An overview of water for environmental management*

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Abstract

This overview considers the current situation in South Africa regarding the allocation of water for management of the environment. Included are statements on the current policy of the Department of Water Affairs, some case studies (Pongolo Floodplain, Nylsvlei and the Kruger Park rivers), environmental ethics and research and manpower. Opinion is expressed that this aspect of water resource management has been badly neglected. Some measures to rectify the situation are suggested. These include a change in national environmental ethic, improved integrated catchment planning, development of appropriate expertise and increased funding for research.

Introduction

In South Africa, with its arid and highly variable hydrological conditions, the problem of supplying water to the nation has proved to be a challenging one which has led to many innovative solutions (Department of Water Affairs, 1986). In the past, the main emphasis has been on impoundment and the allocation and transfer of water to areas with high industrial, commercial and agricultural activity. Where supply has exceeded demand, we have seen both the establishment of, and planning for, numerous inter-basin water transfer schemes on the subcontinent (Department of Water Affairs, 1986; Petitjean and Davies, 1988a; b). To date it has been a relatively easy task to allocate water to sectors where economic gains can be quantified (e.g. irrigation schemes, industrial plants and municipalities). By contrast, the economic implications of allocating water for the perceived "wasteful" process of maintaining river processes and ecological functioning of the environment have not been quantified and have recently initiated considerable debate (Bruwer, in preparation).

As early as 1970 it was recognised that water should be allocated to the sector designated "nature conservation" (Commission of Enquiry into Water Matters, 1970). However, insufficient research and/or managerial input has been devoted towards defining and assessing the needs of the environment. Our contention is that a distinct bias of attention to other sectors (e.g. agricultural, municipal, industrial and forestry), away from the water requirements to maintain ecological functioning, has created many of the water management problems which we are facing today.

To highlight just one of these problems we may usefully examine river regulation. Water storage and inter-basin water transfers have led to the increased regulation of nearly every South African river system and have created a number of severe problems for management and for the ecological functioning of the systems concerned. For example we may list:

- flow reduction and/or seasonal reversal in most South African rivers (e.g. the Vaal, Orange, Sabie and Palmiet Rivers);
- flow cessation and the conversion of perennial systems to systems with seasonal characteristics (e.g. the Luvuvhu and Letaba Rivers);
- temperature and water quality regime alteration; and
- concomitant biological changes such as disruption of food chains, loss of species, development of pest and invasive organisms.

Only recently has research begun to pinpoint and to quantify some of these impacts (e.g. Byren and Davies, 1989; O'Keeffe *et al.*, 1989, 1990), while on a global scale research interest has been mounting rapidly (see for example the synthesis volumes of Ward and Stanford, 1979; Lellehammer and Saltviet, 1984; Petts, 1984; Craig and Kemper, 1987; Petts *et al.*, 1989). This overview attempts to define some of the broader issues facing water resource managers and scientists who are seeking solutions to what is indeed not only a problem in South Africa, but one which also faces other arid countries of the world. The topics which are discussed include:

- current policy on water for environmental management;
- some case studies;
- environmental ethics in South Africa; and
- research and manpower needs.

Current policy on the allocation of water for management of the environment

Understanding of what is meant by the term "water for management of the environment" can be obtained by examining the recently published book by the Department of Water Affairs (1986). The term is interpreted to include 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, flushing-flows and drinking water for wildlife (Department of Water Affairs, 1986). In many instances policy has changed in the past and will continue to evolve as understanding develops further. Interpretation of current policy on water allocation is derived from three documents, notably the Water Act of 1954 (and amendments), Commission of Enquiry into Water Matters (1970) and the publication by the Department of Water Affairs (1986).

There is much legislation on aspects pertaining to effluent/water quality standards and to water abstraction from rivers. The Water Act of 1954 empowers the Department of Water Affairs to be sole custodian and policy maker for water resource management in South Africa. There is, however, no formal legislation which stipulates the quantity of water to be designated for environmental management. This does not mean that there is no policy by the Department of Water Affairs. On the contrary, careful attention

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has been devoted to this issue in the 1986 publication where the Department identified "water for the environment" as a legitimate target for water use.

The need to allocate water for "conservation purposes" was first expressed by the Commission of Enquiry into Water Matters (1970), who specifically mentioned the Kruger National Park and Lake St. Lucia as being areas of concern. The Commission recommended that "in the utilisation of our water resources, provision should be made for the reasonable needs of nature conservation areas, but that in each case a thorough investigation be undertaken to ensure that waste of water is avoided".

The need to allocate water for environmental needs (as opposed to conservation) was first expressed by Roberts (1981; 1983) who noted that this allocation could represent approximately 11% of the mean annual runoff (MAR) from the country (Fig. 1) and constitute approximately 13% of the total water demand of South Africa. The estimates were based on:

- water requirements of estuaries and lakes - evaporative and flooding requirements; and
- water demand for nature conservation areas - including domestic water for visitors, game watering and the maintenance of riverine habitats.

Evaporative and flooding requirements of estuaries and lakes are by far the dominant volumes of water involved and the allocation to conservation areas is a relatively small percentage of the total (Fig. 1). On a national basis it has been estimated that for 1990 only 182 x 10^6 m^3 would have to be allocated to nature conservation areas of which the Kruger National Park would account for approximately 61% (110 x 10^6 m^3). Such estimates published by the Department of Water Affairs (1986) merely indicate a statement of recognition and goodwill towards the use of water for the purposes of environmental management. The Department of Water Affairs stresses that the requirements of estuaries, lakes and conservation areas will be in competition with other demands and that it will not necessarily be possible to meet the management demands of aquatic habitats. Considerable emphasis is placed by the Department on the need for further research into water requirements for environmental management. For most rivers a clear policy of water allocation has not been developed. This will require a considerable amount of negotiation between all parties involved in water resource utilisation within any specific catchment.

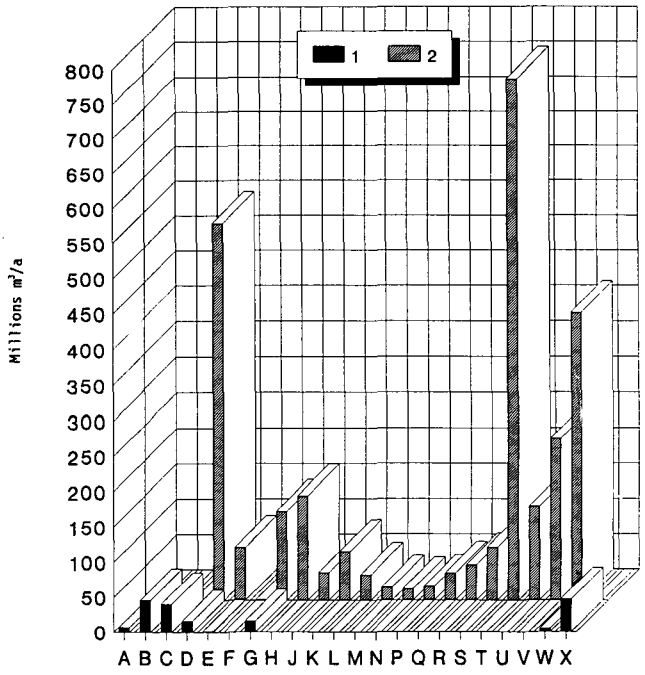


Figure 1

Estimated freshwater requirements of rivers in the primary drainage regions (A - X) of South Africa

Case studies

There have been many important inland water ecosystems which have given cause for concern with respect to water allocation and their future management: systems such as the Pongolo Floodplain, Mkuze Swamp, Lake St. Lucia, and the Kruger National Park rivers, the Buffalo and Palmiet systems and the Orange and Mgeni estuaries, to name but a few. In each case, conservation, socio-economic and development objectives will have to be reconciled with water allocation. They are all areas with totally different requirements in terms of high and low flows, and quantities of water, and each has unique characteristics, uses and jurisdictional problems within their catchments. Thus, each system almost certainly requires a different approach in terms of water allocation and accompanying research will be essential before such allocations can sensibly be made. It is beyond the scope of this overview to go into great detail on each of these ecosystems. However, for some select cases, an outline of the major problems associated with water allocation is presented in order to highlight some of the problems that each system faces.

Pongolo Floodplain

This floodplain (Fig. 2), one of the largest in South Africa, has been rated as one of South Africa's key wetland areas on the basis of its biological diversity, current utilisation by its resident population and the potential for agricultural development (Heeg and Breen, 1982). A development plan for the floodplain revolves around the use of water from the Pongolapoort Dam through a large-scale irrigation scheme. The natural seasonal inundation of the floodplain is now dependent on artificial flood releases from the dam. The floodplain is of particular importance to some 60 000 people who depend on subsistence agriculture (maize), pastoral practices (cattle) and fishing for their survival. In addition, the area has the potential to be a key tourist resource with the inclusion of the Ndumu Game Reserve and duck hunting activities.

Bruwer (1989) considers that the water requirements of the floodplain should be viewed from four perspectives and an amount be allocated to satisfy the demands of:

Ecological water

- Destruction of riverine vegetation and pan perimeter vegetation should be prevented as they stabilise levees and reduce erosion;
- fish populations in pans should be maximised as they form an important food source;
- floodplain lawns should be maintained as they form an important food source for grazing animals as well as nutrient input into pan water;
- reedbeds should be maintained as they form an important source of raw materials for manufacture of everyday articles; and

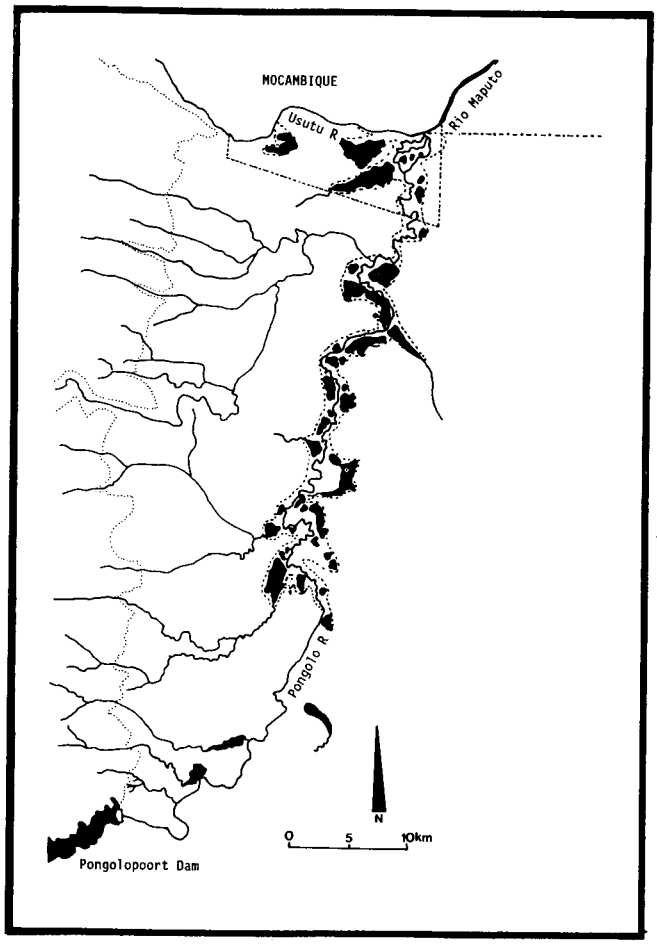


Figure 2
Map of the Pongolo Floodplain and associated pans

- the stability of Nyamithi Pan in the Ndumu Game Reserve should be maintained because of its attractiveness for tourism as regards its birds, hippo, crocodile and fish populations.

Agricultural water

- Flooding - two separate events, preferably before September and towards the middle of March each year to prolong the maize-growing season and to minimise crop damage due to flooding;
- maintenance of low flow in the river prior to the summer season or during the first rains, to enable easy access to fields to prepare for planting;
- maintenance of flow in the river during the planting season to prevent cattle from crossing into fields and damaging crops; and
- maintenance of adequate water levels in the pans to cater for the small pumps that are coming into use in agriculture.

Sociological water

- The pans and the river provide a water source for domestic consumption, and this water should, therefore, be of adequate quantity and quality;
- there is an increasing need to supply water to off-floodplain areas and this would most likely be developed using the pans as storage facilities and the river as a supply facility; and
- the international agreement on water flow between South Africa and Mozambique must be addressed in respect of flood control and minimum water flow.

Practical constraints

- The maximum capacity of the gauging weir below the dam is 500 m^3s^{-1}. Higher flow would be expected to damage the weir.
- The Pongolapoort Dam can only discharge floods larger thar 80 m^3s^{-1} if it is above 52% of full supply capacity (FSC). The level of the dam would therefore have to be maintained above 60% FSC before floods of 500 m^3s^{-1} could be released.

Bruwer (1989) reported that an estimate of 125 x 10^6 m^3a^{-1} was provisionally suggested by the Department of Water Affairs as the allocation for the region downstream of the Pongolapoort Dam, of which 65 x 10^6 m^3 was required for Mozambique. This estimate did not, however, take into account the above-mentioned considerations of Bruwer (1989). Whilst Bruwer (1989) considered that some of the ecological, agricultural and sociological water requirements could be met simultaneously, he stressed that the provisional estimate is grossly inadequate and in personal communication has suggested a figure of 300 x 10^6 m^3a^{-1} as being more realistic.

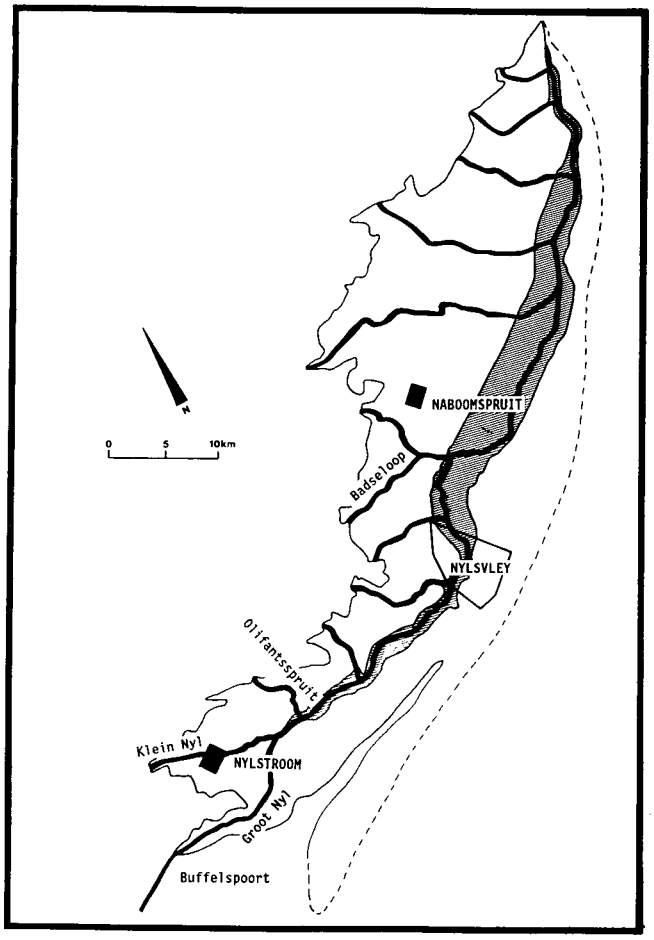


Figure 3
Map of the Nyl Floodplain (from Tarboton, 1987)

The Nyl Floodplain

The Nyl Floodplain (Fig. 3), when fully flooded, occupies an area of 16 000 ha. The importance of the floodplain as a conservation area has been emphasised by Tarboton (1987). He considers that its survival depends on a continued supply of runoff in addition to periodic flooding. Recently, the effective catchment of the floodplain was reduced by the construction of farm dams which had been built during the past five drought years. Authorities also planned an additional impoundment to cater for the water requirements of Nylstroom, but postponed action pending a more intensive investigation. A recent study by Nel *et al.* (1989) has shown that the absorption effects of the proposed impoundment would comprise only 4,2% of the mean annual rainfall (MAR). Current estimates have indicated that the floodplain requires quantities of the order of 40 to 50 x 10^6 m^3 per flood event, but how such flooding should be managed still has to be elucidated (Tarboton, 1989). Tarboton (1987) has recommended the following:

- No more dams should be built in the catchment area until a detailed assessment has been made of the effects that both existing dams and possible future dams may have on river flow.
- Concurrent with this hydrological study, an integrated assessment should be made of the floodplain system as a whole. Bird populations and their productivity should be monitored systematically.

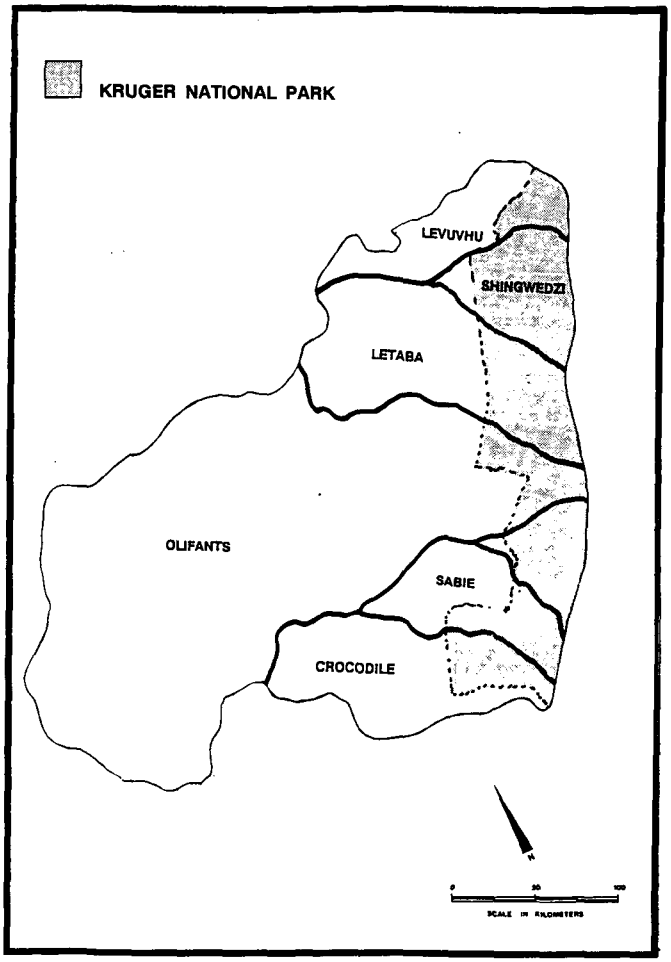


Figure 4
Catchment boundaries of rivers flowing into the Kruger National Park

TABLE 1
PRELIMINARY ESTIMATES FOR ENVIRONMENTAL WATER REQUIREMENTS OF KRUGER PARK RIVERS (AFTER BRUWER, IN PREPARATION)

River	Minimum flow requirement x 10^6 m^3	% MAR
Levuvhu	71	22
Shingwedzi	22 - 33	40 - 60
Letaba	90 - 122	13 - 17
Olifants	192 - 620	8,5 - 27,5
Sabie	153	20
Crocodile	97	8

- No further dams, dykes or impoundments should be built on the floodplain.
- Nylsvlei Nature Reserve should be expanded to include more floodplain habitat.

The Kruger National Park and its rivers

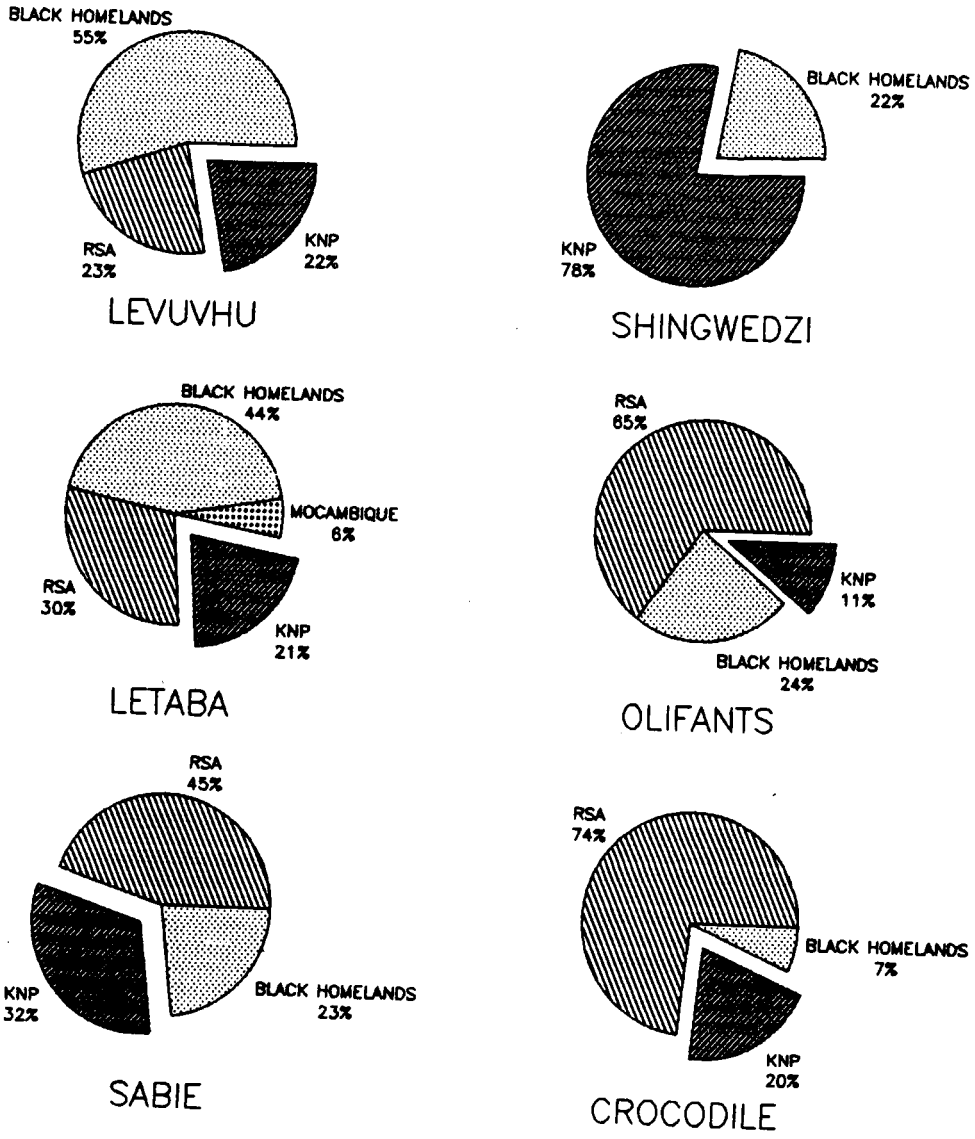
The problem of allocating water to the Kruger National Park (KNP) represents the most complex of the three cases outlined here. By virtue of its position on the eastern border of South Africa, the KNP receives the flow of six main rivers (Fig. 4), each of which has different proportions of catchment within the park itself (Fig. 5).

The problem is compounded by the demand for water from outside the boundaries of the KNP by the industrial, urban and agricultural sectors of South Africa and also by several national and self-governing states. In each catchment, most of the runoff originates outside the western borders of KNP (Van Zyl, 1989). Thus rivers inside the park are dependent upon flow from outside. It is reported that all of the rivers, except the Shingwedzi, were originally perennial before catchment development altered both their flow and water quality characteristics (Bruwer, in preparation). The river systems are invaluable to the park in that they:

- provide riparian zones which are prime wildlife habitat in the park;
- provide migratory corridors for game;
- provide sources of food during droughts and adverse periods;
- are major waterways connecting land areas of the KNP in a north/south direction; and
- are areas of aesthetic appeal, hence attracting tourists.

As early as 1970 it was recommended that an annual volume of approximately 90 x 10^6 m^3 be allocated to the KNP (Commission of Enquiry into Water Matters, 1970). Recognising that this estimate required reassessment, the Department of Water Affairs convened a workshop in 1987 to generate some preliminary ideas on the general requirements of these rivers. Although the document from this workshop has not yet been published, some extremely valuable concepts were developed (Bruwer, in preparation). The general consensus of the workshop was that water is required in the following categories:

- an annual consumptive volume for evaporation, evapotranspiration and drinking water for animals;
- an annual non-consumptive volume needed to maintain daily flow rate;
- a non-consumptive volume for flushing-flows (e.g. several small



CATCHMENT AREA CHARACTERISTICS OF KRUGER NATIONAL PARK RIVERS

Figure 5
Proportions of catchment area situated in the Republic of South Africa (RSA), the Black homelands and the Kruger National Park (KNP) for the six major river systems flowing into the KNP

floods per year);
- large flood volumes (e.g once every three years); and
- major flood volumes (e.g. every 10 to 12 years).

It was felt by the workshop participants that such volumes would maintain the integrity of all of the components of the river ecosystems in the KNP: components such as floodplains, riparian zones and river channels. Although opinions differed widely, some preliminary figures were proposed for each system (Table 1), and a general consensus was reached that considerably more research was required to refine the assessments for decision-making purposes. Such research is currently being defined and initiated under the auspices of the recently constituted multidisciplinary and multi-institutional Kruger Park Rivers Research Coordinating Committee.

General comment

These three case studies exhibit several common features which are probably also pertinent to most catchments in South Africa, namely that:

- river management objectives have not been defined adequately;
- human carrying capacities have not been taken into consideration during previous planning and development phases;
- ecological functioning has only very recently received any attention, but in any case there is a paucity of sound research data upon which to base management decisions; and
- minimum flow requirements have not been defined adequately.

Environmental and conservation ethics

One of the major problems facing any company in the business world, and one requiring continual attention, is whether or not its policies are appropriate in order to ensure that the company can continue to survive and/or to develop in the market place. By the same token, the South African community should be continually asking itself whether or not current environmental and conservation practices are going to ensure the survival of the country into the next century. During recent years we have seen a plethora of excellent documentation (both national and international) in which this general subject is debated (e.g. IUCN, 1980; Fuggle, 1983; Huntley, 1989; Huntley *et al.*, 1989) - to name but a few. An almost singular feature about this material is that most of it originates from the ecological fraternity, with very little from the commercial or industrial sector. There is an inescapable impression that, to date, environmental issues have received a relatively low priority within the sector which drives the economy of the country. As such, environmental issues have received little attention in political forums with a resultant low status in terms of funding for appropriate research and management actions. Recent publicity given to environmentally damaging events both in South Africa and abroad indicates that there is a growing ground-swell of support acting to change this situation. Accordingly, the South African community and policy makers will have to alter their ideology in order to compensate for the stronger opinions on the environment which will soon and inevitably surface. Many European governments have already taken cognisance of such lobbies (e.g. Denmark, West Germany, the United Kingdom), and one recently fell on an environmental issue (the Dutch Government early in 1989).

The IUCN (1980) definition of conservation and one which should perhaps be built into the mission statements of all organisations involved with activities which have environmental impacts is "the management of the human use of the biosphere so that it may yield the greatest sustainable benefit to present generations whilst maintaining its potential to meet the needs and aspirations of future generations". Living resource conservation, concerned with plants, animals and microorganisms, can be regarded as the management of existing renewable resources which are rationally utilised and passed on for continued utilisation by future generations. Living resource conservation has three main objectives (IUCN, 1980), namely to:

- maintain the essential ecological processes and life support systems of the planet;
- preserve genetic diversity; and
- ensure the sustainable utilisation of species and ecosystems globally.

Water is vital for the conservation of living resources and, therefore, the issue of how much water should be allocated for environmental management is indeed an extremely important one. However, the issue extends far wider than simply one, for example, of releasing water down a river channel in order to conserve an endangered fish species. Huntley *et al.* (1989) have summarised their perception of the "rules of the environmental game" in South Africa. These include:

- natural diversity and richness;
- variability in climate and weather patterns;
- population dynamics: the "First World"/"Third World" dichotomy;
- mass urbanisation;
- agriculture divided: prosperity and poverty;
- mismatch of industrial growth points and water availability;
- coal, energy and atmospheric pollution;
- restricted access to domestic energy and water;
- limits to growth in the marine environment; and
- economic growth and consumption patterns.

Water supply is associated with almost all of these "rules", indicating the complexity (and significance) of sound water resource planning and management to the country. Within the context of water allocation we believe that there are two issues which require accentuation: a sound economic approach and integrated river management.

Economic approach

Conservation and environmental management requires economic solutions which should be built into a national ethic and should mesh with the national policies and management style. It is appropriate here to note a recently published report which proposes an environmental philosophy for the United Kingdom (Pearce, 1989). An excerpt from an associated editorial comment in the London Financial Times (August 19, 1989) reads as follows: "During the past two centuries, the pursuit of self-interest within a broadly unfettered market system has led to phenomenal growth of the man-made economy. But this has been at a cost: the indiscriminate exploitation of natural assets, which have been treated as "free goods" and therefore over-utilised. Thus while the costing of a factory will take account of the price of inputs such as labour and capital, it will tend not to reflect the full value to society of the landscape destroyed during construction. Further, pricing decisions rarely recognise that economic processes, while transforming matter, do not create or destroy it. Thus the full social cost of waste products is not factored into corporate decision-making, nor, during the productive stage, is account taken of the eventual costs of disposing of products once they become obsolescent."

This message reiterates that of Stauth (1983) who considers that South African practices in environmental economics are inadequate. In South Africa, the custodians of the so-called "free goods" or "environment" have not quantified the economic or social value of what they are protecting. Without such a foundation it is difficult to compete for resources with parties (commerce and industry) who can provide such values.

Integrated river management

The development of any region causes changes to the landscape as humans alter the land for food production, transport, communication, industry, energy production and recreation. In so doing it is important that development proceeds in a fashion which ensures sustainability with minimal adverse environmental impacts. During this century, South Africa has undergone major land transformations (Macdonald, 1989), but yet it still differs considerably from a country such as the United Kingdom where the percentage of land set aside for urban/industrial development is similar to the amount set aside for agriculture in South Africa (Fig. 6). Furthermore, there is an enormous disparity in the amount of land set aside for the purposes of conservation in the two countries: in the United Kingdom, nature conservation is allocated 8% of the land mass which, together with an additional 8% for "conserved farmland", provides a total of 16% of the land mass for conservation purposes and in so doing have fallen badly behind most of the rest of the world. To compound the problem, river systems essentially do not feature in this small area, despite their significance to

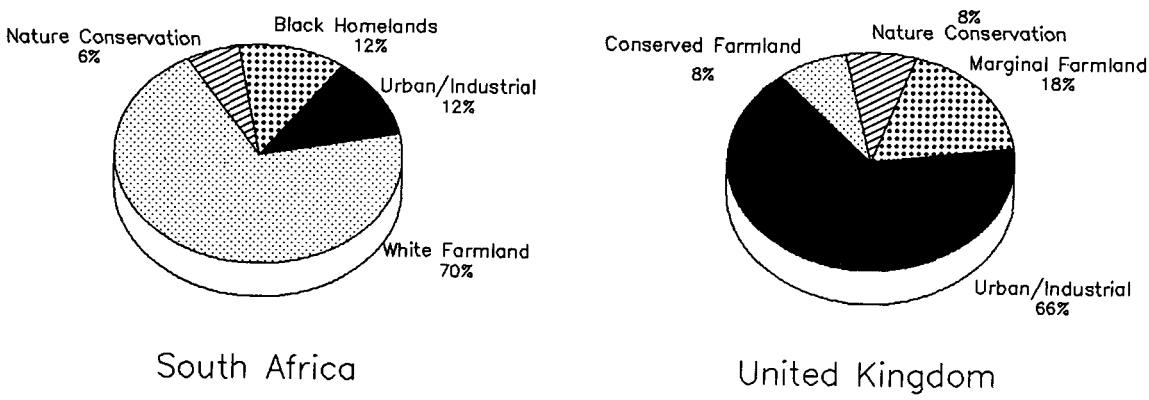


Figure 6
Pie diagrams comparing the relative proportions of land use in the RSA and United Kingdom

the long-term survival of the country.

Rivers have been described as drains of the landscape, their condition reflecting the activities which impinge on the quality and quantity of water draining into them. In addition, the river ecosystem extends across the boundaries of all land uses within any catchment and, therefore, demands special consideration with respect to its management. Water allocation is strongly associated with land-use planning and development and demands an integrated plan of action for each catchment. There is evidence to indicate that this aspect requires urgent attention. For example, a statement made by Allanson and Rabie (1983) is perhaps appropriate to this topic. They comment that "South Africa has no defined policy for the management of river systems so as to ensure their optimum utilisation and conservation. Water utilisation by local authorities especially in metropolitan areas, lacks proper coordinated planning...". Whilst certain parties might dispute the point that we have "no policy", it must be accepted that our practices in the area of integrated catchment management and planning are certainly obscure. It would appear that the key to resolving this problem will be the acceptance of the principal and the subsequent coordination of the numerous organisations who regulate water usage and associated riverine habitats. Compounding the issue is the problem of multiple ownership along all river systems and the consequent varied perceptions of the how, what and why of water rights. The custodians of our river systems appear to be in disarray.

Research and manpower needs

Limnological research in South Africa has only recently changed emphasis from reservoir to river ecosystem studies. The realisation that reservoir problems are merely symptoms of problems emanating from the wider catchment has been emphasised during several workshops (Breen *et al.* (1985); Bruwer *et al.* (1985); Braune and Rogers (1987); Walmsley and Furness (1988)). Recently, the participants operating within the framework of the Inland Water Ecosystems Programme of the Foundation for Research Development (FRD) developed into a keen corps of river ecologists as well as aiding in the transfer of river ecosystem concepts to water resource agencies (e.g. Hart and Allanson, 1984; O'Keeffe, 1986; Braune and Rogers, 1987; Ferrar *et al.*, 1988; Ferrar, 1989). However, the question arises as to whether or not we currently have the capability to provide an adequate input into the myriad questions which planners and decision-makers need to answer. If we accept the concept of the scientific research community as being an "organisation" and consider a SWOT analysis of the present situation, it rapidly becomes apparent that there are several weaknesses and threats which require resolution (Table 2).

It is beyond the scope of this overview to provide solutions to all of these apparent weaknesses and threats. Solutions need to be generated in the appropriate forums, and action taken by the community where it is deemed necessary. However, in addition to observing that there is a requirement for inter-disciplinary training within the scientific community, and that there is an apparent inability on the part of the management community to place research recommendations into effect, we should like to pass comment on two issues which, without resolution, will merely perpetuate our inability to make sound management decisions on the problem of water allocation for the environment. They are: the shortage of trained manpower, and the low level of funding allocated to research in the field of minimum flow requirements.

To date, inland waters research activities in South Africa have been dominated by ecologists, most with zoological interests. A great deal of research has concentrated on the biota, particularly fish and invertebrates, but there has been relatively little input from chemists (water quality specialists), botanists, geomorphologists, and, most importantly, hydrologists. The problem of quantifying the amounts of water required for environmental management demands a multidisciplinary team approach, so that a common understanding of the complexities of river ecosystem functioning may be developed for each system, while at the same time seeking the most appropriate quantitative solutions which take into account the numerous political and socio-economic factors which pertain to each system (e.g. plans for development, available funding, utilisation, etc). Such an approach requires the input of research specialists from numerous disciplines. Despite the mobilisation of scientists to generate appropriate information the "game" will be far from won. The problem which still arises is: how can such information justify additional or decreased allocations of water to river ecosystems? Quite clearly, expertise which is capable of integrating the complex spectrum of scientific, social, economic and political facts, and then negotiating for an acceptable allocation, will have to be developed. Walmsley and Ashton (1988)

TABLE 2
SWOT ANALYSIS OF THE CURRENT CAPABILITY OF THE SCIENTIFIC COMMUNITY TO MEET THE OBJECTIVES OF A RESEARCH PROGRAMME WHICH ASSESSES ALLOCATION OF WATER FOR ENVIRONMENTAL MANAGEMENT

INTERNAL ENVIRONMENT

A. STRENGTHS

- adequate facilities for education
- adequate facilities for research
- enthusiastic ecological/hydrological community
- small community with a good history of interaction
- ability to transfer information rapidly

B. WEAKNESSES

- insufficient manpower
- lack of funding
- deficiency in leadership
- deficiency of expertise in certain key fields
- weak interaction with resource agencies

EXTERNAL ENVIRONMENT

A. OPPORTUNITIES

- problem is relevant to South Africa's needs
- growing awareness of environmental concern

B. THREATS

- obscure policy on catchment planning and management
- relatively poor perception of relevance of research to solving water resource problems
- lack of defined policy on funding of research
- competition from other sectors requiring water allocation
- uncertain future with regards to coordination of research effort
- disinvolvement of the state from research activities

considered that such expertise should be developed by the parties who wish to secure a water allocation from the Department of Water Affairs. South African Departments of Nature and Environmental Conservation should, therefore, be endeavouring to develop and nurture such expertise within their own ranks, rather than dispersing their research experts, as is the case presently. The problem of water allocation will be a perennial one which will require continual negotiation depending on changing social, political, economic and climatic conditions.

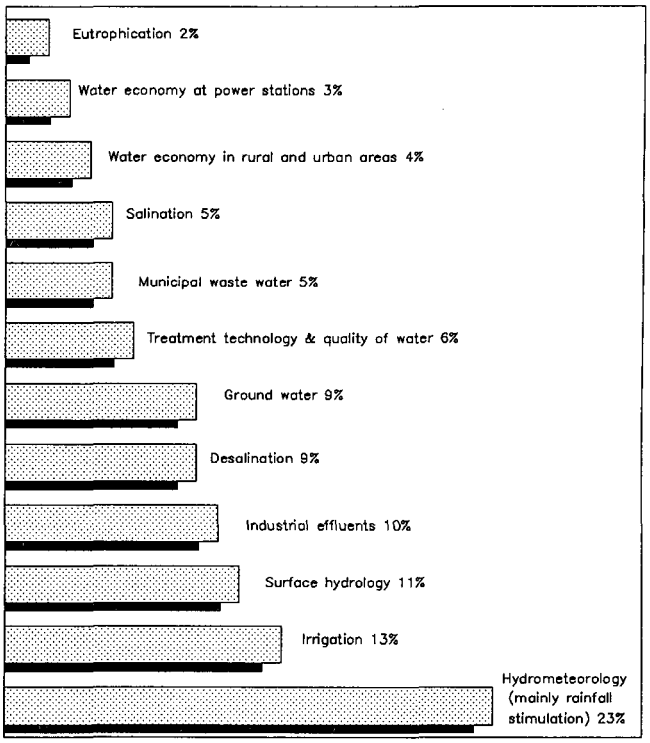
Research funding

Research requires an investment of funds, and the return on this investment is generally a package of products (viz.: information, methodology, trained manpower, and so on), which contributes to solving a socio-economic or political problem. Have we invested enough in developing the required expertise to confidently assess minimum flow requirements? Obviously this question must be answered in the negative. When one considers that more than 11% of MAR is necessary for water allocation for environmental management it is surprising to find how little attention has been given to research and management of this resource problem. For example, Joubert (1988) reports that the South African Government sector spends more than 23% of its research and development (R and D) budget on agricultural research alone, while agriculture contributes only of the order of 5% to the gross national product (GNP) of the country. At the same time, agriculture is allocated almost 55% of South Africa's available water supplies by the Department of Water Affairs. To compound these disproportional figures, the problem of water for environmental management receives an exceptionally low profile. For example, an examination of the 1988 research funding allocations by the Water Research Commission (Fig. 7) reveals that no funding was allocated to direct research in this area.

Following a recent visit to South Africa, a prominent Australian limnologist remarked that financial support for South African limnologists was "ridiculously small" compared to support given to the Australian community where, for example, the annual budget of a single institute (the Murray Darling Freshwater Centre, Albury) exceeds the total national support for similar research in South Africa. Clearly the parties who are concerned with this problem urgently need to review funding policies and to revise their priorities in order to cater for this discrepancy.

Conclusions

- Policy regarding the allocation of water for environmental management is largely based on a statement of recognition and goodwill. It is envisaged that the requirements of rivers, estuaries, lakes and conservation areas will be in competition with the demands of other sectors. It will therefore not necessarily be possible to meet the total demands of aquatic habitats.
- Despite a recent focus of attention estimating the water demands of aquatic habitats, minimum flow requirements of most rivers have still not been adequately defined for decision-making purposes.
- Future water resource planning and development will have to take greater cognisance of conservation and environmental issues. By the same token, conservation organisations will have to make stronger economic motivations for their water requirements.



ALLOCATION OF FUNDS TO VARIOUS RESEARCH AREAS DURING 1988
(from Water Research Commission Annual Report)

Figure 7
Relative proportions of funding allocated to specific fields during 1988 by the Water Research Commission

- It is recommended that a concerted effort be made to further develop the appropriate research expertise for determining the water requirements of aquatic habitats.

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