecosystems is not impaired.
- Mechanisms need to be found to reallocate waters so that the environmental requirements of rivers can be met. These mechanisms may include transfer or sale of water right allocations, reallocation by regulation, or placing of a moratorium on further allocation pending adequate environmental review.

One of the mechanisms for water allocation to the environment (river systems in particular) which would meet some of the needs expressed above, and the one advocated by this paper, is the use of a water market system. The advantages of such a system include: the promotion of growth industries, and a shift away from non-growth industries such as agriculture; competitive pricing and the abolition of subsidisation; a greater awareness of water conservation; sustainability in the development of water resources, and the conservation of South Africa's river ecosystems. There are, however, problems involved in the implementation of such a system in South Africa. One of the problems is that of property rights. Water resources can be harnessed and property rights attached, but the river ecosystems which provide the water are common property with open access. The distribution of property rights thus requires government intervention and legal backing. Additionally, there exists an economic dichotomy in South Africa between underdeveloped and developed communities. It would be unfair for individuals in poor communities to pay equivalent prices to those in affluent communities. Thus equity of benefit distribution needs to be taken into serious consideration. According to the interim constitution domestic water should be a free resource. This immediately undermines the possibility of a free water market becoming established, although it does not preclude the possibility of a mixed water economy (Fig. 2) with some government intervention. Much investigation and research are required in South Africa to establish the optimum system which would allow for sustainable development as well as conservation of river ecosystems.

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